

Steven A. Treese

History and Measurement of the Base and Derived Units

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Steven A. Treese
Gig Harbor, WA
USA

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Preface

This book began with a desire to collect various conversion factors into a personal, convenient, and time-saving reference that would enable easy conversion between metric and English/US units used in engineering. It always seemed like needed data for a calculation were available, but the data were often in units different from those required and scattered among several references. The so-called “standard” systems were also not all that standard.

There are Internet modules available for conversion among many common units. These are very helpful when you have Internet access. It has been noted, however, that the conversions are sometimes not correct or use different measurement system bases. It was found that the online conversions needed to be verified independently or corrected in many cases. The online converters provided by www.engineeringtoolbox.com and www.calculator.org were found to be useful and fairly reliable, however.

While assembling information on the conversion factors, it seemed logical to provide a little bit of background about the history of the units. The deeper one looked into the history, however, the more interesting and complex the development of measurement units and systems proved to be.

The history of measurement includes the influences of trade, agriculture, conquest, colonization, politics, and even adventure as units have been defined and redefined over the centuries. It follows the development of technology from the most primitive to the most esoteric, with a glimpse of where the definition of measurement units may be headed in the future.

Some of the measurement concepts are fairly easy to envision and understand on a basic level, like length or weight/mass. We can relate to them from common experience; that is, we can “feel” them. Others, like electric current or time, are much more abstract and the ways they may be measured are indirect.

The focus of this book is primarily on the factors pertinent to engineering practice; but others still find their way into the story. This is not primarily a work of strict metrology. This book has more of a historical and “lay” context. Informal language and style are used throughout the book. An effort was made to keep “jargon” to a minimum. Hence, some of the terms used are for convenience and lay

understanding of units. They are not necessarily used by those in the metrology business.

An excellent reference book entitled *Encyclopaedia of Scientific Units, Weights, and Measures: Their SI Equivalents and Origins*, by Francois Cardelli provides very good and thorough technical information on some of the more esoteric and less common units that will not be included here in any detail.

Another excellent reference on many historical units is *Weights, Measures, and Money, of All Nations*, by F. W. Clarke. This reference, published in 1891, also includes monetary units, which are interesting, but have not been included in the current work since currencies are actively traded and the values vary significantly with time.

In organization, this book begins with a general perspective of measurement and its overall historical development through different civilizations. The concepts behind interconversion of units are addressed. A more detailed history of the developments of the English/U.S. and various metric systems follows. There are individual chapters then devoted to the history of measurement of the fundamental or base quantities: length/distance, area, volume/capacity, weight/mass, time, temperature, angles, electricity, chemistry, and light. There is a discussion of how the base units are used to define other measurements. The book concludes with the original objective: a summary of the most commonly needed conversion factors today.

I hope you enjoy this journey through the history of measurements that we often take for granted, and that you appreciate the rich heritage represented by our units of measurement.

Gig Harbor, USA

Steven A. Treese
P.E.

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About the Author



Steven A. Treese retired from Phillips 66 as the Hydroprocessing Team Lead in 2013; but continues to take on the occasional consulting assignment in process engineering and refining. He started his professional career with Union Oil Company of California in 1973 as a Research Engineer with a BS in Chemical Engineering from Washington State University. He followed company heritages through Unocal, Tosco, Phillips, ConocoPhillips, and Phillips 66. Steve's range of experience includes hydroprocessing, hydrogen production, operations, process safety, catalyst development, utilities, sulfur recovery, geothermal, shale oil, nitrogen fertilizers, process design, procurement, and licensing.

Steve is a licensed Professional Engineer with a handful of publications. He was on the 1994 NPRA Question and Answer Panel and was Lead Editor for the "Handbook of Petroleum Processing, 2nd Edition" (Springer, 2015). He has been an inventor on patents in diverse areas, including vessel internals, enhanced oil recovery, and hydroprocessing. He is a member of the American Institute of Chemical Engineers.

Steve's hobbies include woodworking, boating, fermentation, robotics, and photography. He is a mentor for FIRST Robotics Team 3049 in Bremerton, WA.

Chapter 1

Measurement Perspectives



Abstract The measurement of important factors about the world around us has enjoyed a long and colorful history. The overall development and evolution of measurement systems is explored in this chapter, along with new perspectives to place measurement and units in an historical context. This chapter sets out the conceptual arrangement for the balance of this book.

Introduction

The history of measurement is rooted in the needs to quantify or size objects or distances by early mankind. These early applications were very basic, such as how large to make a shelter or how far to some destination. Measurement evolved from these early applications under the influences of trade, agriculture, conquest, colonization, politics, and adventure as units have been defined, redefined, and changed over the intervening centuries. The technological needs for new types of measurements developed alongside the drive toward improved accuracy and wider range, which continues today.

We will begin the discussion of the history of measurement units with a general exploration of the reasons for common units of measurement and how these relate to the units that have and are being used. We will then consider the migration of measurement concepts and units throughout our world over a few thousand years of recorded history and the drivers behind these movements.

Let us start by considering why we need measurement units in the first place.

The Need for Measurement [14, 15, 20]

Suppose you have a pile of barley grain and you want to give some of it to 3 other people. Suppose further that you want the shares to be equally divided. How would you do that?

You could count out the grains into 4 equal piles (“One for you, one for you, one for you, etc.”) until you went through the whole pile. This would take all day, but the piles would be even.

You could take a bulk approach and make a pile of all the grain. Then you could try to estimate where the middle of the pile is and divide the pile in the middle to create two new piles of about equal size. You would repeat the process for each of the two new piles to end up with 4 piles of approximately equal size. This would have been a common approach to the problem in early history.

You could also take a fixed volume container, like a gourd or cup, to scoop the grains into 4 different, approximately equal piles. This would be a more even distribution than just splitting the pile and would take a lot less time than counting individual grains. You might have a remainder of grain that would still have to be split some other way.

A fourth way of splitting the grain would be by comparing weights using a balance scale to create two piles of equal weight. Then using the scale again to divide each of the two piles. This would end up with four piles of very equal weights. A certain amount of trial and error is involved in adjusting the amounts on each balance pan.

All these approaches avoid the need for a specific measurement unit, but they would each be time consuming and some only result in approximately equal splits. If you wanted to split the grain in other proportions or if you only wanted to take a small portion of the grain for use, you would need some other approach.

Units of measurement allow us to quantify amounts of items. The simplest approach to measurement would be to count “each” item. This is analogous to counting all the grains of barley in the above example. This unit works for many items. It is still often used as a pricing basis, but it becomes cumbersome for bulk or large items. It is much more convenient to group bulk quantities.

The common needs for measurement include:

- Sizing items (length, area, capacity)
- Determining distances and travel times (length, time)
- Trading goods and services (weight, capacity, length, area, time, electricity)
- Taxation (weight, area, volume, number)
- Property ownership (area, length)
- Building and manufacturing (length, area, volume, weight, angles)
- Science (length, area, volume, mass, temperature, time, electricity, magnetism, angles)

To provide the flexibility necessary for the various needs, units of measurement with appropriate magnitudes were developed and standardized in some fashion. The fundamental, primary, or base units we apply for measurement are [11, 34]:

- Length
- Mass
- Time
- Electric Current

- Temperature
- Amount of Substance
- Luminous Intensity

Other units are created by combinations of these units. Note that, for most of recorded history, electric current, amount of substance, and luminous intensity were not really known or quantifiable, so they would not normally be considered “historical units,” but we will consider them as such in this discussion.

We would also note that area and volume or capacity were historically considered fundamental, even though they can be described as mathematical combinations of length measurements. We will include them here in their historical context.

Angular measurement is a separate category that is worth some consideration in its historical perspective. Angle measurement is really a mathematical abstraction describing the relationship between two lines or planes. It has a history of its own.

Hence, the units we will consider from an historical perspective (i.e. consider them “base” units of measurement) are:

- Length
- Area
- Volume/capacity
- Mass/weight
- Time
- Temperature
- Angle
- Electric Charge or Current
- Amount of Substance
- Luminous or Radiant Intensity

For these measurement units there are sufficient historical data available to define their genesis and magnitudes in a number of cases.

Relationships Among Units, Needs, and Accuracy

The absolute values of measurement units generally have to be appropriate for the intended use. For instance, it would not be practical to measure the large area of a field in square angstroms. One hectare would be equal to 10^{18} square angstroms. A field is better measured in hectares or acres where the values of the numbers are reasonable.

Similarly, the accuracy associated with units needs to be appropriate to the item being measured. Measuring a large amount of steel in grams would not be appropriate, hence we have a metric ton unit of measurement.

In general, over time the range of measurement units has expanded along with technology needs and the ability to perform the measurement. Better measurement methods have enabled more accurate measurements and have enabled us to measure smaller and larger things.

For instance, measurement of weights smaller than a handful of grain at one time was not really possible or necessary from a practical standpoint. The development of the balance scale in the third or fourth millennium BC enabled the accurate measurement of smaller quantities. The ability to accurately measure even smaller quantities has developed along with the need to make such measurements until we can now measure the masses of atoms, molecules, and subatomic particles when necessary with reasonable accuracy.

Need drives improvements in measurement accuracy which, in turn, drive additional needs for accuracy.

The desire to have units with magnitudes appropriate to the items being measured over history gave rise to what we might call “families” of units or measurement systems. U.S. Customary common lengths are an example of such a system, or rather a group of about three systems using slightly different bases. Starting with a base unit, each named unit is usually a multiple or fraction of the base unit. Of course, to complicate things, the multiple is not always a nice whole number and, in most systems, the multiples are not consistent. The U.S. Customary systems for lengths have units related in Table 1.1. The common measurements are used generally, but different systems with different units are used for surveying and

Table 1.1 U.S. customary length relationships [3, 10]

Unit name	Relationship
<i>Common Measure System</i>	
mil	Smallest unit
line	25 mils
inch	1000 mils or 40 lines
hand	4 inches
span	9 inches
foot	12 inches
yard	3 feet
bolt	40 yards
<i>Survey Measure System (used for land, roads, distances)</i>	
link	$^{33}/_{50}$ ft ($^{2}/_{3}$ foot, wouldn’t want it easy)
foot	12 inches (1 common foot)
rod, perche, pole	25 links
chain	4 rods
furlong	10 chains
mile	80 chains or 8 furlongs
league	3 miles
<i>Nautical Measure System (used for navigation, depths)</i>	
fathom	2 yards (6 common feet)
cable	120 fathoms
mile	8.439 cables (again, wouldn’t want it easy)
league	3 miles

nautical applications. The survey and nautical units are generally much larger than the common system units, consistent with their use. Measurements may move between systems in some cases—following one system until it makes sense to switch to the other.

Influence of Measurement Capabilities

[5, 7, 8, 16, 17, 19]

The earliest consistent measurements were defined by very simple standards. Lengths, for instance, were usually based on parts of the body. This gave rise to units like the foot or inch or cubit (forearm length). Of course, the absolute values of these measurements would vary from person-to-person. The capability of measuring depended on individuals. The ability to consistently and accurately measure something was poor, but the accuracy was good enough.

At some point in ancient practice, people began using tools to get consistent measurements. A stick with standard length markings or a rawhide string with knots at standard lengths might be used. These tools would enable consistency in measurement to the necessary accuracy of the time. For lengths, it was probably enough to be within ± 2 or 3 cm (± 1 inch). A stick or a string are not completely consistent in length either. The lengths would vary with humidity and temperature, but these variations were within the accuracy of the necessary measurement. This approach was still in use in the 19th century by native North Americans. A Shoshone tribe member [18], for instance, might have a rawhide string that was knotted in lengths based on that person's body proportions. When the person would build something, he would use his own standard measurements so the resulting item, like a hunting bow, would be a size appropriate for that person. There is some sense to this reasoning from a humanistic standpoint.

When civilizations and societies began building larger structures, it became necessary to develop more accurate measurements to ensure structures or devices fit together correctly and to facilitate commerce. This led to the advent of devices such as marked metal rods or bars for lengths, for instance. These devices could improve measurement accuracy and consistency one or two orders of magnitude. They were still subject to temperature expansion and contraction, but the variation was not significant for their uses. These types of measurement tools still persist today for most applications, like rulers, yard or meter sticks, and tape measures.

Industrialization, technology, and science created a demand for much more accuracy and range in measurement. Tools and techniques to measure much smaller units, down to angstrom levels (10^{-10} meters) and smaller for lengths, as examples, were developed to satisfy the needs. Today we can accurately measure wavelengths of light or masses of individual subatomic particles.

While this discussion has cited primarily examples using length units, similar advances in measuring the other fundamental units has progressed. For instance, determining a weight by holding a “known” rock in one hand and an item to be

weighed in the other and comparing how they “feel” (± 0.1 kg accuracy) [18] gave way to the use of a balance scale (say ± 1 gram accuracy) which developed into the analytical scale (± 0.0001 gram accuracy). Modern weight measurement techniques can determine weights to $\pm 10^{-10}$ grams accuracy or better. We still use various types of balances or scales for most weights in everyday use, however. We can measure time to the nearest pico-second ($\pm 10^{-12}$ seconds), whereas the earliest measurements were to the nearest year or season.

In the foregoing, development of the ability to measure smaller and smaller units was discussed; however, there have also been advances in measuring larger and larger quantities with accuracy as the need arose. Today, it is common to determine shipping weights in millions of tonnes accurate to $\pm 0.1\%$ or better, for instance, using load-cell scales and other principles. We measure the distance to the moon at any given time to within a few meters using time-of-flight laser reflection. Surveyors can measure land dimensions within fractions of an inch using laser equipment.

As noted previously, the needs of civilization drove the need for improvements in measurement accuracy which enabled further technological development needing more accuracy in a loop that continues to this day.

Historical Perspectives

Measurement Eras

For convenience in discussing the historical development of measurement units, the history of measurement practices has been divided into six basic “eras”. The eras are roughly defined in Table 1.2 by several, mostly qualitative, criteria using examples:

- **Prevalent technology level.** This classification characterizes the types of tools used and the types of technologies being applied. Stone and wood tools are the lowest level of technology. Application of advanced materials, electronics, complex machinery, and aerospace capabilities are the most advanced.
- **Scientific knowledge level.** This classification considers the complexity of the scientific knowledge applied in the society. The lowest level would involve minimal scientific knowledge, such as how to make and use a fire. The highest level of science would include understanding and application of more complex knowledge of scientific fundamentals down to a sub-atomic scale or up to astronomical scale.
- **Measurement methods and accuracy.** Table 1.2 describes eras by typical, common measurement methods for length, area, capacity/volume, mass/weight, and time. The notional maximum accuracy of the measurement methods available during each era is indicated for perspective. Note that measurement methods could improve a few orders of magnitude between eras.

Table 1.2 Definitions for eras of measurement. Refer to References section for data sources

Era	Early	Ancient	Middle	Expansion	Pre-Metric	Modern
Technology level	Stone, wood, pottery, baskets, simple tools	Bronze, copper, other metals, pottery, more complex tools, early machines	Iron, other metals, simple machines, complex tools, low explosives	Iron, steel, other metals, extensive simple machines, complex tools, explosives	More advanced metals, complex machines, industry, steam power, high explosives	Advanced materials, electronics, extensive industry, complex machines, aerospace applications
Science level	Minimal, fire	Beginnings of science, basic knowledge, civil engineering	Retrenchment of science, mechanical engineering, chemical knowledge	Advances in knowledge, mechanical, chemical, other	Well-developed basics, focus on fundamentals, electricity, light, chemistry	Understanding of many fundamentals at sub-atomic level, space exploration, microelectronics

Measurement methods (common accuracy)

Length	Stick, string, body parts, travel time ($\pm 0.1\text{--}0.2$ m)	Rods/bars, sticks, chains, cables, travel time ($\pm 0.01\text{--}0.05$ m)	Rods/bars, sticks, chains, cables, travel time ($\pm 0.01\text{--}0.05$ m)	Rods/bars, sticks, chains, cables, travel time ($\pm 0.001\text{--}0.005$ m)	Bars, sticks, chains, cables, travel time, interferometer ($\pm 0.00001\text{--}0.00005$ m)	Rods/bars, sticks, chains, cables, travel time, interferometer, ultrasonic, laser ($\pm 10^{-10}$ m)
Area	Landmarks (± 1 m ²)	Using length tools (± 0.1 m ²); larger areas by survey using trigonometry	Using length tools (± 0.1 m ²); larger areas by survey using trigonometry	Using length tools (± 0.01 m ²); larger areas by survey using trigonometry	Using length tools (± 0.0001 m ²); larger areas by survey using trigonometry and transits	Using length tools (± 0.0000001 m ²); larger areas by survey using trigonometry and transits or lasers

(continued)

Table 1.2 (continued)

Era	Early	Ancient	Middle	Expansion	Pre-Metric	Modern
Volume/ capacity	Basket or pottery (±0.1– 0.5 liter)	Basket or pottery, vats, large pottery vessels, small metal vessels (±0.01–0.05 liter)	Basket or pottery, vats, large pottery vessels, large metal vessels (±0.01–0.05 liter)	Metal vessels, vats, tanks (±0.001–0.005 liter)	Metal or glass vessels, vats, tanks, basins (±0.0001–0.0005 liter)	Metal or glass vessels, tanks, basins (±0.00001–0.00005 liter)
Mass/weight	Manual comparisons of items (±0.2 kg)	Balance with standard weights (±0.001 kg); higher accuracy for precious metals	Balance with standard weights (±0.001 kg); higher accuracy for precious metals & drugs	Balance with standard weights (±0.001 kg); higher accuracy for precious metals, drugs, & spices	Analytical balance with standard weights, mechanical scales (±0.000001 kg); higher accuracy for precious metals, drugs, spices	Analytical balance with standard weights, mechanical scales, electronic scales, force-balance scales (±10 ⁻¹⁰ kg)
Time	Celestial (year, season, day/ night)	Celestial, water clock (±2000–4000 s; year, season, day, rough time)	Celestial, mechanical clock (±100– 500 s; year, season, day, hour)	Celestial, chronometer (±1– 10 s; year, season, day, hour, minute, sec)	Celestial, higher accuracy (±0.001 s; year, season, day, hour, minute, sec, fractions)	Celestial, atomic clock (±10 ⁻¹² s; year to picosecond or smaller)
Societal organization	Tribal	Tribal and empires	Localized fiefdoms and loose empires	Countries and empires	Countries and empires	Countries, international organizations (like United Nations)

(continued)

Table 1.2 (continued)

Era	Early	Ancient	Middle	Expansion	Pre-Metric	Modern
Extent of trade	Minimal: between tribes	Local to longer distances	Local to overland or ocean trade, long distances	Extensive long-distance trade overland and ocean, exploration for trade	Extensive international trade along with local trade, esp. in perishables	Extensive international trade in all types of commodities, including perishables
Degree of standardization	Individual basis	Individual with some standards within empires	Feudal locality set standards plus some set by empires, export of standards through trade	Local municipal standards, national standards, export of standards to colonies	Local municipal standards giving way to international standards supporting trade	International standards, but some local units of measure persist for convenience
Examples	Native North Americans before colonization [18]; Sumeria before about 4500 BC [9]	Mesopotamia (~4000–700 BC), Egypt (~3200–50 BC), Greece (~700–0 BC), Roman Empire (500 BC–350 AD) [9]	Europe (~400–1500 AD), Byzantine Empire (~300–1450 AD) [9]	Europe (~1500–1800 AD), Ottoman Empire (~1300–1900 AD) [9]	Europe (~1800–1950 AD) [9]	Worldwide (~21st Century AD)

Societal organization. How a society is organized can have a significant impact on the needs for measurement and accuracy. A tribal society has minimal use for high measurement accuracy, while a complex society with extensive interactions among countries and complex science needs more accurate measurements.

- Extent of trade. The extent of trade among societies has heavily influenced the diffusion or movement of measurement units from one society to another. Sometimes, the results were just additional units added to an existing system and other times the existing system was entirely displaced from the historic record. Today, trade is globalized and common.
- Degree of standardization. Extensive application of measurement for trade, manufacturing, and scientific endeavors necessitates standardization. Even the earliest eras required standardization of individual measurements. In some cases, standardization might merely mean standardizing definitions, such as what is meant by a “cubit.” During the Middle Ages, when city-states set their own standards for units that otherwise might have the same name, there would often be trade disputes because of the differences in the exact values between locations. To avoid disputes in Europe, for instance, it was common to post the standards used at a walled city’s entrance gates. Today, global trade and interaction have driven standardization toward a common basis; yet, even so, most locales have different units of measurement in everyday use that are still related to old units with which the local residents are familiar.

This division of measurement units into eras is necessarily very rough. Not all the criteria flowed evenly for each society. Some societies jump over entire eras. This is particularly true for the Americas where the European explorers and colonizers brought in much more advanced measurement systems that displaced what were, essentially, Early or Ancient systems over a relatively short time span. The Americas missed the whole Middle era and the Ancient era was largely truncated by this European influence.

Drivers Toward Standardization

Measurement units need to be consistent to be of practical use. In early history, it was sufficient that units be specific to individuals or small groups of people. There was little trade or barter, so there was no need to use units that were consistent or standard among several people or between tribes. Trade and barter were most likely based on exchanging numbers of items between individuals. Bulk items would have simply been divided up in agreed proportions.

As societies developed, the frequency and volume of trade increased among the societies. Within a society or an empire, it was important to trade in more or less consistent units of measurement to prevent disagreements. The rulers usually assumed the function of standardizing the measurement system so that trade was facilitated within the society or empire. We see this in the Roman Empire [9qqq] ,

the Holy Roman Empire [9qqq], and the Byzantine Empire [9g]. This does not mean the units were necessarily the same all the time. New rulers often reset standards to their own liking. Standards were subject to political whims.

When trade occurred historically among different societies, you most likely would have encountered conflicting absolute values of measurement units, even though the units may be standardized within each of the societies. Often, the names, definitions, and relative proportions of the units might be the same, but the absolute values would be different. This would create conflicts and miscommunication in trades. For example [1], consider an Egyptian selling 100 rotls of grain to an Arab (1891 time frame). To an Arab, the Egyptian's 100 rotls would be about 5% short of the amount he would expect using Arab units of measurement. The names of the units were the same, but the absolute values were different.

Facilitation of trade has been the strongest driver toward standardization of measurement units throughout history. Only in the past 200 years or so has there been a drive to standardize measurement units on a global scale, following along with the development of global trade.

Another driver for standardization has been scientific and technological development. As recently as the 1800s, interpreting a scientific paper might be an exercise in frustration. Papers used the units of measurement prevalent at the time the paper was produced in the location it was produced. Since the units might differ locally or over time, you would have to know where and when the work was done if you wanted to use the information. This is still sometimes necessary.

In the late 1700s and early 1800s, efforts were made to standardize measurement units worldwide for scientific work. The English created a consistent system of standards that persists today in the British Weights and Measures Act of 1824 [28, 29, 33] and earlier British acts. Parts of this system survive in the U.S. Customary system [3, 10] or English engineering system. Before the metric system was developed, the English system was nearly a worldwide standard.

In the late 18th century, the French took a step back and made an effort to define a completely new and rational system of units for scientific and common use based on physical properties that were believed to be independent of human influence, with proportions between units determined by powers of 10 (decimal system) [11, 13]. This is the metric system. Thus, we have the meter defined as 1/10,000,000th of the distance from the North Pole to the Equator. Areas and volumes were defined by dimensions based on the standard meter. The mass standard was based on the mass of water of a particular volume at a specific temperature and pressure. This system was adopted fairly rapidly by the scientific community. Almost all scientific work is now done in metric units. It has taken much longer to be adopted in common practice and engineering applications.

Local units still persist in common practice in many areas, even where the metric system is mandatory. In some cases, the name of a unit is historical, but the value has been re-defined to some metric equivalent. This complicates conversions between units measured long ago and modern units.

In engineering practice, U.S. Customary units are commonly applied alongside S.I. metric units, especially in the United States. Pipe and flange sizes, for instance, still use the U.S. Customary or English Engineering designations.

The parallel application of metric and US units has frequently led to mismatches in equipment or commodities sourced from different locations around the world (globalization). In some cases this can become a serious safety problem, as in the case of an airliner a few years ago that nearly ran out of fuel because the fuel had been measured in metric units; whereas the pilots had specified the fuel quantity in English units.

Increasingly, globalization of industry and trade is requiring common units be used and the clear trend is toward metric units. The only nations still using U.S. Customary units as standards are Burma, Liberia, and the United States. In the United States, the U.S. Customary measures are actually defined in terms of metric measurements.

There is an incredibly large economic base in the U.S. founded on the U.S. Customary system of measurement. Converting this to metric would be extremely costly and risky. These are the primary reasons holding back conversion. At some point, the U.S. will have to make metric measurement mandatory and the old systems will disappear. When this will happen is unknown.

The metric and U.S. Customary units and their histories will be explored in more detail in a later chapter. For now, the key drivers toward standardization of units are:

- Development of trade
- Development of science and technology
- Globalization of industry

Measurement Units and Mathematics

If we look at the way measurement units are built into systems, we see that generally each successively larger unit is a multiple of the previous smaller unit or may be a specific fraction of a still larger unit. The multiples do not always seem to make sense at first glance. Why would a troy pound be 12 ounces and an Imperial pound be 16 ounces?

A measurement system for a property starts with a named, base unit. The relevant quantity is described as multiples or fractions of the base unit. For convenience, additional “named” units are often defined which are usually multiples or fractions of the base unit. For example, with “pound” as a base unit, a couple of the named fractions are “ounce” ($1/16$ th of a pound) and “grain” ($1/7000$ th of a pound). Multiples include “hundredweight” (100 pounds in U.S.) and “ton” (2000 pounds in U.S.).

To understand the way the systems were developed, you need to consider the mathematical systems used within a society and the practical problems of dividing quantities of items or bulk materials.

For convenience, we can think of the relationships among the units as being based on whole numbers, fractions, or the special case of decimals and magnitudes.

Whole Numbers

Many measurement systems started with the smallest unit being something like a grain of barley or a carob seed. Each next larger unit is an even number multiple of the smallest unit. Hence, the system is based on whole numbers. This simplifies the mathematics somewhat.

The whole numbers that were selected for the multiples were not necessarily random. They offered certain advantages in simplifying calculations, especially the ability to divide quantities easily.

For instance, the 12 ounces in a troy pound could be divided evenly by 1, 2, 3, 4, 6, and 12 in our number system. This provides a large number of ways to split the troy pound.

An Imperial pound (or U.S. Customary pound) has 16 ounces. It can be divided by 1, 2, 4, 8, and 16. These are all based on 2^n . Hence, if you had 16 ounces of grain, you can just repeatedly divide by 2 to create smaller units.

In the absence of calculators, this approach is easy to use for trade.

For larger units, a base unit, like a pound or gram, is just multiplied by a whole number or added a whole number of times to create larger units. So, a yard is 3 times a foot and a rod is 2 times a yard, as examples.

We work today primarily in the base 10 number system, where we use 9 digits plus zero. This has not always been the basis for mathematics. Originally, things were just counted by tally marks—essentially a base 1 system. Eventually, the tally marks were grouped to make the first number systems. Logical groupings for counting based on anatomical features would have been one hand (base 5), two hands (base 10), fingers-only (bases 4 or 8), and all fingers and toes (base 20). The Mesopotamians, used a base 60 number system about 3400 BC. The Mayas used a system based on 4, 5, and 20 which originated from a much older Olmec system around the 4th century BC [9ddd, 30, 32].

The Chinese and much of eastern Asia used a base 10 system for relative sizes of units, with some odd divisions thrown in [9, 26]. The use of the abacus for calculation made base 10 (or sometimes base 8) easy to use.

When you consider the units of measurement used in these societies, you can see the influence of the number system bases on the relative sizes of the units.

Fractions and Rational Numbers

Some measurement unit systems employ rational numbers or fractions instead of whole numbers to create the proportions of units. This practice probably dates from very early times. You see this practice in Maltese weight measures, for instance, where one rotolo is $7/4$ of a libra and one qsimma is $5/4$ of a rotolo [9zz]. When relative proportions of measurement units look a little odd, it is probably because they are based on fractions of rational numbers.

***Decimals* [4]**

The metric system commonly used today is based on decimals for proportions between units. Hence, we have each successively larger unit being 10 times the next smaller unit. Using this base 10 system or decade arrangement works well with the common base 10 mathematical system we use today.

Evolution of Measurement Units and Historical Influences

The units of measurement within a region evolve over time along with the history of that region. This was alluded to earlier. Table 1.3, is an attempt to summarize the historical and political changes that have shaped the units of measurement in each current and proposed nation and region in the world over the past, roughly, 6000 years of recorded history. Essentially, it is a timeline for what would have influenced measurement. The data for this table has been compiled from virtually all the sources listed in the “References” section; hence, the reference numbers are not repeated here.

Table 1.3 is necessarily a rough outline, but you can infer how units would have evolved.

Few original, native or prehistoric units are still found in most areas. Invasion, conquest, migration, trade, occupation, colonization, and many other factors have influenced units throughout history. Understanding how the measurement units in each locale would have evolved can help in understanding and quantifying the archeological record. You can infer what units the area might have been using at a particular point in history.

A couple of general patterns can be seen in the data:

- There are a few dominant systems which spread from their origins to other parts of the world:
 - Middle-eastern units (Mesopotamian [9], Egyptian [9, 27], Arab [7, 9], Byzantine [9], Ottoman [9]).
 - Indian units [9, 31].
 - Chinese units [9, 25, 26].
- Native units, if any, were essentially wiped out in most cases or adapted in other cases by invaders and colonizers.
- Metric units have been adopted only slowly over the past two centuries [2, 11, 21].

You can trace the spread of the dominant systems fairly easily in the timeline of Table 1.3. For instance, the early measurement systems developed in the Middle East can be seen to spread westward into Egypt and then southward from Egypt into Ethiopia. The system also spread northward into Turkey, across the Straits to Greece and on into Europe, as well as along the coasts of the Indian Ocean and into

Table 1.3 Historical origins and evolution of regional measurement systems. Refer to References section for data sources

Nation (English Name)	Region	Short history notes relevant to measurement units	Metric System [11], Nominally SI
Afghanistan	South-Central Asia	Prehistoric native & local. Persian Empire. ~ 333 BC: Alexander the Great. Trade route to India. 7th century AD: Arabs & Islam. 13th & 14th centuries AD: Mogol invasions. 19th century AD: British & Russian fighting over area. 1893: British control. 1919: independent	1923
Albania	Southern Europe	Prehistoric native & local units. As early as 8th century BC: Part of Illyria (Greece). ~ 168 BC: Roman Empire. 535 AD–1204 AD: Byzantine Empire. 1460s–1912 AD: Ottoman Empire. 1912: Independent	1948
Algeria	Northern Africa	Prehistoric native & local units. ~ 500,000–700,000 years ago: Earliest habitation indicated. ~ 1000 BC: Phoenician trade. 145 BC: Part of Roman colony. 440 AD: Vandal conquest. 650 AD: Arabs & Islam. 1536 AD: Ottoman Empire. 1830–1962 AD: French control. 1962 AD: independent	1840, under French
American Samoa	Polynesia, Oceania	Prehistoric native & local units. 1830s AD: English missionary influx. 1800 s AD: USA-German conflict. 20th century AD: USA control, customary units	Not applicable
Andorra	Southern Europe	Prehistoric native & local units. Early Roman influences. 988 AD: Formed as a nation. 1278 AD: Joint Spanish/French control, but mostly Spanish influence. To 19th century AD: Medieval organization. Probably metric with Spain & France in 1800s AD	Probably 1800s with Spain & France
Angola	Central Africa	Prehistoric native & local units. 16th century AD: Portuguese control. 1975 AD: Independent	w/Portugal ~ 1872
Anguilla	Leeward Islands, Caribbean	Prehistoric native & local units. ~ 1564 AD: French colonizers. 1650 AD: English colonizers. British Protectorate	w/UK ~ 1960s
Antarctica	Antarctica	No native population. Starting 19th century AD: Measurement systems brought by explorers. Primarily scientific use with SI units. Not a formal nation	Yes

(continued)

Table 1.3 (continued)

Nation (English Name)	Region	Short history notes relevant to measurement units	Metric System [11], Nominally SI
Antigua and Barbuda	Leeward Islands, Caribbean	Prehistoric native & local units. ~1632 AD: English colonization. 1981 AD: Independent	w/UK ~1960s
Argentina	Southern South America	Prehistoric native & local units. ~1550 AD: Spanish colonization. 1810 AD start of revolt for independence. 1861 AD: Independent modern state. Retained Spanish units until SI units were adopted	1886
Armenia	Western Asia	Prehistoric native & local units. ~3000 BC: Mesopotamian influence. ~300 BC: Greeks. ~150 BC Romans. 1045 AD: Byzantine Empire. Arab influence. 16th century AD to 1800 s AD: Ottoman Empire. 19th to 20th centuries AD: Russian influence and control. 1990 AD: Independent	w/Russia ~1925
Aruba	Leeward Islands, Caribbean	Prehistoric native & local units. 1636 AD: Dutch colonization. 1986 AD: Autonomous member of Kingdom of the Netherlands	w/Netherlands ~1820
Australia	Australia/Oceania	Prehistoric native & local units. ~1820 AD: English colonization with local standards. 1800s AD: standardized to English units. Since ~1960 AD: Mixture of SI and non-SI units	1969
Austria	Western Europe	Prehistoric native & local units. Since ~150 BC: Roman and local influences. ~1756 AD: Standardized units similar to rest of Europe. 1871 AD: adopted SI system	1871
Azerbaijan	Caucasus, Western Asia	Prehistoric native & local units. Successive Arab, Kazar, and Turkish influences. 11th century AD: Turkish & Persian control. 1813 & 1828 AD: Russia. 1991 AD: Independent	w/Russia ~1925
Bahamas	Caribbean	Prehistoric native & local units. 17th century AD: English colonization. 1717 AD: English crown colony. 1964 AD: Self rule under UK. 1969 AD: British Commonwealth. 1973 AD: Independent	w/UK ~1965
Bahrain	Arabian Peninsula, Middle East	Prehistoric native & local units. 3rd century BC: Arab. 4th century AD: Persian. 4th century AD–1541 AD: Arab control. 1541 AD: Portuguese control. 1602 AD: Persian control. 1820 AD: British Protectorate. 1971: Independent	w/UK ~1960s

(continued)

Table 1.3 (continued)

Nation (English Name)	Region	Short history notes relevant to measurement units	Metric System [11], Nominally SI
Bangladesh	South-Central Asia	Prehistoric native & local units. ~1000 BC; Indian influence. ~1576 AD; Arab & Persian influence. 1757–1947 AD; British control. 1947–1971 AD; Pakistani control. 1971 AD; Independent	w/Pakistan ~1967
Barbados	Lesser Antilles, Caribbean	Prehistoric native & local units. Native Arawaks. 1627 AD; British colony. 1966 AD; Independent member of British Commonwealth	w/UK ~1960s
Belarus	Eastern Europe	Prehistoric native & local units. 5th century AD; Slavic and Russian influence. 9th–12th century AD; Russian control. 13th century AD to ~1795 AD; Various Eastern European dominations. 1795–1918 AD; Russian influence. Satellite of USSR. 1991 AD; Independent	w/Russia ~1925
Belgium	Western Europe	Prehistoric native & local units. 57 BC; Roman Empire. 5th century AD; Franks. 8th century AD; Charlemagne and Holy Roman Empire. Various influences and occupiers—French, Spanish, Austrians. French control. Dutch control. 1830 AD; Independent	w/Netherlands ~1820
Belize	Central America	Prehistoric native & local units. 1500 BC - ~1200 AD; Mayan control. ~1638; English control. 1840; British colony. 1964 AD; Self government in British Commonwealth. 1981; Independent	w/UK ~1960s
Benin, Republic of	West Africa	Prehistoric native & local units. 1893 AD; French control. 1958 AD; Autonomous French territory. 1960 AD; Independent. Probably already metric under French	1960
Bermuda	North America	Prehistoric native & local units. 1612 AD; English settlement. 1684 AD; British colony. 1968 AD; Self government in British Commonwealth	w/UK ~1960s
Bhutan	South-Central Asia	Prehistoric native & local units. ~2000 BC; evidence of civilization. Feudal organization. 1907 AD; British influence. Indian influence. Never colonized. Probably metric adopted from Indian influence	1954
Bolivia	Central South America	Prehistoric native & local units. Incan domination. 16th century AD; Spanish conquest. 1825 AD; Independent.	1891

(continued)

Table 1.3 (continued)

Nation (English Name)	Region	Short history notes relevant to measurement units	Metric System [11], Nominally SI
Bosnia and Herzegovina	Southern Europe	Prehistoric native & local units. 2nd to 1st centuries BC: Roman Empire. 4th–5th centuries AD: Goths. 6th century AD: Byzantine Empire. 7th century AD: Slavic influx. 1200–1460 AD: Independent state. 1463 AD: Ottoman Empire. 1908 AD: Austro-Hungarian Empire. 1929 AD: Part of Yugoslavia. 1941 AD: German control. 1945 AD: Russian influence and control. 1991 AD: Independent	w/Aust./Hung. influence 1870s
Botswana	Southern Africa	Prehistoric native & local units. 1870s–1880 AD: Dutch influence. 1885 AD: British control. 1966 AD: Independent	w/UK ~ 1960s
Brazil	Central Eastern South America	Prehistoric native & local units. 1500 AD: Portuguese colonization. 1822 AD: Independent	1862
Brunei Darussalam	Southeast Asia	Prehistoric native & local units. 6th century AD: Chinese influence. 13th–15th centuries AD: Indian/Hindu influx. 16th–19th centuries AD: Islamic influence. 1888 AD: British control. 1984 AD: Independent	w/UK ~ 1960s
Bulgaria	Balkan, Eastern Europe	Prehistoric native & local units. ~3500 BC: Greece. 1st century AD: Roman Empire. 679–865 AD: Bulgar and other invaders. 1396 AD: Ottoman Empire. 1878 AD: Russian influences. 1908: Independent, but still Russian influenced	1891
Burkina Faso	West Africa	Prehistoric native & local units. 1897–1960 AD: French control. 1960 AD: Independent. Metric units from French influence	1960
Burundi	Eastern Africa, African Great Lakes	Prehistoric native & local units. To ~ 1923 AD: German influence. 1923–1962 AD: Belgium control. 1962 AD: Independent. Metric adoption during German influence	1910
Cambodia	South-East Asia	Prehistoric native & local units. ~600 AD: Khmer rule from India (Hindus). 1863 AD: French colony. 1949 AD: Independent rule as part of French Union. 1960 AD: More or less independent	1922

(continued)

Table 1.3 (continued)

Nation (English Name)	Region	Short history notes relevant to measurement units	Metric System [11], Nominally SI
Cameroon	Central Africa	Prehistoric native & local units. Bantu people. 18th–19th century AD: Muslim influence. 1884 AD: German colony. ~ 1920–1940 AD: British and French control. 1946 AD: Reunified and independent	1961
Canada	North North America	Prehistoric native & local units. ~ 1000 AD: Viking exploration. British exploration. 1534 AD: French settlement. 1670 AD: Competing English & French colonization. 1763 AD: British control. 1849 AD: Self rule under British. 1968 AD: French-speaking groups control politics	1970
Cape Verde	West Africa	Originally uninhabited when discovered. 1495 AD: Portuguese settlement. 1951 AD: Portuguese province. 1961 AD: Portuguese citizenship. 1975 AD: Independent	~ 1872 with Portugal
Cayman Islands	Greater Antilles, Caribbean	Prehistoric native & local units. Discovery to 1959 AD: British administered as part of Jamaica. 1962 AD: British control	w/UK ~ 1960s
Central African Republic	Central Africa	Prehistoric native & local units. 16th–19th centuries AD: Raided by slave traders. 1894 AD: French occupation. 1946 AD: Self-rule under French. 1958 AD: Autonomous French Community. 1960 AD: Independent. Inherited SI system from France	1960
Chad	Central Africa	Prehistoric native & local units before 500 BC. 8th century AD: Berbers. 1085 AD: Islam influence. 16th century AD: Fragmented rule. 1883–1893 AD: Ruled by Sudan. 1900 AD: Occupied by French. 1946 AD: Autonomous French Colony. 1960 AD: Independent. Inherited SI units from French	1960
Chile	Western South America	Prehistoric native & local units. Pre-1500 AD: Incan control. 1541 AD: Spanish conquest and colonization. 1824 AD: Independent	1865

(continued)

Table 1.3 (continued)

Nation (English Name)	Region	Short history notes relevant to measurement units	Metric System [11], Nominally SI
China	Eastern Asia	Prehistoric native & local units as early as 5000 BC. 1500–1000 BC: Shang Dynasty. Various dynasties for many centuries provided some continuity. Periodic feudal periods. 1271–1368 AD: Mongol control starting with Genghis Khan. 1644 AD: Invasion from north. To ~18th century AD: Maintained isolation. 1839–1908 AD: Various Western powers vied for control. 1911 AD: Independent. 1931 AD: Japanese control. 1945 AD: Independent. 1949 AD: Establishment of People’s Republic of China	1925
Christmas Island	Southeast Asia	Originally uninhabited. 1600s AD: Discovered by English and Dutch. 1857 AD: First exploration by English. 1888 AD: Annexed by Britain with administration by Singapore colony. Indentured Chinese labor used. 1942–1945 AD: Japanese occupation. 1958 AD: Administration passed to Australia	w/Australia
Cocos (Keeling) Islands	South-East Asia, Australia	Originally uninhabited. 1609 AD: Discovered by English. 1814 AD: Earliest settlement by English. 1857 AD: Annexed by Britain with administration from Singapore colony most of this period. 1955 AD: Administration passed to Australia	w/Australia
Colombia	North West South America	Prehistoric native & local units. 1510 AD: Spanish conquest. 1824 AD: Independent	1853
Comoros	Eastern Africa	Prehistoric native & local units. Visits by traders from Africa, Madagascar, Indonesia, and Arabia with Arabs dominating. 1843–1904 AD: French control. 1975 AD: Independent	Probably 1800s w/ France
Democratic Republic of the Congo (Kinshasa, Zaire)	Central Africa	Prehistoric native & local units were likely Negrito, Bantu, and Nibotic based. 1885 AD: Belgium influence and territory. 1960 AD: Independent. Inherited SI system from Belgians	1960
Congo, Republic of (Brazzaville)	Central Africa	Prehistoric native & local units. ~1000 AD: Kongo people. To 17th century AD: Loango. Tio people. 1482 AD: Portuguese control. 1880 AD: French control. 1910 AD: French colony. 1960 AD: Independent within the French Community. Adopted SI units with French	1910

(continued)

Table 1.3 (continued)

Nation (English Name)	Region	Short history notes relevant to measurement units	Metric System [11], Nominally SI
Cook Islands	Polynesia, Oceania	Originally uninhabited. 600 AD: Polynesians from Tahiti. 1595 AD: First Spanish contact. 1821 AD: English missionaries. Peruvian raiders for labor. 1888 AD: British Protectorate. 1901 AD: Included in British Colony of New Zealand. 1965 AD: Self-governing territory freely associated with New Zealand	With New Zealand & UK in 1960s
Costa Rica	Central America	Prehistoric native & local units. 1524 AD: Spanish control. 1821 AD: Independent, but combined with Mexico. 1848 AD: Independent nation	1909
Ivory Coast (Côte d'Ivoire)	West Africa	Prehistoric native & local units. 15th century AD: Portuguese and French trade. 1842 AD: French control. 1893 AD: French territory. 1940s AD: Autonomous French Republic. 1959 AD: Customs Union (French). 1960 AD: Independent. Inherited metric units from French	1959
Croatia	Southern Europe	Prehistoric native & local units. Known as Pannonia in Roman times. 7th century AD: Croats. 7th–9th centuries AD: Charlemagne & Holy Roman Empire dominated. 11th century AD: Independent nation. 1091 AD: Hungarian control. 1867 AD: Austrian control. 1918 AD: Independent again. 1929 AD: Part of Yugoslavia. 1941 AD: German control. 1945–1991 AD: Russian (USSR) sphere of influence. 1991 AD: Independent. metric probably introduced during Austrian control	Probably during 1800s
Cuba	Greater Antilles, Caribbean	Prehistoric native & local units from Arawaks and Tainos. 1511 AD: Spanish control. 1898 AD: Independent. 1899 AD: USA Protectorate. 1933 AD: Independent. 1960–1990 AD: USSR influence. Still basically independent. Metric units probably inherited from Spain	1858
Cyprus	Mediterranean, Western Asia	Prehistoric native & local units. BC period: Phoenician and then Greek colony. Multiple rulers over centuries. 1571 AD: Turkish (Ottoman) rule. ~ 1915 AD: British control. 1925 AD: British Colony. 1960s–1980s AD: Turkish & Greek fighting over island. 1960 AD: Independent	Unclear timing

(continued)

Table 1.3 (continued)

Nation (English Name)	Region	Short history notes relevant to measurement units	Metric System [11], Nominally SI
Czech Republic	Eastern Europe	Prehistoric native & local units. 5th century AD: Slavic tribes influx. 10th–16th centuries AD: Bohemian control. 1300–1400 AD: Holy Roman Empire influence. 1620–1918 AD: Austrian Empire. ~1920 AD: Independent. 1946–1989 AD: Russian (USSR) sphere of influence. 1993 AD: Split with Slovakia to become separate nation	1875 during Austrian period
Denmark	Northern Europe	Prehistoric native & local units. 10,000–1500 BC: Habitation evidence. 9th–11th centuries AD: Raided Europe and British Isles. Engaged or involved in various wars, unions, and splits for centuries. 1800s AD: French and Austrian influence, but essentially remained independent. 1940s AD: German control. Independent again following World War II	1909
Djibouti	Eastern Africa	Prehistoric native & local units. 3rd century BC: Arab influence. 825 AD: Islam influx. 1843–1977 AD: French control. 1977 AD: Independent. Metric inherited from French	Probably 1800s
Dominica	Lesser Antilles, Caribbean	Prehistoric native & local units. Before 1763 AD: British & French influence. 1763 AD: British control. 1967 ADF: Self government under UK	w/UK ~1960s
Dominican Republic	Greater Antilles, Caribbean	Prehistoric native & local units. 1496 AD: Spanish influx and settlement. 1795 AD: French control. 1801 AD: Haitian control. 1801–1814 AD: Independent. 1814 AD: Spanish control. 1822 AD: Return to Haitian control. 1844 AD: Independent. 1861–1865 AD: Spanish protection. 1870 AD: Attempts to be annexed by USA failed. 1916–1924 AD: USA intervention. 1930 AD: Essentially independent, but continuing foreign intervention until ~1966 AD	1912
East Timor (Timor-Leste)	South-East Asia	Prehistoric native & local units. 1520 AD: Portuguese colony. 1613 AD: Dutch colonization. Portuguese/Dutch fighting. 1860 AD: Portuguese control. ~1941–1945 AD: Australian & Japanese fighting. 1945–1976 AD: Portuguese control. 1976 AD: Indonesian control. 1999 AD Independent	Probably w/Portugal 1870s

(continued)

Table 1.3 (continued)

Nation (English Name)	Region	Short history notes relevant to measurement units	Metric System [11], Nominally SI
Ecuador	North West South America	Prehistoric native & local units. 1000s AD: Kingdom of Quito. Incan control. 1532 AD: Spanish conquest. 1819 AD: Part of Greater Colombia after independence from Spain. 1830 AD: Independent	1865
Egypt	Africa, Middle East	Prehistoric native & local units. ~4000 BC: Upper & Lower Egypt united. 525 BC: Persian control. 332 BC: Alexander the Great conquest. To 30 BC: Ptolemaic control. Roman Empire. Byzantine Empire. 641-1577 AD: Arab control and Islam. Ottoman Empire. 1798-1801 AD: French control. 1882 AD: British & Turkish control. 1914 AD: British Protectorate. 1922 AD: Independent. USSR Influence. Controlled by various powers over years since	Probably w/French 1800s
El Salvador	Central America	Prehistoric native & local units. 11th century AD: Aztec and Pipil peoples. 1525 AD: Spanish conquest. 1821 AD: Independent along with other nearby nations. Various disputes since independence	1884
Equatorial Guinea	Central Africa	Prehistoric native & local units (Pygmies). 17th to 19th centuries AD: Fang and Bubi peoples. Portuguese influence. 18th century AD: Spanish control. 1827-1844 AD: British influence. 1968 AD: Independence from Spain	Probably w/Spain in 1800s
Eritrea	Eastern Africa	Prehistoric native & local units. To 8th century AD: Part of Ethiopian Kingdom of Aksum. 16th century AD: Ottoman Empire. 18th century AD: Egyptian control. 1885-1940 AD: Italian colony. 1941 AD: British control. 1952 AD: Ethiopian control. 1993 AD: Independent	Probably w/Ethiopia 1960s
Estonia	Northern Europe	Prehistoric native & local units. Before 13th century AD: Invasion attempts by Vikings, Danes, Swedes, and Russians. Danish control. 1346 AD: German control. 1526 AD: Swedish control. 1721 AD: Russian control. 1920 AD: Independent. 1940 AD: Russian control. 1941-1945 AD: German control. 1944-1990 AD: Russian sphere of influence. 1990 AD: Independent	Probably during Russian periods

(continued)

Table 1.3 (continued)

Nation (English Name)	Region	Short history notes relevant to measurement units	Metric System [11], Nominally SI
Ethiopia	Eastern Africa	Prehistoric native & local units. 5.8–5.2 million BC: Earliest occupation. Originally Abyssinia. Roman Empire. Byzantine Empire. 3rd–7th centuries AD: Arab invasion & Islam. 1896 AD: Independent. 1935 AD: Italian control. 1941 AD: British control. ~1950 AD: Returned to independence. Various ongoing conflicts since independence	1962
Falkland Islands	Southern South America	Prehistoric native & local units. 1690 AD: British control. 1690–1820 AD: French, Spanish, & British fighting over islands. Argentine control. 1833 AD: British control established. 1892 AD: British colony. 1995 AD: British territory. Disputed with Argentina	Probably with UK in 1960s
Faroe Islands	Northern Europe	Prehistoric native & local units. ~8th century AD: Vikings. 1386 AD: Denmark. 1948 AD: Home rule under Denmark	Probably with Denmark 1900s
Fiji	Melanesia, Oceania	Prehistoric native & local units. ~2 million BC: Earliest evidence of habitation. British & Dutch influences. 1874 AD: British control. 1880–1920 AD: Influx of Indian labor as indentured servants. 1970 AD: Independent	w/UK ~1960s
Finland	Northern Europe	Prehistoric native & local units of Sami & Lapp peoples. 1st millennium BC: Influx of Finnish. 1157 AD: Swedish control. 1809 AD: Russian influence. 1917 AD: Independent. 1939 AD: USSR sphere of influence. 1941 AD: German influence. 1941–1948 AD: USSR sphere of influence. Independent	1886 w/Russian influence
France	Western Europe	Prehistoric native & local units beginning in Paleolithic period. Celts & Gauls. ~600 BC: Greek & Phoenician influences. 57 BC–5th century AD: Roman Empire. 5th century AD: Franks and German invasions. 9th century AD: Charlemagne and Holy Roman Empire. ~900 AD: Independent. ~1453 AD: Unification of France. 1789 AD: French revolution. 1790s AD: Metric system developed. Various conflicts and metric system in and out various times	1795 (initially)

(continued)

Table 1.3 (continued)

Nation (English Name)	Region	Short history notes relevant to measurement units	Metric System [11], Nominally SI
French Guiana	Northern South America	Prehistoric native & local units. Spanish, Dutch, & French settlements and influences. 1667 AD: French control. 1852-1939 AD: French penal colony. 1947 AD: French Overseas Department	Probably ~1800 with France
French Polynesia	Polynesia, Oceania	Prehistoric native & local units. ~1798 AD: French control. 1903 AD: Consolidated as a French colony	Probably ~1800 with France
French Southern Territories	Southern South America, Antarctic	Mostly originally uninhabited. French control	Probably ~1800 with France
Gabon	West Africa	Prehistoric native & local units from Babinga and Pygmy peoples starting ~7000 BC. Bantu influx. 15th century AD: Portuguese exploration. 1593 AD: Dutch exploration. 1630 AD French exploration. 1839-1888 AD: French settlement and territory. ~1945 AD: French Autonomous Republic. 1960 AD: Independent. Metric inherited from French	1960
Gambia, The	West Africa	Prehistoric native & local units. Since 13th century AD have seen Wolof, Malinke, and Fulani peoples. 1455 AD: Portuguese exploration. 1681 AD: French influx. 17th century AD: English colonization. 1843 AD: British Crown Colony. 1965 AD: Member of British Commonwealth. 1970 AD: Independent	w/UK ~1960s
Georgia	Western Asia	Prehistoric native & local units. 4 BC: Independent kingdom. 337 AD: Arrival of Christianity. ~1200 AD: Part of Transcaucasia. 13th century AD: Mongol & Tamerlane invasions. 16th-18th centuries AD: Fought over by Persia and Turkey. 18th century AD: Russian control. 1917 AD: Independent. 1922 AD: USSR member state. 1991 AD: Independent	w/USSR 1920s

(continued)

Table 1.3 (continued)

Nation (English Name)	Region	Short history notes relevant to measurement units	Metric System [11], Nominally SI
Germany	Western Europe	Prehistoric native & local units. Celts. By end of 2nd century BC: Influx of Germanic tribes. ~1st century BS-4th/5th centuries AD: Roman control or influence. ~800 AD: Charlemagne and Holy Roman Empire control. 1600s AD: Fragmented feudal organization. 1700s AD: Prussian control. 1860 s AD: Involved in Austrian/Prussian conflicts. 1871 AD: Unified nation. Various periods of outside control from 1845–1990. 1945–1990 AD: Cold war, East versus West with Germany between—two Germanys. 1990 AD: Reunified and independent	1872
Ghana	West Africa	Prehistoric native & local units. Before 13th century AD: Several civilizations rose and fell in country. 13th century AD: Akan civilization. 18th–19th centuries AD: Ashanti civilization. 1820 AD: British rule. 1956 AD: Incorporated into Togoland by Germany. 1957–1960 AD: Independent. Since 1960 AD: Influenced by Soviets and Chinese at various times, upheaval but independent	Unknown timing, likely inherited during 1960s
Gibraltar	Southern Europe	Prehistoric native & local units. 711 AD: Moor control. 15th century AD: Spanish control. 1704 AD: British and Dutch control. 1713 AD: British Protectorate	w/UK ~1960s
Great Britain (England, Wales, Scotland)	Northern Europe	Prehistoric native & local units. Celts. 1st century BC-5th century AD: Roman Empire. Invasions by Angles, Saxons, and Jutes. Established Anglo-Saxon kingdoms during middle ages and feudal period. 10th century AD: Mostly unified. 1066 AD: French/Norman conquest. After ~1450 AD: Increasingly independent nation and empire. Home of the United Kingdom or British Empire	1965
Greece	Southern Europe	Prehistoric native & local units. ~2000 BC: Influx if Indo-European peoples, Mycenaeans. ~1200 BC: Dorians. ~750 BC: Classical Greek period started. Extensive trade contacts. 5th century BC: Peak of Greek culture. ~400 BC: Macedonian dominance. 2nd century BC-1204 AD: Roman Empire and Roman control/influence. 1453 AD: Turkish control. 1460 AD: Ottoman Empire. 1827 AD: Independent, despite numerous territorial conflicts ongoing to present	1957

(continued)

Table 1.3 (continued)

Nation (English Name)	Region	Short history notes relevant to measurement units	Metric System [11], Nominally SI
Greenland	North America	4000 BC–1000 AD: Prehistoric native & local units from Inuit. 985–986 AD: Colonized by Norse people, but abandoned in 5th century AD. 1721 AD: Recolonized by Denmark. ~1941–1945 AD: USA Protectorate with Danish government. 1953 AD: Danish control. 1979 AD: Home rule under Denmark. ~2009: Independent	w/Denmark early 1900s
Grenada	Lesser Antilles, Caribbean	Prehistoric native & local units from Arawak Indians. Before ~1500 AD: Driven off by Carib Indians. 1672–1762 AD: French control. 1762 AD: British control. 1974 AD: Independent	w/UK ~1960s
Guadeloupe	Lesser Antilles, Caribbean	Prehistoric native & local units. 1635 AD: French colonization. 1674 AD: French Domain. 1946 AD: Overseas Department of France	w/France 1800s
Guam	Micronesia, Oceania	Prehistoric native & local units. 1565 AD: Spanish control. 1898 AD: USA control. 1941–1944 AD: Japanese occupation. ~1950 AD: USA territory	Not applicable
Guatemala	Central America	Prehistoric native & local units. To 1524 AD: Dominance of Mayan civilization. 1524 AD: Spanish conquest and control. 1839 AD: Independent republic. Various regimes controlled nation, but remains independent	1915
Guinea	West Africa	Prehistoric native & local units. ~900 AD: Susi migration, reached height in 13th century AD. 13th–19th centuries AD: Fulani Empire. 1849 AD: French Protectorate. 1895 AD: Part of French West Africa. 1958 AD: Independent. Inherited metric units from French	1959
Guinea-Bissau	West Africa	Prehistoric native & local units. Was Kingdom of Gabú in the Mali Empire. 1546 AD: Mostly autonomous. Starting 1446 AD: Increasing Portuguese control. 1974 AD: Independent. Inherited metric units during Portuguese period	w/Portugal 1870s

(continued)

Table 1.3 (continued)

Nation (English Name)	Region	Short history notes relevant to measurement units	Metric System [11], Nominally SI
Guyana	North Eastern South America	Prehistoric native & local units. Warrow people. Dutch, English, and French colonies over parts of area. 17th century AD: Majority of area was Dutch. 1831 AD: British take control of some of the area. 1928 AD: British Crown Colony. 1953 AD: Home rule granted under British. 1961 AD: Autonomous rule within British Empire. 1966 AD: Independent	w/UK ~1960s
Haiti	Greater Antilles, Caribbean	Prehistoric native & local units. Inhabited by Arawak Indians before 1500s AD. 16th century AD: Spanish exploration. 1697 AD: French colony. 1804 AD: Independent. 1905–1941 AD: USA “Customs Receivership”, but still essentially independent. 1941 AD: Independent	1920
Holy See	Southern Europe within Italy	See Vatican City	Unknown timing
Honduras	Central America	Prehistoric native & local units. 1st millennium AD: Dominated by Mayan civilization. ~1502–1821 AD: Spanish conquest and control. 1838 AD: Independent. Early 1900s AD: USA occupation, still considered independent. 1969 AD: El Salvador invasion. 1972 AD: Independent	1911
Hong Kong	Eastern Asia	Ancient Chinese units. British control and English units during British occupation along with traditional Chinese units. Chinese zone since ~1999 AD. Inherited metric units from British	Probably w/UK during 1960s
Hungary	Eastern Europe	Prehistoric native & local units. 14 BC: Roman Empire along with Germanic & Asiatic peoples. 896 AD: Magyar invasion. 977–1038 AD: Christianity. 1241 AD: Mongol invasion. 1300s AD: Peak of Medieval state. 1389 AD: Turkish invasion. 1526 AD: Austrian/Hapsburg rule. To 1699 AD: Warring with Turks for control. 1867 AD: Austro-Hungarian Empire. 1919 AD: Russian influence and control. ~1940–1945 AD: German control. 1945–1990 AD: USSR sphere of influence. ~1990 AD: Independent	1876 during Austrian period
			(continued)

Table 1.3 (continued)

Nation (English Name)	Region	Short history notes relevant to measurement units	Metric System [11], Nominally SI
Iceland	Northern Europe	Once inhabited by Irish hermits. ~900 AD: Norse settlement. ~930–1262 AD: Independent. 1262–1264 AD: Beginning of rule by Norway. 1397 AD: Danish rule established. 1918 AD: Independent, but still Danish. 1944 AD: Independent. Inherited metric units from Danish	1900
India	South-Central Asia	Prehistoric native & local units. ~2600–2000 BC: Part of Indus Valley civilization. ~1500 BC: Aryan invasion. 6th century BC: Buddhism influence. 269–232 BC: Unified area. 1526 AD: Muslim invasion and Mogul Empire established. 1857 AD: Akbar the Great standardized measurements. 1498–1598 AD: Portuguese trade. 1612 AD: British East India Company influence and control. 1687 AD: British rule. 1858 AD: British Crown Colony. 1935 AD: Self rule within British Empire. 1947 AD: Full independence. Muslim portion split off as Pakistan. Continuing border issues. Until 1961 AD, still foreign claims and possessions in India	1954
Indonesia	Maritime South-East Asia	Prehistoric native & local units. 1st–2nd centuries AD: Hindu influx. 13th–15th centuries AD: Muslim invasions. 15th century AD: Portuguese influence. 16th century AD: Dutch influence and control. 1811 AD: British control. 1816 AD: Dutch regained control. ~1941–1944 AD: Japanese occupation. 1949 AD: Netherlands/Indonesian Union. 1956 AD: Independent	1946
Iran (Islamic Republic of)	South-Central Asia	Prehistoric native & local units. 1500 s BC: Dominated by Mede and Persian Empires. 525 BC: Peak of Achaemenid Empire. 331 BC: Conquered by Alexander the Great. ~312 BC–640 AD: Successive invasions and control by Seleucids, Greeks, Parthians, Sasanians, and Arab Muslims. Mid 800 s AD: Persian peak. 12th century AD: Mongol invasion and rule. 1501–1722 AD: Safavid Dynasty (Shiite Muslim). 1794–1925 AD: Qajar Dynasty, with Russian and British influence. 1925 AD: Unified area and independent. 1941 AD: Anglo-Russian occupation. Since 1979 AD: Theocracy	1927

(continued)

Table 1.3 (continued)

Nation (English Name)	Region	Short history notes relevant to measurement units	Metric System [11], Nominally SI
Iraq	Middle East, Western Asia	Prehistoric native & local units. Before 4000 BC: Mesopotamia, root of many measurement systems. To ~2000 BC: Babylonian and Assyrian Empires. 538 BC: Conquered by Persian Empire. 331 BC: Conquered by Alexander the Great. 637–640 AD: Arab conquest. 1258 AD: Mongol conquest. 16th–18th centuries AD: Turkish and Persian rule. 1831 AD: Turkish control. World War I -1922 AD: British occupation. 1932 AD: Full independence. Unrest and various influences and control since independence. USA invasion and influence since 2002	1930
Ireland	Northern Europe	Prehistoric native & local units. Stone and Bronze Age: Picts in north, Eranums in south. 4th century BC: Invasion by Celts from Gaul. Divided into 5 kingdoms. 432 AD: Christianity introduced. 795–1014 AD: Norse invasions. 12th century AD: English influence and control. 17th century AD: British rule. 1801 AD: Part of United Kingdom. 1922 AD: Irish Free State. 1949 AD: Majority of country independent. Northern Ireland still part of UK	1967
Israel [22, 23, 24]	Middle East, Western Asia	Prehistoric native & local units. Before 1200s BC: Philistines occupied area. 1000 BC: Hebrew invasion/influx. Invaded subsequently by Assyrians, Babylonians, Egyptians, Persians, Alexander the Great, and Romans. 135 AD: Few Jews remaining. Byzantine Empire rule. 634–640 AD: Arab/Muslim invasion and control. Remained Muslim to 20th century AD. Turkish control. 1923 AD: British control. 1947 AD: Partitioned to establish Jewish state. Various unsuccessful Arab invasions. Since 1949 AD: Independent	1946
Italy	Southern Europe	Prehistoric native & local units. ~2000–1000 BC: Indo-European migration. 9th–3rd Centuries BC: Etruscans. 264 BC: Roman Empire established. 4th & 5th centuries AD: Barbarian invasions. 800 AD: Holy Roman Empire. Period of city-states and feudalism. 805 AD: Unified by Napoleon. 1815 AD: Austrian control. 1870 AD: Reunified and independent	1863

(continued)

Table 1.3 (continued)

Nation (English Name)	Region	Short history notes relevant to measurement units	Metric System [11], Nominally SI
Jamaica	Greater Antilles, Caribbean	Originally inhabited by Arawak Indians before 1500 AD. ~1500–1655 AD: Spanish exploration and control. 1655 AD: British control. 1866 AD: British Crown Colony. 1953 AD: Home rule within British Empire. 1962 AD: Independent	1998
Japan	Eastern Asia	Prehistoric native & local units. 400 AD: Yamato unification. Through 700 s AD: Chinese influences, basically copied the culture. 700–1867 AD: Shogun period, feudal states, limited outside trade except with Dutch. 1853 AD: USA forced opening of trade. 1868 AD: Imperial system replaced Shoguns, more unified. To 1942 AD: Imperial expansion. 1945–1952 AD: World War II defeat and occupation. 1952 AD: Independent	1957
Jordan	Middle East, Western Asia	Prehistoric native & local units. During Biblical times, succession of empires: Edom, Moab, Ammon, and Bashan. Controlled by Assyrians, Babylonians, Persians. 330 BC: Seleucids, Nabataeans. 106 AD: Roman Empire. 633–636 AD: Arab invasion and control, Islam. 16th century AD: Ottoman Empire. World War I: British control. 1923 AD: Independent under British Empire. Since 1946 AD: Essentially independent	1952
Kazakhstan	Central Asia	Prehistoric native & local units came from Kazahks—unified and nomadic. 13th century AD: Mongols. 14th–18th centuries AD: Tatars. 18th century AD: Russian control. 1925 AD: Part of USSR. 1991 AD: Independent	From USSR
Kenya	Eastern Africa	Prehistoric habitation evidence ~2 million BC. Native & local units. 700s AD: Arab coastal contacts. 1500s AD: Portuguese control. 1890 AD: British Protectorate. 1920 AD: British Crown Colony. 1952–1956 AD: Mau Mau uprising. 1963 AD: Independent, with continued infighting	1967

(continued)

Table 1.3 (continued)

Nation (English Name)	Region	Short history notes relevant to measurement units	Metric System [11], Nominally SI
Kiribati, formerly Gilbert Islands	Micronesia, Oceania	Before 1st century AD: Settled by Austronesians. 14th century AD: Invaded by Fijians from Tonga. 1837 AD: British settlement. 1892 AD: British Protectorate. 1915–1916 AD: British Crown Colony. ~ 1941–1945 AD: Japanese occupation. 1975 AD: British self rule. 1979 AD: Independent	w/UK ~1960s
Korea, Democratic People's Rep. (North Korea)	Eastern Asia	Prehistoric native & local units. Inhabited since Neolithic times. Turk, Mongol, and Manchurian migrations from China. ~6000 BC; Agrarian settlements. ~2333 BC: Choson civilization. 17th century AD: Chinese vassal state. 1895 AD: Sino-Japanese War. 1910 AD: Annexed by Japan. Post World war II (1948 AD) partitioned from South Korea, placed under USSR sphere of influence. Continues as independent communist nation. See also South Korea	1948
Korea, Republic of (South Korea)	Eastern Asia	Prehistoric native & local units. Inhabited since Neolithic times. Turk, Mongol, and Manchurian migrations from China. ~6000 BC; Agrarian settlements. ~2333 BC: Choson civilization. 17th century AD: Chinese vassal state. 1895 AD: Sino-Japanese War. 1910 AD: Annexed by Japan. Post World war II (1948 AD) partitioned from North Korea, placed under USA sphere of influence. Continues as independent capitalist nation. See also North Korea	1948
Kosovo	Southern Europe	History intertwined with Albania, Macedonia, Serbia, and Montenegro. Prehistoric native & local units. As early as 8th century BC: Part of Illyria (Greece). ~ 168 BC: Roman Empire. 535 AD–1204 AD: Byzantine Empire. 1460s–1912 AD: Ottoman Empire. 1912: Independent. USSR sphere of influence following World War II (1945–1989 AD). Independent ~1990 AD	w/USSR influence

(continued)

Table 1.3 (continued)

Nation (English Name)	Region	Short history notes relevant to measurement units	Metric System [11], Nominally SI
Kuwait	Middle East, Western Asia	Prehistoric native & local units. Earliest civilization evidence ~3rd millennium BC. Mesopotamian trade. To 18th century AD: Arab influence. 1756 AD: Autonomous sheikdom. 18th–19th centuries AD: Ottoman Empire influence. 1897 AD: British Protectorate. 1961 AD: Independent	Unclear timing, probably 1960s
Kyrgyzstan	Central Asia	Prehistoric native & local units. Kyrgyz/Turkic. 1900s AD: Russian colonization. 1924 AD: Part of USSR. 1936 AD: Republic within USSR. 1991 AD: Independent. Inherited metric units from USSR	w/USSR 1920s
Laos, People's Democratic Republic	South-East Asia	Prehistoric native & local units. 8th century AD: Lao migration from China. 14th century AD: Lan Xang Kingdom. 1713 AD: Fragmented/feudal government. 18th century AD: Siamese rule. 1893 AD: French control. 1949 AD: Semi-autonomous under French Union. 1954 AD: Independent	1963
Latvia	Northern Europe	Prehistoric native & local units. Baltic tribe settlement. 13th century AD: German influx and Christianity introduced. 1561 AD: State of Lithonia, German control. 1562 AD: Polish control. 1629 AD: Swedish control. 1721–1918 AD: Russian control. 1920 AD: Independent. 1939 AD: Associated with Russians. ~1940–1944 AD: German control. 1945 AD: Russian control. 1991 AD: Independent	w/USSR influence likely 1920s
Lebanon	Middle East, Western Asia	Prehistoric native & local units. ~2000 BC: Qaraoun culture. Canaanite civilization. 8th century BC: Developed into Phoenician, maritime culture. Colonization around Mediterranean as far as Spain and Tunisia. 539 BC: Conquered by Achaemenid Persians. 332 BC: Alexander the Great. Absorbed by Seleucid Empire. Roman Empire. 1st century AD: Christianity introduced. Byzantine Empire rule. 619–629 AD: Persian	1934

(continued)

Table 1.3 (continued)

Nation (English Name)	Region	Short history notes relevant to measurement units	Metric System [11], Nominally SI
		occupation. 7th century AD: Arab/Muslim conquest and control. 11th–12th centuries AD: Crusades, French & Italian contact, eventual defeat. Muslim rule. 13th to mid-19th centuries: Ottoman Empire. 1858 AD: Overthrow of feudal government. ~1918 AD: French domination. Independent 1941–1946. Many subsequent conflicts and clan warfare since independence. Metric inherited from French influence	
Lesotho, Basutoland	Southern Africa	Prehistoric native & local units. 1843 AD: British control. 1871 AD: British colony. 1966 AD: Independent	w/UK ~1960s
Liberia	West Africa	Prehistoric native & local units. 1822 AD: American Colonization Society brought black slaves back to Africa in attempt to return them to settle free slaves. 1847 AD: Independent. Use USA Customary units of measure based on 1824 standards	Not Applicable
Libya	Northern Africa	Prehistoric native & local units. Berber tribes. 7th century BC: Phoenician and Greek influences and control. 46 BC–436 AD: Roman Empire. Sacked by Vandals. 642 AD: Arab and Muslim influx. 16th century AD: Ottoman Empire. 1934 AD: Italian colony. 1949–1951 AD: Established independence	1923
Liechtenstein	Western Europe	Prehistoric native & local units. ~500 AD: Alemanni tribe influx. 1719 AD: Initially founded as political unit. 1815–1866 AD: German control. 1866 AD: Independent	1871
Lithuania	Northern Europe	Prehistoric native & local units. 12th century AD: Lithis united. 1386 AD: United with Poland. 14th–16th centuries: Empire with Poland. 1795 AD: Poland partitioned. 1795–1918 AD: Russian rule. 1918 AD: Independent under German protection. 1940 AD: Annexed to USSR. 1941–1944 AD: German occupation. 1944 AD: USSR occupation and sphere of influence. 1990 AD: Independent	w/USSR 1920s

(continued)

Table 1.3 (continued)

Nation (English Name)	Region	Short history notes relevant to measurement units	Metric System [11], Nominally SI
Luxembourg	Western Europe	Prehistoric native & local units. Part of Charlemagne's Empire/Holy Roman Empire. 963 AD: Independent state. 15th–19th centuries AD: Controlled at times by Spain, France, and Austria. 1815 AD: Dutch control. 1839 AD: Dutch and Belgian control. To 1944 AD: German control. Essentially independent since 1944	1820
Macau	Eastern Asia	Prehistoric native & local units. 11th century AD: Xiangshan County, China. 1277 AD: Influx of Chinese fleeing Mongols during Song Dynasty. 16th century AD: Portuguese control. Territorial disputes with China. 1887 AD: Granted perpetual Portuguese occupation. 1943–1945 AD: Japanese protectorate. 1999 AD: Returned to China	w/Portugal ~1870s
Macedonia, Rep. of	Southern Europe	Prehistoric native & local units. Ancient kingdom. 148 BC–395 AD: Roman Empire. Byzantine Empire. 1371–1913 AD: Ottoman Empire, Turkish. 19th & 20th centuries AD: Constant struggle for control. 1878 AD: Bulgarian control. 1913 AD: Serbian & Greek control. 1929 AD: Part of Yugoslavia. ~1940–1944 AD: German occupation & control. 1945 AD: Back to part of Yugoslavia. USSR sphere of influence. 1991 AD: Independent	Probably during Yugoslavian period
Madagascar	Eastern Africa	Malayo-Indonesian and African-Arab settlements. ~700 AD: Indonesians. ~1828 AD: Unified. 1885 AD: French protectorate. 1908 AD: French colony. World War II: British occupation, retained French ties. 1958 AD: Autonomous Republic in French Community. 1960 AD: Independent within French Community. Metric units probably adopted much earlier from French	1960
Malawi	Eastern Africa	Prehistoric native & local units. 8000–2000 BC: Evidence of earliest inhabitants. 1st–4th centuries AD: bantu migration to area. 1410 AD: Maravi Empire. ~1600 AD: Ngonde Empire. 18th century AD:	w/UK ~1960s

(continued)

Table 1.3 (continued)

Nation (English Name)	Region	Short history notes relevant to measurement units	Metric System [11], Nominally SI
		Chikulamayembe Empire. 18th–19th centuries: Islam influx along with slave trade and Christianity. 1884 AD: British development. 1892 AD: British protectorate. 1951–1952 AD: British combined Malawi with other nearby colonies. 1964 AD: Independent within British Commonwealth. Metric units inherited from British	
Malaysia	Southeast Asia	Prehistoric native & local units. 2500–1500 BC: Earliest evidence of inhabitants. Chinese & Indian contacts from trade. 15th century AD: Islam introduced. 1800 s AD: British and Dutch trade. 1880 s AD: British protectorate. ~ 1941–1944 AD: Japanese occupation. 1948 AD: Semi-autonomous in British Commonwealth. Metric units inherited from British	w/UK ~ 1960s
Maldives	South-Central Asia	5th century BC: First settled by Buddhists from India & Sri Lanka. 1153 AD: Arrival of Islam. 1887–1948 AD: British protectorate. 1965 AD: Independent. Metric units likely inherited from British	w/UK ~ 1960s
Mali	West Africa	Prehistoric native & local units. ~ 300 AD: Contact with outside world through caravans. 12th–16th centuries AD: Malinke Empire. 15th century AD: Songhai Empire. 1591–1790: Moroccan control. 1904 AD: French colony. 1946 AD: Member of French Union. 1960 AD: Independent. Metric units inherited from French	1960
Malta	Southern Europe	Prehistoric native & local units. Early contacts with Phoenicians, Greeks, Carthaginians, and Roma Empire. 395 AD: Part of Holy Roman Empire. 870–1090 AD: Arab influx and control. 1091 AD: Sicilian control. 1798 AD: Napoleon/French control. 1964 AD: Independent member of British Commonwealth. 1979: Independent. Metric probably from French period	1920
Marshall Islands	Micronesia, Oceania	~ 1000 BC: Evidence of migration from southeast Asia. 1874 AD: Spanish control. 1885 AD: German Protectorate. World War I: Japanese control. 1944 AD: USA control. 1979 AD: Independent	Unclear timing

(continued)

Table 1.3 (continued)

Nation (English Name)	Region	Short history notes relevant to measurement units	Metric System [11], Nominally SI
Martinique	Lesser Antilles, Caribbean	Prehistoric native & local units. 1635 AD: Spanish influence. 1674 AD: French domain and control. 1946 AD: Overseas Department of France	w/France ~1800
Mauritania	West Africa	Prehistoric native & local units. Black & Berber people. 11th century AD: Islam domination. 15th century AD: Portuguese exploration. 19th century AD: French control. 1904 AD: French Territory. 1920 AD: French colony. 1946 AD: French Overseas Territory. 1960 AD: Independent. Inherited metric units from France	1960
Mauritius	Eastern Africa, Indian Ocean	Prehistoric native & local units. Dutch exploration & influence. 1715 AD: French control. 1810 AD: British control. 1835–1869+ AD: Indian migration. 1968 AD: Independent. Unclear source of metrication	1878
Mayotte	Eastern Africa	Prehistoric native & local units. 1843 AD: French control. Inherited metric units from French	Unclear timing
Mexico	North America	Prehistoric native & local units. Before 1515 AD: Succession of civilizations: Mayas, Olmecs, Toltecs, and Aztecs. 1515–1521 AD: Spanish conquest. 1821 AD: Independent. Multiple political changes in the 1800s, including invasions by France (1861 AD) and Austria (1864 AD)	1862
Micronesia, Federated States of	Micronesia, Oceania	Prehistoric native & local units. Spanish exploration. 1898 AD: Germany. 1914 AD: Japanese occupation. 1920 AD: Japanese control. 1947 AD: USA territory. 1979 AD: Self-governing under USA. 1986 AD: Essentially independent	Unclear timing
Moldova, Republic of	Eastern Europe	Prehistoric native & local units. 14th century AD: Independent. 16th century AD: Ottoman Empire. 1791–1821 AD: Russian control. To 1918 AD: Russian and Turkish control. 1918 AD: Romanian control. 1924 AD: USSR controlled, sphere of influence. 1991 AD: Independent	w/USSR 1920s

(continued)

Table 1.3 (continued)

Nation (English Name)	Region	Short history notes relevant to measurement units	Metric System [11], Nominally SI
Monaco	Southern Europe	Prehistoric native & local units. Phoenician influence. Greek control. ~ 1100–1793 AD: Independent. 1793 AD: French control. 1861 AD: Independent under French “guardianship.” 1918 AD: Autonomous state under French. Inherited metric units from France	1853
Mongolia	Eastern Asia	Prehistoric native & local units from nomadic tribes (before 200 BC). Pre-14th century AD: Mongol Empire. 1689 AD: Chinese control. 1912 AD: Independent. 1924 AD: part of USSR, semi-independent. ~ 1991 AD: Independent	1916
Montenegro	Southern Europe	Prehistoric native & local units. Earliest evidence of Illyrians. 6th–7th centuries AD: Slavic influx. 14th century AD: Serbian control. 14th–19th centuries AD: Ottoman Empire. Part of Austro-Hungarian Empire. 1878 AD: Independent. 1929 AD: Part of Serbia and Yugoslavia. USSR sphere of influence. 2003 AD: Part of Serbia 2006 AD: Independent	Unclear timing
Montserrat	Lesser Antilles, Caribbean	Little information on native & local history. British colony	w/UK ~ 1960s
Morocco	Northern Africa	Prehistoric native & local units. ~ 2000 BC: Berber control. 46 AD: Roman Empire. 685 AD: Arabs and Islam introduced. 1086–3th century AD: Berber control. Rarely unified. 15th century AD: Vandal invasion. Portuguese and Spanish invasions at times. 1660 AD: Alawite Dynasty. 1840 AD and later: Various French and Spanish attempts at colonization. 1904 AD: Divided between France and Spain for control. 1912 AD: French protectorate. 1956 AD: Independent. Inherited metric units from France	1922
Mozambique	Eastern Africa	Prehistoric native & local units. 1st millennium AD: Bantu influx. 1505: Arab and Swahili influxes. Became Portuguese Colony. 1975: Independent	Probably with Portuguese ~ 1870s

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Table 1.3 (continued)

Nation (English Name)	Region	Short history notes relevant to measurement units	Metric System [11], Nominally SI
Myanmar, Burma	Southeast Asia	Prehistoric native & local units. Starting ~700 BC: Indo/Aryan influx. 13th century AD: Mongolian and Chinese influx. Starting ~1612 AD: British and other outside influence. 1826 AD: British control established. 1886 AD: Annexed to India. 1937 AD: Independent colony under British	Own Syst + Metric
Namibia	Southern Africa	Before 0 AD: Native & local units from San people. 1600s AD: Influx of Bantu and Herem peoples. 1800s AD: Avambo migration. 1884 AD: German colony. 1921 AD: Territory under South African administration. To 1990 AD: South African influence and control. 1990 AD: Independent	Probably w/South Africa in 1960s
Nauru	Micronesia, Oceania	Prehistoric native & local units. 1888 AD: German control. World War I: British mandate (control). ~1941–1945 AD: Japanese occupation. 1947 AD: UN Trust under Australian control. 1968 AD: Independent. Probably adopted metric system with Australia	Unclear timing
Nepal	South-Central Asia	Prehistoric native & local units. Before ~6th century BC: Maintained civilization. ~545 BC: Arrival of Buddhism. 12th century AD: Indian influx and Hinduism. Between 100 and 1769 AD: Various dynasties rose and fell: Gopala, Kiratis, Licchavis-Malla. 1792 AD: British trade and control. 1923 AD: Independent. Continuing border disputes	Unclear timing
Netherlands, The	Western Europe	Prehistoric native & local units. Before 13 BC: various Germanic tribes migrated to area: Nervii, Frisii, Batavi. 4th–8th centuries AD: Migration of Franks. 8th–9th centuries AD: Charlemagne and Holy Roman Empire. French control. Austrian control. 16th century AD: Spanish control. 1648 AD: Independent from Spain. 1814 AD: United with Belgium. 1830 AD: separated from Belgium and Independent. 1940–1944 AD: German occupation. 1945 AD: Independent. Metric units adopted during union with Belgium	1820
Netherlands Antilles	Caribbean	Prehistoric native & local units from Arawak and Carib Indians. 1527 AD: Spanish exploration. 1643 AD: Dutch control	w/Netherlands ~1820
New Caledonia	Melanesia, Oceania		w/France 1800s (continued)

Table 1.3 (continued)

Nation (English Name)	Region	Short history notes relevant to measurement units	Metric System [11], Nominally SI
New Zealand	Oceania; Australia	Prehistoric native & local units, likely from Polynesian settlement. 1853 AD: French control. 1984 AD: Autonomous in French Community. Inherited metric units through French ~ 1280 AD: Earliest evidence of settlement. 1300 AD: Settled by Polynesian people. 1400–1500 AD: Māori culture and settlement. 1642 AD: Dutch exploration. 18th century AD: French and British explorations. 1840 AD: British Colony, continued Māori resistance. 1907 AD: Dominion of New Zealand under British. 1947–1983 AD: Moved to full independence. Inherited metric units from British	1976
Nicaragua	Central America	Prehistoric native & local units. Nicaraguan Indians. 1522 AD: Spanish conquest. 1838 AD: Independent	1893
Niger	West Africa	Prehistoric native & local units. Before 14th century AD: Influx of Tuareg and Hausa peoples. 17th century AD: Zerma people. 18th century AD: Gobir people. 19th century AD: Fulani people. 1896 AD: French established control. 1922 AD: French Colony. 1959 AD: Republic in the French Community. 1960 AD: Independent. Inherited metric units from French	1960
Nigeria	West Africa	Prehistoric native & local units. 500 BC–200 AD: Nok people. Kanuri people. 11th–14th centuries AD: Kanem Empire. 13th century AD: Introduction of Islam. 14th century AD: Hausa people. 19th century AD: Fulani people. 1851–1886 AD: Increasing British influence. 1914 AD: British Colony. 1960 AD: Independent	1962
Niue	Polynesia, Oceania	See the history of New Zealand. Inherited metric system with New Zealand	w/New Zealand 1976
Northern Ireland	Northern Europe	Prehistoric native & local units. Stone and Bronze Age: Picts in north, Eranums in south. 4th century BC: Invasion by Celts from Gaul. Divided into 5 kingdoms. 432 AD: Christianity introduced. 795–1014 AD: Norse	w/UK ~1960s

(continued)

Table 1.3 (continued)

Nation (English Name)	Region	Short history notes relevant to measurement units	Metric System [11], Nominally SI
		invasions. 12th century AD: English influence and control. 17th century AD: British rule. 1801 AD: Part of United Kingdom. 1922 AD: Irish Free State. 1949 AD: Majority of country independent. Northern Ireland still part of UK	
Northern Mariana Islands	Micronesia, Oceania	Prehistoric native & local units with Polynesian migration. 1668 AD: Settlement by Europeans, introduction of Christianity. Control passed among Spanish, Germans, and Japanese. ~ 1947 AD: Made UN Trustee. 1986 AD: USA control, but strong continuing Spanish influence	Not applicable
Norway	Northern Europe	Prehistoric native & local units. Teutonic settlement. 8th–11th centuries AD: Vikings. 1015 AD: Unified country. 1442–1814 AD: Danish control. 1814 AD: United with Sweden. 1905 AD: Separated from Sweden to become independent. World War II: German invasion and occupation. 1945 AD: Reasserted independence	1875
Oman	Middle East	Prehistoric native & local units. 6000 BC: Earliest evidence of settlement. 9th century BC: Arab influx. 7th century AD: Conversion to Islam. 1508–1648 AD: Portuguese control. 1648-1741 AD: Ottoman Empire influence. Essentially independent since ~ 1741	Unclear timing
Pakistan	South-Central Asia	Prehistoric native & local units. 2500–1700 BC: Indus Valley Civilization. Invaded over next centuries by: Aryans, Persians, Greeks, Arabs, Turks, and others. 711 AD: Islam introduced. 1526 AD: Mogul Empire. 1857 AD: British domain. 1947 AD: British Commonwealth. 1956 AD: Independent	1967
Palau	Micronesia, Oceania	~ 2500 BC: Originally settled by Indonesians. Mixed settlements by Malaysians, Melanesians, Filipinos, and Polynesians. ~ 1543–1899 AD: Spanish control. 1899 AD: German control. World War I: Japanese occupation. 1920 AD: Japanese control. World War II: USA control. 1947 AD: UN Trust under USA administration. 1994 AD: Independent. Probably inherited metric units during German or Japanese periods	Unclear timing

(continued)

Table 1.3 (continued)

Nation (English Name)	Region	Short history notes relevant to measurement units	Metric System [11], Nominally SI
Palestinian territories	Middle East, Western Asia	Not an actual nation; proposed nation. Regional history similar to Israel. Native & local units, mostly from other Middle Eastern areas. 1923–1948 AD: British control. Disputed region since 1947 AD, mostly under Israeli control	Unclear timing
Panama	Central America	Prehistoric native & local units. 1502–1513 AD: Spanish conquest and control began. 1821 AD: Joined with Colombia in revolution against Spanish. 1903 AD: Independent with USA backing. 1903–1999 AD: Canal Zone under USA control. 1999 AD: Independent	1915
Papua New Guinea	Maritime Southeast Asia, Melanesia, Oceania	Prehistoric native & local units from Papuan, Melanesian, and Negrito peoples. 1828 AD: Dutch controlled western portion. 1885 AD: Germans took control of northern portion and British took control of south 1906 AD: Australia gets British portion and begins expanding. World War II: Japanese occupation. 1947 AD: UN Trust under Australian administration. 1951 AD: Home Rule under Australia. 1975 AD: Independent. Inherited metric units from Australians	Probably w/Australia 1960s
Paraguay	Central South America	Prehistoric native & local units from Guarani-speaking peoples. 1608–1767 AD: Spanish settlements, Jesuits. 1811 AD: Independent. Many political upheavals since, but maintained independence	1900
Peru	Western South America	Prehistoric native & local units. Before 1500 AD: Incan Empire. 1531–1533 AD: Spanish conquest and control started. 1821–1824: Established independence from Spain. Various internal revolts continue. Still independent	1868
Philippines, The	Southeast Asia	Prehistoric native & local units. ~25,000 BC: Originally settled. After 3000 BC: Indonesian and Malayan settlement. By 14th century AD: Extensive trade with India, Indonesia, China, and Japan. 1521: Spanish control established. 1899 AD: USA control. World War II: Japanese occupation. 1946 AD: Independent	1916

(continued)

Table 1.3 (continued)

Nation (English Name)	Region	Short history notes relevant to measurement units	Metric System [11], Nominally SI
Pitcairn Islands	Polynesia, Oceania	1790 AD: Settled by British mutineers and Tahitian women. 1838 AD: British Crown Colony	w/UK ~1960s
Poland	Eastern Europe	Prehistoric native & local units. 966 AD: Piast Dynasty. 1047 AD: Area united. 1386–16th century AD: Polish/Lithuanian State. Attempted invasions by Germans, Russians, and Turks over next centuries. 1772–1795 AD: Area was divided among Russia, Prussia, and Austria. 1918 AD: Independent. World War II: German invasion and occupation. 1945 AD: USSR control and sphere of influence. 1990 s AD: Independent	1918
Portugal	Southern Europe	Prehistoric native & local units. Settled by Celts and Lusitanians. 140 BC: Roman Empire. Visigoth invasion. To 1143 AD: Moorish Spain. 1143 AD: Unified and independent. 1488–16th century AD: Spanish Empire. 1581 AD: Spanish control. 1640 AD: Independent	1872
Puerto Rico	Greater Antilles, Caribbean	Prehistoric native & local units from Arawak and Carib Indians. 1500s AD: Spanish control. 1897 AD: Self government under Spain. 1898: USA control, unincorporated US Territory. Inherited metric units from Spain	1868
Qatar	Arabian Peninsula, Middle East	Once part of Bahrain. Prehistoric native & local units. 3rd century BC: Arab. 4th century AD: Persian. 4th century AD–1541 AD: Arab control. 1541 AD: Portuguese control. 1602 AD: Persian control. 1867 AD: British control. 1893 AD: Ottoman Turks tried to invade and failed. 1916 AD: British Protectorate. 1971: Independent	w/UK ~1960s
Reunion Island	Eastern Africa	Uninhabited at time of discovery by French in 1642 AD. To 1848 AD: Slaves imported until slavery banned. After 1648 AD: Indentured servants from Indochina, India, and East Africa replaced slave labor. 1947 AD: Overseas Department of France. Inherited metric units from French	w/France

(continued)

Table 1.3 (continued)

Nation (English Name)	Region	Short history notes relevant to measurement units	Metric System [11], Nominally SI
Romania	Eastern Europe	Prehistoric native & local units. 100–271 AD: Roman Empire. 3rd–12th centuries AD: Invasions by various barbarians. 8th–11th centuries AD: Bulgarian Empire. 11th century AD: Partially absorbed by Hungarian Empire. 16 _{th} –19th centuries AD: Ottoman Empire. 1829 AD: Russian Protectorate. USSR sphere of influence throughout 20th century. ~ 1990 AD: Independent. Inherited metric system from Russia	1884
Russian Federation, Russia	Eastern Europe— Northern Asia	Prehistoric native & local units. 862 AD: According to tradition, Viking Rurik from Russia. Novgorod Dynasty. 10–11th centuries AD: Tribes were united by Christianity. 11th century AD: Administration centralized to Kiev. 1240 AD: Mongol invasion. Area split. Late 15th century AD: Ivan III unified area and expelled Mongols. Political structure was medieval until ~1700 AD. 1800s AD: Russia expanded. 1917 AD: Bolshevik Revolution threw out monarchy and established Communist state. 1920 AD: Communist control, independent. 1922 AD: USSR formed. 1986 AD: USSR began easing control. 1980s–1990s: Major economic changes, dissolution of USSR. Many former states and nations in sphere of influence gained independence	1925
Rwanda	Eastern Africa, African Great Lakes	Prehistoric native & local units from Twa and Pygmy peoples. Hutu and Tutsi control. 1890 AD: German control. 1916 AD: Belgian control. After World War I: Combined with Burundi under Belgian control. 1946 AD: Part of UN Trust administered by Belgium as Belgian Congo. 1962 AD: Independent. Inherited metric system from Belgium	1910
Saint Kitts and Nevis	Lesser Antilles, Caribbean	Prehistoric native & local units from Carib Indians. Saint Kitts originally St. Christopher. 1623 AD: British settlement of St. Kitts. 1628 AD: British settlement on Nevis. Starting 1627 AD: British and French rivalry over islands. 1782 AD: Permanent British control. 1882 AD: Islands were united. 1958 AD: Part of West Indies Federation. 1967 AD: Free association with British. 1983 AD: Independent	w/UK ~1960s

(continued)

Table 1.3 (continued)

Nation (English Name)	Region	Short history notes relevant to measurement units	Metric System [11], Nominally SI
Saint Lucia	Lesser Antilles, Caribbean	Prehistoric native & local units from Arawak Indians. Arawaks driven off by Carib Indians. 1814 AD: British territory and control. 1967 AD: Home rule under British. 1979 AD: Independent, with continuing British influence	w/UK ~1960s
Saint Vincent and the Grenadines	Lesser Antilles, Caribbean	Prehistoric native & local units from Carib Indians. 16th century AD: Claimed by both British and French. 1763 AD: British control. 1776 AD: Caribs were deported. African, Portuguese, and East Indian slaves/laborers brought in. 1958–1962 AD: Part of West Indies Federation. 1969 AD: Home Rule under British. 1979 AD: Independent	w/UK ~1960s
Samoa	Polynesia, Oceania	Prehistoric native & local units. ~1000 BC: Evidence of Polynesian settlement. 18th century AD: Dutch & French exploration. 1899 AD: USA and German interests established. 1914 AD: New Zealand seized German areas. 1946 AD: Made UN Trust administered by New Zealand. 1962 AD: Independent, but USA still controls some islands. Metric units inherited from Germans or New Zealand	Unclear timing
San Marino	Southern Europe within Italy	Prehistoric native & local units. ~350 AD: Founded as independent state by tradition. Has endured many outside attacks, but maintains independence	1915
São Tomé and Príncipe	African Coast, West of New Guinea	Believed to have been originally uninhabited. 1471 AD: Portuguese exploration. ~1500 AD: Portuguese settlement. Imported slave labor for plantations. 1953 and 1974 AD: Revolts against Portuguese. 1975 AD: São Tomé independent. 1995 AD: Príncipe independent. Merged after 1995. Inherited metric units from Portugal	Probably 1800s
Saudi Arabia	Arabian Peninsula, Middle East	Prehistoric native & local units consistent with region and trade. Arab and Islamic influence. 1517 AD: Ottoman Empire. ~1811 AD: Area united, but still under sphere of influence of Ottoman Empire. 1818 AD: Egyptian influence. 1901–1932 AD: Unified and independent	1964

(continued)

Table 1.3 (continued)

Nation (English Name)	Region	Short history notes relevant to measurement units	Metric System [11], Nominally SI
Scotland, Part of Great Britain	British Islands	Early units from Picts and Celts. 82–208 AD: Roman Empire. ~500 AD: Influx of Scots from Ireland. ~843 AD: United area. 1th century AD: Expanded area of control. ~1100 AD: Increasing English influence. 1296 AD: English invasion. 1314 AD: Drove out the English. 1328 AD: Independent. 1603 AD: Combined crown with English. 1707 AD: Officially united with England to form United Kingdom	w/UK ~1960s
Senegal	West Africa	Prehistoric native & local units from Toucouleur people. 11th century AD: Islam introduced. 15th century AD: Portuguese contacts. 1659 AD: French settlement. 1700s AD: Extensive slave trade. Some British incursions. 1840 AD: French control of region. 1946 AD: Overseas Territory of France. 1960 AD: Independent. Inherited metric units from France	1960
Serbia	Southern Europe	Prehistoric native & local units. 6th–7th centuries AD: Serb settlement. 9th century AD: Christianity introduced. 1166 AD: First State. 1389 AD: Ottoman Empire. 1878 AD: Independent. 1912–1913 AD: Balkan expansion. 1929 AD: Part of Yugoslavia when formed. 1941 AD: German occupation. ~1945 AD: In USSR sphere of influence. Communist state. 1995 AD: Breakup of Yugoslavia. Independent. Probably adopted metric units during USSR influence	Probably ~1920s
Seychelles	Eastern Africa	Originally uninhabited. 1609 AD: British exploration and settlement. Pirate base. 1756 AD: French combined with Mauritius for control. 1814 AD: British control. 1975 AD: Self Governing under British. 1976 AD: Independent	1878
Sierra Leone	West Africa	Prehistoric native & local units from Bulom people. 15th century AD: Mende & Temne peoples. Fulani influx. Portuguese exploration. 1787 AD: British settlement. 1808 AD: British colony. 1896 AD: Brash protectorate. 1961 AD: Independent	Probably 1960s

(continued)

Table 1.3 (continued)

Nation (English Name)	Region	Short history notes relevant to measurement units	Metric System [11], Nominally SI
Singapore	Southeast Asia	2500–1500 BC: Prehistoric native & local units from initial migration to area. British and Dutch interest in area. 1819 AD: British trade. 1946 AD: British Crown Colony. Various divisions and islands split off. 1959 AD: Self Governing under British. 1963 AD: Part of Federation of Malaysia. 1965 AD: Independent	Probably 1960s
Slovakia, Slovak Republic	Eastern Europe	Prehistoric native & local units. ~6th century AD: Slovak settlement. 9th century AD: Moravian Empire. 907 AD: German and Magyar conquest. 10th century-1918 AD: Hungarian control. 1918 AD: Part of Czechoslovakia. 1939 AD: Invaded and occupied by Germany. 1945 AD: Liberated by USSR. Communist controlled. Yugoslavia re-formed. 1993 AD: Independent with breakup of Yugoslavia. Inherited metric units while part of Hungarian Empire	1875
Slovenia	Southern Europe	Prehistoric native & local units. Settled by Illyrian and Celtic people. 1st century BC: Roman Empire. 6th century AD: Slovans/Slavic settlement. 7th century AD: Part of State of Samu (Hungarian). 8th century AD: Charlemagne conquest. ~1526-1867 AD: Austro-Hungarian Empire. 1929 AD: Included in Yugoslavia. World War II: German invasion and occupation. 1945 AD: Liberated by USSR. Communist controlled. Yugoslavia re-formed. 1991 AD: Independent with breakup of Yugoslavia. Inherited metric units while part of Hungarian Empire	Probably 1870s
Solomon Islands	Melanesia, Oceania	Prehistoric native & local units with settlement as early as 2000 BC. 1568 AD: Spanish exploration, not settled. 1886 AD: Germany and British divided the islands for control. Primarily British control. World War II: Japanese invasion and occupation. 1945 AD: British control. 1976 AD: Self Rule under Britain. 1978 AD: Independent. Inherited metric units from UK	w/UK ~1960s

(continued)

Table 1.3 (continued)

Nation (English Name)	Region	Short history notes relevant to measurement units	Metric System [11], Nominally SI
Somalia	Eastern Africa	Prehistoric native & local units. 7th–10th centuries AD: Arab and Persian trade. 16th century AD: Turkish rule in north and Zanzibar rule in south. 1839–late 1800s AD: British, French, and Italian settlements in various areas. 1920 AD: British and Italian Protectorates. 1941 AD: British control. 1950s AD: Italians return to area. 1960 AD: Independent	1960
South Africa	Southern Africa	Prehistoric native & local units from San people. Khoikhoi and Bantu people influxes. 1652 AD: Dutch control. 1795–1815 AD: Multiple unsuccessful attempts to overthrow Dutch. 1815 AD: British control. 1899–1902 AD: War with Boers (Dutch ancestry). 1910 AD: Union of South Africa. 1961 AD: Independent	1968
South Sudan	East-Central Africa	Prehistoric native & local units. 2600 BC: Egyptian rule. ~350 AD: Kush Civilization. 6th century AD: Christianity introduced. Muslim Arabs subsequently replaced Christianity. 1500s AD: Succession of groups: Dinka, Shilluk, Nuer, and Azande peoples. 1874 AD: Egyptian rule. 1898–1955 AD: British control. 1953 AD: Self Rule under British. 1956 AD: Independent	1954
Spain	Southern Europe	Prehistoric native & local units. Successive settlements by Celts, Iberians, and Basques in various areas. 206 BC: Roman Empire. 412 AD: Invasion by Visigoths. 711 AD: Invaded by Muslims. 732 AD: Franks limited extent of Muslim control. 12th–15th centuries AD: Broken into various medieval, independent states. 1469 AD: Region primarily united. 1478–1492: Spanish Inquisition. ~1500–1700 AD: Developed Spanish Empire. 1700–1800s AD: Lost the empire. Maintained independence	1858
Sri Lanka, formerly Ceylon	South-Central Asia	Prehistoric native & local units. 5th century BC: Indo-Aryan (Sinhalese) migration from India. 3rd century BC 1200 AD: Migration of Tamils from India. 1505 AD: Portuguese trade. 1658–1796 AD: Dutch control. 1796 AD: British control. 1802 AD: British Crown Colony of Ceylon. 1948 AD: Self Rule under Britain. Essentially independent. Probably inherited metric units from Britain	w/UK ~1960s

(continued)

Table 1.3 (continued)

Nation (English Name)	Region	Short history notes relevant to measurement units	Metric System [11], Nominally SI
Sudan	Northern Africa	Prehistoric native & local units. Originally Nubia in the north. 2600 BC: Egyptian rule. ~350 AD: Kush Civilization. 6th century AD: Christianity introduced. Muslim Arabs subsequently replaced Christianity. 1500s AD: Funj people. 1874 AD: Egyptian rule again. 1898–1955 AD: British control. 1953 AD: Self Rule under British. 1956 AD: Independent	1954
Suriname	North-Eastern South America	Prehistoric native & local units from Surinen people. Before 16th century AD: Other South American tribes moved into area. 1593 AD: Spanish exploration. 1602 AD: Dutch settlement. English settlement. 1667 AD: Dutch control. Before 1863 AD: Extensive slave labor until abolished. After 1870: Indentured servants from East Indies and Java replaced slaves. 1948 AD: Part of Kingdom of the Netherlands. 1950 AD: Home Rule under the Dutch. 1975 AD: Independent. Inherited metric units from Dutch	1916
Swaziland	Southern Africa	Prehistoric native & local units. 16th–18th centuries AD: Inhabited by Bantu people. 19th century AD: Bantu clans united against Zulus. 1881 AD: British Protectorate. 1894–1899 AD: South African Protectorate. 1902 AD: British administration. 1963 AD: British Protectorate. 1968 AD: Independent	w/UK ~1960s
Sweden	Northern Europe	Prehistoric native & local units from Sviones people. 11th century AD: Christianity introduced. 1520 AD: Danish control. ~1550 AD: Separated from Denmark. Various wars, combinations, splits, and losses of territory over centuries. 1905 AD: Separated from a union with Norway to become independent. 1999 AD: Joined the EU	1876
Switzerland	Western Europe	Prehistoric native & local units from Helvetica people. 1291 AD: part of the Holy Roman Empire League. 1648 AD: Independent of the League. 1798–1803 AD: French occupation. 1815 AD: Independent and establish neutrality. 1848 AD: Unified and became independent country	1876

(continued)

Table 1.3 (continued)

Nation (English Name)	Region	Short history notes relevant to measurement units	Metric System [11], Nominally SI
Syria, Syrian Arab Republic	Middle East, Western Asia	Prehistoric native & local units. 1500 BC: Conquered by Egypt. Egyptian conquest followed by Hebrews, Assyrians, Chaldeans, Persians, and Alexander the Great over centuries. 64 BC–636 AD: Roman Empire. 636–1260 AD: Arab control. 1260 AD: Mongol invasion and occupation. 1516 AD: Ottoman Empire. ~1918 AD: French control. 1930 AD: Independent under French	1934
Taiwan, Republic of China	Eastern Asian Island	Prehistoric native & local units from original inhabitants of Malaysians descent. 7th century AD: Chinese from Fukien and Kwangtung. 1590 AD: Portuguese exploration, named island Formosa. 1624 AD: Dutch forts in south and Spanish forts in north. 1661 AD: Dutch control. 1661 AD: Chinese declared independent. 1683–1895 AD: Ruled by Chinese Manchu Dynasty. 1895 AD: Japanese control. 1946 AD: Restored to Chinese control. 1949 AD: Separated from mainland China and established separate nation. China still claims island. 1971 AD: Increasing Chinese influence and cooperation	1952
Tajikistan	Central Asia	Prehistoric native & local units from Tajiks. Persian Empire. 333 BC: Alexander the Great. 7th–8th centuries AD: Arabs and Islam. Controlled by Uzbeks and Afghans. 1860s AD: Russian control. 1924 AD: Autonomous Socialist Republic associated with USSR. 1929 AD: Socialist Republic within USSR. 1990 AD: Independent	w/USSR 1920s
Tanzania, United Republic of Tanzania	Eastern Africa	Prehistoric native & local units. ~700 AD: Arab colonizers and Islam. ~1500–17th century AD: Portuguese exploration and some controlled areas. Oman control. 1885 AD: German East African Colony. Post World War I: Trust Territory. 1961 AD: Most independent, with Zanzibar becoming independent in 1962 AD–1964 AD: Merged with Zanzibar	1967

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Table 1.3 (continued)

Nation (English Name)	Region	Short history notes relevant to measurement units	Metric System [11], Nominally SI
Thailand	South-East Asia	Prehistoric native & local units. 6th century AD: Thais settled area. 13th century AD: Thai rule. 1824 AD: British colony, but terminated in 1896 AD–1941 AD: Japanese occupation. 1960s–1970s AD: Multiple conflicts with neighbors. Independent	1946
Tibet	South-Central Asia	Prehistoric native & local units. ~10,000–9000 BC: Earliest habitation evidence. Along trade routes for China, India, and Central Asia. 7th century AD: Independent. ~8th century AD: Buddhism introduced. 600s–900s AD: Conflicts with Chinese over area. 12th century AD: Indian Buddhist influx. 13th century AD: Mongol invasion. 1270–1720 AD: Mongol rule. 1720 AD: Chinese rule. Not really ever permanently colonized by imperial powers. 1906–1907 AD: British recognized Chinese rule. 1912 AD: Expelled Chinese from area to become independent. 1930s AD: Drifted into Chinese sphere of influence. 1965 AD: Established as Tibetan Autonomous Region under China. Primarily controlled by China	w/China Probably mid-1900s
Timor-Leste (East Timor)	Maritime South-East Asia	Earliest settlement by Malay and Papuan people. 1613 AD: Portuguese & Dutch claims to area. 1859–1914 AD: Timor divided between Dutch & Portuguese. Dutch held Timor. Portuguese held Timor Leste. World War I: Japanese occupation. 1950 AD: Dutch Timor joined to Indonesia. 1975 AD: Portuguese Timor declared independence and became Timor-Leste or East Timor. Inherited metric units from French	Unclear timing
Togo	West Africa	Prehistoric native & local units. Earliest known Voltaic and Kwa peoples. 14th century AD: Ewe people. 18th century AD: Ane people. 18th century AD: Denmark claimed area. 1884 AD: German colony. After World War I: Split between Britain and France. After World War II: UN Trust administered by Britain & France. British portion joined with Ghana. 1960 AD: French portion became Togo. Inherited metric units from France	1960

(continued)

Table 1.3 (continued)

Nation (English Name)	Region	Short history notes relevant to measurement units	Metric System [11], Nominally SI
Tokelau, formerly Union Islands	Oceania/Australia	Prehistoric native & local units. 1765 AD: British exploration. 1877 AD: British Protectorate. 1916–1925: Part of British Crown Colony. 1948 AD: New Zealand control. 1949 AD: Added to New Zealand. 1996 AD: Limited self government under New Zealand. Continuing partnership with New Zealand	w/New Zealand ~1970s
Tonga	Polynesia, Oceania	~1000 BC: Inhabited by Polynesians. 1616 AD: Dutch exploration. 1773–1777 AD: British exploration. 1831–1875 AD: Consolidated into single kingdom. 1900 AD: British Protectorate. 1970 AD: Independent	w/UK ~1960s
Trinidad and Tobago	Northern South America, Caribbean	Prehistoric native & local units from Arawaks on Trinidad & Caribs on Tobago. 1498 AD: Spanish exploration. To 1802 AD: Spanish control. 1802 AD: British control. Starting 1814 AD: Islands traded back and forth between Britain & France. 1834 AD: Slavery abolished. 1845–1917 AD: Indians brought over as indentured servants. 1889 AD: British combined two islands into one colony. 1925 AD: Partial self government under British. 1958–1962 AD: Member of West Indies Federation. 1976 AD: Independent member of British Commonwealth	w/UK ~1960s
Tunisia	Northern Africa	Prehistoric native & local units. 12th century BC: Phoenician settlement. By 6th–5th century BC: Dominated Mediterranean trade. 146 BC: Roman Empire. 439–533 AD: Vandal incursions. 648–669 AD: Arab conquest. Arab and Berber rule established. 1570–1574 AD: Turkish rule. Into 19th century AD: Ottoman Empire. 1881 AD: French occupation led to French Protectorate status. 1956 AD: Independent. metric units inherited from French	1893
Turkey	Southeastern Europe, Western Asia	Prehistoric native & local units. 1900–1200 BC: As Anatolia, was occupied by Indo-European Hittites. Successive occupation by Phrygians and Lydians. 6th century BC: Persian Empire occupied. Roman Empire. Byzantine Empire. 13th century AD: Rise of Ottoman Turks to form Ottoman Empire. Spread through Balkans. Independent. Post World War I: Lost territory. 1923 AD: Independent	1930

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Table 1.3 (continued)

Nation (English Name)	Region	Short history notes relevant to measurement units	Metric System [11], Nominally SI
Turkmenistan	Central Asia	Prehistoric native & local units. Early part of Persian Empire (nomadic). 11th century AD: Seljuk Turks. 13th–15th centuries AD: Mongol invasion and control. 15th–19th centuries AD: Divided area. 1868 AD: Incorporated into Russia. 1922 AD: Autonomous Region of USSR. 1925 AD: Socialist Republic member of USSR. 1990 AD: Independent	w/USSR 1920s
Turks and Caicos Islands	Caribbean, parts of the Bahamas island chain	Prehistoric native & local units. 1678 AD: British settlement. 1874 AD: Part of British colony of Jamaica. ~1962 AD: British Crown Colony	w/UK ~1960s
Tuvalu, formerly Ellice Islands	Polynesia, Oceania	Earliest settlers probably Samoan or Tongan. 1892 AD: British Protectorate. 1915–1916 AD: British Crown Colony. 1975 AD: Separate British colony with home rule. 1979 AD: Independent, but still associated with Britain	w/UK ~1960s
Uganda	Eastern Africa	Prehistoric native & local units. ~500 BC: Bantu people. 14th century AD: Three dominate kingdoms in area. 1844 AD: Arab and European traders explored area. 1890s AD: Designated as British sphere of influence. 1894 AD: British Protectorate. Influx of people from India. 1962 AD: Independent, but with continuing conflicts. Inherited metric units from British	1967
Ukraine	Eastern Europe	Prehistoric native & local units. By 9th–13th centuries AD: Kiev was major political & cultural center in Eastern Europe. 1240 AD: Mongol conquest and occupation. 13th–16th centuries AD: Polish and Western European influences. 1596 AD: Divided by religion. 1654 AD: Russians controlled region. 1654 AD: Absorbed into Russia. 1918–1920 AD: Unsuccessfully attempted to become independent. 1922 AD: One of founding nations of USSR. 1991 AD: Independent with breakup of USSR	w/USSR 1920s

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Table 1.3 (continued)

Nation (English Name)	Region	Short history notes relevant to measurement units	Metric System [11], Nominally SI
United Arab Emirates	Arabian Peninsula, Middle East	Originally inhabited by seafarers. 7th century AD: Islam conversion. 18th century AD: Haven for pirates. 1820 AD: British control. ~1853 AD: British Protectorate. 1971 AD: Independent. Metric units adopted along with British	1961
United Kingdom	Northern Europe	Prehistoric native & local units. Celtic people occupied. 1st century BC: Roman Empire occupation. 5th century AD: Romans withdrew. Subsequently invaded by Angles, Saxons, and Jutes. Groups had little effect on Scotland & Wales. Original Britons forced into Wales and Scotland by Anglo-Saxon kingdoms. 10th century: England, Scotland, & Wales united. 1066 AD: Norman/French invasion and occupation. Feudal society for centuries. 1215 AD: Magna carta signed. Various wars, expansions, & contractions through 19th century. 1824 AD: Standard for “English” measurement units established, still used for USA Customary Units. Ultimately adopted metric units in 1965	1965
United States	North America	Prehistoric native & local units from Asian migration starting about 12,000 BC–1000 AD; Possible Norse exploration. 1513 AD: Spanish colonization in southeastern US. 1607 AD: English colonization began, along with colonies from Dutch and French. Exploration and expansion throughout 17th–20th centuries with native peoples displaced. 1824 AD: Standardized on the English units promulgated at that time. 1866 AD: Metric units became an option. In many cases, metric and US Customary units are used side-by-side	Optional Since 1866
Uruguay	Central East South America	Prehistoric native & local units from Charruas 1516 AD; Spanish exploration. 1680 AD: Portuguese colonization. 1778 AD: Spain kicked out Portugal. By this time, most natives had been exterminated. 1811 AD: Revolted against Spain. 1817 AD: Conquered by Portuguese. 1825 AD: Independent. Adopted metric system at about the same time as other independent South American nations	1863

(continued)

Table 1.3 (continued)

Nation (English Name)	Region	Short history notes relevant to measurement units	Metric System [11], Nominally SI
Uzbekistan	Central Asia	Prehistoric native & local units. Persian Empire occupation. 4th century BC: Alexander the Great conquest. 8th century AD: Arab invasion and Islam introduced. 13th century AD: Mongols took region from Turks. 16th century AD: Uzbeks invaded and merged with inhabitants. Uzbek Empire subsequently broke up. 19th century AD: Russian conquest and control. 1924–1925 AD: Uzbek Republic became part of USSR. 1991 AD: Independent with breakup of USSR. Metric units inherited from USSR	w/USSR 1920s
Vanuatu, formerly New Hebrides Islands	Melanesia, Oceania	Inhabited since about 1000 BC, starting with the Lapita culture. 1606 AD: Portuguese exploration. 1774 AD: British exploration. 19th century AD: British settlement and missionaries. Natives kidnapped and sold into slavery in Australia. 1887 AD: Anglo-French community. 1906 AD: Joint British/French control. 1980 AD: Independent. Inherited metric units during French & English period	Unclear timing
Vatican City State, Holy See	Southern Europe within Italy	Previously was part of Italy. 5th century AD: Established by Emperor Constantine for Catholic Church administration. To 14th century AD: Residence of the Pope. 14th century AD: Pope's residence moved to France. 1377 AD: Pope's residence returned to Vatican City. Continues as Papal residence. 1929 AD: Independent of Italy	Unclear timing
Venezuela	Northern South America	Prehistoric native & local units. Early inhabitants were Arawaks, Caribs, and nomadic hunting & fishing tribes. 1499 AD: Spanish exploration. 1520 AD: Spanish settlement. German conquests also in area. 16th–18th centuries AD: Area know for pirate attacks. 18th century AD: Smuggling operations and haven. 1795–1811 AD: Revolted against Spanish and gained independence. 1821 AD: Final independence as part of Greater Colombia. 1830 AD: Separated from Greater Colombia to become independent nation	1915

(continued)

Table 1.3 (continued)

Nation (English Name)	Region	Short history notes relevant to measurement units	Metric System [11], Nominally SI
Vietnam	South-East Asia	Prehistoric native & local units. Early migrations of Chinese, Mongols, and Indonesians. ~2879 BC: Original nation established. 111 BC-15th century AD: Chinese rule. 16th century AD: Portuguese exploration. 19th century AD: French influence and control over area. 1887 AD: Area unified by France. Divided into 3 separate regions subsequently. 1940-1945 AD: Occupied by Japan. 1950s AD: French lose control of region. 1960s-1970s AD: Vietnam War, involving USA and Chinese support. 1973 AD: War ended with country divided between north and south. 1975 AD: Reunified as communist state. Metric units are holdover from French occupation	1963
Virgin Islands (British)	Lesser Antilles, Caribbean	Inhabited by Carib Indians before 1493 discovery. 1596 AD: Caribs driven off or killed by British. 1672 AD: Annexed to Britain. Used slavery on plantations into 19th century. 1956 AD: British Crown Colony	w/UK ~1960s
Virgin Islands (U.S.)	Lesser Antilles, Caribbean	Inhabited by Carib Indians before 1493 discovery. 1596 AD: Caribs driven off or killed. 1666 AD: Split between British and Danish. 1917 AD: USA bought Danish interests. 1927 AD: Islanders granted US Citizenship with similar rights as mainland, but cannot vote for President. Continue as part of USA using US Customary units	Not applicable
Wales, part of Great Britain or UK	Western Europe, British Isles	Prehistoric culture from Celts. 1st century BC-5th century AD: Roman Empire. Subsequent invasions by Angles, Saxons, and Jutes—but did not stay. 8th century AD: Fought with Anglo-Saxons over region. 1093 AD: Normans take portions of Wales. 1284 AD: Under English control. 1400-1410 AD: Rebellion against England failed. Made Henry VII (who was Welsh) king of Great Britain and quelled many problems. 1999 AD: Self governing within the UK. Inherited metric units with other parts of UK in 1960s. Still have some unique Welsh units	w/UK 1965

(continued)

Table 1.3 (continued)

Nation (English Name)	Region	Short history notes relevant to measurement units	Metric System [11], Nominally SI
Wallis and Futuna Islands	Polynesia, Oceania	Prehistoric native & local units. 19th century AD: Settled by French missionaries. 1880s AD: French Protectorate. Local and internal rule. 1961 AD: French Overseas Territory. Metric units from French	w/France 1800s
Western Sahara (proposed nation)	Northern Africa	Prehistoric native & local units. Since 4th century BC: Has seen European trade. Middle Ages: Occupied by Berbers and Arabic Muslim Bedouins. 19th century AD: Spanish claimed part of area. 1958 AD: Established Spanish Sahara. 1976 AD: Spain left area. Divided area between Morocco and Mauritania. Western Sahara is currently part of Morocco. Probably inherited metric units from Spain in 1950s	w/Spain 1950s
Yemen	Arabian Peninsula, Middle East	Prehistoric native & local units. 1200–650 BC: Minaean Kingdom. 750–115 BC: Sabaeen Kingdom. Extensive trade contact. 1st century AD: Roman Empire. Ethiopians. 6th century AD: Persians. 628 AD: Conversion to Islam. 10th century–1962 AD: Rassite Dynasty. 1538–1918 AD: Ottoman Empire occupied region. Since ~1680, turmoil has kept north and south separated. 1990 AD: Area was united and independent	Unclear timing
Zambia	Eastern Africa	Prehistoric native & local units. ~800 AD: Bantu influx. 16th–18th centuries: Angola and Congo influx. 18th century—about 1835–1864 AD: Arab, Swahili, and other traders. Nation split into sections ruled by Ngonis and Kololos. 1851 AD: Scottish exploration. 1890 AD: British control established. to 1911 AD: British Protectorates for area. 1924 AD: British Protectorate. 1964–1965 AD: Independence	w/UK ~1960s
Zimbabwe	Eastern Africa	Prehistoric native & local units. Earliest evidence of habitation ~500,000 years ago. 200 BC: Earliest settlers. Bantu domination. Ring groups followed: Shona, Nguni, and Zulu. To Mid 19th century AD: descendants of early tribe ruled (Ndebele). 1850s AD: British influx and control. 1923 AD: Self-governing British Colony. After World War II: South Rhodesia remained British colony. 1965 AD: Declared independence. Area has seen continued racial and inter-tribal strife	w/UK ~1960s

central Asia. The units applied in India, similarly spread across southeast Asia. They mingled with middle-eastern units in many areas. Chinese units moved also into southeast Asia toward Vietnam and eastward to Japan and Korea. The units would evolve, but similar units can be found in old practices for many areas.

An obvious, relatively recent replacement of native units by colonizers occurred in the Americas, where European measurement systems basically erased systems used previously. South and Central American measurement units became Spanish or Portuguese units for the most part, to the point where we have very limited information on Incan or Mayan or Olmec measurement systems. In North America, the native units were replaced by English, French, and Spanish units, eventually ending up mostly as English. It is still possible to identify how many native North American tribes handled measurement through older tribal members because there are still functioning tribal governments and historians.

Table 1.3 indicates when and how each locale came to adopt metric units over the past couple of centuries. This adoption has largely been voluntary and practical, although a number of areas inherited the units as colonies or protectorates of another nation.

Conclusion

Measurement units have developed and evolved against a rich, historical background that included the rise and fall of civilizations. The units have been influenced by trade, agriculture, politics, religion, conquest, colonization, and technology. There has even been a touch of adventure. This book focuses on the development and use of our fundamental measurement units and the many measures derived from those units. It provides a wide range of historical and useful current conversion factors of interest in engineering.

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Chapter 2

Interconversion of Units



Abstract This chapter reviews the simple interconversion of measurement units between systems that is facilitated by available linear conversion factor tables. It discusses the background for application of dimensional analysis to help ensure a dimensionally consistent final result from complex conversions, but also notes why dimensional consistency will not always ensure you end up with the correct units or values. The use of the “Factor-Label” approach to conversion is discussed as one way to reduce the chance of error in conversions involving multiple units and factors and to reduce the risk of missing a factor. The handful of interconversions which require non-linear approaches, such as converting degrees Baumé to specific gravity, are highlighted along with a few other conversion exceptions.

Introduction

A primary focus of this book is the history of measurements and conversions from one set of units into another set of units. The sets of units can be anything appropriate for measuring the quantity of interest.

The units have to make sense. You can only convert “like to like” units. In this chapter, we will look briefly at the considerations and approaches to interconversion of units. The discussion will center on the use of dimensional analysis. It will not be an exhaustive treatment of that approach; but we will review useful methods for making conversions and situations in which dimensional analysis can be used. We will also touch on conversions which use certain defined, scales for specific types of measurements.

What Is Dimensional Analysis? [1, 3]

“Dimensional analysis”, for our situation here, considers the relationships between actual physical quantities in terms of fundamental types of measurement units (dimensions) as calculations and conversions are performed to ensure that the

dimensions used are consistent among quantities expressed in different measurement systems. In other words, the dimensions of the same quantity must be the same before and after conversion.

Suppose we step back and consider measurements from a very basic standpoint. In Chap. 1, we defined the base types of measurements as:

- Length
- Mass
- Time
- Electric charge
- Temperature
- Amount of substance
- Luminous intensity

Each of these measurement types defines a specific “dimension” of something we are measuring. Length, mass, time, and temperature are fairly obvious. The others are a little more esoteric.

These measurements are “fundamental” in that you can’t break them down into simpler factors. For instance, we don’t really have any smaller dimension measurement for length. The only dimension smaller than length would be a point in space, which has no physical meaning.

Suppose, then, that we assign letters to these fundamental dimensions for convenience in referencing them. The most common designations are:

- Length $\rightarrow L$
- Mass $\rightarrow M$
- Time $\rightarrow T$
- Electric charge $\rightarrow Q$
- Temperature $\rightarrow \Theta$ (Absolute temperature)
- Amount of substance $\rightarrow N$
- Luminous intensity $\rightarrow J$

Using these fundamental dimensions for notation, consider the case of length and various derivatives of length:

- Length has the dimension L (e.g. meters)
- Speed has the dimension L/T (e.g. meters per second)
- Acceleration has the dimension L/T^2 (e.g. meters per second squared)
- Rate of change in acceleration has the dimensions L/T^3 (e.g. meters per second cubed)
- And so on with additional derivatives

In dimensional analysis, the dimensions are independent of the measurement units we use. For instance, a flow rate can be expressed as liters per minute, gallons per hour, barrels per day, or firkins per fortnight and they can all represent the same physical quantity. All these units would have the dimensions of L^3/T . Note that generally we agree to use certain units for quantities for simplicity and accurate communications. We probably would not specify a pump in units of firkins per fortnight; but would specify gallons per minute or liters per hour.

The dimensions can be used in mathematical operations like any other variables. If we want to calculate flow rate in volume per unit time, we would combine dimensions as follows:

$$\text{Volume} = L \times L \times L = L^3$$

$$\text{Time} = T$$

$$\text{Volumetric flow rate} = \text{Volume/Time} = L^3/T \text{ or } L^3T^{-1}$$

Similarly, we can determine the dimensions of force using the definition of force:

$$\text{Force} = \text{mass times acceleration (F = ma)}$$

Mass has the dimension M

Acceleration, from above, has the dimensions L/T^2

So, the dimensions for force are $M \times L/T^2 = ML/T^2$ or MLT^{-2}

Now, for convenience (and to create confusion), we define a new unit of force as a Newton (N—not the same as the dimension “N”) or a Pound Force (lb_f) in the two most common systems. A “Newton” is defined as the force required to accelerate a 1 kg mass at 1 m per second squared. A “Pound Force” has two different, but equivalent, definitions:

- 1 pound force is the force required to accelerate 1 pound mass (lb_m) at the standard acceleration of gravity (about 32.174 ft/s^2).
- 1 pound force is the force required to accelerate 1 slug at 1 ft/sec^2 , where a slug is equivalent to 32.174 pounds mass.

Further complicating the English units, we also have a “poundal” defined as the force required to accelerate 1 pound mass at 1 ft/sec^2 .

While each of these definitions of force may result in a different absolute value for the same physical quantity, they all have the same fundamental dimensions that are carried through the calculations: ML/T^2 or MLT^{-2} .

Table 2.1 indicates the fundamental dimensions for several common measurements in both the U.S. or English system and the SI system. Note that force is used as a fundamental unit in the US system; this is common in engineering.

Using Dimensional Analysis in Conversions

Dimensional analysis provides two valuable services for us in conversion between measurement units: (1) the ability to use the equivalence or similitude of units in one system with those in another to make a conversion and (2) the ability to verify that the dimensions are consistent between two units so we can check our answers.

Let’s start with basic conversions, the first service. From dimensional analysis, we know that the dimension of length (or distance in some publications) can be expressed in different units, but the dimension of the length is still “L”. So if we have a length measured in one system of units, we can convert that length to a new set of units by knowing the equivalence of length between the two systems. This is

Table 2.1 Basic dimensions for common engineering quantities [1]

Quantity	Dimensions	
	US system (FLT)	SI system (MLT)
Acceleration	LT^{-2}	LT^{-2}
Angular Velocity	T^{-1}	T^{-1}
Area	L^2	L^2
Density, Mass	$FL^{-4}T^2$	ML^{-3}
Density, Weight	FL^{-3}	$ML^{-2}T^{-2}$
Diameter	L	L
Energy	FL	ML^2T^{-2}
Force	F	MLT^{-2}
Kinematic Viscosity	L^2T^{-1}	L^2T^{-1}
Length	L	L
Mass	$FL^{-1}T^2$	M
Pipe Roughness	L	L
Power	FLT^{-1}	ML^2T^{-3}
Pressure	FL^{-2}	$ML^{-1}T^{-2}$
Pressure Drop per Length	FL^{-3}	$ML^{-1}T^{-2}$
Speed	LT^{-1}	LT^{-1}
Stress	FL^{-2}	$ML^{-1}T^{-2}$
Surface Tension	FL^{-1}	MT^{-2}
Velocity	LT^{-1}	LT^{-1}
Viscosity	$FL^{-2}T$	$ML^{-1}T^{-1}$
Volume	L^3	L^3
Volumetric Flow Rate	L^3T^{-1}	L^3T^{-1}
Weight	F	MLT^{-2}
Work	FL	ML^2T^{-2}
Pressure Drop per Length	FL^{-3}	$ML^{-1}T^{-2}$

application of the “Great Principle of Similitude” as termed by Sir Isaac Newton in 1686. The principle really predated Newton. This simply means, loosely stated, that a physical quantity in one system of measurement is the same no matter what units you use to measure it.

Most commonly today, for example, to convert a meter in the SI system to a foot in the U.S. Customary or English system we just need to know either how many feet are in a meter or how many meters are in a foot. These factors we can get from the conversion tables. Then we make use of the following relationship:

$$Z = n[Z_a] = m[Z_b] \quad (2.1)$$

where:

- Z the true physical quantity
- n the number of units in measurement system “a”
- Z_a the basic unit for this type of measurement in system “a”
- m the number of units in measurement system “b”
- Z_b the basic unit for this type of measurement in system “b”

So, to convert from system “a” to system “b”, we solve for “m”, the number of system “b” units represented by “Z”:

$$m = n ([Z_a]/[Z_b]) \quad (2.2)$$

We can get Z_a/Z_b from standard conversion tables, but we have to make sure we are using the correct values for the units in the two systems. Note that the “correct” values have changed over time as discussed in Chap. 1, but have been fairly constant and consistent over the past century or so.

While this all seems complicated when you express it this way, what it fundamentally comes down to is that you can usually take a quantity measured in one system of units and just multiply it by the appropriate linear “conversion factor” to get to another set of units. We refer to this as “direct” conversion later in this book, as opposed to non-linear and indirect conversions required for some measurements.

In terms of dimensional analysis, a correct conversion factor has the same dimensions in both systems of units, so essentially you are multiplying by 1. Meters in the SI system have dimension “L” and feet in the English system also have dimension “L”.

Application of dimensional analysis in converting units from one system to another simply means multiplying the value of a quantity in one system by the appropriate conversion factor for another system. By appropriate, we mean the conversion factor for a length must be a ratio of the dimension of length in both systems, for example.

Now, for the second use of dimensional analysis, suppose we are making a calculation and need to be sure the final result has appropriate units. We can follow the units in the calculation through as well as follow the dimensions at the same time.

Consider the case of pressure (or stress). By definition, pressure is:

$$\text{Pressure} = \text{Force}/\text{Area} \quad (2.3)$$

$$\text{Now: Force} = \text{Mass} \times \text{acceleration} \quad (2.4)$$

$$\text{Area} = \text{Length} \times \text{width} \quad (2.5)$$

$$\begin{aligned} \text{Dimensionally: } \text{Mass} &\rightarrow M \\ \text{Acceleration} &\rightarrow L/T^2 \\ \text{Area} &\rightarrow L^2 \end{aligned}$$

Pressure then has the dimensions: $(ML/T^2)/L^2 \rightarrow M/(LT^2)$
 Suppose we have 14.7 psi and want to convert to Newtons/m².

$$\frac{14.7 \text{ lb}_f}{1 \text{ in}^2} \times \frac{4.448 \text{ Newtons}}{1 \text{ lb}_f} \times \frac{1550 \text{ in}^2}{1 \text{ m}^2} = 4.85 \times 10^6 \text{ Newtons/m}^2$$

Dimensionally:

$$\frac{M}{LT^2} \times \frac{ML/T^2}{ML/T^2} \times \frac{L^2}{L^2} = \frac{M}{LT^2}$$

So the units are consistent.

Factor-Label Method for Conversion [2, 3]

Above, we applied a useful approach for converting quantities from one set of units to another called the “factor-label” method. This helps ensure you keep the dimensions consistent and that you remember all the factors.

To apply the factor-label method:

1. Write down the quantity you want to convert along with its measurement units using a fractional format. For example, express 20 feet per second as:

$$\frac{20 \text{ ft}}{\text{sec}}$$

2. Now write down the conversion or equivalence factors for each unit to your new set of units as a ratio of the units in the original measurement system to those in the desired system. The ratio of the two units in the two systems will be physically equivalent to 1, so the original quantity is not changed. Treat the units algebraically. Suppose we want to convert our 20 ft/sec to meters per hour. We need to convert feet to meters. From available tables, we know that 1 foot is 0.3048 m. Using the factor-label approach, our conversion becomes:

$$\frac{20 \text{ ft}}{\text{sec}} \times \frac{0.3048 \text{ m}}{1 \text{ ft}} \quad \leftarrow \text{Essentially} = 1$$

Note that, since we need to have the meters in the numerator, for our factor we put meters in the numerator and the feet go in the denominator.

At this point, if we multiplied it out, we would have meters per second. Now to get to an hour we recognize that 1 h is 3600 s, so we multiply by that factor.

Since we need to have hours in the denominator, we put it there in the conversion factor and put seconds in the numerator. Again, the ratio of 3600 sec to 1 h is essentially 1 since the quantities are physically equivalent:

$$\frac{20 \text{ ft}}{\text{sec}} \times \frac{0.3048 \text{ m}}{1 \text{ ft}} \times \frac{3600 \text{ sec}}{1 \text{ hr}}$$

3. Now multiply the original quantity by the conversion factors and cancel out the units to arrive at:

$$\frac{20 \text{ ft}}{\text{sec}} \times \frac{0.3048 \text{ m}}{1 \text{ ft}} \times \frac{3600 \text{ sec}}{1 \text{ hr}} = \frac{21.946 \text{ m}}{1 \text{ hr}}$$

Of course, the answer would normally be expressed with the appropriate number of significant figures, which could be two or four, depending on how accurate the original 20 ft/sec was. Most conversion factors have been rounded off anyway, but some are exact and need not be considered in the significant figures. If we assumed the 20 ft/sec was exact in the first place, then we are entitled to 4 significant figures, so the answer would be 21,950 meters per hour when rounded to the proper digits.

Types of Conversion Factor Tables

You will generally encounter two types of conversion factor information for simple conversions. For convenience, we will describe them as:

- Simple, Direct Conversion Factor Tables
- Equivalent Factor Matrices

Simple Conversion Factor Tables consist of columns listing original units, the conversion or multiplication factor, and the final units. These are normally arranged with the original factors in alphabetical order to make them relatively easy to use. The columns can be in any order, by author preference. An example of a typical arrangement is in Table 2.2. For most of our conversions in this book, we will use this format.

Etc.

Equivalent factor matrices are preferred by some authors. In these matrices, the units are listed along the top row and along the left side. If you want to convert from one unit to another, you find your initial unit in the left row and then go across the matrix row until you find the column for your new unit. The entry at the intersection of the column and row should be the conversion factor from one unit to the other. To confuse things, sometimes the initial unit is listed on the top and the new unit at the left. Be sure you are clear on the conversions.

Table 2.2 Example simple conversion factor table for lengths

From	To	Multiply by
Arabic foot	Foot	1.050
Arabic foot	Meter	0.320
Assba (Arab)	Foot	0.0738
Assba (Arab)	Meter	0.0225
Cubit (Arab)	Foot	1.837
Cubit (Arab)	Meter	0.560

Table 2.3 Example conversion factor matrix for lengths (Bold Values are Exact)

Unit	Symbol	meter	yard	foot	inch	centimeter
meter	m	1	1.0936	3.2808	39.3701	100
yard	yd	0.9144	1	3	36	91.4402
foot	ft	0.3048	0.3333	1	12	30.4801
inch	in	0.0254	0.02778	12	1	2.54
centimeter	cm	0.01	0.01094	0.03281	2.54	1

An example of a partial matrix is in Table 2.3.

It is possible to use either type of table to convert units either direction. The basic factors convert from units a to units b by multiplying by the factor. Similarly, you can convert values from units b to units a by dividing by the same factor.

Some Cautions and Limitations

When making conversions there are some common mistakes of which to be aware and to avoid:

1. Applying a simple, direct conversion factor to operations that are not algebraic will result in a set of units that don't make sense. Conversion factors can only be applied to algebraic conversions, i.e. where each measurement unit is of the form a^n .
2. Using a simple, direct, linear conversion factor for applications where zero in one measurement system is not also zero in the other measurement system or where the units sizes are not linear within each of the two systems. The most familiar example of this is in temperature conversions between Celsius and Fahrenheit degrees. The water freezing point reference is 0°C on the Celsius scale and 32°F on the Fahrenheit scale. Similarly, the boiling point of water is defined as 100°C or 212°F . Since at least the scales are linear, we can see there are 1.8°F per 1.0°C . If we wanted to use simple conversion factors for temperatures, we could use the corresponding absolute scales, where both scales are zero at absolute zero and then the Rankin scale (Fahrenheit equivalent) increases

1.8° for every degree increase on the Kelvin scale (Celsius equivalent). There are many other measurement scales which fall into this category. As examples, consider density scales (Baumé, API Gravity, Brix, and others), viscosity scales (Saybolt, Redwood, Engler, and others), sound (decibel, phon, Neper, etc.), and map projections and coordinates.

3. Picking the wrong factor. For example, be sure the factor you use is for converting feet to cubits if that is what you are trying to do and that it is not for cubits to feet. This is a risk with the matrix-type tables
4. Missing factors. While dimensional analysis might indicate that you have converted a length using an L/L factor, the “L” that you ended up with might not be the appropriate one. You have to look at both the dimensions and the actual units to be sure.
5. Incomplete conversion. Sometimes there are hidden factors in units. For instance, there are many standard temperature and pressure bases used. While dimensional analysis may indicate that you have the correct set of units, it is possible that the standard base needs to be adjusted to another set of standard units, in addition to making the conversion. It helps to understand the basis for the calculations.

Conclusion

Interconversion of measurement units is facilitated by available linear conversion factor tables. Application of dimensional analysis helps ensure the final result from complex conversions is dimensionally consistent, but will not always ensure you end up with the correct units or values. Use of the “Factor-Label” approach to conversion reduces the chance of error in conversions involving multiple units and factors and reduces the risk of missing a factor. There are some types of inter-conversions which require non-linear approaches, such as converting degrees Baumé to specific gravity. Slightly more complex methods are required in these non-linear cases which may rely on a table or an equation.

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Chapter 3

Metric and U.S. Customary/English Systems



Abstract This chapter explores the two commonly used measurement systems today: (1) the *Système internationale d'unités* (SI) metric system and (2) the U.S. Customary or English system. The English system, with roots back over 6000 years ago in ancient Mesopotamia, has changed significantly over the intervening centuries. The history of these changes is highlighted up to the current definitions of the units, which actually use SI metric units as a basis. Similarly, the genesis of the metric system is traced from its earliest roots before the French Revolution to its adoption over the past 200 years by almost all countries, with the exceptions of the United States, Liberia, and Burma. The SI metric system's role as the international standard for weights and measures is discussed. The trend toward base unit definitions using natural constants and how this approach is progressing are discussed.

Introduction

Today, the *Système internationale d'unités* or S.I. metric units are the standards throughout most of the world. A handful of countries still primarily use the older U.S. Customary or English system of measurement as a standard, notably the United States.

This chapter will explore the origins and applications of these two disparate systems of measurement. We will look at why it is so difficult to change measurement systems; it is not a trivial issue.

History of the U.S. Customary/English System

[1–4, 6–8, 10, 11, 15, 16, 18–24, 27, 28, 33–35, 42]

The English System [19–21, 23, 34]

We will start with a short history and evolution of the U.S./English measurement system from some very early records. This system has its roots in the oldest known measurement systems, at least 6000 years ago.

The English system began with definitions of units in Mesopotamia and Egypt sometime before 3000 BC. At this time, many of the basic units for length and weight were defined.

Of course, England did not directly glean the ancient units from the Middle East or Egypt. The units moved and evolved through the Greek and Roman periods via trade and conquest, with Romans bringing the general system of measurement to the British Isles beginning in 43 AD. Prior to that time, there were undoubtedly native units of measurement, but these were largely displaced by the Roman units over time, although a few native, local units still survive.

In the ancient systems, shorter lengths were defined in terms of human proportions (“natural”, anatomically-based, or anthropomorphic units). Longer lengths or distances were less rigidly defined in terms of travel times or multiples of the smaller units. Some English units of length dating from the time period of Roman occupation include:

- Inch—defined as the breadth of a man’s thumb originally, but later defined as the length of 3 barleycorns. The Roman term was *uncia pollex*, hence the word “inch”. The old English term “*uncia*” meant 1/12.
- Foot—conceptually, this is the length of a man’s foot. The Romans brought the division of the foot into 12 inches. At some point, the present absolute value of a foot was developed. This was a Roman unit called a *pes* or *pes pedis*. In Irish measures, this was a *troighid*.
- Cubit—defined as the length of the forearm to the tip of the middle finger, this is one of the oldest units. Historically, the actual value of a cubit varied through civilizations from 17.47 to 20.8 modern inches. In Rome, the term was *cubitus*.
- Pace—basically two steps of a man when marching (left-right-left). About 5 modern feet. The Roman term was *passus*.
- Mile—defined as 1000 paces by the Romans. This has been changed over the years and varied by location. Traditionally, 5000 *pedes*.
- League—usually considered to be the distance a person could walk in one hour, or about 3 modern statute miles.

Weights were based on the sizes of specific types of grains, such as barley or wheat or carob. Some of the weights that can be traced back to ancient times include:

- Carat—weight of a typical carob seed. From the Egyptian unit “karat”.
- Grain—weight of a wheat seed from the middle of an ear of wheat. This weight definition can be traced back through the Byzantine, Roman, Greek, and Biblical eras to Mesopotamia.
- Shekel or scruple—defined as 20 grains today. This measurement also goes back to Mesopotamia. The name comes from the Latin: *scrupus*, meaning something small.
- Dram—this references the weight of a Greek drachma coin. It is normally about 1/16th ounce.

- Ounce—the words ounce and inch have the same origin as 1/12 of something. This relationship works for Troy weight measurements in the English system, but for the Avoirdupois system, an ounce is 1/16th of a pound.
- Pound—this is a basic measurement unit comprising 7000 grains in the Avoirdupois system or 5250 grains in the Troy system. The term “pound” comes from the Latin word *pondus* for weight. Interestingly enough, the abbreviation for pound (lb) comes from the Roman term *libro* (to weigh), which absolute value was actually closer to a modern Troy pound.

Following the exit of Rome from the British Isles, there were successive invasions and influxes of other peoples into the Isles. The Celts, Anglo-Saxons, and Normans all brought new measures or modified the measurement units in place. The crusades brought English people into further contact with Europe and the Middle East, where new units were found in addition to relatively familiar units, with different names. The number and variety of units used in England grew. Some new units and terms introduced during the Middle Ages included:

- Ton—this was the weight of liquid in a large container. The term derives from *tunne*, which was used in the Scandinavian and Germanic areas. The actual weight represented by a *tunne* might vary considerably with commodity.
- Mark—this Troy measure came from a similar term found in Western Europe.

Units existing in the Middle Ages for volume or capacity included:

- Sester—from Roman and Greek origins as *sextarius* and *xestes*, respectively. Represented about 0.546 liters.
- Amber—in Old English dry measures this was about 4 bushels or 140 liters.
- Mitta—this may have been a specific quantity at the end of the middle ages (around 14th century), but the value(s) is not available now. The word “mitta” is of Scandinavian origin where it means simply a “measure”.
- Coomb—this is essentially the same as an amber, at 4 Imperial bushels or about 145 liters.
- Seam—this is a measure of dry volume equal to 8 Imperial bushels or about 291 liters. It, or its variation “soam”, is an Anglo-Saxon word for a pack animal load. In more recent times, the term has been replaced by “quarter”.

While the evolution of the measurement units is interesting, it also presents challenges because the absolute values represented by these measurement units varied considerably with time from location to location and, for some measures like volume or weight, by commodity.

Efforts to standardize the English measurements began in earnest before the 10th century by the Saxons. Many of those efforts have been lost to time; however, a statute during the reign of King Edgar the Peaceable, a Saxon king, established “Winchester measures”, i.e. standards that were to be held at Winchester (also spelled as Westchester in some references). Early standards included physical embodiments that were the “standards”. A standard royal bushel and possibly other standards, such as a standard yard or ell, were created in an attempt at uniformity.

Interestingly, the statute establishing Winchester measures also set an allowable price for wool and the amount of fines for anyone buying and selling at any other price. Why the buyer would be fined is not particularly clear unless this was an acknowledgement of possible collusion among buyers at the time.

Under William I in the 11th century, a 1068 AD act “On Measures and Weights” reaffirmed that the weights and measures throughout the realm were to be consistent with those established by “our worthy predecessors”. This would also imply they were to be standardized. This re-affirmation of prior measures occurred several times in statute over the next few centuries.

In 1197 AD, under Richard I, specific standards of size and quality were promulgated for woolen cloth which was to be 2 ells wide. The ell was defined to be the same everywhere. It is stated that “the ell shall be of iron”. This implies there was a physical iron bar that was defined to be the official “ell”.

The Assize of Bread and Ale statute, believed to have been enacted by Parliament around 1258 AD during the reign of Henry III, standardized weights, proportions and volumes. Under this statute the following measures were defined:

- English Penny or Sterling weighed 32 wheat corns from the middle of the ear.
- 20 Penys make one ounce
- 12 ounces make one pound
- 8 pounds make a gallon of wine
- 8 gallons of wine make a London bushel
- 8 bushels made a quarter

The Bread and Ale statute of 1258 also reaffirmed the prior units of measurement and called for the standards, “at the request of the Bakers of our Town of Coventry” to be “exemplified”. We would interpret this to mean that physical examples of the measures were to be created. This would be consistent with prior practice.

The *Tractatus de Ponderibus et Mensuris*, passed in 1303 AD under Edward I, reaffirmed some prior measures and defined some new ones specifically. From this act of Parliament we would get:

- Penny or Sterling of 32 grains of wheat in the middle of the ear (consistent with the 1258 AD act)
- 20 pence to the ounce (consistent)
- 12 ounces to the pound of London (consistent)
- 12½ pounds to the stone of London
- 8 pounds of wheat to the gallon (consistent)
- 20 shillings to the pound
- 8 gallons to the bushel (consistent)
- 28 stones to a “sack of wool” or a “weigh of wheat” (this is also stated as 1/6 of a load of lead, so this is not totally consistent)
- 120 stone (6 times 20) to a load of lead (also called the great load of London). It was acknowledged that the “load of the Peak” is much less, but this is not defined.
- 30 fotmals to a load of lead

- 6 stone minus 2 pounds made a fotmal
- 12 pounds in a stone (inconsistent)
- 25 shillings in a pound (inconsistent)
- 70 pounds in a fotmal
- 175 stone in a Load
- 12 Wey in a load by “troni weight” (troy?)—this was stated as an alternative measure
- 14 stones to the Wey for lead, wool, linen, tallow, and cheese
- 2 Wey of wool to the sack
- 12 sacks of wool to the last
- 10 thousand herrings to the last of herring
- 10 hundred herrings to a thousand of herring
- 120 herring to the hundred of herring (this would really imply a last of herring would be 12,000 by our current terminology)
- 20 dicker to a last of leather
- 10 skins to a dicker of leather
- 10 pairs of gloves to a dicker of gloves
- 20 horseshoes to a dicker of horseshoes
- 12 skins or 12 pairs of gloves made a dozen
- 13½ stones in a “hundred” of wax, sugar, pepper, cumin, almonds, and alum
- 8 pounds in a stone of wax, sugar, etc.
- 20 shillings to a pound of money, but 25 shillings to the pound for commodities
- 20 pence to the ounce
- 12 or 15 ounces to the pound (apparently depended on commodity)
- One hundred ells to the “hundred” of canvass or linen cloth, but hundred is defined here as 120
- For iron and shillings, “hundred” is defined as 100
- 30 pieces to the sheaf of steel
- 6 pieces to the “Dozen” of iron
- 24 stones or 120 pounds to the “seam” of glass
- 5 pounds to the stone of glass
- 10 sticks per bind of eels
- 25 eels per stick
- 32 timber of rabbits or squirrels per bind
- 40 pelts per timber (unclear) of rabbits or squirrels
- 13 ells per “Chef of Fustian” and 10 ells per “Chef of Sindon”
- 15 ropes per hundred of garlic
- 15 heads of garlic per rope of garlic
- Hundred of “Mulvells and Hard Fish” numbered 160

The items defined by the act were sort of standards, but not by our current thinking. They depended heavily on the commodity and recognized local variations. The definition of the word hundred also appears to be somewhat “flexible” as it was defined in various places as 100, 120, or 160. “Thousand” was similarly flexible in its application.

Also during the reign of King Edward I, in 1305, early standard definitions of areas were made by the *Statutum de Admensuratione Terrase*, or Statute for the Measurement of Land. From this we get an acre defined as 10 Perches by 16 Perches.

Somewhere between 1266 and 1303, the *Compositio Ulnarum et Perticarum* (Statute on the Composition of Yards and Perches) was promulgated. This statute defined the basic measures of length, more or less consistently with those we use today:

- One inch is 3 grains of barley dry and round
- 12 inches to the foot
- 3 feet to the yard (which was termed an ell, even though the current definition of an ell would be about $\frac{1}{2}$ a yard)
- $5\frac{1}{2}$ yards per perch (or rod)
- 40 perches $\times$ 4 perches are an acre (consistent)

Reference is made to an iron yard “of Our Lord the King”, implying that there existed, in fact, a physical standard for the yard. Not obvious here is that the definitions of length measurements changed to about 10/11ths of prior values, but the rod and acre definitions as multiples were still consistent, if smaller.

In the 14th century, the actual standard for a yard was the distance between two marks on a bar that was a little over 1 yard long. Idiomatically, the inch was still thought of as 3 barleycorns long, a foot 12 inches long, and a yard was 3 feet long.

Additional acts in the 14th century attempted to further standardize measures and defined how measurements were to be made in commerce:

- 1340 AD: bushel and weight standards were to be distributed throughout “every Country”.
- 1344 AD: “Commissions to assay Weights and Measures” were repealed. This was likely an attempt to control dishonesty and to establish a central authority for setting standards.
- 1350 AD: it was defined that weight shall be measured by equal balance (with the balance beam level) to prevent “Damage and Deceit” in commerce. Any Buyer not following the law would be “grievously punished” and sued. It is interesting that the onus was put on the buyer, not the seller for punishment in the case of cheating. In the previous act in the 10th century, both buyer and seller paid the penalty. This act further defined:
 - 26 stones per sack of wool
 - 14 “l” to the stone (probably 14 pounds or “lb” in modern abbreviations)
- 1350 AD: It was acknowledged that the Great Charter (the Magna Carta of 1215 AD) had defined that there would be one “Measure” throughout England and that this had not been established well or enforced. It was restated that the measurements would be according to the King’s Standard. This document defined that a quarter was 8 level bushels (there was also discussion of “heaped” versus level measures). The Lords were still allowed to collect rents based on whatever measures they had used in the past. The King assigned “Justices” in every County to enforce the standards and mete out punishment.

- 1353 AD: Statute of the Staple. Those found guilty of fraudulent measurement were liable for quadruple damages and up to 2 years in prison.
- 1389 AD: Interestingly, a statute reiterated that there was to be one set of standards throughout England, “saving in the County of Lancaster”. It is not apparent why Lancaster got a pass on the standards.
- 1392 AD: It was stated that “The Clerk of the Market shall carry with him all his Weights and Measures signed.” Each market location had a set of standards which were used at that market and those would be related to the King’s standards.

In the 15th century, King Henry VII further established standards throughout the realm by reaffirming the Winchester standards and setting additional standards for capacity or volume and length. He proceeded to distribute actual physical copies of the standards throughout his governed area.

It was also in 1496, under Henry VII, that An Act for Weights and Measures reiterated the Winchester measures specifically and called out the Troy pound:

- 8 gallons per bushel of wheat
- 8 lbs of wheat per gallon
- 12 ounces Troy per pound
- 20 sterlings per ounce
- 32 corns of wheat (middle of ear) per sterling

These standards were updated by Queen Elizabeth I and additional definitions were added in the 16th century. For example, the length of a rod was standardized at 5.5 yards, idiomatically defined as the total length of the left feet of 16 men lined up as they emerged from church. Queen Elizabeth distributed physical copies of the standards to her subjects.

Some specific definitions in the 16th century included:

- 1527 AD: The Tower pound had been in use for various commodities and sometimes for precious metals. The Verdict of the Pyx under Henry III defined that precious metals were to be measured using the Troy system. A Troy pound was stated as exceeding the Tower pound in weight by $\frac{3}{4}$ ounce.
- 1581 AD: An act about Wax included the following standards for bulk liquid honey volumes:
 - 32 wine gallons per barrel
 - 16 wine gallons per kilderkin
 - 8 wine gallons per firken
- 1593 AD: In the first definition of a statute mile:
 - 8 furlongs per mile
 - 40 poles (or rods) per furlong
 - $16\frac{1}{2}$ feet per pole (or rod)

By the 17th century, more units became standardized, some by custom and some by law. Many reached their current, standard values at this time, such as the acre and

furlong. There had previously been multiple versions of the pound in use, but the systems were reduced to just two: avoirdupois and troy. The Winchester bushel was formally defined as 18 ½ inches diameter by 8 inches deep or about 2150 cubic inches.

In 1706, an act of Parliament defined the gallon as 231 cubic inches exactly. This established the “Queen Anne” gallon or wine gallon. This was the gallon that became the U.S. Customary gallon.

Because this was now the period the English were busy building an empire, the 17th and 18th century British measurement system(s) were propagated to their colonies and among their trade partners. Still, the systems presented a smattering of units, with varying relationships to each other. It was during this period that the United States became independent. By default, the U.S. inherited the English system as it existed in the late 1700s, primarily based on Winchester measure.

Several times during the 19th century, various weights and measures acts developed standardization. Most importantly, in 1824, and again in 1878–1893, the British Weights and Measures Acts established the Imperial System of measurement, which standardized all the English units and relationships. The Winchester measures were primarily abandoned in favor of new definitions for units. Most specifically, a new Imperial gallon was defined which had 10 lbs of water at 62 °F and 30 inches mercury pressure (net 277.274 cubic inches). Additional changes included the Imperial standard yard and the adoption of the troy pound as a basis (later for fine materials only).

In 1897, the use of the metric system was legalized by statute in England. The system did not replace the English standards of the time, however. Thus the English system of measurement continued along with metric measures for almost three-quarters of a century.

Starting in 1963, the English system was further refined and many old terms were dropped. The standard units were defined based on metric equivalents. Two years later, 1965, the British began their conversion to the metric (SI) system and formally discontinued “English” units in 1985. However, you still find many of the traditional units in common usage today among British citizens.

It was around 1824, that the English system of units and the U.S. system began to diverge.

The U.S. Customary/English System [3, 8, 10, 11, 14, 16, 18, 22–24, 34]

At the time the United States gained its independence from England, the predominant measurement system in use in the U.S. was English Winchester measures as modified by various statutes over several hundred years of English history. This was not the only set of units in use, however. While the 13 original colonies that became states were primarily English, there were also areas of what was to become the U.S. that used French, Spanish, Dutch, Native American, and other measures.

In the Constitution of the United States of America in 1789, Article I, Section 8 stated that Congress had the power “to ... fix the Standard of Weights and Measures.” Pursuant to this, in 1790, Thomas Jefferson, the Secretary of State, initiated a study to define which measurement system the U.S. should use. Jefferson proposed a decimal-based system, which was adopted for money in 1792, but not for other measures. He did, however, advocate the use of a more modern system of weights and measures. The metric system for measurements did not yet exist when Jefferson issued his report.

France had begun to develop their metric measurement system (base 10). They attempted to convince the U.S. to join in this metric system beginning in 1795, but the U.S. did not act on this idea. Instead, the measurement standards were developed following the English model.

Under this model, some of the primary measurement units for length, weight, area, and volume in the U.S. compared to the units in England in the early 19th century would have included those in Table 3.1. Some of the English values were as defined by the British Weights and Measures Act of 1824, but many were much older.

In 1821, John Quincy Adams, then Secretary of State, submitted a comprehensive report to Congress following a four year study that included consideration of the metric system, which had, by then, been much better defined. At this time, the United States still had no standards for critical measures, such as the yard. There had, however, been increasing political animosity between the United States and France in the early 1800s, so interest in adopting a “French” system for a measurement standard was limited.

In 1832, the Treasury Department decided to define the yard as the distance between two finely-etched marks in an 82 inch long bronze bar. This bar had been procured in England in 1813 for the U.S. Federal Survey Department. When the British had to replace their standard yard due to a fire, a copy of the new British yard was brought to the United States to become the legal American Standard Yard in 1855.

In the rest of the world, the metric system was gaining traction toward a worldwide standard for use in trade. In 1863, the U.S. participated in international meetings on weights and measures which (1) established the importance of uniform measures for international trade and (2) recommended adoption of the metric system as the international postal standard.

In 1866, a bill passed in the U.S. Congress permitting legal use of the metric system in the U.S. Specific conversion values for key measures were set between U.S. Customary and metric units. The standards were related to existing physical standards, some held by France. Eventually, all the U.S. standards were defined in metric equivalents related to international standards held in France, including coinage weights.

The United States entered into a treaty with 50 other nations in 1875 AD following the “Metre Convention” which established the International Bureau of Weights and Measures (BIPM). The Bureau facilities, located in Sèvres, France, maintain the international standards for metric measurements to this day.

Table 3.1 Early measurement units in the United States [20]

Unit	United States Units		English Units	
	US Basis	Metric Equivalent	English Basis	Metric Equivalent
Length				
thou	1/1000 inch	0.0000254 m	1/1000 inch	0.0000254 m
inch	Base unit	0.0254 m	1/36 yard	0.025 m
shaftment	Not used		½ foot after 1066	0.152 m
foot	12 inches	0.305 m	1/3 yard	0.305 m
ell	Not used		5 span	0.381 m
cubit	18 inches	0.458 m	18 inches	0.457 m
yard	36 inches, 3 feet	0.914 m	36 inches, 3 feet	0.914 m
step	Not used		5 shaftments	0.762 m
pace	60 inches, 5 feet	1.52 m	60 inches, 5 feet	1.52 m
fathom	6 feet	1.829 m	6 feet	1.829 m
rod	16½ feet	5.029 m	16½ feet	5.029 m
chain	66 feet, 4 rods	20.12 m	66 feet, 4 rods	20.12 m
furlong	10 chains, 660 ft	201.2 m	10 chains, 660 ft	201.2 m
statute mile	8 furlongs, 5280 ft	1609 m	8 furlongs, 5280 ft	1609 m
nautical mile	6076 ft	1852 m	6076 ft	1853 m
league	3 statute miles	4828 m	Not used	
Avoirdupois Weight				
grain	1/7000 lb av	0.0000648 kg	1/7000 lb av	0.0000648 kg
dram or drachm	27 ¹¹ / ₃₂ gr	0.00177 kg	1/16 ounces	0.00177 kg
ounce	16 dram	0.0283 kg	16 dram, 437.5 gr	0.0283 kg
pound	16 ounces, 7000 gr	0.4536 kg	16 ounces	0.4536 kg
nail	Not used		7 lb av, 1/16 cwt	3.175 kg

(continued)

Table 3.1 (continued)

Unit	United States Units		English Units	
	US Basis	Metric Equivalent	English Basis	Metric Equivalent
stone	Not used		14 lbs	6.35 kg
quarter	Not used		¼ cwt	12.70 kg
hundred weight	100 pounds	45.36 kg	112 pounds	50.80 kg
ton	20 cwt, 2000 lbs	907.2 kg	20 cwt, 2240 lbs	1016 kg
Troy Weight				
grain	1/7000 lb av	0.0000648 kg	1/7000 lb av	0.0000648 kg
pennyweight	24 grains	0.00156 kg	24 grains	0.00156 kg
ounce	20 dwt t	0.0311 kg	20 dwt t, 480 gr	0.0311 kg
mark	Not used		8 ounces t	0.249 kg
pound	12 ounces t, 5760 gr	0.373 kg	12 ounces t, 5760 gr	0.373 kg
Apothecary Weight				
grain	1/7000 lb av	0.0000648 kg	1/7000 lb av	0.0000648 kg
scruple	20 grains	0.00130 kg	20 grains	0.00130 kg
dram	3 scruple, 60 gr	0.00389 kg	3 scruple, 60 gr	0.00389 kg
ounce	480 gr	0.0311 kg	480 gr	0.0311 kg
pound	12 ounces ap	0.373 kg	12 ounces ap	0.373 kg
Area				
square foot	144 sq inches	0.0929 sq m	144 sq inches	0.0929 sq m
square yard	9 sq feet	0.836 sq m	9 sq feet	0.836 sq m
perch	Not used		1 sq rod	25.3 sq m
rood	Not used		¼ acre	1011 sq m
acre	43,560 sq feet	4047 sq m	4840-7840 sq yds	4047 sq m
bovate/oxgang	Not used		~ 15 acres	60,650 sq m

(continued)

Table 3.1 (continued)

Unit	United States Units		English Units	
	US Basis	Metric Equivalent	English Basis	Metric Equivalent
virgate/yardland	Not used		~ 30 acres	121,300 sq m
hide	Not used		4–8 bovates	363,900 sq m
carucate, carue	Not used		~ 120 acres	485,200 sq m
sq. mile/section	640 acres	2,590,000 sq m	640 acres	2,590,080 sq m
hundred	Not used		100 hides, ~ 14 sq miles	36,390,000 sq m
township	36 sections	93,239,930 sq m	Not used	
Liquid Volume				
minim	~ 1 drop	6.16E-5 liters	~ 1 drop	5.92E-5 liters
fluid dram	60 minim	0.003697 liters	60 minim	0.00355 liters
teaspoon	80 minim	0.004929 liters	80 minim	0.00474 liters
tablespoon	3 teaspoons, 4 fluid drams	0.01479 liters	3 teaspoons, 4 fluid drams	0.0142 liters
pony	Not used	Not used	6 dram	0.0213 liters
fluid ounce	2 tablespoons, 1/128 gallon	0.02957 liters	2 tablespoons	0.0284 liters
gill	4 fluid ounces	0.1183 liters	5 fl ounces (10 fl ounces for beer and milk)	0.142 liters
cup	8 fluid ounces	0.2366 liters	10 fl ounces	0.284 liters
pint	2 cups, 16 fluid ounces	0.4732 liters	20 fl ounces	0.568 liters
quart	2 pints, 32 fluid ounces	0.9464 liters	40 fl ounces	1.137 liters
gallon	4 quarts, 128 fluid ounces	3.7854 liters	4 qts (Imperial)	4.546 liters, Beer: 4.621 liters, Wine: 3.785 liters

(continued)

Table 3.1 (continued)

Unit	United States Units		English Units	
	US Basis	Metric Equivalent	English Basis	Metric Equivalent
barrel	31–42 gals, commodity-specific	117–159 liters, 158.99 liters for oil	42 wine gals or 35 Imp gallons, commodity specific	159 liters
hogshead	63 gals	238.48 liters	Commodity specific	Variable
demijohn	3–10 gals, varied	Variable	Commodity specific	Variable
Dry Volume				
pint	33.6 cu inches	0.5506		0.5685 liters
quart	2 dry pints	1.1012	2 dry pints	1.137 liters
gallon	4 dry quarts	4.4049 liters	4 dry quarts	4.546 liters
peck	2 dry gallons	8.8098 liters	2 dry gallons	9.092 liters
kenning	Not used		2 pecks	18.18 liters
bushel	4 pecks	35.24 liters	4 pecks	36.37 liters
strike	Not used		2 bushels	72.74 liters
barrel	3.281 bushels	115.6 liters	4 bushels (coomb)	145.5 liters
dry hogshead	Not used		2 dry barrels	290.9 liters
dry tun	Not used			1164 liters

The drive toward metrication internationally, but especially in the United States, was resisted in the late 1800s by an organization called the International Institute for Preserving and Perfecting Weights and Measures. This organization saw metric units as atheistic. They advocated a “perfect inch” and “perfect pint”. The historical measures were considered by the group to be the only ones “acceptable to the Lord”. Why this would be the case is unclear, since many of these traditional units were originally developed by the ancient idol worshipers before 4000 BC.

In 1890, the U.S. received two copies each of the international prototype standards for the meter and kilogram from the BIPM. One of each of these was chosen as the standard for meter and kilogram in the U.S. The length and weight standards in U.S. Customary units were then defined in terms of these metric standards, with the standard yard passing into history. The metric standards are maintained by the National Bureau of Standards.

Over the many years since the United States accepted metric measurement as an option, there have been several attempts to make metric measurement the standard (1896, 1901, etc.). None of the bills has passed. Meanwhile, almost all other countries which had used the English system of measurement, including the United Kingdom and all its possessions and protectorates, switched to metric measurements. The UK was pushed by the desire to become part of the European Economic Community in the 1960s, eventually the European Union.

The issue was again studied in the U.S. in 1968–1970, with a report entitled “A Metric America—A Decision Whose Time Has Come”, issued in 1971. The report recommended a 10 year transition plan. Apparently, the time didn’t actually come for four more years, when, in 1975, Congress passed the Metric Conversion Act to move the country toward metrication.

Provisions of the Metric Conversion Act included:

- Adoption of SI (*Système international d’unités*) standards
- No time table
- Use of the system was voluntary
- A Metric Board was to be established, appointed in 1976
- Costs of conversion were to be treated as costs of doing business, with no tax credits or subsidies

There was a flurry of activity around converting units and educating the public on the metric system that lasted until about 1980, when it died down again. During this time, many U.S. Government and other standards were moved to SI units. Most scientific work was already being done in SI units, since the 1800s.

However, the progress toward metrication in the United States has been very slow for three reasons, all directly related to the Act:

1. Wholesale conversion is expensive. The Act put the onus for the cost of conversion on business, for which they cannot expect any help or tax breaks. The United States has a huge industrial economic base built upon English units. It is very difficult to change this quickly. In a simple example, there is no standard metric bolt that can replace a ¼ inch bolt in a machine. You can get a 6 mm bolt

or a 7 mm bolt, both with different thread counts per unit length. Neither size can be substituted for the $\frac{1}{4}$ inch bolt. You need to accept a sloppy fit, drill out the holes, use higher strength bolts, or buy new equipment at additional cost.

2. Compliance with the system is voluntary. The metric system has never been adopted voluntarily in any country, including its native France. It was only adopted when it was made mandatory. Even then, the general public continued to use many old units of measurement.
3. No time table means no schedule and no real plan. In business, a project without a time table will never be done. “Failure to plan is planning to fail”.

So, high cost, no incentives, and voluntary commitment to an open schedule have basically doomed attempts at metrication so far in many sectors of the U.S. There are a few industries that have made the conversion, however: science, medicine, a few industries, and government, especially for military specifications and environmental regulations. The Omnibus Trade and Competitiveness Act of 1988 reiterated the desire to move to the metric system as the “preferred system of weights and measures for U.S. trade and commerce”. Little impact of this measure has been observable overall.

The U.S. Customary or English units continue to be used in everyday commerce in the United States, Liberia, and Burma. The balance of the world has made the conversion to SI units. Globalization is the real, primary driver toward metrication.

History of the the Metric/SI System [2, 5–7, 9, 12–15, 17, 18, 22, 25–32, 36–42]

The history of the “metric system” really began with the concept of creating a logical, coherent, and cohesive system for decimal weights, measures, and coinage put forth by Flemish mathematician Simon Stevin in 1586. Use of such a base 10 system by the public was unknown, but the advantages and applications were well known to scientists and mathematicians.

This was not the first application of a base 10 system for measurement. Such systems relating measurement units to each other were already used in the Far East (China, Japan, Korea, Southeast Asia), but this concept had not been common in Europe.

It was in 1668, that John Wilkins, then Secretary of the Royal Society of London, proposed the use of the decimal system for length, area, volume, and mass, in his work: “An Essay on the Real Character and a Philosophical Language.” The proposed unit of length was to be based on the distance covered by a pendulum with a frequency of one stroke per minute. Such a measure could be easily duplicated anywhere on earth.

Gabriel Mouton, a French abbot and scientist, and Gottfried Leibniz, a German mathematician and philosopher, both proposed decimal measurement systems that based the unit of length on a fraction of the length of one of earth’s meridians in 1670. There was interest in these concepts. They were studied, but otherwise no action followed.

The importance of these early proposals for decimal-based systems was that they attempted to define fundamental units of measurement based on physical parameters that were believed to be constants worldwide. In fact the proposed measures are not exactly constant. For instance, the earth is not perfectly spherical so the meridians are not all the same length. They are pretty close to the same length, but not exactly the same length.

Eighteenth century Europe had a wide range of measurement units, some with the same or similar names, which differed from nation to nation, locale to locale, and town to town. Some nations, notably Spain and Russia, pushed for standardizing units to facilitate trade. Other nations, who could benefit from the confusion created by the different systems, opposed standardization.

At the start of the French Revolution in 1789, France had thousands of differing values for the same measurement units. This was, in fact, one of the conflicts that precipitated the revolution. Early in the revolution, a Commission of Weights and Measures was established. The Commission sought to adopt a new set of measurements based on unchanging natural phenomena and a philosophically consistent approach. The Commission presented a proposal for a decimal-based system to the French national assembly in 1791. The base-10 system conceptually was opposed by some representatives, who favored a duodecimal (base 12) system. Eventually, the base-10 supporters prevailed.

During the development of this system, the French attempted to interest other countries in adopting the proposed base-10 approach. As noted above, Thomas Jefferson in the United States was interested in such a system. No countries immediately adopted the system, however.

One of the first “metric” units created was decimal time or “French Revolutionary Time”. It was implemented by France in 1793. In the decimal time system, a day was divided into 10 hours, each having 100 minutes and each minute having 100 seconds. In this system, then, a day consisted of 100,000 decimal seconds. Each decimal second was equivalent to 0.864 conventional, base 12/60 seconds. This was not the first application of base 10 time; the Chinese had used a base 10 time system since at least the first millennium BC, along with duodecimal time. It was also not the last decimal time system proposed; both France and Switzerland have made various additional proposals for decimal time over the past two centuries, without gaining traction.

While several time pieces were produced with both decimal and duodecimal time dials relating the two systems, decimal time was not well-accepted.

In 1795, the initial law establishing the metric system in France was enacted. The system was officially adopted in 1799 and use was decreed to be mandatory in Paris in 1799 and throughout the country in 1800. The population at large, however, did not necessarily observe this decree.

The original units of measurement within the initial metric system were:

- Length: *metre*. One ten-millionth of the length of the earth’s meridian from the North Pole to the equator roughly through Dunkirk, France, and Barcelona, Spain. (The effort to establish the actual length of this meridian by surveying and subsequent calculation required several years and makes a fascinating story in itself.)

- Land Area: *are*. Equal to 100 square meters.
- Volume of Dry Solids, like firewood: *stère*. Equal to one cubic meter.
- Volume of Liquids: *litre*. Equal to one cubic decimeter.
- Mass: *gramme*. 1/1000 of a kilogram. Derived from a *kilogramme*, which originally was called a “grave”. Because the word “grave” had connotations related to the former ruling class and the prevailing mood in France was so heavily anti-ruling-class, the unit name was eventually changed to “kilogramme.”

The law establishing the new metric system also, ironically, repealed the decimal time system that had been enacted only two years before. The time units of measurement reverted to the second-minute-hour-day arrangement that was in use throughout most of the rest of the world.

The initial metric system continued the tradition of defining standards for length, area, and volume separately, even though area and volume were really defined by length units. Today we have prefixes for the base unit terms to indicate different orders of magnitude (e.g. milli-, deci-, centi-, giga-, etc.). In this early system there were fewer prefixes defined. Milli-, representing 1/1000th, and myria-, representing 10,000, were defined prefixes, for example.

The metric system was spread to areas annexed by France beginning in the Napoleonic era. The system was not easily accepted and implemented, even in France.

Napoleon, in 1812, re-introduced old French units of measurement by defining the *mesures usuelles*. These were the units used by people in everyday trade. Official business was still conducted in the metric system. In the *mesures usuelles* system, the values of the units France had used traditionally were re-defined in terms of metric units. From this effort, we have such odd units as the metric pound (*livre metrique*), defined as 0.500 kilograms, and the metric fathom (*toise metrique*), defined as 2 meters. The quantities represented by these *mesures usuelles* were close to the old common definitions, so there was some familiarity, but there was also room for confusion. You could still see remnants of this system in units of various locales around the world where France held sway in the early 1800s before full adoption of the metric system and in such pre-metric units as the German zollpfund (customs pound) of 0.500 kg.

The primary units defined in the *mesures usuelles* were:

- Length
 - *toise* (metric fathom): two metres
 - *pied* (metric foot): 1/6 toise or about 333.3 mm
 - *pouce* (metric inch): 1/72 toise or about 27.78 mm
 - *ligne* (metric line): 1/12 pouce or about 2.32 mm
 - *aune* (metric ell, for cloth): 120 cm
 - *demi aune* (half an ell): 60 cm
 - *tiers aune* (third of an ell): 40 cm
 - There were no units larger than a toise.

- Liquid Volume
 - *litre*: same as a metric litre
 - *demi* (metric pint): $\frac{1}{2}$ litre
 - *quart* (literally, “quarter”): $\frac{1}{4}$ litre
 - *huitième* (literally, “eighths”): $\frac{1}{8}$ litre
 - *seizième* (literally, “sixteenths”): $\frac{1}{16}$ litre
- Dry Volume
 - *boisseau* (metric bushel): $\frac{1}{8}$ hectolitre, but varied with commodity and region
 - *double-boisseau* (double bushel): $\frac{1}{4}$ hectolitre
 - *demi-boisseau* (half bushel): $\frac{1}{16}$ hectolitre
 - *quart-boisseau* (quarter bushel): $\frac{1}{32}$ hectolitre
- Weight
 - *livre* (metric pound): 500 grams or 9216 metric grains, still used today in some areas
 - *once* (metric ounce): $\frac{1}{16}$ livre
 - *gros*: $\frac{1}{8}$ once
 - *grain* (metric grain): $\frac{1}{72}$ gros

The metric system was also adopted by a few other nations in the early 1800s, notably The Netherlands and Belgium. In 1840, the metric system became compulsory in France and the *mesures usuelles* were discontinued. The volume and area standards were eliminated in favor of combinations of linear measures to define area and volume.

Once the French standardized on the metric system, more countries began adopting it, each with its own tweaks. By 1875, nearly half the world was using this system. Russia and the United Kingdom were the primary European holdouts. From 1860 to 2000, the number of countries adopting the metric standards increased fairly steadily, with peak conversion in the 1960s and 1970s when the United Kingdom made the move. Presently, only the United States, Liberia, and Burma still primarily operate on older measurement systems, with the U.S. notably using the English/Winchester measures that existed in the late 1700s.

While countries may officially be using the metric system, everyday usage varies and most countries still use vestiges of prior, non-metric systems.

The *Convention du Metre* (Meter Convention) was an 1875 international treaty that established an international organization to define and manage the metric standards. Initially, this organization was focused on length and mass standards. As technology developed, other fundamental measurements, such as electric charge, quantities of matter, radiation intensity, and so on, were recognized. In 1921, the Meter Convention incorporated all units of measurement into its scope of control.

There is not just one metric system, as the name may imply; but several variants exist. The genesis of the variants lies in the needs for different applications. The most common variants, as depicted in Table 3.2, are:

Table 3.2 Primary metric system variants of base and derived units and US Customary units [2, 4, 8, 9, 12, 13, 17, 20, 29–32, 39] (Units in bold are base units.)

System	Symb	CGS	MKS	MTS	MK _p S, MK _f S	SI	US Cust.
Length, distance	l, d, h, x	centimeter, cm	meter, m	meter, m	meter, m	meter, m	yard, yd
Area	A	cm ²	m ²	m ²		m ²	acre, ft ² , yd ²
Volume	V	cm ³	m ³	m ³ or liter, L		m ³	ft ³ , in ³ , yd ³ , Liquid: gallon, Dry: bushel
Mass	m	gram, g	kilogram, kg	tonne, t	hyl (p s ² /m), AKA TME or metric slug, mug	kilogram, kg	slug, sl, or pound-mass, lb _m
Density	ρ	g/cm ³	kg/m ³	t/m ³		kg/m ³	lb/ft ³
Time	t	second, s	second, s	second, s	second, s	second, s	second, s
Speed	v	cm/s	m/s	m/s		m/s	ft/s
Acceleration	a	galileo, Gal	m/s ²	m/s ²		m/s ²	ft/s ²
Force	F	dyne, dyn	newton, N	sthene, sn (t m/s ²)	kilopond, kp (gram-force)	newton, N	pound force, lb_f
Pressure, stress	p, P	barye or bar, Ba	pascal, Pa	pièze, pz (t/m s ²)	tech, atmosphere, at (kp/cm ²)	pascal, Pa (N/m ²)	lb _f /in ² or psi
Energy	E, Q, W	erg (work), erg, or calorie (heat), cal	joule, J	kilojoule, kJ (t m ² /s ²)	kilopond-meter, kp m	joule, J	British thermal unit, Btu
Power	P	erg/s	watt, W	kilowatt, kW (t m ² /s ³)	poncelet, p _p , or metric horsepower, PS (=3/4 P _p)	watt, W	horsepower, hp, or watt, W
Viscosity, dynamic	μ	poise, P	pascal-sec, Pa s	pièze-sec, pz s		pascal-sec, Pa s	lb _f /ft s ²
Angle	φ					radian, rad	degrees, deg or °
Temperature	T, Θ	kelvin, °K , or celsius, °C	kelvin, °K , or celsius, °C	kelvin, °K , or celsius, °C		kelvin, °K , or celsius, °C	rankin, °R , or Fahrenheit, °F

(continued)

Table 3.2 (continued)

System	Symb	CGS	MKS	MTS	MK _p S, MK _r S	SI	US Cust.
Ant of Substance						mole, mol (gram-mole)	mole, mol (pound-mole)
Elect. current	I	biot, Bi (esu/s)	ampere, A			ampere, A	ampere, A
Specific volume						m ³ /kg	cft/lb
Luminous intensity		stilb, sb				candela, cd	

- Centimeter-gram-second (CGS or cgs). This system was developed in the 1860s and found acceptance among the scientific community. In the CGS system, the primary units for length, mass, and time were as defined by the name. Other units fell out of these basic units. Electrical and magnetic phenomena were not measured all that easily in this system, with two sets of electrical units and two sets of magnetic measurements. We still use some CGS units, but many of the base units were too small for everyday industrial application.
- Meter-kilogram-second (MKS). This system, started in 1893 and further refined in 1901, incorporated a fourth fundamental unit measuring electricity, extended the measurement system. The International System of Units (SI) is an extension of the MKS system. The magnitudes of the base units in this system are consistent with everyday and industrial applications, whereas the CGS units were too small for most commercial uses.
- Meter-tonne-second (MTS). This system was developed in France for industrial use. It saw application in France and the USSR between 1933 and 1955, but is no longer common.
- Gravitational systems (MK_pS, MK_fS). These systems were sort of a combination of the metric concept and units with the English system, employing kilograms force as a unit, with a standard gravitational acceleration applied. These systems are not really used today.
- International System of Units. This is the *Système internationale d’unités* or SI and is the international standard for metric units. Development of this system began about 1948 with requests to develop one standard, consistent, practical system of units that could be used by all countries. Starting with the MKS system, the International Committee for Weights and Measures (CIPM), which had been established by the 1875 Meter Convention, proposed a comprehensive set of units and definitions. The new definitions included derived as well as fundamental units. The system was adopted in 1960. Specific measures and definitions have been refined since, but the units remain essentially unchanged. Table 3.3 lists the SI units and their relationships to prior metric measures.

Table 3.3 Some key SI unit equivalents in prior metric systems [2, 9, 12, 13, 17, 29–32]

System	SI	CGS	MKS	MTS	MK _p S, MK _f S
Length, distance	1 meter	1 cm = 0.01 m	1 meter = 1 m	1 meter = 1 m	1 meter = 1 m
Mass	1 kilogram	1 g = 0.001 kg	1 kilogram = 1 kg	1 tonne = 1000 kg	1 hyl = 9.8066 kg
Time	1 second	1 s = 1 s	1 s = 1 s	1 s = 1 s	1 s = 1 s
Force	1 newton	1 dyn = 0.00001 N	1 newton = 1 N	1 sthene = 1000 N	1 kilopond = 9.8066 N
Temperature	1 °K	1 °K = 1 °K	1 °K = 1 °K	1 °K = 1 °K	1 °K = 1 °K
Elec. Current	1 ampere	1 Biot = 10 A	1 ampere = 1 A		
Luminous intensity	1 candela	1 stilb = cd/cm ² (luminance)			

An early objective in establishing the metric system was to eliminate the reliance of measurement standards on physical objects or artifacts to define those standards. Prior to this, for example, a standard “yard” was actually a bronze bar with two gold disks inset in it and fine lines etched into the disks. The distance between two selected lines was defined as the “yard”. For most everyday uses, these standards might be adequate, but as technology developed and trade expanded, the tiny differences in length with temperature of a bronze bar or the tiny changes in mass of the standard kilogram would change the standard very slightly, but significantly, for some applications. Having a single, physical artifact as a standard means that the standard is not easily reproducible to high accuracy in other locations. The single standard artifact may be subject to damage, as the British yard standard was in a fire in the early 1800 s. Hence, there has been a desire to define the standards in terms of immutable physical phenomena that could be reproduced anywhere to the same accuracy.

Today, the fundamental metric units (and, coincidentally, the standard U.S. Customary units by reference) are defined by:

- *Length*: In 1960, the meter was defined as the length of 1,650,763.73 wavelengths of the orange-red emission line in the electromagnetic spectrum of krypton-86 in a vacuum. This could be measured by interferometry. Somehow this was not specific enough, so it was redefined in 1983 as the distance light travels in a vacuum in $1/299,792,458$ th of a second. This is the current definition.
- *Mass*: The fundamental unit of mass, the kilogram, is the only unit in the SI system defined by a physical artifact or standard. The standard is the International Prototype Kilogram (IPK) maintained by the International Bureau of Weights and Measures (BIPM) in France. This prototype was defined in 1889 as the official kilogram. It is a platinum-iridium cylinder 39.17 mm diameter and 39.17 mm high. It has been recognized that this artifact has lost weight, in the range of a few micrograms, since it was initially produced. Efforts have been underway over the past decade to redefine the kilogram using the Planck constant, which can be related to specific numbers of atoms of an element. Proposed approaches to do this with sufficient accuracy have included:
 - “Watt balance” (a very sensitive electric scale)
 - Mass of $5.01845135 \times 10^{25}$ atoms of carbon-12 ($83\frac{1}{3}$ mol)
 - Mass of a specific 93.6 mm diameter sphere of ultrapure silicon-28
 - Mass of $3.05744362 \times 10^{25}$ atoms of pure gold (5.07700371 mol) collected by electrodeposition with a known current and time
 - Mass of a specific number of pure bismuth atoms, similar to the gold concept, collected by electrodeposition with a known current and time
 - Redefine mass based on acceleration created by electrical current in a vacuum

Of the proposed methods of standardization for the kilogram, only the Watt balance and the silicon sphere are still being actively pursued. The other approaches

proved to be impractical for various reasons. For now, mass remains defined by the only physical artifact standard, the International Prototype Kilogram.

- *Time*: The second was at one time defined as 1/86400th of the earth's rotation in 1900 AD. With the development of atomic clocks, the second is now defined as "the duration of 9,192,631,770 cycles of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the cesium-133 atom at 0 °K". A little hard for the average person or engineer to use, but fortunately we have our clocks, cell phones, and innumerable other time-keeping devices that are indirectly related to this definition.
- *Electric Current*: The ampere is the constant current through two straight parallel conductors of infinite length and negligible circular cross-section and placed 1 m apart in vacuum that would produce a force between these conductors of 2×10^{-7} N per meter of length. Again, this is a little hard for the average person to measure, so we conveniently have ammeters to do it.
- *Temperature*: Temperature as used here is defined in terms of thermodynamics. The measurement unit is the "Kelvin," equal to 1/273.16th of the thermodynamic temperature at the triple point of water, which is 0.01 °C, or 32.018 °F. Of course, we normally use physical or electrical phenomena that can be related to this definition for practical measurement, such as thermometers which depend on the thermal expansion of materials or thermocouples that depend on the voltage generated between two dissimilar metals in contact.
- *Amount of Substance*: This is the mole (or mol), which is defined as the number of "elementary entities" represented by 12 grams of carbon-12, essentially a particle count. The types of elementary entities can include individual atoms, molecules, ions, and so on. This is a definition that is useful in chemistry and physics. A mole essentially represents Avogadro's number or constant ($6.022140857(74) \times 10^{23}$) of elementary entities, that can then be related to mass.
- *Luminous Intensity*: The candela unit for luminous intensity is the intensity of light in a given direction of a source that emits monochromatic radiation of frequency 540×10^{12} hertz with a radiant intensity in that direction of 1/683 W per steradian. A steradian is one square radian—essentially a spherical surface that is 1 square radius in area (recognizing the omnidirectional movement of light from a point source).

For all these units, direct everyday use of the definitions outside of scientific applications is impractical, so we routinely use accurate copies of the units or multiples of the units for measurement. These copies can be made to whatever accuracy is required and measure in sizes appropriate for normal applications, but usually take the forms of:

- Rulers, tapes, ultrasonic, or other methods for length
- Various types of scales for mass or weight
- Watches, clocks and timers for time
- Ammeters for electric current

- Molecular weight values for amounts of substances
- Photometers and other methods to measure luminous intensity

From the basic metric units, there are several derived units used in specific applications. A derived unit is a combination of fundamental units that is used to measure or describe a property. There is more discussion of the derived units in Chap. 14. Several of the derived units have their own names (apparently to create confusion). Table 3.4 lists many of the derived units.

There are several units which, although not part of the SI system, are recognized in that system as named units. These are summarized in Table 3.5.

The final element of the metric system that we have touched on briefly is how the units in the system are scaled to make them larger or smaller. This is done by adding a prefix to the base unit name. The prefix used is determined by the order of

Table 3.4 Derived and base SI metric units [2, 9, 39]

Application	Unit Name	Symbol	Dimensions	Definition
Mass	kilogram	kg	M	Base unit
Length/distance	meter	m	L	Base unit
Time	second	s	T	Base unit
Amt. of Substance	mole	mol	N	Base unit
Electric current	ampere	A	I	Base unit
Thermodynamic temperature	kelvin	K	Θ	Base unit
Luminous intensity	candela	cd	J	Base unit
Volume	cubic meter	m ³	L ³	m ³
Area	square meter	m ²	L ²	m ²
Speed/velocity	meters/second	m/s	LT ⁻¹	m/s
Acceleration	meters/second squared	m/s ²	LT ⁻²	m/s ²
Force	newton	N	MLT ⁻²	kg m/s ²
Pressure	pascal	Pa	ML ⁻¹ T ⁻²	N/m ²
Stress	pascal	Pa	ML ⁻¹ T ⁻²	N/m ²
Energy	joule	J	ML ² T ⁻²	N m
Work	joule	J	ML ² T ⁻²	N m
Quantity of heat	joule	J	ML ² T ⁻²	N m
Power	watt	W	ML ² T ⁻³	J/s
Heat flow rate	watt	W	ML ² T ⁻³	J/s
Catalytic activity	katal	kat	NT ⁻¹	mol/s
Electric charge	coulomb	C	I T	A s
Celsius temp.	celsius	°C	[Θ -273.15]	°K-273.15
Magnetic flux	weber	Wb	ML ² T ⁻² I ⁻¹	V s

(continued)

Table 3.4 (continued)

Application	Unit Name	Symbol	Dimensions	Definition
Capacitance	farad	F	$M^{-1}L^{-2}T^4I^2$	C/V
Illuminance	lux	lx	JL^{-2}	lm/m ²
Luminous flux	lumen	lm	J	cd/sr
Abs. radiation dose	gray	Gy	L^2T^{-2}	J/kg
Radiation dose equiv.	sievert	Sv	L^2T^{-2}	J/kg
Radioactivity	becquerel	Bq	T^{-1}	1/s
Frequency	hertz	Hz	T^{-1}	1/s
Inductance	henry	H	$ML^2T^{-2}I^{-2}$	Wb/A
Magnetic flux density	tesla	T	$MT^{-2}I^{-1}$	Wb/m ²
Electric potential	volt	V	$ML^2T^{-3}I^{-1}$	W/A
Electromotive force	volt	V	$ML^2T^{-3}I^{-1}$	W/A
Resistance	ohm	Ω	$ML^2T^{-3}I^{-2}$	V/A
Solid angle	steradian	sr	L^2L^{-2}	m ² /m ² (dimls)
Plane angle	radian	rad	LL^{-1}	m/m (dimls)
Electric conductance	siemens	S	$M^{-1}L^{-2}T^3I^2$	A/V
Magnetic field strength	oersted	Oe	IL^{-1}	A/m
Dynamic viscosity	poise	P	$ML^{-1}T^{-1}$	Pa s
Kinematic viscosity	stokes	St	L^2T^{-1}	m ² /s

Table 3.5 Named, non-SI units used with SI system [9]

Unit Name	Symbol	Dimensions	Equivalent SI value
minute	min	T	60 s
hour	h	T	3600 s
day	d	T	86,400 s
degree	deg	LL^{-1}	$(\pi/180)$ rad
arcminute	'or arcmin	LL^{-1}	$(\pi/10800)$ rad
arcsecond	"or arcsec	LL^{-1}	$(\pi/648000)$ rad
litre	l	L^3	10^{-3} m ³
tonne	t	M	1000 kg
electronvolt	eV	ML^2T^{-2}	$1.602... \times 10^{-19}$ J
atomic mass unit	AMU or u	M	$1.6605... \times 10^{-27}$ kg
nautical mile	—	L	1852 M
knot	—	LT^{-1}	0.5144 M/s
angstrom	Å	L	10^{-10} m
are	a	L^2	100 m ²
hectare	ha	L^2	10,000 m ²
barn	b	L^2	10^{-28} m ²

(continued)

Table 3.5 (continued)

Unit Name	Symbol	Dimensions	Equivalent SI value
bar	bar	$\text{ML}^{-1}\text{T}^{-2}$	100,000 Pa
gallileo	Gal	LT^{-2}	0.01 m/s^2
curie	Ci	T^{-1}	$3.7 \times 10^{10} \text{ Bq}$
roentgen (radiation dose)	R	ITM^{-1}	$2.58 \times 10^{-4} \text{ C/kg}$
rad (radiation dose)	rd or rad	L^2T^{-2}	0.01 Gy
rem (radiation dose)	rem	ITM^{-1}	$2.58 \times 10^{-4} \text{ C/kg} = 1 \text{ R}$

magnitude of the unit value compared to the base value. The prefixes are summarized in Table 3.6. For prefixes larger than 10^{24} or smaller than 10^{-24} the prefix symbols are listed, but these symbols are not necessarily official SI prefixes.

Using this approach, for instance, a kilogram is 10^3 or 1000 times as massive as a gram. A kilometer is 1000 times longer than a meter. A millimeter is 10^{-3} or 0.001 times as large as a meter. The prefixes are similarly applied to all the units defined in the metric (and SI) system.

The metric system continues to develop as needs arise, but the development is slow and deliberate, even ponderous. Many parties need to agree on changes to the system before they are made. The 200 year history of the system certainly has demonstrated that achieving general agreement is not easy, but it is possible.

Table 3.6 Prefixes for SI system units (values outside 10^{24} through 10^{-24} are not part of SI) [40, 41]

Name of prefix	Symbol	Factor	Base 10 Order of Magnitude
–	Ω	10^{96}	96
–	Ψ	10^{93}	93
–	Φ	10^{90}	90
–	T	10^{87}	87
–	Σ	10^{84}	84
–	Π	10^{81}	81
–	Ξ	10^{78}	78
–	Λ	10^{75}	75
–	Θ	10^{72}	72
–	E	10^{69}	69
–	Δ	10^{66}	66
–	Γ	10^{63}	63
–	X	10^{60}	60
–	W	10^{57}	57
–	V	10^{54}	54
–	U	10^{51}	51
–	S	10^{48}	48

(continued)

Table 3.6 (continued)

Name of prefix	Symbol	Factor	Base 10 Order of Magnitude
–	R	10^{45}	45
–	Q	10^{42}	42
–	O	10^{39}	39
–	L	10^{36}	36
–	J	10^{33}	33
–	I	10^{30}	30
–	B	10^{27}	27
yotta	Y	10^{24}	24
zetta	Z	10^{21}	21
exa	E	10^{18}	18
peta	P	10^{15}	15
tera	T	10^{12}	12
giga	G	10^9	9
mega	M	10^6	6
kilo	k	10^3	3
hecto	h	10^2	2
deka	da	10^1	1
Base unit		10^0	0
deci	d	10^{-1}	–1
centi	c	10^{-2}	–2
milli	m	10^{-3}	–3
micro	μ	10^{-6}	–6
nano	n	10^{-9}	–9
pico	p	10^{-12}	–12
femto	f	10^{-15}	–15
atto	a	10^{-18}	–18
zepto	z	10^{-21}	–21
yocto	y	10^{-24}	–24
–	b	10^{-27}	–27
–	i	10^{-30}	–30
–	j	10^{-33}	–33
–	l	10^{-36}	–36
–	o	10^{-39}	–39
–	q	10^{-42}	–42
–	r	10^{-45}	–45
–	s	10^{-48}	–48
–	u	10^{-51}	–51
–	v	10^{-54}	–54
–	w	10^{-57}	–57
–	x	10^{-60}	–60

(continued)

Table 3.6 (continued)

Name of prefix	Symbol	Factor	Base 10 Order of Magnitude
–	γ	10^{-63}	–63
–	δ	10^{-66}	–66
–	ε	10^{-69}	–69
–	θ	10^{-72}	–72
–	λ	10^{-75}	–75
–	ζ	10^{-78}	–78
–	π	10^{-81}	–81
–	σ	10^{-84}	–84
–	υ	10^{-87}	–87
–	ϕ	10^{-90}	–90
–	ψ	10^{-93}	–93
–	ω	10^{-96}	–96

Future Developments in Standards [9, 42]

Future standards for measurement continue to develop. The trend is toward standards based on fundamental constants of nature that are not believed to change with time or location. The constants under consideration (with some currently in use) and their targets are:

- Length definition of meter: Speed of light in vacuum ($c = 299,792,458$ m/s, current definition of a meter)
- Mass definition of kilogram: Planck’s constant ($h = 6.626070... \times 10^{-34}$ J s)
- Electric current definition of ampere: Elementary charge ($e = 1.602176... \times 10^{-19}$ C)
- Thermodynamic temperature definition: Boltzmann constant ($k = 1.3806488 \times 10^{-23}$ J/°K)
- Quantity of matter in gram-moles of a given entity: Avogadro constant ($N_A = 6.0221367... \times 10^{23}$ units/mol)
- Time definition for second: Transition time between the two energy levels of a specific element (currently duration of 9,192,631,770 cycles of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the cesium-133 atom at 0 °K)
- Luminous intensity in candelas: Based on intensity of monochromatic light (defined as the intensity of monochromatic light of frequency 540×10^{12} hertz equal to exactly 683 lumens/W; the current definition is similar).

The future objective is to define the natural constants to be exactly equal to specific values and then back-calculate the metric units based on those exact values. Certainly, for most of us, this won’t change any definitions significantly; but the changes may be significant for some specialized scientific applications.

Conclusion

The two commonly used measurement systems today are the *Système internationale d'unités* (SI) metric system and the U.S. Customary or English system. The English system can trace its roots back over 6000 years to ancient Mesopotamia. The system has evolved and changed significantly over the intervening centuries, but has been relatively unchanged since the early 1800s. The units of the U.S. Customary/English system are actually defined in terms of SI metric units today.

The metric system is used in all countries except the United States, Liberia, and Burma. The SI metric system is the international standard for weights and measures. With some earlier proposals for such a system, the current metric system embodiment traces its roots to the French Revolution around 1793, when a comprehensive system was proposed using a base 10 relationship between successively larger or smaller units of a given type (mass, length, etc.). The ease of using this system in calculation was evident. Its use has expanded steadily over the past 200 years.

Definitions of measurement units continue to develop, although the changes in the absolute magnitudes will be very small. The trend is toward definitions based on natural constants that will be defined to be exact values, with the measurement unit values back-calculated from the fixed constants.

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Chapter 4

Historical Length or Distance



Abstract Length is one of the oldest (if not the oldest) measures used by humans. It is a measure of the physical size or extent of something along a straight line. This chapter reviews the evolution of length measurement from the simple use of the size of body parts or paces to gauge a length to sophisticated methods based on light and time which enable measurements on both sub-atomic or astronomical scales. An extensive compilation of conversion factors for many ancient and historical length measurements is provided.

Introduction

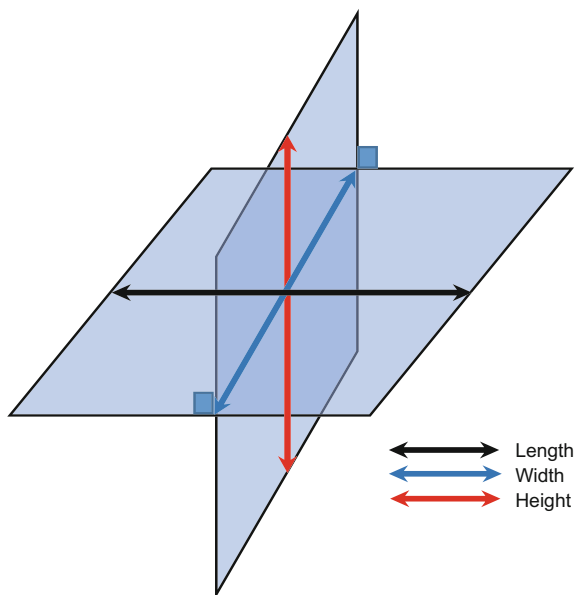
The first thing people think about when you mention measurement is probably length or its larger cousin: distance. Length was likely one of the earliest quantities people attempted to measure. This quantity was important in everyday life for sizing property, clothing, shelter, and other necessities. Distance was also important from the standpoint of travel times or sizes of fields.

For our purposes, length is a linear measurement of a physical extent or dimension of a given object or distance along one or more axes. In SI measurement, length is defined as any quantity with the dimension of distance. This is all a bit circular in definition, but we are all more or less familiar with what a length or distance measurement is.

Length is a fundamental unit in all measurement systems. In many systems, area and volume are also treated as fundamental units, but modern systems define area and volume in terms of lengths in a plane or in 3 dimensions, respectively. Still, historical systems separate length, area, and volume, so we will maintain that distinction in the next few historical chapters.

In some contexts, length is distinguished from width or height by the axis along which the measurement is made. Height refers to measurement along a vertical axis and width refers to measurement along a horizontal axis perpendicular to both the height and length (See Fig. 4.1). Of course, you can measure distance along any other axis, too. Regardless, the measurements are linear in these directions and the

Fig. 4.1 Length, width, and height definitions



same conversion factors can be applied to the measurements. Length can also refer to distances along an arc, such as circumference of a circle. In this chapter we will focus on linear measures, but the units apply as well to curvilinear measurement.

We will use the terms “length” or “distance” more or less interchangeably in this book to refer to all similar measurements, regardless of the axis along which they are measured. Length will generally refer primarily to shorter dimensions and distance will refer to longer dimensions, which may not follow a single axis.

In this chapter, we explore the development of length measurement from the smallest to the largest quantities and provide conversion factors for a large number of historical length measurements.

Historical Development [6, 7, 10, 13-16, 20-22, 27-32, 34, 35, 39]

Length measurement in the ancient world likely began with anatomically-based measurements, i.e. measurements based on the lengths of human body parts. As recently as the 20th century, some Native American tribes still based sizes for various items on an individual’s body parts.

It can be argued that lengths based on body parts would have many practical advantages:

- Dwellings, tools, clothing, etc. based on an individual’s measurements make those items of an appropriate size for that individual.

- The measurement basis is entirely portable, taking up no additional room for persons with a nomadic lifestyle.
- Most things that needed to be measured in everyday life are easily within the scale of body parts in size.

The obvious difficulties in measuring sizes based on body parts were that people are not all the same size and people’s bodies change with age. What was an appropriate size for one person was not necessarily the right size for another. This approach to sizing also did not help facilitate trade as civilization moved from nomadic to agricultural lifestyles.

Eventually, the length measurements based on body parts became more formally defined and standardized to overcome some of the difficulties.

Some of the formalized length measurements based on body parts are illustrated in Figs. 4.2, 4.3 and 4.4. Some of these have varied over time and by civilization. The normal definitions for these units, along with a few other units based on larger parts of the body, from smallest to largest, are in Table 4.1.

If you consider the origins and sources in Table 4.1, you can see that similar anatomically-based length measurements arose in several different civilizations more or less independently, as well as being spread by trade, conquest, and other contacts between civilizations.

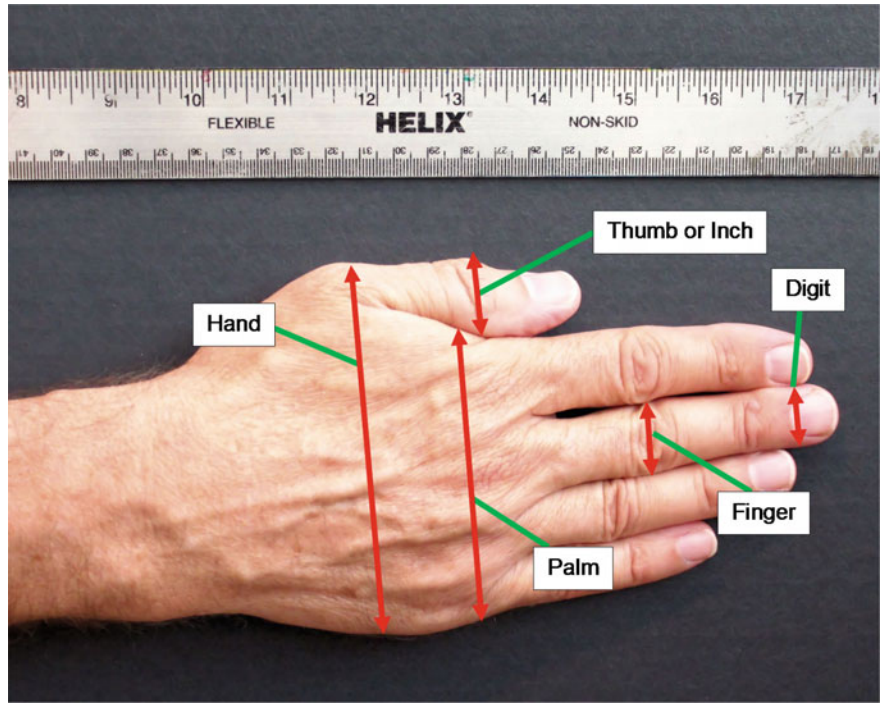


Fig. 4.2 Small anatomically-based length measurements [40]

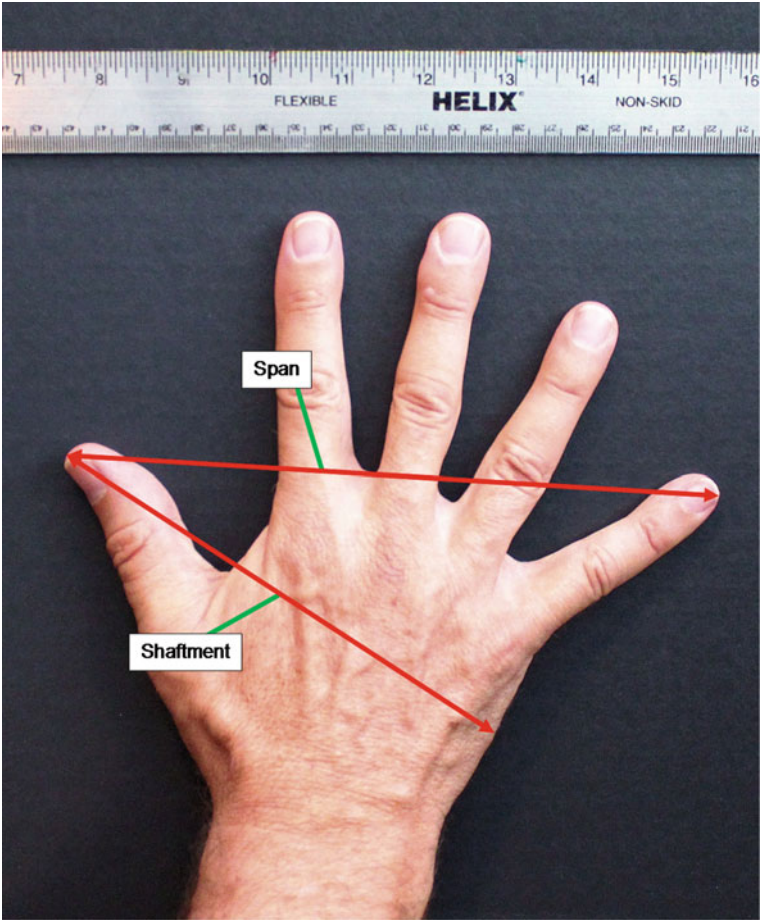


Fig. 4.3 Intermediate anatomically-based length measurements [40]

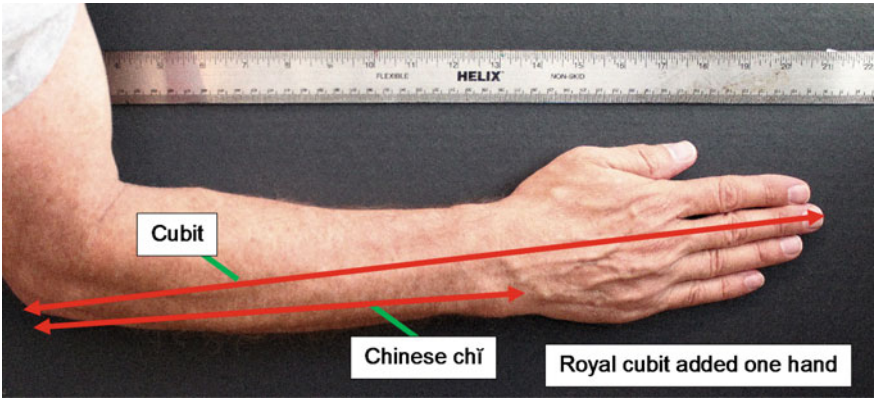


Fig. 4.4 Larger anatomically-based length measurements [19, 26–28]

Table 4.1 Some original anatomically-based length definitions (all based on an adult male human) [6, 8, 13, 14, 19, 23–28, 37, 38, 40]

Unit name (English)	Definition	Typical values		Historical notes, earliest information
		Meters	Feet	
digit	Width of the middle finger at the base of the nail	0.0191	0.0625	Byzantine Empire
finger	Width of the middle finger at the middle knuckle	0.015–0.022	0.049–0.073	Mesopotamian, ~4000 BC
thumb or inch	Width of the thumb at the knuckle	0.024–0.025	0.080–0.083	Before Biblical times, ~3000 BC
palm	Width of the palm of the hand across the four fingers, excluding the thumb	0.074–0.077	0.24–0.25	Before Biblical times, ~3000 BC
hand	Width of the hand across all fingers and including the thumb at the widest part	0.094–0.10	0.31–0.34	Egyptian
fist	Width of a fist, about 6 fingers	0.11	0.37	Egyptian amm
shaftment	Distance from the tip of the thumb to the opposite side of the splayed hand	0.152	0.500	English
lick	Distance from tip of thumb to tip of the index finger with hand spread	0.18	0.59	Greek
span or palm length	Distance from tip of the thumb to the tip of the little finger with the hand splayed	0.20–0.26	0.66–0.85	Before Biblical times, ~3000 BC
foot or chik	Length of the foot from back to heel to the tip of the big toe	0.29–0.33	0.97–1.1	Mesopotamian, ~4000 BC
chi, ell, pic, pygmē	Length of the forearm from the elbow to the wrist	0.25–0.38	0.82–1.3	Chinese, Mesopotamian
cubit	Length of the arm from the elbow to the tip of the middle finger	0.44–0.50	1.46–1.64	Mesopotamian, ~4000 BC
royal or great cubit	One normal cubit plus one hand	0.53–0.64	1.72–2.11	Egyptian
pace	Length of one step, from heel to heel	0.57–1.50	1.86–4.92	Mesopotamian, ~4000 BC, as a “step”

(continued)

Table 4.1 (continued)

Unit name (English)	Definition	Typical values		Historical notes, earliest information
		Meters	Feet	
yard, gaz, vara, archin, braccio	Originally the length of a man's belt or, alternately, the distance between tip of the nose to the tip of the middle finger on an outstretched arm	0.71– 0.91	2.33– 3.00	English, Indian, Spanish, Italian, Russian variants, medieval origin
pace (Roman)	Length of a double step	1.5	5	Roman
fathom, bu, wingspan, kanna, toise, klafter, sazhen	Distance from the tip one middle finger to the tip of the other middle finger with both arms outstretched	1.78– 2.13	5.86– 7.00	Byzantine, Incan, Chinese, English, French, Germanic, Russia, other variants

The longer units of distances developed primarily from human activities, such as travel times or agriculture. The distance units that were used by the Tatars, descendants of the Mongols in Eastern Europe and western Asia beginning in the 12th century, are examples of how distances were measured for often nomadic people. Table 4.2 lists some of the Tatar distance units and their definitions.

Longer distances to the Tatars were based on travel times, specifically when riding a horse. This made sense for the Tatar civilization, which depended so heavily on horses for daily life. Smaller units in their civilization were anatomically-based and appear to have been inherited from the Middle East via the Byzantine Empire.

Table 4.2 Tatar distance units [8gggg]

Unit	Equivalents (Approximate)		Definition
	Meters	Feet	
çaqırım	1067	3500	500 sajin
färsâx	6934	22,747	6–7 çaqırım, used average
mil	7470	24,500	Mile, geographic, 7 çaqırım
atnı tuqtawsız yurıyu	20,000	65,600	Dist horse travels between stops, 15–25 km, used avg
cäyawleneñ könek yulı	37,300	122,000	A day of riding, 35 çaqırım
atnıñ könek yulı	45,000	148,000	Distance horse travels in one day, 40–50 km, avg used
cäyawleneñ aylıq yulı	1,120,000	3,680,000	Month of riding, 1050 çaqırım

The Romans based longer distances on the number of steps or paces when marching, but this traces back the anatomically-based unit of a foot. Table 4.3 demonstrates this application.

For structures, the Romans employed a set of intermediate-sized units that bridged the dimensions from smaller to larger units. These are illustrated in Table 4.4.

The above systems for common measure, distances, and architecture illustrate how length measurements often have varied over history based on the commodity, item, or application. Historically, there have also been specific length measurements for sea voyages, cloth goods, time between rest stops, railroad distances, and many other applications.

Comparison of Historical Unit Magnitudes

Figure 4.5 provides a side-by-side comparison of many length measurement units used throughout history. Note that the data in Fig. 4.5 are compiled from all the sources listed in the “References” section; hence, they are not listed separately here.

Table 4.3 Roman units for distance [1, 8qqq]

Unit	Equivalents (Approximate)		Definition
	Meters	Feet	
pes pedis	0.296	0.971	Roman foot
gradus pes sestertius	0.736	2.41	One step or simple pace, 2.5 pedes
passus	1.47	4.83	Double pace, 5 pedes
actus	35.3	116	120 pedes
stadium	184	604	stade, 625 pedes, 600 Greek ft, =furlong
mille passuum	1480	4860	Roman mile, 5000 pedes
legua	2210	7240	Gallic league, 7500 pedes
schoenus	5890	19,300	20,000 pes

Table 4.4 Roman units for architecture [1, 8qqq]

Unit	Equivalents (Approximate)		Definition
	Meters	Feet	
architect’s decimi	0.00246	0.00807	1/10 arch. oncie
architect’s oncie	0.0177	0.0580	1/12 architect’s palmo
architect’s palmo	0.223	0.732	
architect’s pié	0.298	0.977	Foot
architect’s stajoli	1.284	4.212	1/10 architect’s catena
architect’s canna	2.233	7.325	10 architect’s palmi
architect’s catena	12.84	42.12	57.5 architect’s palmi

The figure's y-axis is the $\log_{10}$ of the historical length converted to meters. Along the x-axis are some of the length units used by various significant civilizations throughout history, from the ancient Mesopotamian period to the current U.S. Customary units. Each civilization or region is represented by a column with the names of the units beside their data points.

From the Fig. 4.5 information, you can observe that several civilizations had units similar in size, and in many cases similar in definition, to a league, a mile, a furlong, a fathom, a yard, a foot, and various hand parts.

With the desire to standardize units over the past two or three hundred years, length measurements have moved toward being independent of activity. About the only common vestige of the earlier activity-dependent units are nautical measures in the English/US Customary system, which still maintains specific units for nautical applications.

Evolution of Length Measurement Tools

A distinguishing element of humans is the use of tools to perform tasks. Length measurement is no exception to this. The earliest length measures were likely based on body parts such as the foot or the arm as noted above. For many applications, this was adequate; although the magnitude of a measure would differ from person to person. Accuracy of this type of measurement would be something like $\pm 10\text{--}15\%$.

To gain consistency and accuracy, people began using sticks and strings of standard lengths. The lengths might still be based on a person's anatomy, but measurement was easier and consistent. Also, another person could cut a stick or cord to the same length and use that as well. Accuracy improved to something like $\pm 1\%$.

The movement toward standardized rods, rulers, and chains is a short, next step. These physical or "artifact" standards could be adopted and used by anyone. A great deal of effort went into standardizing lengths based on physical representations of length. Until nearly the 20th century, physical standards were commonly used. The initial meter standard was a physical bar with marks etched on it. Note that the definition was in terms of the circumference of the earth conceptually, but the actual standard was an artifact. Accuracy of physical measures could go down to less than 1 micron or much less than $\pm 0.001\%$.

The 19th and 20th centuries saw a need for measurements of even smaller magnitudes, as well as much larger magnitudes. Measurement technology has more recently incorporated optical methods (e.g. interferometer) and time of flight methods (e.g. ultrasonic and laser). These techniques get small measurements down to below the nanometer range and large measurements to astronomical scales.

Generally, the need for increased accuracy has driven the development of new technologies to measure ever smaller and larger lengths, which, in turn, has enabled further scientific and technical advancements. This cycle continues today.

English and U.S. Customary Length Measurements

[8y, 13, 14, 21, 29, 31, 34]

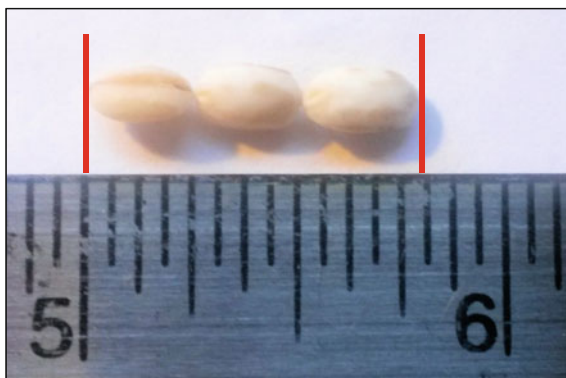
Standard definitions of length units began for the English/US Customary system before the 10th century AD by the Saxons. For example, an inch was defined as the length of three barleycorns from the middle of an ear placed end-to-end in medieval times. This standard was not terribly consistent. Figure 4.6 illustrates this definition with modern barleycorns. You can see that the corns are more like $\frac{3}{4}$ inch long for this variety. Barleycorns vary considerably in size based on the variety. The smaller reported corns are 4–7 mm (0.16"–0.28") long, similar to Fig. 4.6. Other varieties produce corns as long as 12–15 mm (0.47"–0.59"). Older varieties of barley reportedly produced corns averaging about 8.8 mm (0.345"), which would result in 3 barleycorns being very close to an inch. Still, it was sort of a sloppy definition.

Around 1300 AD, the length standard in the English system was shifted to a one yard standard using a physical iron bar that was defined to be one yard long and the standard was maintained at Winchester. Other lengths were then based on fractions or multiples of this standard yard that was maintained by the King. The standard yard was kept as a physical artifact until the 19th century when it was redefined to be a specific size using metric units.

The United States adopted English standard measurements as they existed in the late 1700s. These were essentially the Winchester measures. In 1890, the U.S. received copies of the standard meter bars. These were then used to redefine the U.S. yard and related measures. Eventually the measurements in the U.S. were established and maintained as the U.S. Customary Standards. Subsequent changes in the meter standards and U.S. Customary standards have not substantially changed the absolute value of the length measurements.

For more detailed information on the development of English/US Customary measures, refer to Chap. 3.

Fig. 4.6 Three modern, husked barley corns compared to an inch



Metric Length Measurements [2, 6, 7, 10, 13, 16, 21, 39]

The present general system of metric measurements (primarily SI) began with the French Revolution. There was a desire to reject anything that related to the previous standards established by the French crown as well as a desire to base measurements on more fundamental physical properties rather than depending on a physical artifact for a standard. Chapter 3 details this development.

The initial concept in 1789 for a universal standard of length was to define a unit, the metre or meter, that would be 1/10,000,000th of the surface distance from the equator to the North Pole along a specific meridian running through Dunkirk, France, and Barcelona, Spain—close to the prime meridian at 0° longitude. The presumption was that the earth was perfectly spherical, which is not quite the case. At any rate, for those times the definition was adequate. Other units were then defined as 10^n times a meter, where n was a whole number (both negative and positive values). The order of magnitude (n) was indicated by adding a prefix to the word “metre”, forming names of units such as “millimetre” (10^{-3} meters or 0.001 meter) and “kilometer” (10^3 meters or 1000 meters).

The definition of a meter has been refined over the roughly two centuries since this initial definition, but the changes have been very small and insignificant for most purposes. In 1960, it was redefined to be the length of 1,650,763.73 wavelengths of the orange-red emission line in the electromagnetic spectrum of krypton-86 in a vacuum, which could be measured by interferometry. In 1983, a meter was redefined as the distance light travels in a vacuum in 1/299,792,458th of a second. This is the current definition.

Historical Length Conversion Tables

[1-5, 8-15, 17-20, 23-30, 33, 34, 36-38, 40]

We offer here two historical length conversion tables:

- Table 4.5 provides direct length conversion factors for different locations, regions, eras, and historical civilizations listed alphabetically by location in both metric and English/U.S. Customary units.
- Table 4.6 provides the same length conversion options as Table 4.5, except that the initial units are all listed alphabetically, without regard to location or era.

Please note that these tables make use of data compiled from all the sources listed in the “References” section; hence the reference numbers are not repeated here.

Table 4.5 Historical length measurement conversion factors by location and era. Refer to References section for data sources

Region and Unit	Equivalent meters	Equivalent feet, US	Notes	Era
Abyssinia (1891 Reference)				1891
pic	0.686	2.25	2003 reference	
berri	1690	5545	2464 pic, 2003 reference	
farsang	5070	16,634	3 berri, 2003 reference	
Afghanistan (1891 Reference)				1891
goess	1.160	3.806		
Algeria				Medieval to pre-metric
roby	0.0779	0.255	1/8 pic, using dzera a torky basis, 2003 reference	
termin	0.0779	0.255	1/8 pic, using dzera a torky basis, 2003 reference	
rebia	0.156	0.511	1/4 pic, 2 termin, using dzera a torky basis, 2003 reference	
nus	0.312	1.02	1/2 pic, 2 rebia, using dzera a torky basis, 2003 reference	
dzera a rabry	0.467	1.53	Arabic pic with different basis, varied, 2 nus, also reported as 0.482 m, value from 2003 reference	
dzera a torky	0.623	2.04	Turkish pic, 2 nus, varied, 2003 reference	
America (See United States)				
Annam (Multiple systems in 1891: cloth, architects/builders, roads, see also Vietnam)				Pre-metric
Cloth Measure				
ly	0.000650	0.00213		
phan	0.00650	0.0213	10 ly	
tac	0.0650	0.213	10 phan	
thuoc	0.650	2.13	10 tac	
truong	6.50	21.3	10 thuoc	
that	19.5	63.9	3 truong	
gon	195	639	10 that	

(continued)

Table 4.5 (continued)

Region and Unit	Equivalent meters	Equivalent feet, US	Notes	Era
Architects & Builders				
ly	0.000487	0.00160		
phan	0.00487	0.0160	10 ly	
tac	0.0487	0.160	10 phan	
thuoc	0.487	1.60	10 tac	
ngu	2.44	7.99	5 thuoc	
sao	7.31	24.0	3 ngu	
mau	73.1	240	10 sao	
Road Measure				
ly	442	1,452		
dam	885	2,903	2 ly road measure, 0.55 mi	
Arabia (Significant variations over time and locale)				Ancient to medieval
assbā	0.0225	0.0738	1/16 Ar ft, reported as 0.0200 m in 2003	
assbaa	0.0225	0.0738	1/16 Ar ft, reported as 0.0200 m in 2003	
cabda	0.0900	0.295	1/4 Ar ft, reported as 0.0800 m in 2003	
	0.320	1.05	Consistent with 2003 reference	
cobido	0.483	1.58	In 1891 reference, reported as 0.480 m in 2003	
covid	0.483	1.58	In 1891 reference, reported as 0.480 m in 2003	
cubit (new)	0.483	1.58	In 1891 reference, reported as 0.480 m in 2003	
cubit	0.560	1.84	1.5–2 Ar ft	
gez	0.635	2.08	Old cubit (hashemic), in 1891 reference, reported as 0.640 m in 2003	
guz	0.635	2.08	Old cubit (hashemic), in 1891 reference, reported as 0.640 m in 2003	
cubit (old)	0.635	2.08	Old cubit (hashemic), in 1891 reference, reported as 0.640 m in 2003	
goess	0.635	2.08	Old cubit (hashemic), in 1891 reference, reported as 0.640 m in 2003	
orgye	1.92	6.30	“Pace”, 6 Ar ft, consistent with 2003 reference	

(continued)

Table 4.5 (continued)

Region and Unit	Equivalent meters	Equivalent feet, US	Notes	Era
qasab	3.84	12.6	12 Ar ft, also reported as 3.75 m in 1891, 2003 reference value	
kassaba	3.84	12.6	12 Ar ft, also reported as 3.75 m in 1891, 2003 reference value	
seir	192.0	629.9	600 Ar ft, consistent with 2003 reference	
stadion	192.0	629.9	600 Ar ft, consistent with 2003 reference	
ghalva	230.4	755.9	720 Ar ft, consistent with 2003 reference	
farsakh	5760	18,897	18000 Ar ft, consistent with 2003 reference	
parasang	5760	18,897	18000 Ar ft, consistent with 2003 reference	
barid	23,040	75,590	4 parasang, also reported as 19,300 m in 1891, consistent with 2003 reference	
baryd	23,040	75,590	4 parasang, also reported as 19,300 m in 1891, consistent with 2003 reference	
veredus	23,040	75,590	4 parasang, also reported as 19,300 m in 1891, consistent with 2003 reference	
marhala	46,080	151,179	8 paras, village-length, consistent with 2003 reference	
Argentina (Older units of Spanish origin)				Colonial to pre-metric
linéa	0.002006	0.006581	1/432 vara, 2003 reference	
línea	0.002006	0.006581	1/432 vara, 2003 reference	
pulgada	0.02407	0.07898	Inch or thumb, 1/86 vara, 12 línea, 2003 reference	
palmas	0.2167	0.7108	Palm, 1/4 vara	
pie	0.2889	0.9477	Foot, 1/3 vara, 12 pulgada, 2003 reference	
pie	0.2889	0.9477	Foot, 1/3 vara, 12 pulgada, 2003 reference	
vara	0.8666	2.843	Yard, 3 pie, 2003 reference	
braza	1.733	5.686	2 vara, 2003 reference	

(continued)

Table 4.5 (continued)

Region and Unit	Equivalent meters	Equivalent feet, US	Notes	Era
cuadra	130.0	426.5	150 vara, 75 braza, 2003 reference	
legua (railroad)	520	1,706	Railroad distance only, 600 vara	
milla (railroad)	1850	6069	Railroad measure	
legua	5200	17,059	League, 6000 vara, 40 cuadra, 2003 reference	
Australia (See English, older aboriginal units not available)				1891
Austrian Empire				Pre-metric
Common Measure				
punkt	0.0001829	0.0006001	2003 reference	
punkte	0.0001829	0.0006001	2003 reference	
linie	0.002195	0.007201	12 punkt, 2003 reference	
zoll	0.02634	0.08642	Inch, 12 linen, 2003 reference	
fuss (Bohemia)	0.302	0.990	Reported in Bohemia 1891	
fuß (Bohemia)	0.302	0.990	Reported in Bohemia 1891	
fuss (Average)	0.3161	1.037	Foot, 12 zoll, 2003 reference	
fuß (Average)	0.3161	1.037	Foot, 12 zoll, 2003 reference	
elle (Bohemia)	0.589	1.93	Reported in Bohemia 1891	
elle (Average)	0.779	2.56	2.465 fuss, 2003 reference	
klafter	1.896	6.222	6 fuss, 2003 reference	
ruthe	3.793	12.44	2 klafter, 2003 reference	
meile	7586	24,888	2000 ruthe, 2003 reference	
Engineers & Surveyors Measure (Estimated)				
decimal linie	0.00316	0.0104		
decimal zoll	0.0316	0.104	10 decimal linie	
decimal fuss	0.316	1.04	10 decimal zoll (Used this as base)	
decimal fuß	0.316	1.04	10 decimal zoll (Used this as base)	
ruthe	3.16	10.4	10 decimal fuss	

(continued)

Table 4.5 (continued)

Region and Unit	Equivalent meters	Equivalent feet, US	Notes	Era
Azores (Similar to Portugal)				
Aztec (Sizes are speculative, very limited details available)				Colonial to pre-metric
heart	0.6	1.8	2/5 land rod, “monad” unit	
♥	0.6	1.8	2/5 land rod, “monad” unit	
arrow	0.7	2.3	1/2 land rod, possibly distance from shoulder to outstretched hand (like an arrow), “monad” unit	
↑	0.7	2.3	1/2 land rod, possibly distance from shoulder to outstretched hand (like an arrow), “monad” unit	
hand	0.8	2.6	3/5 land rod, “monad” unit	
☞	0.8	2.6	3/5 land rod, “monad” unit	
land rod	1.4	4.6	Basic unit	
tlalquahuitl	1.4	4.6	Basic unit	
bone			Unknown value	
arm			Unknown value	
Bahamas (See West Indies)				1891
Balearic Islands (Pre-metric)				Pre-Metric
palmas	0.1955	0.6414	2003 reference	
canna	1.564	5.131	8 palmas, 2003 reference	
Belgium (Used units of France, early metric system adoption, below are pre-metric)				1816
pied	0.3249	1.066	Foot, 2003 reference	
perche	6.498	21.32	20 pied, 2003 reference	
Bermudas (See West Indies)				1891
Biblical and Talmudic (approx)				Ancient
etsba	0.0222	0.0729	Thumb breadth, inch	
etzba	0.0222	0.0729	Thumb breadth, inch	
tefach	0.0880	0.289	Palm or hand breadth, 4 finger-breadths, avg, also reported as 0.74 m	

(continued)

Table 4.5 (continued)

Region and Unit	Equivalent meters	Equivalent feet, US	Notes	Era
topah	0.0880	0.289	Palm or hand breadth, 4 finger-breadths, avg, also reported as 0.74 m	
tepah	0.0880	0.289	Palm or hand breadth, 4 finger-breadths, avg, also reported as 0.74 m	
hasit	0.176	0.577	Double palm, Talmudic	
zeret	0.264	0.866	Span, 3 palms, avg	
amah	0.528	1.73	Ell or cubit, 2 spans, avg, Talmudic pace, also reported as 0.518 in Ezekiel 40.5	
ammah	0.528	1.73	Ell or cubit, 2 spans, avg, Talmudic pace, also reported as 0.518 in Ezekiel 40.5	
pesiah	0.528	1.73	Ell or cubit, 2 spans, avg, Talmudic pace, also reported as 0.518 in Ezekiel 40.5	
cord—Gemara	2.112	6.929	4 ells	
cord—Mishnah	26.40	86.61	50 ells	
ris	104.8	343.8	Stadium, avg	
ris—Talmudic	140.8	461.9	1600 palms	
mil	1056	3465	Mile, 2000 ells, avg	
parasa	4224	13,858	Parasang, 4 mils, avg	
derekh yom	42,240	138,581	Day's journey, Talmudic, 10 parasangs	
Bolivia (Generally Spanish units used pre-Metric)				1891
Borneo (English and Dutch units used in colonized parts of the island)				1891
Brazil (pre-1862, varied, primarily Portuguese origins)				Colonial to pre-metric
polegada	0.0275	0.0902	Inch or thumb, 1/12 pé, also reported as 0.02778 m in 2003 reference	
palmo	0.220	0.722	Palm, 2/3 pés, 8 pulgado, also reported as 0.2222 m in 2003 reference	
pé	0.330	1.08	Foot, 1/3 vara, 12 pulgado, also reported as 0.3333 m in 2003 reference	
Brazil (pre-1862, varied, primarily Portuguese origins)				Colonial to pre-metric
pe	0.330	1.08	Foot, 1/3 vara, 12 pulgado, also reported as 0.3333 m in 2003 reference	
vara	1.100	3.609	Yard, 3-1/3 pés, 40 pulgado, also reported as 1.111 m in 2003 reference	
passo geométrico	1.650	5.413	5 pés, also reported as 1.667 m in 2003 reference	

(continued)

Table 4.5 (continued)

Region and Unit	Equivalent meters	Equivalent feet, US	Notes	Era
braça	2.200	7.218	Fathom, 6-2/3 pés, also reported as 2.222 m in 2003 reference	
braca	2.200	7.218	Fathom, 6-2/3 pés, also reported as 2.222 m in 2003 reference	
légua	6600	21,653	League, 20000 pés, also reported as 6667 m in 2003 reference	
legoa	6600	21,653	League, 20000 pés, also reported as 6667 m in 2003 reference	
Burma or Birmah (AKA Rangoon, now Republic of the Union of Myanmar)				Pre-metric
Cambodia (See also Annam and Vietnam, appear to be pre-metric names and post metric values)				Post metric?
mot thuoc	1	3	2003 reference	
muoi	1	3	2003 reference	
phyeam	2	7	2 muoi, 2003 reference	
sen	40	131	40 muoi, 20 phyeam, 2003 reference	
yoch	800	2625	20 sen, 2003 reference	
Canadian				pre-metric
General: Pre-metric conversion (1970s), Canada used English Imperial system with some residual French units in certain areas				
Canary Islands (Spanish weights and measures used)				1891
Castilian foot	0.283	0.927	Local variation	
pié	0.283	0.927	Local variation	
Candia (See Crete)				1891
Cape Colony (Cape of Good Hope, English measurements used)				1891
Cape Verde Islands (Portuguese measurements used)				1891
Celebes (Generally Dutch measurements used)				1891
Central America (See also individual countries, generally Spanish Castilian units used)				Colonial to pre-metric
pulgada	0.0232	0.0761	Inch, 2003 & 1891 references	
cuarta	0.209	0.685	1/4 vara, 9 pulgada, 2003 & 1891 references	

(continued)

Table 4.5 (continued)

Region and Unit	Equivalent meters	Equivalent feet, US	Notes	Era
tercia	0.278	0.913	Foot, 1/3 vara, 12 pulgada, 2003 & 1891 references	
vara	0.835	2.74	Yard, 3 tercia, 2003 & 1891 references	
mecate	20.0	65.7	24 vara, 2003 & 1891 references	
Ceylon (See Sri Lanka)				Pre-metric
covid (Ceylon)	0.464	1.52	2003 reference	
covid (Madras)	0.472	1.55	2003 reference	
Chile (pre-1848, varied, primarily Spanish Castilian)				Colonial to pre-metric
linea	0.00194	0.00635	Line, 1/432 bara, 2003 reference	
pulgada	0.0232	0.0762	Inch or thumb, 1/36 bara, 12 linea, 2003 reference	
pié	0.279	0.914	Foot, 1/3 bara, 12 pulgada, 2003 reference	
bara	0.836	2.74	Yard, 3 pie, 2003 reference, also reported as 0.847 m in 1891	
vara	0.836	2.74	Yard, 3 pie, 2003 reference, also reported as 0.847 m in 1891	
cuadra	125.4	411.4	150 bara, 2003 reference	
legua	4514	14,811	League, 5400 bara, 2003 reference	
China (To distinguish traditional from metric units, the prefix “yīng” is added to units)				Ancient to pre-metric
hoé	0.00000032	0.0000010		
su	0.0000032	0.000010	10 hoé	
hao	0.000032	0.00010	10 su	
lǐ	0.00032	0.0010	10 hao	
fen	0.0032	0.010	10 lǐ	
fan (official)	0.0033	0.011	1/10000 yan, 10 li, value reported in 1891, similar in 1966	
fen (official)	0.0033	0.011	1/10000 yan, 10 li, value reported in 1891, similar in 1966	

(continued)

Table 4.5 (continued)

Region and Unit	Equivalent meters	Equivalent feet, US	Notes	Era
cun (official)	0.033	0.11	1/1000 yan, 10 Fen, value reported 1891, similar in 1966	
tsouen (official)	0.033	0.11	1/1000 yan, 10 Fen, value reported 1891, similar in 1966	
tsun (official)	0.033	0.11	1/1000 yan, 10 Fen, value reported 1891, similar in 1966	
cùn	0.089	0.29	Length of a finger, est at 3.5 inches	
China (To distinguish traditional from metric units, the prefix “yīng” is added to units)				Ancient to pre-metric
chǐ	0.251	0.823	varied, roughly a foot, length of a forearm (not including hand)	
chik (itinerary)	0.309	1.01	Value in 1891	
chik (surveyors, engineers)	0.323	1.06	Value in 1891	
chik (official, average)	0.333	1.09	Value in 1891, 1/100 yan, 10 cun, similar in 1966	
tchi (official, average)	0.333	1.09	Value in 1891, 1/100 yan, 10 cun, similar in 1966	
chik (commercial)	0.375	1.23	Value in 1891	
bu	1.341	4.398	varied, 5–6 chǐ, roughly a fathom	
pou	1.6	5.2	5 tchi	
zhàng	2.510	8.235	10 chǐ, old value	
zhàng	3.2	10.5	2 pou, reported in 1966	
cheung (official)	3.334	10.94	Value in 1891, 1/10 yan	
bolt (cloth)	13.00	42.65	Traditional measure	
yan	32.0	105	10 zhang, reported in 1966	
yin	32.0	105	10 zhang, reported in 1966	
yan (official)	33.34	109.4	Base value fixed as of 1891	
fen	38.4	126	12 zhang, 1966 value	
kyo	96.0	315	3 yin, 1966 value	
lǐ	452.5	1485	Chinese mile, 300–360 bu, varied, usually about 1/3 English mile	

(continued)

Table 4.5 (continued)

Region and Unit	Equivalent meters	Equivalent feet, US	Notes	Era
li (itinerary)	556.4	1825	Value in 1891	
li	576.0	1890	6 kyo, reported in 1966	
poû	5760	18,897	10 Li, reported in 1966	
thsan	46,080	151,179	8 poû, reported in 1966	
tou	144,000	472,435	25 poû, reported in 1966	
Circassia (See Russia)				1891
Cochin China (See also Annam and Vietnam)				1891
covid	0.381	1.25		
Colombia (pre-1854, some additional data below, also called New Granada, system originally Spanish Castilian)				Colonial to pre-metric
pulgada	0.0263	0.0861	Inch or thumb, 1/32 vara, also reported as 0.0222 m in 2003 reference	
cuarta	0.210	0.689	1/4 vara, 9 pulgada, also reported as 0.200 m in 2003 reference	
pie	0.280	0.919	Foot, 1/3 vara, 12 pulgada, also reported as 0.267 m in 2003 reference	
vara	0.840	2.76	Yard, 3 pie, also reported as 0.800 m in 2003 reference	
cuadra	84.00	275.6	100 vara, also reported as 80.0 m in 2003 reference	
legua	5250	17,224	League, 6250 vara, also reported as 5000 m in 2003 reference	
Cornwall (Approximate values, primarily used English units of measurement)				Medieval to pre-metric
Cornish fathom	1.5	5.0	5 feet, estd	
Cornish mile	2400	7874	1.5 miles, est	
Corsica (Used French units of measurement)				1891
Costa Rica (pre-1910, see also Central America)				Colonial to pre-metric
pulgada	0.02331	0.07648	Inch, 2003 reference	
cuarta	0.2098	0.6884	1/4 vara, 9 pulgada, 2003 reference	
tercia	0.2798	0.9179	Foot, 1/3 vara, 12 pulgada, 2003 reference	
vara	0.8393	2.754	Yard, 3 tercia, 2003 reference	

(continued)

Table 4.5 (continued)

Region and Unit	Equivalent meters	Equivalent feet, US	Notes	Era
mecate	20.14	66.09	24 vara, 2003 reference	
Crete or Candia				1891
pic	0.637	2.09		
Cuba (mostly Spanish basis, pre-1858)				Colonial to pre-metric
legua	0.0677	0.222	2–2/3 in, questionable value	
vara	0.848	2.78		
Curaçao (See West Indies)				1891
Cypress (primarily British units, pre-1972)				Colonial to pre-metric
foot	0.3048	1.000	2003 reference	
pic	0.6096	2.000	2 feet, also reported as 0.672 m in 1891, 2003 reference	
pace	0.9144	3.000	2003 reference	
Czechoslovakia (pre-1876, continuing to mid 1900s)				pre-metric
stopa (Moravian)	0.284	0.932	Regional variation, 2003 reference	
stopa (Silesian)	0.290	0.950	Regional variation, 2003 reference	
stopa (Bohemian)	0.296	0.971	2003 reference	
strevic (Bohemian)	0.296	0.971	2003 reference	
stopa (Praha)	0.297	0.973	Regional variation, 2003 reference	
loket (Bohemian)	0.592	1.94	2 stopa, 2003 reference	
sah (Bohemian)	1.776	5.827	3 loket, 2003 reference	
latro (Bohemian)	1.909	6.264	6.45 stopa, 2003 reference	
latro	1.917	6.289		
mile (Bohemian)	6988	22,925	3660 latro, 2003 reference	
Demerara (See Guiana)				pre-metric
Denmark				Medieval to pre-metric
skrupel	0.000182	0.000596	Scruple, 1/12 Linie	
linie	0.002180	0.007152	Line, 1/12 tomme, 2003 reference	

(continued)

Table 4.5 (continued)

Region and Unit	Equivalent meters	Equivalent feet, US	Notes	Era
tomme	0.02615	0.08579	Thumb, 1/12 fod, 2003 reference	
palme	0.0886	0.291	Palm, Circumfer.	
kvarter	0.157	0.515	Quarter, 1/4 alen	
fod	0.3139	1.030	Foot, Varied, 2003 reference	
alen	0.6277	2.059	Ell, 2 fod, 2003 reference	
aln	0.6277	2.059	Ell, 2 fod, 2003 reference	
favn	1.883	6.178	3 aln, 2003 reference	
ruthe	3.766	12.36	2 favn, 2003 reference	
rode	5.026	16.49	16 fod, also reported as 5 alen = 10 fod or 3.14 m in 1891	
rut	5.026	16.49	16 fod, also reported as 5 alen = 10 fod or 3.14 m in 1891	
mil	7533	24,714	Mile, reported in 1891, consistent with value reported in 2003 reference	
miil	7533	24,714	Mile, reported in 1891, consistent with value reported in 2003 reference	
mil (alt)	11,130	36,515	Danish mile, 12,000–17,600 alen, see alternate values	
miil (alt)	11,130	36,515	Danish mile, 12,000–17,600 alen, see alternate values	
Dominica or Dominican Republic (See West Indies)				1891
East Indies (See individual countries of region)				1891
Ecuador (Spanish Castilian before conversion to Metric)				1891
Egypt (Ancient to pre-metric, System of the Pharaon, general measures)				Ancient to pre-metric
digits	0.01091	0.03579	2003 reference	
db	0.0188	0.0615	“Finger”, 1/4 palm	
djeba	0.0188	0.0615	“Finger”, 1/4 palm	
thebs	0.02181	0.07155	“Finger”, 2003 reference, 2 digits	
kérat	0.0242	0.0793	1/24 dirra, 1891 value, consistent with 2003 reference, pre-metric	

(continued)

Table 4.5 (continued)

Region and Unit	Equivalent meters	Equivalent feet, US	Notes	Era
kirat	0.0242	0.0793	1/24 dirra, 1891 value, consistent with 2003 reference, pre-metric	
shesep	0.0750	0.246	“Palm”, 4 fingers	
šsp	0.0750	0.246	“Palm”, 4 fingers	
choryos	0.08725	0.2862	“Palm”, 4 fingers, 2003 reference	
drt	0.0938	0.308	“Hand”, 5 fingers	
abdat	0.0967	0.317	1/6 dirra, 4 kirat, 1891 value, consistent with 2003 reference	
3 mm	0.113	0.369	“Fist”, 6 fingers	
amm	0.113	0.369	“Fist”, 6 fingers	
dichas	0.1745	0.5725	2 palms	
pedj-sheser	0.225	0.738	“Small span”, 3 palms = 12 fingers	
spd	0.225	0.738	“Small span”, 3 palms = 12 fingers	
Nile derah	0.255	0.835	“Nile pic”	
Nile dirra	0.255	0.835	“Nile pic”	
pedj-aa	0.260	0.853	“Large span”, 3.5 palms = 14 fingers	
spithame	0.2618	0.8589	“Span”, 2003 reference	
kadam	0.290	0.951	1/2 dirra, 3 abdat, 1891 value, consistent with 2003 reference	
bw	0.300	0.984	foot, 4 palms = 16 fingers	
djeser	0.300	0.984	foot, 4 palms = 16 fingers	
zereth	0.3490	1.145	“Royal foot”, 2003 reference	
remen	0.375	1.23	remen, 5 palms = 20 fingers	
rmn	0.375	1.23	remen, 5 palms = 20 fingers	
pigon	0.4363	1.431	1.25 zereth, 2003 reference	
meh nedjes	0.450	1.48	Short (Greek) or ordinary cubit, 6 palms = 24 fingers, also called natural cubit in 1891	
mh	0.450	1.48	Short (Greek) or ordinary cubit, 6 palms = 24 fingers, also called natural cubit in 1891	

(continued)

Table 4.5 (continued)

Region and Unit	Equivalent meters	Equivalent feet, US	Notes	Era
derah	0.5235	1.717	“Royal cubit”, 1.5 zereth, 2003 reference	
meh niswt	0.525	1.72	“Royal cubit”, 7 palms—28 fingers	
mh	0.525	1.72	“Royal cubit”, 7 palms—28 fingers	
derah baladi	0.568	1.86	Native pic or deraâ	
diraa	0.580	1.90	2 kadam, 1891 value, consistent with 2003 reference	
dirra baladi	0.580	1.90	2 kadam, 1891 value, consistent with 2003 reference	
pic	0.580	1.90	2 kadam, 1891 value, consistent with 2003 reference	
nibw	0.600	1.97	Pole, 6 hands, 8 palms, 32 fingers	
derah hendazeh	0.648	2.13	Cloth pic	
derah Istambuli	0.669	2.20	Constantinople pic	
long cubit	0.6980	2.290	2 zereth, 2003 reference	
itinerary derah	0.739	2.42	“Road measure pic”, also reported as 0.7889 m in 1891	
itinerary pic	0.739	2.42	“Road measure pic”, also reported as 0.7889 m in 1891	
double remen	0.741	2.43	Diag of square royal cubit	
derah meimari	0.750	2.46	Builder’s pic	
xilon	1.571	5.154	3 derah, 2003 reference	
bââh	1.847	6.060	5/2 derah, road measure	
orgye	2.094	6.870	“Fathom”, 3 long cubits, 2003 reference	
gasab	2.320	7.611	4 dirra, 1891 value, consistent with 2003 reference	
kassabah	3.480	11.42	6 dirra, 2003 reference, also reported as 3.550 m in 1891	
cassaba	3.695	12.12	(1891), 5 derah, road measure	

(continued)

Table 4.5 (continued)

Region and Unit	Equivalent meters	Equivalent feet, US	Notes	Era
canne	4.072	13.36	2003 reference	
rod	5.250	17.22		
h3yt	5.250	17.22		
khet	52.50	172.2	“Rod of cord”, 100 cubits	
ht	52.50	172.2	“Rod of cord”, 100 cubits	
ht n nhw	52.50	172.2	“Rod of cord”, 100 cubits	
minute of march	183.8	602.8		
stade	209.4	687.0	“Stadium”, 4 senus, 2003 reference	
mil hachmi	580.0	1,903	1000 dirra, 1891 value, consistent with 2003 reference	
farsakh	1740	5709	3000 dirra, 1891 value, consistent with 2003 reference	
mille	1745	5725	“Mile”, 2500 long cubits, 2003 reference	
mili	1847	6060	500 cassabas	
atour	5235	17,175	3 mille, 2003 reference	
farsakh	5541	18,179	3 mili, road measure, league	
shoëme	6282	20,610	30 stade, 2003 reference	
parasange	6980	22,900	4 mille, 2003 reference	
royal atour	10,470	34,350	2 atour, 2003 reference	
iteru	10,500	34,448	“River measure”, 20,000 cubits	
hour of march	11,000	36,089	21,000 Royal cubits	
atur	11,000	36,089	21,000 Royal cubits	
itrw	11,000	36,089	21,000 Royal cubits	
baride	22,164	72,716	4 farsakh, road measure	
safar yome	44,328	145,431	2.5 safar yome = 1° meridian = 60 mili, 2 baride	
El Salvador (See also Central America, approximate values from Spanish)				Colonial to pre-metric
pulgada	0.023	0.076	Inch, 2003 reference	
cuarta	0.21	0.68	1/4 vara, 9 pulgada, 2003 reference	

(continued)

Table 4.5 (continued)

Region and Unit	Equivalent meters	Equivalent feet, US	Notes	Era
tercia	0.28	0.91	Foot, 1/3 vara, 12 pulgada, 2003 reference	
vara	0.83	2.7	Yard, 3 tercia, 2003 reference	
mecate	19.9	65.4	24 vara, 2003 reference	
Eritrea (varied)				Medieval to pre-Metric
cubi	0.320	1.05	Varied by location, 2003 reference	
derah	0.460	1.51	Essentially pic, 23/16 cubi, 2003 reference	
emmet	0.460	1.51	Essentially pic, 23/16 cubi, 2003 reference	
Estonia				Medieval to pre-metric
elle	0.5334	1.750	2003 reference	
kuunar	0.5334	1.750	2003 reference	
foute	0.7112	2.333	Russian, foot, 4/3 elle, 2003 reference	
arshine	1.659	5.444	7/3 foute, 2003 reference	
faden	2.134	7.000	Fathom, 3 archine, 2003 reference	
Ethiopia (appx)				Medieval to pre-Metric
tat	0.025	0.082	2003 reference	
gat	0.080	0.26	16/5 tat, 2003 reference	
sinzer	0.160	0.525	2 gat, 2003 reference	
kend	0.490	1.61	49/16 sinzer, 2003 reference	
pic	0.686	2.25	Roughly	
berri	1690	5545	1/3 farsang	
farsang	5070	16,634	Roughly	
Fayal (See Azores)				1891
Finland (Similar to Russian units of measurement)				Medieval to pre-Metric
linja	0.00206	0.00676	1/144 ft, width of a barleycorn	
tuuma	0.0247	0.0812	1/12 ft, width of thumb	
vaaksa	0.148	0.487	Span: tips of little finger to thumb extended	

(continued)

Table 4.5 (continued)

Region and Unit	Equivalent meters	Equivalent feet, US	Notes	Era
jalka	0.297	0.974	Foot	
meritertia	0.514	1.69	1/3600 Naut mile	
kyynärä	0.594	1.95	2 ft, Cubit, everyday measure	
askel	1.00	3.28	“Pace”, approx value for adult male	
syli	1.80	5.91	6 ft, fathom, fingertip to fingertip with arms spread	
syli	1.85	6.08	1/1000 Naut mile, seldom used	
merisekunti	30.87	101.3	1/60 Naut Mile	
kivenheitto	59.38	194.8	“Throw of a rock”, used to describe something near	
kaapelinmitta	185.2	607.6	1/10 Naut mile	
vakomitta	213.6	700.8	Furrow’s length in field, furlong	
virsta	1069	3507	Varied	
meripeninkulma	1852	6076	Maritime distance, Naut mil, 1 angular minute at equator	
peninkulma (old)	5344	17,533	Dist a dog barking can be heard, before 1600 = 5 virsta	
poronkusema	7500	24,606	Sami measure, distance reindeer can travel before urinating, used to describe obscure distance	
peninkulma (new)	10,688	35,067	Dist a dog barking can be heard, after 1600 = 10 virsta	
päivämatka	20,000	65,616	One day’s travel	
Flanders (approx)				Medieval to pre-metric
Flemish ell	0.700	2.30	Arm pit to tip of middle finger outstretched	
Formosa (See China and Taiwan)				1891
France (pre-1795, many variations, Paris basis where applicable)				Medieval to pre-metric
point	0.0001880	0.0006168	Called Truchet point in English	
Didot point	0.000376	0.00123	Typographic measure, 1/72 inch	

(continued)

Table 4.5 (continued)

Region and Unit	Equivalent meters	Equivalent feet, US	Notes	Era
ligne	0.002256	0.007401	Line	
Cicéro	0.00451	0.0148	Typographic, 12 Didot pts, French pica	
pounce	0.02707	0.08881	inch	
pied du roi	0.3248	1.066	Royal foot, also known as “pied de Paris”, 2003 reference	
pied	0.326	1.07	790 AD by Charlemagne	
aune	0.6496	2.131	“El”, varied greatly, used for cloth measure, estd, also reported as length from right elbow to left middle finger tip with arms outstretched (~ 1.4 m), 2003 reference	
brasse (nautical)	1.624	5.328	“Fathom”, 5 pied, nautical, 2003 reference	
toise du Châtelet or du Pérou	1.945	6.381	Introduced 1668 as a correction, fathom	
toise	1.949	6.394	“Fathom”, 3 long cubits, 2003 reference	
toise (nautical)	1.949	6.394	6 pied, nautical, 2003 reference	
toise de l’Écritoire	1.956	6.417	6 pied, fathom	
perch	5.846	19.181	3 toise, 2003 reference	
perche ordinaire	6.496	21.31	Local use, 20 pieds, 2003 reference	
perche d’arpent	7.146	23.44	“Perch” or “rood”, 2003 reference	
perch (eaux & forêts)	7.146	23.44	“Perch” or “rood”, 2003 reference	
arpent ordinaire	64.97	213.2	Local use	
arpent	71.46	234.4	Varied	
encablure (nautical)	194.9	639.4	“Cable length”, 100 toise, nautical, 2003 reference	
mille marin (nautical)	1949	6394	“Nautical Mile”, 20 encablure, 2003 reference	
lieue (Gauloise)	2222	7290		
lieue ancienne	3247	10,653	League, old French—10,000 feet, used until 1674	

(continued)

Table 4.5 (continued)

Region and Unit	Equivalent meters	Equivalent feet, US	Notes	Era
lieue de Paris	3898	12,789	Paris league, defined as 2000 toises, 1674–1737, AKA league of bridges and roads (des Ponts et des Chaussées)	
lieue des Postes	4288	14,068	2200 toises, created in 1737	
lieue (de Paris)	4443	14,577	“League”, 2003 reference, 1737–1794	
lieue de 25 au degré	4448	14,593	2282 toises, represents 1/25 of an equatorial degree	
lieue tarifaire	4678	15,348	2400 toises, created 1737	
lieue marine (nautical)	5846	19,180	“Nautical League”, 3 mille marin, 2003 reference	
France (1812–840, metric with old names used)				1812–1840
ligne (metric)	0.002315	0.007594		
pouche (metric)	0.02778	0.09112	12 ligne (metric), 2003 reference	
pied (metric)	0.3333	1.093	12 pouche (metric), 2003 reference	
toise (metric)	2.000	6.561	6 pied (metric), 2003 reference	
mille (metric)	1333	4374	4000 pied (metric), 2003 reference	
lieue (metric)	4000	13,122	3 mille (metric), 2003 reference	
French Guiana (See Guiana)				1891
Germany (Significant variations over time and locally, a few indicated)				Medieval to pre-metric
punkte (Wurtemberg)	0.000286	0.000939	Reported in 1891	
punkte (Lubeck)	0.000333	0.00109	1/12 linie, 1891	
linie (typical average)	0.00205	0.00672	1/6 to 1/12 inch, usually 1/12 inch	
linie (Prussian system)	0.002180	0.007151	2003 reference	
linie (Wurtemberg)	0.00286	0.00939	10 punkte, reported in 1891	
achtel (Hamburg)	0.00307	0.0101	1/8 zoll	
linie (Lubeck)	0.00400	0.0131	1/6 zoll, 1891	
zoll (Lubeck)	0.0240	0.0787	1/12 fuss, 1891	

(continued)

Table 4.5 (continued)

Region and Unit	Equivalent meters	Equivalent feet, US	Notes	Era
zoll (typical average)	0.0246	0.0807	Inch, 1/10 through 1/12 ft, common 1/12	
zoll (Prussian system)	0.02615	0.08581	12 linien, 2003 reference	
zoll (Wurtemberg)	0.0286	0.0939	10 linien, reported in 1891	
fuß (Hesse-Darmstadt)	0.250	0.820	Reported in Hesse-Darmstadt 1821	
architect's fuß (Leipsic)	0.283	0.927	Reported in Liebsic 1891	
fuß (Saxony)	0.283	0.929	Reported in Saxony 1891	
fuß (Frankfort)	0.285	0.934	Reported in Frankfort 1891	
workshuh (Frankfort)	0.285	0.934	Reported in Frankfort 1891	
land fuß (Hesse-Cassel)	0.285	0.935	Reported in Hesse-Cassel 1891	
surveyor's fuß (Hesse-Cassel)	0.285	0.935	Reported in Hesse-Cassel 1891	
schuh (Braunschweig, Brunswick)	0.285	0.935	Reported in Brunswick 1891	
fuss (Wurtemberg)	0.286	0.939	10 zoll, reported in 1891	
fuß (Wurtemberg)	0.286	0.939	10 zoll, reported in 1891	
fuß (Hamburg)	0.286	0.939	Reported in Hamburg 1891	
fuß (Hesse-Cassel)	0.288	0.944	Reported in Hesse-Cassel 1891	
fuß (Lubeck)	0.288	0.945	Reported in Lubeck 1891	
fuß (Bremen)	0.289	0.949	Reported in Bremen 1891	
fuß (Bavaria)	0.292	0.957	Reported in Bavaria 1891	
fuß (Hanover)	0.292	0.958	Reported in Hanover 1891	
fuß (average, typical)	0.295	0.968	Foot, varied a lot, typical average	
fuß (Baden)	0.300	0.984	Reported in Baden 1891	
fuß (Prussian system)	0.3139	1.030	12 zoll, 2003 reference	

(continued)

Table 4.5 (continued)

Region and Unit	Equivalent meters	Equivalent feet, US	Notes	Era
fuss (Prussian system)	0.3139	1.030	12 zoll, 2003 reference	
Rheinfuß	0.314	1.03	Reported in Hamburg 1891	
feldfuß (surveyors)	0.356	1.17	Reported in Frankfort 1891	
elle (Frankfort)	0.547	1.80	Reported in Frankfort 1891	
elle (Hesse-Cassel)	0.570	1.87	Reported in Hesse-Cassel 1891, 2 landfuß	
elle (Lubeck)	0.576	1.89	Reported in Lubeck 1821	
elle (average)	0.600	1.97	Cubit, Elbow to fingertip, varied 0.4–0.8 m	
elle (Stuttgart)	0.614	2.01	Reported in 1891	
elle (Prussian system)	0.6669	2.188	17/8 fuss, 2003 reference	
elle (Hesse-Darmstadt)	0.800	2.62	Reported in Hesse-Darmstadt 1821	
klafter (Wurtemberg)	1.717	5.633	6 fuss, reported in 1891	
klafter	1.800	5.905	Fathom, 6 ft before metric, varied 1.75 to 3 m	
faden	1.883	6.178	Fathom, 6 fuss, 2003 reference	
lachter	2.000	6.562	Mining, varied 1.9 to 2.1 m	
ruthe (Wurtemberg)	2.862	9.388	10 fuss, reported in 1891	
ruthe (Baden)	3.000	9.842	Rod, reported in 1891	
ruthe (Prussian system)	3.766	12.36	12 fuss, 2003 reference	
ruthe (Hesse-Cassel)	3.989	13.09	Reported in Hesse-Cassel 1891, 7 ellen	
rute	4.191	13.75	Rod, land measure, varied 2.9–5.9 m	
ruthe	4.191	13.75	Rod, land measure, varied 2.9–5.9 m	
ruthe (Brunswick)	4.560	14.96	8 ellen or 16 schuh, reported in Brunswick 1891	

(continued)

Table 4.5 (continued)

Region and Unit	Equivalent meters	Equivalent feet, US	Notes	Era
ruthe (Bremen)	4.627	15.18	Rod, reported in 1891	
wegstunde	3710	12,172	1 h travel, 1/2 meile, Swiss = 4880 m	
meile (Bremen)	6280	20,603	Reported in Bremen 1891	
postmeile (Saxony)	6795	22,292	Reported in Saxony 1891, 24,000 fuß	
meile (Hanover)	7415	24,328	Reported in Hanover 1891, 25,400 fuß	
meile (Bavaria)	7424	24,358	Reported in Bavaria 1891	
meile (Average, typical)	7500	24,606	Varied from 1000 to over 11000 m locally, 1/15 equatorial deg	
meile (Hamburg)	7530	24,705	Reported in Hamburg 1891, 24,000 Rhenish fuß	
meile (Prussian system)	7533	24,713	2000 ruthe, 2003 reference	
meile (Anspach)	8633	28,322	Reported in Bavaria 1891	
meile (Baden)	8887	29,157	Reported in Baden 1891	
polizei-meile (Saxony)	9059	29,721	Reported in Saxony 1891, 32,000 fuß	
meile (Braunschweig or Brunswick)	10,802	35,440	Reported in Brunswick 1891, 34,424 Rhenish feet	
Greece (Significant variation over time and locally, includes Attic system)				Ancient to pre-metric
daktylos	0.01929	0.06329	“Finger”, consistent with 2003 reference	
condylos	0.03857	0.1265	2 daktyloi, consistent with 2003 reference	
kondylos	0.03857	0.1265	2 daktyloi, consistent with 2003 reference	
palaistē	0.07714	0.2531	“Palm”, 4 dak, consistent with 2003 reference	
palestra	0.07714	0.2531	“Palm”, 4 dak, consistent with 2003 reference	
dōron	0.07714	0.2531	“Palm”, 4 dak, consistent with 2003 reference	

(continued)

Table 4.5 (continued)

Region and Unit	Equivalent meters	Equivalent feet, US	Notes	Era
dichas	0.1543	0.5062	Half foot, 8 dak, consistent with 2003 reference	
hēmipodion	0.1543	0.5062	Half foot, 8 dak, consistent with 2003 reference	
lichas	0.193	0.632	10 dak	
orthodōron	0.212	0.695	11 dak	
spithamē	0.2314	0.7592	“Span”, 12 dak, consistent with 2003 reference	
pous	0.3086	1.012	“Foot”, 16 dak, also reported as 0.300 m (1891), consistent with 2003 reference	
pygmē	0.347	1.14	forearm, 18 dak	
pygōn	0.3858	1.266	20 dak, consistent with 2003 reference	
pēchys	0.4628	1.518	“Cubit”, 24 dak, consistent with 2003 reference	
pechya	0.4628	1.518	“Cubit”, 24 dak, consistent with 2003 reference	
long cubit	0.6171	2.025	2 pous, 2003 reference	
pic (silks)	0.635	2.08	Reported in 1891	
piki (short)	0.648	2.13	2003 reference, pre-1836	
pic (average, common)	0.655	2.15	piki, average, varied	
piki (long)	0.669	2.19	2003 reference, pre-1836	
pic (linen, wool)	0.686	2.25	Reported in 1891	
piki (masonry)	0.750	2.46	2003 reference, pre-1836	
haploun bēma	0.770	2.53	2.5 podes	
bema	0.7714	2.531	“Pace”, 2003 reference	
xylon	1.389	4.557	4.5 pous, 2003 reference	
bēma	1.540	5.052	5 podes	
diployn bēma	1.540	5.052	5 podes	
orgyia	1.851	6.073	6 podes, 3 long cubits, consistent with 2003 reference	

(continued)

Table 4.5 (continued)

Region and Unit	Equivalent meters	Equivalent feet, US	Notes	Era
orguia	1.851	6.073	6 podes, 3 long cubits, consistent with 2003 reference	
akaina	2.777	9.111	9 pous, 2003 reference	
kalamos	3.080	10.10	10 podes	
akaina	3.080	10.10	10 podes	
dekapous	3.080	10.10	10 podes	
amma	18.51	60.73	“Cord”, 60 podes, consistent with 2003 reference	
hamma	18.51	60.73	“Cord”, 60 podes, consistent with 2003 reference	
plethron	30.86	101.2	100 podes, 2003 value	
stadion	185.1	607.3	600 podes, ~ 1/8 Roman mile, 2003 value	
stadium	185.1	607.3	600 podes, ~ 1/8 Roman mile, 2003 value	
diaulos	370.2	1,215	2 stadia, consistent with 2003 reference	
hippikon	739.7	2,427	4 stadia	
mile	1389	4555	45 plethron, 2003 value	
milion	1479	4852	8 stadia, Roman mile	
dolichos	2221	7287	12 stadia, consistent with 2003 reference	
parasanges	5548	18,202	30 stadia, Persian origin	
league	5548	18,202	30 stadia, Persian origin	
schoinos	7397	24,268	40 stadia, Egypt origin	
stathmos	24,685	80,987	80000 pous, 2003 reference	
stage	29,800	97,768	160 stadia	
Greenland (See Denmark)				1891
Grenada (See West Indies)				1891
Guadeloupe (See West Indies)				1891
Guatemala (See Central America)				Colonial to pre-metric
pulgada	0.02322	0.07618	Inch, 2003 reference	

(continued)

Table 4.5 (continued)

Region and Unit	Equivalent meters	Equivalent feet, US	Notes	Era
cuarta	0.2090	0.6856	1/4 vara, 9 pulgada, 2003 reference	
tercia	0.2786	0.9141	Foot, 1/3 vara, 12 pulgada, 2003 reference	
vara	0.8359	2.742	Yard, 3 tercia, 2003 reference	
mecate	20.06	65.82	24 vara, 2003 reference	
Guiana, British (See England)				1891
Guiana, French (See France)				1891
Guiana, Dutch (See Netherlands)				1891
Guinean				Medieval to pre-metric
pic	0.578	1.90	2003 reference	
pik	0.578	1.90	2003 reference	
jacktan	3.658	12.00	6.329 pic, 2003 reference	
Haiti (Mixed heritages, see West Indies, AKA Hayti)				Colonial to pre-metric
anne	0.1188	0.3898	2003 reference	
toise	1.949	6.394	1624/99 aune, 2003 reference	
Hawaii (See Sandwich Islands)				1891
Hebrew (See also Biblical and Talmudic, local variations, rough values)				Ancient to pre-metric
finger (common)	0.0231	0.0759	2003 Reference	
finger (sacred)	0.0267	0.0875	2003 Reference	
palm (common)	0.0925	0.303	4 fingers, 2003 reference	
palm (sacred)	0.107	0.350	4 fingers, 2003 reference	
zereth (common)	0.278	0.910	“Foot”, 3 palms, 2003 reference	
zereth (sacred)	0.320	1.05	“Foot”, 3 palms, 2003 reference	
cubit (common)	0.555	1.82	Long cubit, 2 feet, 2003 reference	
cubit (sacred)	0.640	2.10	Long cubit, 2 feet, 2003 reference	

(continued)

Table 4.5 (continued)

Region and Unit	Equivalent meters	Equivalent feet, US	Notes	Era
Hindustan (See India)				1891
Holland (See Netherlands)				1891
Honduras (See also Central America)				Colonial to pre-metric
pulgada	0.02258	0.07407	Inch, 2003 reference	
cuarta	0.2032	0.6667	1/4 vara, 9 pulgada, 2003 reference	
tercia	0.2709	0.8889	Foot, 1/3 vara, 12 pulgada, 2003 reference	
vara	0.8128	2.667	Yard, 3 tercia, 2003 reference	
mecate	19.51	64.00	24 vara, 2003 reference	
Hungary (Pre-metric, pre-1876, local variations)				Medieval to pre-metric
faust	0.1054	0.3457	2003 reference	
marok	0.1054	0.3457	2003 reference	
arsin	0.584	1.92	Like a cubit	
stab	1.581	5.186	Like a rod or fathom	
meile	8354	27,406	2003 reference	
mertföld	8354	27,406	2003 reference	
Iceland (See also Denmark)				Medieval to pre-metric
lina	0.002180	0.007152		
pumlungur	0.02616	0.08582	Thumb, 12 lina, 2003 reference	
fet	0.3139	1.030	Foot, 12 pumlungur, 2003 reference	
alen	0.6278	2.060	Cubit, 2 fet, 2003 reference, also reported as 0.57 m in 1891	
alin	0.6278	2.060	Cubit, 2 fet, 2003 reference, also reported as 0.57 m in 1891	
faðmur	1.883	6.179	Fathom, 6 fet, 3 alin, 2003 reference	
sjomila	1855	6086		
mila a landi	7534	24,716	Mile on land, 4000 faðmur, 2003 reference	
Inca				Pre-colonial
finger	0.0180	0.0591	Est'd	

(continued)

Table 4.5 (continued)

Region and Unit	Equivalent meters	Equivalent feet, US	Notes	Era
thumb to forefinger	0.0540	0.177	Est'd	
palm	0.0750	0.246	Est'd	
cubit	0.500	1.64	Est'd	
thatkiy	1.283	4.210	basic distance, one pace	
wingspan	1620	5315	Est'd	
topo	7700	25,262	6000 thatkiys	
tupu	7700	25,262	6000 thatkiys	
wamani	232,000	761,146	30 topos	
India (pre Akbar Systems—avg)				Medieval to pre-colonial
jaob (Bombay)	0.004763	0.01562	2003 reference	
jow (Bombay)	0.004763	0.01562	2003 reference	
jow (Bengal, Calcutta)	0.00635	0.0208	Barleycorns, 1891 reference	
angula (Bombay)	0.01429	0.04687	Finger, 3 jow, 2003 reference	
unglee (Bombay)	0.01429	0.04687	Finger, 3 jow, 2003 reference	
angula (Bengal, Calcutta)	0.0190	0.0625	Finger, 3 jows, 1891 reference, consistent with 1966 reference	
unglee (Bengal, Calcutta)	0.0190	0.0625	Finger, 3 jows, 1891 reference, consistent with 1966 reference	
tassoo (Bombay)	0.02858	0.09375	2 unglee, 2003 reference	
tussoo (Bombay)	0.0288	0.0944	1891 reference	
jaob (Bengal, Calcutta)	0.0508	0.167	1/9 covid, alternate units, 1891 reference	
anguli	0.0520	0.171	3 fingers	
girah	0.0520	0.171	3 fingers	
gheria (Bengal, Calcutta)	0.0571	0.187	3 fingers, 1/8 covid, alternate units, 1891 reference	
moot (Bombay)	0.05715	0.1875	Hand, 2 tassoo, 2003 reference	
moot (Bengal, Calcutta)	0.0762	0.250	Hand, 4 unglees, 1891 reference	
span (Bombay)	0.1715	0.5625	3 moot, 2003 reference	
span (Bengal, Calcutta)	0.229	0.750	3 moot, 1891 reference	

(continued)

Table 4.5 (continued)

Region and Unit	Equivalent meters	Equivalent feet, US	Notes	Era
vistati	0.229	0.751	12 angula, “span”, 1966 value	
ady (Madras, Malabar coast)	0.266	0.872	Local unit?, 1891 reference	
covid (Bombay)	0.3429	1.125	2 span, 2003 reference	
hath (Ahmednuggur)	0.356	1.17	Local value, 1891 reference	
haut (Ahmednuggur)	0.356	1.17	Local value, 1891 reference	
covid (Ahmednuggur)	0.356	1.17	Local value, 1891 reference	
hath	0.419	1.37	8 girah (like cubit)	
cubit (Bengal, Calcutta)	0.457	1.50	2 spans, 1891 reference	
covid (Bengal, Calcutta)	0.457	1.50	2 spans, 1891 reference	
haut (Bengal, Calcutta)	0.457	1.50	2 spans, 1891 reference	
hasta	0.457	1.50	2 vistati, “cubit”, 1966 value	
cubit (Bombay)	0.460	1.51	16 tussoos, 1891 reference	
hath (Bombay)	0.460	1.51	16 tussoos, 1891 reference	
cubit (Madras)	0.472	1.55	2 spans, varied significantly by location, value shown is for Madras, 1891 reference	
covid (Madras)	0.472	1.55	2 spans, varied significantly by location, value shown is for Madras, 1891 reference	
haut (Madras)	0.472	1.55	2 spans, varied significantly by location, value shown is for Madras, 1891 reference	
hath (Surat)	0.531	1.74	Local value, 1891 reference	
haut (Surat)	0.531	1.74	Local value, 1891 reference	
covid (Surat)	0.531	1.74	Local value, 1891 reference	
guz (Guzerat)	0.593	1.94	Local value, 1891 reference	
guz (Bombay)	0.6858	2.250	2 covid, 2003 reference	
guz (Bombay)	0.690	2.26	24 tussoos, 1891 reference	

(continued)

Table 4.5 (continued)

Region and Unit	Equivalent meters	Equivalent feet, US	Notes	Era
yard (Bombay)	0.690	2.26	24 tussoos, 1891 reference	
kole (Travancore)	0.738	2.42	Local unit?, 1891 reference	
gaz	0.838	2.75	2 hath	
gez (Bengal)	0.914	3.00	2 covids, also reported as 1.08 m in Patna, 1891 reference	
gus (Bengal)	0.914	3.00	2 covids, also reported as 1.08 m in Patna, 1891 reference	
yard (Bengal)	0.914	3.00	2 covids, also reported as 1.08 m in Patna, 1891 reference	
guz (Calcutta)	0.915	3.00	Variation, buildup of other units same as Bombay, 2003 reference	
gulah (Madras)	0.945	3.10	2 covids, 1891 reference	
danda (Bombay)	1.372	4.500	2 guz, 2003 reference	
fathom (Bengal)	1.828	5.997	2 guz, 1891 reference	
dhanush	1.83	6.00	4 hasta, 1966 value	
orgyla	1.83	6.00	4 hasta, 1966 value	
kathi	2.440	8.005	5–5/6 hath	
2 karams	2.514	8.248	3 gaz	
kan	3.771	12.37	3 karams	
niranga (Bombay)	6.858	22.50	5 danda, 2003 reference	
pand	48.88	160.38	20 kathi	
begah	977.7	3,208	20 pand	
coss (Bombay)	1372	4500	200 niranga, 2003 reference	
coss (Bengal)	1828	5997	1000 fathoms, 1891 reference	
crosa	3656	11,995	2000 dhanush, 1966 value	
hardary (Mysore)	4400	14,434	Local unit?, 1891 reference	
coss (Seringapatam)	5866	19,245	Local unit?, 1891 reference	
gavyuti	7312	23,989	2 crosa, 1966 value	
yodjana	14,624	47,978	2 gavyuti, 1966 value	

(continued)

Table 4.5 (continued)

Region and Unit	Equivalent meters	Equivalent feet, US	Notes	Era
gavada (Mysore)	23,465	76,982	Local unit?, 1891 reference	
Indonesia (Local Units, Normally Dutch)				Colonial to pre-metric
kilan	0.2125	0.6972	1/8 depa, 2003 reference	
jankal	0.229	0.750	Sumatra, 1/2 etto	
hasta	0.425	1.39	1/4 depa, 2 kilan, 2003 reference	
etto	0.457	1.50	Sumatra, 2 jankal	
covid	0.686	2.25	Java, appx 3/4 yard, roughly a cubit	
hailoh	0.914	3.00	Sumatra, 2 etto	
depa	1.700	5.577	4 hasta, 2003 reference	
tung	3.658	12.00	Sumatra, 4 hailoh, appx 12 ft	
Ionian Islands (Italian and Turkish measures used primarily, some additional local units)				1891
jarda Ionia	0.914	3.00	1 yard	
stadio	20.12	66.00	22 yards	
Ireland (See also England, note that different references provide different values, values varied by location and over time)				Medieval to pre-metric
grain	0.0070	0.023	Grain, 1/36 troighid	
ordlach	0.0210	0.0689	Thumb length, 1/12 troighid	
inch	0.02540	0.08333	Pre-1824 value, 2003 reference	
palm	0.07620	0.2500	3 inches, pre-1824 value, 2003 reference	
bas	0.0840	0.276	Palm, 1/3 troighid	
dorn	0.125	0.410	Fist, 5/12 or 1/2 troighid	
span	0.2286	0.7500	3 palm, pre-1824 value, 2003 reference	
troighid	0.250	0.820	Foot, basic unit	
foot	0.3048	1.000	12 inches, pre-1824 value, 2003 reference	
cubit	0.4572	1.500	18 inches, pre-1824 value, 2003 reference	
ceim	0.625	2.05	Step, 2.5 troighid	
yard	0.9144	3.000	36 inches, pre-1824 value, 2003 reference	
deiscéim	1.500	4.921	Double step, 6 troighid	

(continued)

Table 4.5 (continued)

Region and Unit	Equivalent meters	Equivalent feet, US	Notes	Era
pace	1.524	5.000	5 feet, pre-1824 value, 2003 reference	
link	2.560	8.400	8.4 feet, pre-1824 value, 2003 reference	
fertach	3.000	9.842	Rod, 12 troighid, AKA inntrit?	
inntrit	3.000	9.842	Uncertain value, possibly equal to 1 fertach	
fathom	4.267	14.00	14 feet, pre-1824 value, 2003 reference	
lait	6.000	19.68	Unknown, perhaps 2 fertach	
perch	6.401	21.00	7 yards, pre-1824 value, 2003 reference	
pole	6.401	21.00	7 yards, pre-1824 value, 2003 reference	
chain	25.60	84.00	4 perch, pre-1824 value, 2003 reference	
forrach	36.00	118.1	144 troighid	
furlong	256.0	840.0	10 chains, pre-1824 value, 2003 reference	
Irish mile	2,048	6,718	1–3/11 English mile, 8 furlongs, pre-1824 value, 2003 reference	
magh-space			Unknown, similar to mile, based on how far a cock's crow or a bell can be heard	
Italy				Medieval to pre-metric
atomo (typical)	0.000297	0.000975	1/12 Punto	
atomo (Parma)	0.000314	0.00103	1/12 Punto, reported in 1891	
atomo (Venice)	0.000402	0.00132	Reported in 1891	
denaro (Tuscany)	0.00243	0.00798	Reported in 1891	
punto (typical)	0.003568	0.01171	Point, 1/144 piede liprando, pre-1861, 2003 reference	
punto (Parma)	0.00376	0.0124	Point, 1/12 oncie, reported in 1891	
minuti (Naples)	0.00439	0.0144	1/5 oncia, Reported in 1891	
punto (Venice)	0.00483	0.0158	12 atomi, reported in 1891	

(continued)

Table 4.5 (continued)

Region and Unit	Equivalent meters	Equivalent feet, US	Notes	Era
minuti	0.00856	0.0281	1/5 oncia	
onzia (Naples)	0.0220	0.0721	1/12 palmo, reported in 1891	
soldo (Tuscany)	0.0292	0.0957	12 denari, reported in 1891	
onzia (typical)	0.04281	0.1405	Inch, 1/12 piede liprando, 12 punto, pre-1861, 2003 reference	
onzie (Parma)	0.0452	0.148	1/12 braccio di legno, reported in 1891	
onzia (Venice)	0.0580	0.190	12 punti, reported in 1891	
mercier's palmo	0.212	0.696	Roman, fabric	
architect's palmo	0.223	0.732	Roman, buildings	
commercial palmo	0.223	0.733	Roman	
palmo (Sicily)	0.242	0.794	Palm, 12 oncia, reported in 1891	
palmo	0.260	0.853	Palm, varied by area	
palmo (Naples)	0.264	0.865	Palm, 12 oncia, reported in 1891	
palmo (Tuscany)	0.292	0.957	10 soldi, reported in 1891	
pié manuale (Genoa)	0.343	1.13	Reported in 1891	
piè (Venice)	0.348	1.14	Reported in 1891, consistent with 2003 reference	
piede (Venice)	0.348	1.14	Reported in 1891, consistent with 2003 reference	
piede (typical)	0.348	1.14	Used in some areas, varied	
piè (Milan)	0.396	1.30	Reported in 1891	
piede (typical)	0.5138	1.686	Basic unit, foot, varied, 12 onci, pre-1861, 2003 reference	
pié liprando (typical)	0.5138	1.686	Basic unit, foot, varied, 12 onci, pre-1861, 2003 reference	
piè (Sardinia)	0.515	1.69	Reported in 1891	
piede (Modena)	0.523	1.72	Reported in 1891	
pié (Modena)	0.523	1.72	Reported in 1891	

(continued)

Table 4.5 (continued)

Region and Unit	Equivalent meters	Equivalent feet, US	Notes	Era
braccio di legno (Parma)	0.542	1.78	Reported in 1891	
stajoli	0.569	1.87	Architect	
pié (Parma)	0.570	1.87	Reported in 1891	
braccio (Modena)	0.578	1.90	Reported at Modena 1891	
braccio (Tuscany)	0.584	1.91	2 palmi, reported in 1891	
brabucco (Milan)	0.595	1.95	12 once, typical, 2003 reference	
braccio (Milan)	0.595	1.95	12 once, typical, 2003 reference	
raso	0.600	1.97	Some areas	
braccio	0.680	2.23	Like a large foot, varied, appx value	
braccio (Venice)	0.695	2.28	12 oncia, 2 piede, reported in 1891, reported as 0.683 m in 2003 reference	
canna (Sicily)	1.936	6.353	8 palmo, reported in 1891	
pertica	1.950	6.398	7.5 palmi	
passo	1.950	6.398	7.5 palmi	
passo (Naples)	1.978	6.488	7.5 palmi, reported in 1891	
pertica (Naples)	1.978	6.488	7.5 palmi, reported in 1891	
canna (typical)	2.055	6.742	4 piede liprando, 8–10 palmi, varied, pre-1861, 2003 reference	
canna (Naples)	2.109	6.921	8 palmo, reported in 1891	
canna (Tuscany)	2.335	7.660	4 braccia, reported in 1891	
architect's canna (Tuscany)	2.918	9.575	5 braccia, reported in 1891	
trabucco (typical)	3.083	10.11	6 piede liprando, pre-1861, 2003 reference, regional variations	
trabucoo (typical)	3.083	10.11	6 piede liprando, pre-1861, 2003 reference, regional variations	

(continued)

Table 4.5 (continued)

Region and Unit	Equivalent meters	Equivalent feet, US	Notes	Era
cavezzo (typical)	3.083	10.11	6 piede liprando, pre-1861, 2003 reference, regional variations	
cavezzo (Modena)	3.138	10.30	6 piede (Modena)	
passo (Parma)	3.253	10.67	6 braccia, reported in 1891	
pertica (Parma)	3.253	10.67	6 braccia, reported in 1891	
catena	5.693	18.68	Architect, 10 stajoli, 25.5 palmi	
miglio (Venice)	1000	3280	Reported in 1891	
miglio (Tuscany)	1654	5425	2833-1/3 braccia, reported in 1891	
miglio (Naples)	1846	6056	Mile, 7000 palmi	
miglio (typical)	2226	7304	Mile, 4333.33 piede liprando, 7000 palmi, consistent with reported value in Sardinia in 1891 and 2003 reference for pre-1861 value	
Jamaica (See West Indies)				1891
Japan (related to taxation, standardized 1891)				Medieval to pre-metric
shi	0.0000303	0.0000994	2003 reference	
mō	0.0000303	0.0000994	10 shi, 2003 reference	
mō	0.0000303	0.0000994	10 shi, 2003 reference	
rin	0.000303	0.000994	10 mō, 2003 reference	
bu	0.00303	0.00994	10 rin, 2003 reference	
sun	0.0303	0.0994	10 bu, 2003 reference	
shakkanho (ancient)	0.180	0.591	Origin: length from thumb to middle finger	
sals	0.3030	0.9941	Foot, 10 sun, 100 bu, 2003 reference	
shaku	0.3030	0.9941	Foot, 10 sun, 100 bu, 2003 reference	
yabiki	0.7575	2.485	25 sun, 2003 reference	
hiro	1.515	4.970	2 yabiki, 2003 reference	
ken	1.818	5.964	6 shaku, distance between support poles in homes or length of tatami mat, 2003 reference	
inc	1.906	6.253	1891 value	
jō	3.030	9.941	10 shaku, 2003 reference	

(continued)

Table 4.5 (continued)

Region and Unit	Equivalent meters	Equivalent feet, US	Notes	Era
jō	3.030	9.941	10 shaku, 2003 reference	
chō	109.1	357.9	360 shaku, 60 ken, 2003 reference	
chō	109.1	357.9	360 shaku, 60 ken, 2003 reference	
ri (ancient)	600	1,968		
ri	3927	12,884	12,960 shaku, 36 chō, 2003 reference	
Java (See also Netherlands, values vary by location)				1891
covid	0.686	2.25		
Jewish				Medieval to modern
digit	0.0222	0.0729	0.875 inches	
finger's breadth	0.0222	0.0729	0.875 inches	
inch	0.0295	0.0967	1.16 inches	
thumb's breadth	0.0295	0.0967	1.16 inches	
palm	0.0889	0.292	3.5 inches	
hand's breadth	0.0889	0.292	3.5 inches	
small span	0.178	0.583	7 inches	
large span	0.267	0.875	10.5 inches	
zereth	0.267	0.875	10.5 inches	
cubit	0.533	1.75	21 inches	
fathom	2.134	7.000	84 inches	
orgyia	2.134	7.000	84 inches	
Ezekiel's canneh	3.200	10.50	126 inches	
reed	3.200	10.50	126 inches	
Arabian canneh	4.267	14.00	168 inches	
pole	4.267	14.00	168 inches	
Schaenus line	42.67	140.0	1680 inches	
chain	42.67	140.0	1680 inches	
Sabbath-day's journey	1067	3500	42,000 inches	
Jewish mile	2134	7000	84,000 inches	
stadium	2134	7000	84,000 inches	
furlong	2134	7000	84,000 inches	
parasang	6401	21,000	252,000 inches	
Korea (or Corea)				Medieval or pre-metric
p'un	0.00300	0.00984		
chi	0.0330	0.108		

(continued)

Table 4.5 (continued)

Region and Unit	Equivalent meters	Equivalent feet, US	Notes	Era
cha	0.303	0.994		
kan	1.818	5.965	6 cha	
li	393.0	1289		
Latvia				Medieval to pre-metric
quartier	0.134	0.440	1/4 elle, 2003 reference	
elle	0.537	1.76	4 quartier, 2003 reference	
latro	1.917	6.289		
verste	1067	3500	2003 reference	
meile	7468	24,501	Mile, 7 verste (Russian), 2003 reference	
Liberia (See United States)				1891 to Present
Libya				Medieval to pre-metric
palmo	0.227	0.744	1/3 pik, 2003 reference	
draa	0.453	1.49	Basic, 2 palmo, 2003 reference	
arabi draa	0.483	1.59	Lesser pik	
Tripoli draa	0.671	2.20		
pik	0.680	2.23	3 palmo, 2003 reference	
pic	0.680	2.23	3 palmo, 2003 reference	
handaze	0.680	2.23	3 palmo, 2003 reference	
Lombardy (See Italy)				1891
Madagascar (Limited information available)				1891
rahf—southern	1.180	3.871	Southern Madagascar	
rahf—northern	2.360	7.743	Northern Madagascar	
Madeira Islands (See Portugal)				1891
Malacca (See also Singapore)				1891
jumba	0.366	1.20		
covid	0.457	1.50	Also reported as 0.459	
hasta	0.457	1.50	Also reported as 0.459	
Malta (pre-1910)				Medieval to pre-metric
pulzier	0.0118	0.0388	1/12 Xiber, inch	

(continued)

Table 4.5 (continued)

Region and Unit	Equivalent meters	Equivalent feet, US	Notes	Era
fitel	0.142	0.465	1/2 xiber, half foot	
palmo	0.261	0.856	2003 reference	
palmi	0.262	0.859		
xiber	0.262	0.859		
foot	0.284	0.931	Reported 1891	
canna	2.088	6.850	8 palmo, reported in 2003 reference	
canna	2.096	6.877	Fathom essentially, reported 1891, 8 palmi	
qasba	2.096	6.877	Fathom essentially, reported 1891, 8 palmi	
Manilla (See Philippines)				1891
Marquesas (See France)				1891
Martinique (See West Indies)				1891
Maya				pre-colonial
1/4 PHU	0.009	0.03		
1/3 PHU	0.012	0.039		
3/4 PHU	0.032	0.10		
PHU	0.036	0.12	Base size, unknown name	
1-1/4 PHU	0.045	0.15		
hunab	1.048	3.437	Reported in literature	
Mesopotamia (Sumerian/Akkadian—Mesopotamian designations used)				Ancient
še	0.00250	0.00820	grain, 1/180th cubit	
uṭṭatu	0.00250	0.00820	grain, 1/180th cubit	
šu-si	0.0150	0.0492	finger, 1/30 cubit	
shusi	0.0150	0.0492	finger, 1/30 cubit	
ubānu	0.0150	0.0492	finger, 1/30 cubit	
link	0.201	0.660	7.92"	
šīzu	0.333	1.09	foot, 2/3 cubit	
šu-du ₃ -a	0.333	1.09	foot, 2/3 cubit	
ammatu	0.497	1.63	cubit	
kuš ₃	0.497	1.63	cubit	
ġiri ₃	1.000	3.281	step, 2 cubits	
šēpu	1.000	3.281	step, 2 cubits	
gi	3.000	9.842	reed, 6 cubits	
qanû	3.000	9.842	reed, 6 cubits	
nindan	6.000	19.68	rod, 12 cubits, also reported as 16.5 ft or ~5 meters as a "pole"	

(continued)

Table 4.5 (continued)

Region and Unit	Equivalent meters	Equivalent feet, US	Notes	Era
nindanu	6.000	19.68	rod, 12 cubits, also reported as 16.5 ft or ~5 meters as a “pole”	
aslu	60.00	196.8	cord, 120 cubits	
eše2	60.00	196.8	cord, 120 cubits	
uš	360.0	1,181	cable	
bêru	10,800	35,433	league, 30 cable	
da-na	10,800	35,433	league, 30 cable	
Mexico (Primarily Spanish)				Colonial to pre-metric
linea	0.00194	0.00636	1/432 vara, 2003 reference	
pulgada	0.00974	0.0320	1/86 vara, 12 linea, 2003 reference	
pie	0.279	0.916	Foot, 1/3 vara, 12 pulgada, 2003 reference	
vara	0.838	2.75	3 pie, 2003 reference, also reported as 0.836 m in 1891	
milla	1397	4582	Mile, 5000 pie, 2003 reference	
legua	4190	13,747	League, 3 milla, 2003 reference	
Mocha (See Arabia)				1891
Moldavia (See Romania)				1891
Molucca Islands (See Netherlands for 1891 measures)				1891
Montenegro (Used the units from neighboring countries)				1891
Montserrat (See West Indies)				1891
Morocco (varied)				Medieval to pre-metric
tonni	0.0763	0.250	1/8 pic, 2003 reference	
codo	0.531	1.74	Varied greatly (0.504 to 0.571), best estimate of typical value	

(continued)

Table 4.5 (continued)

Region and Unit	Equivalent meters	Equivalent feet, US	Notes	Era
covid	0.531	1.74	Varied greatly (0.504 to 0.571), best estimate of typical value	
covado	0.531	1.74	Varied greatly (0.504 to 0.571), best estimate of typical value	
cadee	0.531	1.74	Varied greatly (0.504 to 0.571), best estimate of typical value	
dhra	0.531	1.74	Varied greatly (0.504 to 0.571), best estimate of typical value	
dhr"̄a	0.531	1.74	Varied greatly (0.504 to 0.571), best estimate of typical value	
canna	0.534	1.75	7 tonni, 2003 reference	
cubit	0.534	1.75	7 tonni, 2003 reference	
pic	0.610	2.00	8 tonni, 2003 reference, also reported as 0.660 m in 1891	
Muscat				1891
covid	0.994	3.26		
Native American (Shoshone tribe, many other similar measures)				pre-metric
General: Measured shorter distances using “mana’ ki”, which means “laying of hands”. Many standard units and variations. Body parts used as basis. Sizes of units were specific to the person doing the measuring. Individualized measurement allowed tools, clothes, dwellings, etc. to be appropriate in size to the person they were for. Also used sticks, poles, and rawhide strips that would be kept as standards. Stepped off distances and counted steps (“dategi’p”). Longer distances described as functions of time and/or speed and/or mode of travel. Anything more than 1 pace was a “journey”.				
hand	0.1	0.3	Very rough estimate of typical value, like a palm width	
outstretched arm	0.8	2.6	Very rough estimate of typical value	
paces	1.0	3.3	Very rough estimate of typical value	
suns			Indeterminate, used for long distances, roughly number of days required, depended on mode of transportation	
moons			Similar to use of suns, indeterminate.	

(continued)

Table 4.5 (continued)

Region and Unit	Equivalent meters	Equivalent feet, US	Notes	Era
Netherlands or Holland or Dutch (Many units used in former colonies, early adoption of metric system in 1820)				Medieval to metric
lyne	0.001966	0.006450	2003 reference	
duimen	0.02359	0.07739	12 lyne, thumb or inch, varied 10–14 per Voet, 2003 reference	
duimen	0.0263	0.0862	Thumb or Inch, varied 10–14 per Voet, avg, alternate reference	
kleine palm	0.0300	0.0984	Small palm	
grote palm	0.0980	0.322	Large Palm, varied, avg	
voeten (Amsterdam)	0.2831	0.9288	Foot, 12 duime, 2003 reference, consistent with 1891 reference	
voet	0.296	0.972	Foot, Varied, avg from alternate references	
el	0.672	2.21	Length of arm from armpit to tip of fingers, avg, alternate references	
elle	0.672	2.21	Length of arm from armpit to tip of fingers, avg, alternate references	
el (Amsterdam)	0.688	2.26	Reported for Amsterdam in 1891	
elle (Amsterdam)	0.688	2.26	Reported for Amsterdam in 1891	
el	0.7076	2.321	30 duime, 2003 reference	
elle	0.7076	2.321	30 duime, 2003 reference	
roede	3.680	12.07	13 voeten, 2003 reference	
roeden	3.680	12.07	13 voeten, 2003 reference	
roede	3.970	13.03	Rod, varied, average value, alternate references	
roeden	3.970	13.03	Rod, varied, average value, alternate references	
myl	1000	3281	3533 voeten, 2003 reference, post-metric?	
uren	5000	16,404	5 myl, 2003 reference, post-metric?	

(continued)

Table 4.5 (continued)

Region and Unit	Equivalent meters	Equivalent feet, US	Notes	Era
Hollandse mijl	5000	16,404	Mile, Varied, an hour's walk	
Hollandse myl	5000	16,404	Mile, Varied, an hour's walk	
lieu marine	5555	18,225	French unit	
New Brunswick (See Canada)				1891
New Caledonia (French units used)				1891
Newfoundland (See Canada)				1891
New Granada (See Colombia)				1891
New South Wales (See Australia)				1891
New Zealand (Same or similar units as Australia)				1891
Nicaragua (See also Central America, approximate values from Spanish)				Colonial to pre-metric
pulgada	0.023	0.076	Inch, 2003 reference	
cuarta	0.21	0.68	1/4 vara, 9 pulgada, 2003 reference	
tercia	0.28	0.91	Foot, 1/3 vara, 12 pulgada, 2003 reference	
vara	0.83	2.7	Yard, 3 tercia, 2003 reference	
mecate	19.9	65.4	24 vara, 2003 reference	
Norway				Medieval to pre-metric
skrupel	0.000180	0.000591	1/12 Ligne	
linje	0.00218	0.00715	Line, 1/12 tomme	
tomme	0.0261	0.0856	Thumb or inch, Basic unit	
kvarter	0.157	0.515	Quarter, 1/4 Alen	
fod	0.3137	1.029	Foot, 1/2 alen, 2003 reference, also reported as 0.297 m in 1891	
fot	0.3137	1.029	Foot, 1/2 alen, 2003 reference, also reported as 0.297 m in 1891	

(continued)

Table 4.5 (continued)

Region and Unit	Equivalent meters	Equivalent feet, US	Notes	Era
alen	0.628	2.06	Forearm or ell, cubit?, varied	
favn	1.882	6.174	Fathom, 3 alen, Naut = 1.85 m	
stang	3.137	10.29	Rod, 5 alen	
lås	28.20	92.52	15 favner	
steinkast	47.05	154.4	Stone's throw, 25 favner - still used	
kabellengde	185.2	607.6	Cable-length, Naut, 100 favner	
sjomil	1852	6076	Sea mile, 3950 fathoms	
fjerdingsvei	2820	9252	1/4 mil, quarter mile	
geografisk mil	7421	24,347	1/15 equatorial degree, 4 min arc	
rast	9000	29527	"Rest", Distance between rests, old name for mile pre 1541	
mil	11,295	37,057	Norwegian mile, 17600 to 18000 alen, per 1862 defn, 36000 fot in 1891	
landmil	11,295	37,057	Norwegian mile, 17600 to 18000 alen, per 1862 defn, 36000 fot in 1891	
mül	11,295	37,057	Norwegian mile, 17600 to 18000 alen, per 1862 defn, 36000 fot in 1891	
grenzmül	25,099	82,345	80,000 fot in 1891	
Nova Scotia (See Canada)				1891
Nubia (See Egypt)				1891
Oman (Varied)				Medieval to pre-metric
covid	0.994	3.26	Yard	
Ottoman Empire (See also Turkey)				Ancient to medieval
nokta	0.000219	0.000718	Dot	
hat	0.00263	0.00863	Line, 12 Nokta	
parmark	0.0316	0.104	Finger, 12 Hat	
kerrab	0.0425	0.139		
kirab	0.0425	0.139		
rubu	0.0850	0.279	2 kerrab	
urup	0.0850	0.279	2 kerrab	
ayak	0.379	1.24	Foot, 12 parmak	
kadem	0.379	1.24	Foot, 12 parmak	

(continued)

Table 4.5 (continued)

Region and Unit	Equivalent meters	Equivalent feet, US	Notes	Era
endaze	0.650	2.13	Ell or cubit	
arşin	0.680	2.23	Ell or cubit	
zirai	0.758	2.49	Agriculture, 2 ayak	
kulaç	1.829	6.000	Fathom	
berid	227.0	744.7	Range, 600 ayak	
menzil	227.0	744.7	Range, 600 ayak	
eski mil	1894	6215	Old mile, 5000 ayak	
fersah	5685	18,651	League, 3 eski mil	
merhale	45,480	149,211	Stage or phase, 200 berid	
Palestine (See Ottoman Empire, Turkey, Biblical & Talmudic units)				
Paraguay (Mostly Spanish, pre 1890)				Colonial to pre-metric
linea (old)	0.001941	0.006368	1/432 vara (old), 2003 reference	
ligne (old)	0.001941	0.006368	1/432 vara (old), 2003 reference	
linea (new)	0.002005	0.006577	1/432 vara (new), 2003 reference	
ligne (new)	0.002005	0.006577	1/432 vara (new), 2003 reference	
pulgada (old)	0.02329	0.07642	Inch or thumb, 12 linea (old), 2003 reference	
pounce (old)	0.02329	0.07642	Inch or thumb, 12 linea (old), 2003 reference	
pulgada (new)	0.02406	0.07892	Inch or thumb, 12 linea (new), 2003 reference	
pounce (new)	0.02406	0.07892	Inch or thumb, 12 linea (new), 2003 reference	
piede (old)	0.2795	0.9170	Foot, 12 pulgada (old), 2003 reference	
piede (new)	0.2887	0.9471	Foot, 12 pulgada (new), 2003 reference	
vara (old)	0.8386	2.751	Yard, 3 piede (old), 2003 reference	
vara (new)	0.8660	2.841	Yard, 3 piede (new), 2003 reference	
cuerda (old)	23.29	76.42	1000 pulgada (old), 2003 reference	
cuerda (new)	24.06	78.92	1000 pulgada (new), 2003 reference	

(continued)

Table 4.5 (continued)

Region and Unit	Equivalent meters	Equivalent feet, US	Notes	Era
cuadra (old)	83.86	275.1	100 vara (old), 2003 reference	
cuadra (new)	86.60	284.1	100 vara (new), 2003 reference	
lieue (old)	4193	13,756	League, 5000 vara (old), 2003 reference	
legua (old)	4193	13,756	League, 5000 vara (old), 2003 reference	
lieue (new)	4330	14,206	League, 5000 vara (new), 2003 reference	
legua (new)	4330	14,206	League, 5000 vara (new), 2003 reference	
Persia or Iran (Assyrio-Chaldean-Persian system, generally no unified system applied in 1891, some values from 2003 reference)				Ancient to pre-metric
aiwas	0.0200	0.0656	Finger	
gireh	0.05715	0.1875	2003 reference	
palm	0.0800	0.262	4 fingers, 2003 values	
dva	0.100	0.328	Hand, 5 aiwas	
urub	0.1143	0.3750	2 gireh, 2003 reference	
charak	0.2286	0.7500	2 urub, 2003 reference	
trayas	0.300	0.984	Foot, 3 dva	
zereth	0.320	1.05	Foot, 4 palms, reported 2003	
remen	0.400	1.31	Four-hands, 4 dva	
pank'a dva	0.500	1.64	Cubit, 5 hands, 5 dva	
cubit	0.640	2.10	Reported 2003	
(k)swacsh dva	0.642	2.11	Great cubit, 6 Hands, 6 dva	
archin schah	0.799	2.62	Reported in 1891	
gez	0.9144	3.000	4 charak, 2003 reference	
guerze	0.9144	3.000	4 charak, 2003 reference	
guerze (Ispahan)	0.949	3.11	Reported in 1891	
gueza (Ispahan)	0.949	3.11	Reported in 1891	
archin arisch	0.972	3.19	Reported in 1891	
zar	1.040	3.412	1.137 gez, 2003 reference	
pank'a	1.500	4.921	Pace, 5 trayas	
pace	1.920	6.299	Reported 2003	
daca trayas	3.000	9.842	Ten-foot, 2 pank'a	

(continued)

Table 4.5 (continued)

Region and Unit	Equivalent meters	Equivalent feet, US	Notes	Era
cane	3.840	12.60	Reported 2003	
qasab	3.840	12.60	Reported 2003	
chebel	24.00	78.74	Hundred foot, 8 daca trays	
chebel	25.60	83.99	40 cubits, 2003 reference	
asparsa	191.0	626.6	Varied, avg	
ghalva	230.4	755.9	9 chebel, 2003 reference	
stadion	230.4	755.9	9 chebel, 2003 reference	
mille	1728	5669	2003 reference	
mile	1728	5669	2003 reference	
farsakh	5486	18,000	5275 zar, 2003 reference	
parasang	5486	18,000	5275 zar, 2003 reference	
parasang	6000	19,685	League, dist. for horse over 1 h walking, 250 chebel	
parasang	6400	20,997	20000 zereth, 2003 reference	
schoëme	6912	22,677	4 mille, 2003 reference	
mansion	25,600	83,988	4 parasang, 2003 reference	
stathmos	25,600	83,988	4 parasang, 2003 reference	
stathmos (Greek)	27,000	88,582	Mansion, a day march on Royal Road, 4–5 parasang, avg	
Peru (Orig Spanish Castilian, pre 1869)				Colonial to pre-metric
pie	0.2787	0.9142	Foot, 2003 reference	
vara	0.8360	2.743	Yard, 12 pie, 2003 reference, also reported as 0.847 m in 1891	
Philippines or Philippine Islands (Spanish units used)				1891
Poland (Pre-1919, local variations over time)				Medieval to pre-metric
linja	0.002000	0.006562	2003 reference	
cal	0.02400	0.07874	12 linja, 2003 reference	

(continued)

Table 4.5 (continued)

Region and Unit	Equivalent meters	Equivalent feet, US	Notes	Era
cal	0.0248	0.0814	Inch, alternate reference	
dłoń	0.0744	0.244	Palm, 3 inches	
lokiec	0.1440	0.4724	6 cal, 2003 reference	
ćwierć	0.149	0.488	Quarter łokieć, 2 palms	
szytych	0.198	0.651	1.33 Qtrs	
stopa (Krakow)	0.2356	0.7731	2 lokiec, 2003 reference	
stopa (new)	0.2880	0.9449	2 lokiec, 2003 reference	
stopa (Warsaw)	0.2978	0.9770	Foot, 1.5 szytych, also reported as 0.356 m in 1891, alternate references, consistent with 2003 reference for Warsaw	
łokieć	0.596	1.95	Ell or cubit, see alternate value	
sazen	1.728	5.669	6 stopa, 2003 reference	
sążen	1.787	5.863	Fathom, 3 ells, alternate value	
krok (or piędź?)	2.233	7.327	Step, 3.75 ell, agrarian	
pret	4.320	14.17	15 stopa, 2003 reference	
pręt	4.467	14.65	Rod, agrarian, 2 steps, alternate value	
laska	8.933	29.31	Stick, 2 rods, agrarian	
sznur	44.67	146.5	Cable, agrarian, 5 sticks	
staje	134.0	439.6	Furlong, 3 cables, agrarian	
staje	893.0	2,930	Stage, Distances between points	
Polish mile	7144	23,438	8 staje	
Portugal (Includes various possessions in 1891)				Medieval to pre-metric
ponto	0.000190	0.000623	Point, 1/5760 varos	
linha	0.00229	0.00751	Line, 1/480 varos, 12 pontos, reported as 0.002281 m in 2003 reference	
grano	0.00458	0.0150	2 linhas in 1891	
dedo	0.0183	0.0601	8 linhas in 1891	
polegada	0.0275	0.0902	Inch, 12 linhas, 1/40 varos, reported as 0.02738 m in 2003 reference	
pollegada	0.0275	0.0902	Inch, 12 linhas, 1/40 varos, reported as 0.02738 m in 2003 reference	

(continued)

Table 4.5 (continued)

Region and Unit	Equivalent meters	Equivalent feet, US	Notes	Era
palmo	0.2190	0.7185	8 polegadas, 2003 reference	
palmo de craveira	0.220	0.722	Span, 8 polegadas, 1/5 varos	
pé or pe	0.330	1.08	Foot, 12 polegadas, 3/10 varos, reported as 0.3285 m in 2003 reference	
côvado	0.660	2.17	Cubit, 3 palmos, 2 pes, reported as 0.6570 m in 2003 reference	
covada	0.660	2.17	Cubit, 3 palmos, 2 pes, reported as 0.6570 m in 2003 reference	
vara	1.100	3.609	Yard, 5 palmos, basic unit, reported as 1.099 m in 1891 (consistent), reported as 1.095 m in 2003 reference	
pass geométrico	1.650	5.413	Geometric pace, 5 pes, 1.5 varas	
toesa	1.980	6.496	Toise, 6 pes, 1 4/5 varas	
braça	2.200	7.218	Fathom, 2 varas	
estada	257.2	843.7	Stade, 236 varas, reported in 1891, reported as 258.4 m in 2003 reference	
estadio	257.2	843.7	Stade, 236 varas, reported in 1891, reported as 258.4 m in 2003 reference	
milha geográfica	1851	6073	Geographic mile, 1/3 League, reported as 1852 meters in 2003 reference	
milha (nautical)	1851	6073	Geographic mile, 1/3 League, reported as 1852 meters in 2003 reference	
milha	2057	6749	Mile, reported in 1891, 8 estadios, reported as 2067 m in 2003 reference	
légua de 20 ao grau	5555	18,225	League of 20 degrees, 3 milhas geo., consistent with value reported in 2003 reference	
legoa (nautical)	5555	18,225	League of 20 degrees, 3 milhas geo., consistent with value reported in 2003 reference	
légua de 18 ao grau	6173	20,252	League of 18 degrees, consistent with value reported in 1891, = 3 milha	
legoa	6173	20,252	League of 18 degrees, consistent with value reported in 1891, = 3 milha	
legoa	6202	20,348	League, 2 millha, 2003 reference	

(continued)

Table 4.5 (continued)

Region and Unit	Equivalent meters	Equivalent feet, US	Notes	Era
Prince Edward Island (See Canada)				1891
Puerto Rico (See West Indies)				1891
Prussia (See also Germany)				1891
scrupel	0.000182	0.000596		
linie	0.00218	0.00715	12 scrupel	
decimal linie (Surveyors)	0.00377	0.0124		
zoll	0.0262	0.0858	12 linin	
decimal zoll (Surveyors)	0.0377	0.124		
Rheinfuss	0.314	1.03	12 zoll	
Rheinfuß	0.314	1.03	12 zoll	
decimal fuss (Surveyors)	0.377	1.24		
elle	0.667	2.19		
ruthe	3.766	12.36		
postmeile	7533	24,714	24,000 Rheinfuss	
Queensland (See Australia)				1891
Romania (See also Russia, pre-1884)				1891 and pre-metric
palma	0.277	0.907		
kot (silk, linen)	0.631	2.07		
endasch (common)	0.662	2.17	2003 reference	
endere (common)	0.662	2.17	2003 reference	
khalebi (wool)	0.671	2.20		
halibiu (common)	0.701	2.30	1.06 endere, 2003 reference	
stringene (common)	1.96	6.43	2.8 halibiu, 2003 reference	
Rome (Ancient, Also includes Roman States, See also Italy)				Ancient to 1891
architect's decimi	0.00246	0.00807	1/10 arch. oncie	
architect's oncie	0.0177	0.0580	1/12 architect's palmo, reported in 1891	

(continued)

Table 4.5 (continued)

Region and Unit	Equivalent meters	Equivalent feet, US	Notes	Era
digitu (common)	0.01840	0.06037	finger, 1/16 pes, consistent with 2003 reference	
digitus (common)	0.01840	0.06037	finger, 1/16 pes, consistent with 2003 reference	
uncia pollex (common)	0.0245	0.0805	inch, thumb, 1/12 pes, consistent with 2003 reference	
uncia (common)	0.0245	0.0805	inch, thumb, 1/12 pes, consistent with 2003 reference	
palmus (common)	0.0736	0.241	palm, 1/4 pes, consistent with 2003 reference	
mercator's palmo	0.212	0.696	1891 value	
palmus major	0.222	0.728	palm length, 3/4 pes	
architect's palmo	0.223	0.732	1891 value	
commercial palmo	0.223	0.733	1891 value	
pié	0.294	0.966	1891 value	
pes	0.296	0.971	Roman foot	
pes pedis	0.296	0.971	Roman foot	
pes (common)	0.2944	0.9659	Foot, variation, 2003 reference	
pes (Druisian)	0.3196	1.049	Foot, variation, 2003 reference	
pes (legal, 1st)	0.2962	0.9718	Foot, variation, 2003 reference	
pes (legal, 2nd)	0.2967	0.9734	Foot, variation, 2003 reference	
architect's pié	0.298	0.977	1891 value	
palmipes	0.368	1.21	1–1/4 pedes, consistent with 2003 reference	
pié (Ancona)	0.391	1.28	1891 value reported for Ancona	
cubitus (common)	0.4416	1.449	cubit, 1–1/2 pedes, distance from elbow to wrist., consistent with 2003 reference	
braccio (Ancona)	0.643	2.11	1891 value reported for Ancona	
gradus pes sestertius	0.736	2.41	One step or simple pace, 2.5 pedes, consistent with 2003 reference	
gradus (common)	0.736	2.41	One step or simple pace, 2.5 pedes, consistent with 2003 reference	

(continued)

Table 4.5 (continued)

Region and Unit	Equivalent meters	Equivalent feet, US	Notes	Era
braccio (Rome)	0.781	2.56	1891 value reported for Rome	
architect's stajoli	1.284	4.212	1891 value, 1/10 arch. catena	
passus (common)	1.472	4.829	Double pace, 5 pedes, consistent with 2003 reference	
canna	1.991	6.533	1891 value	
architect's canna	2.233	7.325	1891 value, 10 arch. palmi	
decempeda (common)	2.944	9.659	"Perch", 10 pedes, consistent with 2003 reference	
architect's catena	12.84	42.12	1891 value, 57.5 arch. palmi	
actus (common)	35.33	115.9	120 pedes, consistent with 2003 reference	
stadium (common)	184.0	603.7	stade, 625 pedes, 600 Greek ft, = furlong, consistent with 2003 reference	
mille passus	1480	4856	Roman mile, 5000 pedes	
mille passuum	1480	4856	Roman mile, 5000 pedes	
milliarum (common)	1472	4829	"Mile", consistent with 2003 reference	
leuga	2208	7244	Gallic league, 7500 pedes, consistent with 2003 reference	
legua (common)	2208	7244	Gallic league, 7500 pedes, consistent with 2003 reference	
schoenus (common)	5888	19,317	20000 pes, consistent with 2003 reference	
Russia				Medieval to pre-metric
totchka	0.0002540	0.0008333	Point, 1/2800 arshin, 2003 reference	
tochka	0.0002540	0.0008333	Point, 1/2800 arshin, 2003 reference	
liniya	0.002540	0.008333	Line, 1/280 arshin, 10 tochka, 2003 reference	
line	0.002540	0.008333	Line, 1/280 arshin, 10 tochka, 2003 reference	

(continued)

Table 4.5 (continued)

Region and Unit	Equivalent meters	Equivalent feet, US	Notes	Era
linie	0.002540	0.008333	Line, 1/280 arshin, 10 tochka, 2003 reference	
pal' ets	0.01270	0.04167	5 line, 2003 reference	
sotka	0.02134	0.07000	84 tochka, 2003 reference	
duïme	0.02540	0.08333	Inch, 1/28 arshin, 2 pal' ets, 2003 reference	
dyuim	0.02540	0.08333	Inch, 1/28 arshin, 2 pal' ets, 2003 reference	
vershok	0.04445	0.1458	Tip or top, 1/16 arshin, 1/4 chetvert, 1–3/4 duïme, 2003 reference	
verschok	0.04445	0.1458	Tip or top, 1/16 arshin, 1/4 chetvert, 1–3/4 duïme, 2003 reference	
piad	0.1778	0.5833	Palm or quarter, 1/4 arshin, 4 vershok, 2003 reference	
chetvert	0.1778	0.5833	Palm or quarter, 1/4 arshin, 4 vershok, 2003 reference	
tchetverk	0.1778	0.5833	Palm or quarter, 1/4 arshin, 4 vershok, 2003 reference	
foute	0.3048	1.000	Foot, 3/7 arshin, 12 duïme, 2003 reference	
fut	0.3048	1.000	Foot, 3/7 arshin, 12 duïme, 2003 reference	
arshin	0.7112	2.333	Yard, 4 tchevert, 2003 reference	
archine	0.7112	2.333	Yard, 4 tchevert, 2003 reference	
archeen	0.7112	2.333	Yard, 4 tchevert, 2003 reference	
arsheen	0.7112	2.333	Yard, 4 tchevert, 2003 reference	
swung sazhen	1.760	5.774	Tips of arms outstretched	
sazhen	2.134	7.000	Fathom, 3 yards, 7 fut, 2003 reference	
sagéne	2.134	7.000	Fathom, 3 yards, 7 fut, 2003 reference	
sashen	2.134	7.000	Fathom, 3 yards, 7 fut, 2003 reference	

(continued)

Table 4.5 (continued)

Region and Unit	Equivalent meters	Equivalent feet, US	Notes	Era
saaschen	2.134	7.000	Fathom, 3 yards, 7 fut, 2003 reference	
sachin	2.134	7.000	Fathom, 3 yards, 7 fut, 2003 reference	
skewed sazhen	2.480	8.136	Tip of raised arm to opp. Leg slightly bent	
oblique sazhen	2.480	8.136	Tip of raised arm to opp. Leg slightly bent	
versta	1067	3500	Turn of a plough, 1500 arshin, 2003 reference	
verst	1067	3500	Turn of a plough, 1500 arshin, 2003 reference	
vyorst	1067	3500	Turn of a plough, 1500 arshin, 2003 reference	
werst	1067	3500	Turn of a plough, 1500 arshin, 2003 reference	
double versta	2134	7000	For land and distances between settlements, 2 versta	
border versta	2134	7000	For land and distances between settlements, 2 versta	
milia	7468	24,500	Mile, 10500 arshin	
Lithuanian meile	8040	26,377	1891 value	
St. Bartholomew, St. Christopher's, St. Kitt's, St. Eustatius, St. John, St. Marin, St. Thomas, and St. Vincent (See West Indies)				
St. Helena (See English units as a colony)				1891
Salvador (See El Salvador)				Colonial to pre-metric
Sandwich Islands (Hawaii, See U.S. Customary units)				1891
San Salvador (See El Salvador)				Colonial to pre-metric
Santa Cruz, St. Crois, Santa Lucia, and Santo Domingo (See West Indies)				
Sadinia (See Italy)				1891
Saudi Arabia (pre-Metric (1962), see also Arabia)				pre-metric
covid	4.82	15.8	2003 reference	
guz	6.35	20.8	1.32 covid, 2003 reference	
cassaba	38.4	126	7.97 covid, 2003 reference	

(continued)

Table 4.5 (continued)

Region and Unit	Equivalent meters	Equivalent feet, US	Notes	Era
farsakh	4830	15,846	125.8 cassaba, 2003 reference	
baryd	19,320	63,385	4 farsakh, 2003 reference	
marhala	38,640	126,770	2 baryd, 2003 reference	
Scotland (Not all reported values are consistent, also use English measures, pre-1824)				Medieval to pre-metric
Scottish inch	0.0224	0.0734	Fraudulent inch, 1/42 ell, 2003 reference	
inch	0.02554	0.08378	2003 reference	
foot	0.3064	1.005	12 inches, 2003 reference	
yard	0.9193	3.016	36 inches, 2003 reference	
ell	0.9449	3.100	37 inches, 2003 reference	
fall	5.669	18.60	6 ells, 222 inches, like a rod, 2003 reference	
chain	22.68	74.40	4 fall, 2003 reference	
furlong	226.8	744.0	10 chain, 2003 reference	
Scots mile	1,814	5,952	320 falls, 8 furlongs, but varied, 1–1/8 English mile in 1891, 2003 reference	
Sennaar (See Egypt)				1891
Serbia or Servia (Varied)				1891
archine	0.711	2.33		
Siam (See also Thailand)				1891
sok	0.481	1.58		
ken	0.961	3.15	2 soks	
vouah	1.922	6.306	2 kens	
röenung	3844	12,611	2,000 vouahs	
Siberia (See Russia)				1891
Sicily (See Italy)				1891
Sierra Leone (See England, colonial units)				1891
Singapore (Varied)				Colonial to pre-metric
covid	0.457	1.50	Cubit	
hasta	0.457	1.50	Cubit	

(continued)

Table 4.5 (continued)

Region and Unit	Equivalent meters	Equivalent feet, US	Notes	Era
Society Islands (See France, colonial units)				1891
Slovakia (pre-1876, many different units used)				Medieval to pre-metric
latro	1.917	6.289		
Somalia (varied)				Medieval to pre-metric
cubito	0.560	1.84	cubit, 1/7 top, 2003 reference	
top	3.920	12.86	7 cubito, 2003 reference	
South Africa (Used Dutch, English, pre-1922)				Medieval to pre-metric
elle	0.685	2.25		
South Australia (See Australia)				1891
Spain (varied locally and over time, some values from U.S. California mission records)				Medieval to pre-metric
punto (typical)	0.0001209	0.0003968	Point, pre-1860, 2003 reference	
punto	0.000158	0.000519	Point, 1/1728 pie, alternate reference	
linea (typical)	0.001451	0.004761	Line, 12 punto, pre-1860, 2003 reference	
linea	0.00194	0.00635	Line, 1/144 pie, 12 puntos, alternate reference	
dedo (typical)	0.01741	0.05713	Finger, 12 linea, pre-1860, 2003 reference	
diedo (typical)	0.01741	0.05713	Finger, 12 linea, pre-1860, 2003 reference	
pulgada (typical)	0.02322	0.07618	Inch, 16 linea, pre-1860, 2003 reference	
palmo menor	0.0697	0.229		
jeme (typical)	0.1393	0.4571	6 pulgada, pre-1860, 2003 reference	
sesma (typical)	0.1393	0.4571	6 pulgada, pre-1860, 2003 reference	
palma (typical)	0.2090	0.6856	Palm length, 9 pulgada, pre-1860, 2003 reference	

(continued)

Table 4.5 (continued)

Region and Unit	Equivalent meters	Equivalent feet, US	Notes	Era
palmo mayor (typical)	0.2090	0.6856	Palm length, 9 pulgada, pre-1860, 2003 reference	
pie (typical)	0.2786	0.9141	Foot, 2 sesma, pre-1860, 2003 reference, also reported as 0.283 m in 1891	
piè (typical)	0.2786	0.9141	Foot, 2 sesma, pre-1860, 2003 reference, also reported as 0.283 m in 1891	
codo (typical)	0.4180	1.371	Cubit, 2 palma, pre-1860, 2003 reference	
codos (typical)	0.4180	1.371	Cubit, 2 palma, pre-1860, 2003 reference	
codo de ribera	0.557	1.83		
paso ordinario	0.697	2.29		
vara (typical)	0.8359	2.742	Yard, 2 codos, 3 pies, pre-1860, 2003 reference, literally rod or pole	
paso (typical)	1.393	4.571	Pace, 5 pie, pre-1860, 2003 reference	
paso geometrico (typical)	1.393	4.571	Pace, 5 pie, pre-1860, 2003 reference	
estado (typical)	1.672	5.485	Fathom, 2 vara, pre-1860, 2003 reference	
braza (typical)	1.672	5.485	Fathom, 2 vara, pre-1860, 2003 reference	
toesa	1.944	6.377		
marca	2.403	7.882		
estadal (typical)	3.344	10.97	Perch, 2 estado, 4 varas, pre-1860, 2003 reference	
cordel (10 varas)	8.359	27.42	Variant	
cordel (50 varas)	41.80	137.1	Variant	
cordel (69 varas)	57.68	189.2	Variant	
estadjo	174.1	571.2		
milla (typical)	1393	4571	Mile, 1000 passo, 5000 pies, pre-1860, 2003 reference	
legua (typical)	4180	13,712	League, 3 milla, pre-1860, 2003 reference, also reported as 8000 varas or 6782 m in 1891	

(continued)

Table 4.5 (continued)

Region and Unit	Equivalent meters	Equivalent feet, US	Notes	Era
legua royal (typical)	6687	21,939	Royal league, 24000 pie, pre-1860, 2003 reference	
Sri Lanka (Varied, see also Ceylon)				Medieval to pre-metric
covid	0.464	1.52	Cubit?	
bamba	1.900	6.234	Dist between finger tips, arms outstretched (estimate)	
gavva			Distance on roads	
yoduna			Distance on roads, 4 gavu	
hoo kiyana dura			No reference	
Sudan or Soudan (See Egypt)				1891
Sumatra				1891
jankal	0.229	0.750		
etto	0.457	1.50	2 jankal	
hailoh	0.914	3.00	2 etto	
tung	3.658	12.00	4 hailoh	
Surinam (See Guiana)				1891
Sweden				Medieval to pre-metric
linje (pre-1855)	0.002062	0.006765	Line, 1/12 tum, consistent with 2003 reference	
linje (after 1855)	0.00297	0.00974	Line, 1/10 tum after 1855	
fingerbredd	0.01856	0.06088	3/4 tum, 2003 reference	
tum (pre-1855)	0.02474	0.08117	Thumb or inch, 12 linje before 1855, 2003 reference	
tum (after 1855)	0.0297	0.0974	Thumb or inch, 1/10 fot after 1855	
tvärhand	0.09896	0.3247	Hand, 4 tum, 2003 reference	
tvärhand	0.102	0.333	Hand, 4 inches	
kvarter	0.1484	0.4870	Quarter, 6 tum, 2003 reference	

(continued)

Table 4.5 (continued)

Region and Unit	Equivalent meters	Equivalent feet, US	Notes	Era
fot	0.2969	0.9741	Foot, 1/2 aln, same value in 1891, consistent with 2003 reference	
alen	0.5937	1.948	Forearm, varied, value reported in 2003 reference	
aln	0.5937	1.948	Forearm, varied, value reported in 2003 reference	
steg	0.8905	2.922	1/2 famn, 2003 reference	
famn	1.781	5.843	Fathom, 3 aln, 2003 reference	
fanen	1.781	5.843	Fathom, 3 aln, 2003 reference	
fathom	1.781	5.843	Fathom, 3 aln, 2003 reference	
stång (after 1855)	2.969	9.741	For land measure, reduced to 10 fot after 1855	
stång (pre-1855)	4.750	15.59	16 fot, for land measure, 2003 reference	
alnar	5.344	17.53	3 famn, 2003 reference	
ell	5.344	17.53	3 famn, 2003 reference	
ref (after 1855)	29.69	97.41	Land measure, reduced to 100 fot after 1855	
ref (pre-1855)	47.50	155.9	160 fot, land measure, 2003 reference	
stenkast	50.00	164.0	Stone's throw, still used	
fjärdingsväg	2673	8768	1/4 mil, 500 alnar, 2003 reference	
rast	5000	16,404	Distance between rests in woods	
skogsmil	5000	16,404	Distance between rests in woods	
nymil	10,000	32,808	New mile after 1889	
mil	10,686	35,059	Mile, 18000 aln, distance between inns, 2003 reference	

(continued)

Table 4.5 (continued)

Region and Unit	Equivalent meters	Equivalent feet, US	Notes	Era
lantmil	10,686	35,059	Mile, 18000 aln, distance between inns, 2003 reference	
kyndemil	16,000	52,493	Distance torch will last	
Switzerland (Pre-metric units, value depends on reference)				Medieval to pre-metric
trait	0.000300	0.000984	1/10 ligne, 1891 value	
ligne (new)	0.00208	0.00684	Line, 1/144 pied, 2003 reference	
linie (new)	0.00208	0.00684	Line, 1/144 pied, 2003 reference	
ligne (old)	0.00300	0.00984	Line, 1/10 pounce, 1891 value	
linie (old)	0.00300	0.00984	Line, 1/10 pounce, 1891 value	
pounce (new)	0.0250	0.0820	Inch, 1/12 pied, 2003 reference	
zoll (new)	0.0250	0.0820	Inch, 1/12 pied, 2003 reference	
pounce (old)	0.0300	0.0984	1/10 pied, 1891 value	
zoll (old)	0.0300	0.0984	1/10 pied, 1891 value	
fuss	0.300	0.984	Foot, consistent with value reported in 1891 and 2003 reference	
pied	0.300	0.984	Foot, consistent with value reported in 1891 and 2003 reference	
brache	0.600	1.97	2 pied, depending on source, 1891 value, consistent with 2003 reference	
elle	0.600	1.97	2 pied, depending on source, 1891 value, consistent with 2003 reference	
aune	1.200	3.937	2 braches, 1891 value	
toise	1.800	5.905	6 pied, 3 braches, 2003 reference	
ruthe	1.800	5.905	6 pied, 3 braches, 2003 reference	
perch	3.000	9.842	Reported as 10 peds, 1891 value	
perche	3.000	9.842	Reported as 10 peds, 1891 value	
toise	3.600	11.81	3 aunes, 1891 value	

(continued)

Table 4.5 (continued)

Region and Unit	Equivalent meters	Equivalent feet, US	Notes	Era
lieue	4800	15,748	Road measure, 16,000 pied, 1000 perch, 2003 reference	
Syria (See also Turkey)				Medieval to pre-metric
pic	0.582	1.91	Cubit, 2003 reference	
Tahiti (See France, colonial units)				1891
Taiwan (See also Formosa)				Medieval to pre-metric
chhün	0.0303	0.0994	Same as Japanese sun	
chhioh	0.303	0.994	Foot, same as Japanese shaku	
Tanzania				pre-metric
ohra	0.571	1.87		
Tasmania (Similar to Australia)				1891
Tatar				Medieval to pre-metric
duym	0.0254	0.0833	Thumb or inch	
qariş	0.0445	0.146		
çirek, qarış	0.178	0.583	4 qarıs	
söyäm	0.178	0.583	4 qarıs	
fut	0.305	1.00	Foot, 12 duym	
arşın	0.711	2.33	4 çirek, 16 qarış, 28 duym, essentially a cubit	
sajın	2.133	6.998	3 arşın, 7 fut	
qolaç	2.133	6.998	3 arşın, 7 fut	
tayaq	2.133	6.998	3 arşın, 7 fut	
çaqırım	1067	3500	500 sajin	
färsäx	6934	22,747	6–7 çaqırım, used average	
parasang	6934	22,747	6–7 çaqırım, used average	
mil	7467	24,498	Mile, geographic, 7 çaqırım	
atnı tuqtawsız yurıyu	20,000	65,616	Dist horse travels between stops, 15–25 km, used avg	

(continued)

Table 4.5 (continued)

Region and Unit	Equivalent meters	Equivalent feet, US	Notes	Era
cäyawleneñ köñlek yulı	37,338	122,499	A day of riding, 35 çağrım	
atnıñ köñlek yulı	45,000	147,636	Distance horse travels in one day, 40–50 km, avg used	
cäyawleneñ aylıq yulı	1,120,140	3,674,955	Month of riding, 1050 çağrım	
Thailand (Appear to be pre-metric names and post-metric values, variable values)				Medieval to metric
anukabiet	0.00260	0.00854	2003 reference	
kabiet	0.00521	0.0171	2 anukabiet, 2003 reference	
krabiat	0.00521	0.0171	2 anukabiet, 2003 reference	
nio	0.0208	0.0684	Inch, 4 kabiet, varied, 2003 reference	
niou	0.0208	0.0684	Inch, 4 kabiet, varied, 2003 reference	
keup	0.250	0.820	Span, 12 niou, variable, 2003 reference	
khuep	0.250	0.820	Span, 12 niou, variable, 2003 reference	
sawk	0.500	1.64	Cubit, 2 keup, 2003 reference	
sok	0.500	1.64	Cubit, 2 keup, 2003 reference	
ken	1.00	3.28	2 sawk, 2003 reference	
wa	2.00	6.56	Fathom, 2 ken, outstretched arms, 4 sok, 2003 reference	
wah	2.00	6.56	Fathom, 2 ken, outstretched arms, 4 sok, 2003 reference	
sen	40.0	131	Rope or line of rope, 20 wah, 2003 reference	
roeneung	4000	13,123	100 sen, 2003 reference	
yot	16,000	52,493	League, 4 roeneng, 2003 reference	
yote	16,000	52,493	League, 4 roeneng, 2003 reference	

(continued)

Table 4.5 (continued)

Region and Unit	Equivalent meters	Equivalent feet, US	Notes	Era
Tobago (See West Indies)				1891
Tonquin or Tonkin (See Vietnam or Annam)				1891
Tortola (See West Indies)				1891
Trinidad (See West Indies)				1891
Tripoli (See also Libya)				1891
palm	0.224	0.734		
arbi dra'a	0.483	1.59		
lesser pic	0.483	1.59		
dra'a	0.671	2.20		
pic	0.671	2.20		
Tunisia (varied, many used, values for cloth from 1891)				Ancient to pre-metric
pik—linen	0.473	1.55	Linen goods	
pic Arabic	0.488	1.60	2003 reference	
pik—silk	0.631	2.07	For silk goods	
pic Turkish	0.637	2.09		
dra'a hendaseh	0.673	2.21	For woollen goods	
pic endazé	0.673	2.21	2003 reference	
pic Endezian	0.673	2.21	2003 reference	
Turkmenistan				pre-metric
altschin	0.7112	2.333	Linen goods, 1891 value, consistent with 2003 reference	
hasch	0.7112	2.333	Linen goods, 1891 value, consistent with 2003 reference	
Turkey (mixture of units from various sources, significant local variation and changes over time, values shown in 1891 at Constantinople, see also Ottoman Empire, also 2003 reference values)				1891 and pre-metric
nocktat (builders, surveyors)	0.000217	0.000712	1891 value	
nocktat (common)	0.0002186	0.0007171	2003 reference	
hatt (builders, surveyors)	0.00260	0.00854	12 nocktats, 1891 value	
hatt (common)	0.002623	0.008605	12 nocktat, 2003 reference	
parmack (builders, surveyors)	0.0313	0.103	12 hatts, 1891 value	

(continued)

Table 4.5 (continued)

Region and Unit	Equivalent meters	Equivalent feet, US	Notes	Era
parmack (common)	0.03147	0.1033	12 hatt, 2003 reference	
guiah (cloth)	0.0408	0.134	1891 value	
ouroub (cloth)	0.0816	0.268	2 guirahs, 1891 value	
urumb (common)	0.09442	0.3098	3 parmack, 2003 reference	
pic (Damascus)	0.580	1.90	Reported at Damascus, 1891 value	
endasch (cloth, Smyrna)	0.626	2.05	Reported at Smyrna, 1891 value	
endasch (cloth)	0.653	2.14	8 ouroubs, 1891 value	
pic (typical)	0.668	2.19	1891 value	
pic (Aleppo)	0.676	2.22	Reported at Aleppo, 1891 value	
archine (builders, surveyors)	0.750	2.46	24 parmarks, 1891 value	
pic (common)	0.7554	2.478	8 urumb, 2003 reference	
nul (common)	1,007	3,304	1333.3 pics, 2003 reference	
Tuscany (Florence & Leghorn, see Italy)				1891
United Kingdom (Includes England, Great Britain, and former possessions, customary units, major local variations and changes over time)				Medieval to pre-metric
twip	0.0000176	0.0000579	1/20 point	
point	0.000353	0.00116	1/12 pica or 1/6 line	
poppyseed	0.00212	0.00694	1/4 or 1/5 barleycorn	
line	0.00212	0.00694	1/12 inch or 1/4 barleycorn	
pica	0.00423	0.0139	1/6 inch	
barleycorn	0.00847	0.0278	1/3 inch	
digit	0.0191	0.0625	1/4 palm or 3/4 inch	
finger	0.0222	0.0729	63 points or 7/8 inch	
inch	0.025	0.0833	1/12 foot or 3 barleycorns, also 1/10 foot at times	
stick	0.0508	0.167	2 inches	
nail (cloth measure)	0.0572	0.187	3 digits or 2.5 inches or 1/16 yard, also reported as 2.25 inches in 1891	
palm	0.0762	0.250	3 inches	
palm width	0.0762	0.250	3 inches	
hand	0.102	0.333	2 sticks or 1/3 foot	

(continued)

Table 4.5 (continued)

Region and Unit	Equivalent meters	Equivalent feet, US	Notes	Era
handbreadth	0.102	0.333	2 sticks or 1/3 foot	
shaftment	0.152	0.500	2 palms or 1/2 foot, 6.5 inches before 1066, 6" after	
link	0.201	0.660	1/25 rod or 7.92 inches or 1/100 chain	
span	0.2286	0.7500	3 palms, width of outstretched hand from tip of thumb to tip of little finger, 9 inches	
foot	0.305	1.00	1/3 yard—base unit, starting 13th century—12 inches or 10/11 Anglo-Saxon foot, originally Roman foot of 11.65 inches, N. German foot of 13.2 inches also used in parallel after Anglo-Saxon Invasion	
ell	0.381	1.25	5 span, in other references = distance from right armpit to end of left middle finger on outstretched arm (~ 1.2 yds or ~ 1.1 m)	
cubit	0.457	1.50	3 shaftment or 1/2 yard, elbow to tip of middle finger	
pace	0.762	2.50	5 shaftments	
step	0.762	2.50	5 shaftments	
yard	0.914	3.00	3 feet, from nose to tip middle finger on outstretched arm	
English ell	1.143	3.750	Reported value in 1891	
grade	1.524	5.000	2 paces	
fathom	1.829	6.000	2 yards, width of outstretched arms between tips of middle fingers, 18 handbreadths, 6 feet	
rod	5.029	16.50	11 cubits	
rope	6.096	20.00	4 grades	
Gunter's chain	20.12	66.00	4 rods	
Shackle	27.43	90.00	15 fathoms	
Ramsden chain	30.48	100.0	5 ropes	
skein	36.58	120.0	96 ells	
cable	182.9	600.0	100 fathoms	
furlong	201.2	660.0	10 Gunter's chains	
stade	201.2	660.0	10 Gunter's chains	
Roman mile	1524	5000	50 Ramsden chains	
statute mile	1609	5280	1760 yards	

(continued)

Table 4.5 (continued)

Region and Unit	Equivalent meters	Equivalent feet, US	Notes	Era
nautic mile	1853	6080	6080 feet	
spindle	4389	14,400	120 skeins	
league	5560	18,240	3 Nautic miles or 3 Statute miles, used nautic mile	
degree of meridian	111,095	364,481	1891 value	
degree of equator	111,281	365,089	1891 value	
quarter yard (clothes)	0.2286	0.7500	9 inches, 4 nails	
nail (clothes)	0.05715	0.1875	2–1/4 inches	
inch (clothes)	0.02540	0.08333		
United States (Customary units, based on English units before 1824)				Colonial to modern
mil	0.00002540	0.00008333	1/1000 inch	
point	0.0003528	0.001157		
line	0.0006350	0.002083	1/40 inch	
pica	0.004233	0.01389	12 points	
inch	0.02540	0.08333	6 picas	
hand	0.1016	0.3333	4 inches	
link (survey)	0.2012	0.6601	33/50 ft	
span	0.2286	0.7500	9 inches	
foot	0.3048	1.000	12 inches	
survey foot	0.3048	1.000	1200/3937 m	
yard	0.9144	3.000	3 ft	
fathom (nautical)	1.829	6.000	2 yards	
rod	5.029	16.50	25 links, 16.5 ft	
perch	5.029	16.50	25 links, 16.5 ft	
pole (survey)	5.029	16.50	25 links, 16.5 ft	
chain	20.12	66.00	4 rods, 66 ft, also reported as 100 ft in some references, believe 66 ft is correct	
Ramsden's chain (survey)	20.12	66.00	4 rods, 66 ft, also reported as 100 ft in some references, believe 66 ft is correct	
bolt	36.58	120.0		
furlong (survey)	201.2	660.0	10 chains	
cable	219.5	720.0	120 fathoms	
mile	1609	5280	5280 ft, 80 chains	
survey mile	1609	5280	8 furlongs	
statute mile	1609	5280	8 furlongs	
land	1609	5280	8 furlongs	
mile (nautical)	1853	6080	8,439 cables, 1.151 miles	

(continued)

Table 4.5 (continued)

Region and Unit	Equivalent meters	Equivalent feet, US	Notes	Era
league (survey)	4828	15,840	3 miles	
league (nautical)	5560	18,240	3 nautical miles	
Uruguay (See Spanish units)				1891
Van Diemen's Island (See Tasmania)				1891
Venetian Lombardy (Venice & Milan, see Italy)				1891
Venezuela (Pre 1857/1914)				Colonial to pre-metric
pulgada	0.0222	0.0729	Inch, 1/36 vara, 2003 reference	
cuarta	0.200	0.656	1/4 vara, 9 pulgada, 2003 reference	
pie	0.267	0.875	Foot, 1/3 vara, 12 pulgada, 2003 reference	
vara	0.800	2.62	Yard, 3 pie, also reported as 0.835 m, 2003 reference	
meile	5024	16,483	Mile or league, 6280 vara, 2003 reference	
legua	5024	16,483	Mile or league, 6280 vara, 2003 reference	
Victoria (See Australia)				1891
Vietnam (See also Annam)				Medieval to metric
hào	0.0000425	0.000139		
li	0.000425	0.00139	10 hào, 2003 reference	
ly	0.000425	0.00139	10 hào, 2003 reference	
phân	0.00425	0.0139	10 ly, 2003 reference	
tắc	0.0425	0.139	10 phân, in some areas = 0.047 m, 2003 reference	
túc	0.0425	0.139	10 phân, in some areas = 0.047 m, 2003 reference	
tat	0.0425	0.139	10 phân, in some areas = 0.047 m, 2003 reference	
thước mộc	0.425	1.39	Varied 0.28–0.5 m, 2003 reference used	

(continued)

Table 4.5 (continued)

Region and Unit	Equivalent meters	Equivalent feet, US	Notes	Era
thước ta	0.425	1.39	Varied based on purpose, 10 tấc	
trượng xích	0.470	1.54	2003 and other references	
dien xích	0.470	1.54	2003 and other references	
thuoc de ruong	0.470	1.54	2003 and other references	
thước đo vai	0.644	2.11	Cloth measure, 2003 reference	
thuoc vai	0.644	2.11	Cloth measure, 2003 reference	
ngũ	2.125	6.972	5 thước, 2003 reference	
tam	2.125	6.972	5 thước, 2003 reference	
trượng xích	4.250	13.94	2 ngũ or 10 thước, also defined as 10 Chinese chi (3.33 m) or 4 thước mộc (1.7 m), 2003 reference	
dien xích	4.250	13.94	2 ngũ or 10 thước, also defined as 10 Chinese chi (3.33 m) or 4 thước mộc (1.7 m), 2003 reference	
truong	4.250	13.94	2 ngũ or 10 thước, also defined as 10 Chinese chi (3.33 m) or 4 thước mộc (1.7 m), 2003 reference	
sao	6.375	20.92	3 tam, 2003 reference	
chai vai	12.75	41.83	2 sao, 2003 reference	
that	12.75	41.83	2 sao, 2003 reference	
chai vai	14.63	48.00	Alternate source data	
that	14.63	48.00	Alternate source data	
mao	63.80	209.3	5 that, 2003 reference	
gon	127.6	418.6	2 mao, 2003 reference	
dam	444.4	1458	Reported as 444 or 576 meters, used 444	
thi ly	500.0	1640	1562.55 xích	
cong ly	1000	3281	3125 xích	
Wallachia (See Romania)				1891
Wales (Approx)				Medieval to pre-metric
gronyn heyd	0.00847	0.0278	Barleycorn, 1/3 inch	
heidden	0.00847	0.0278	Barleycorn, 1/3 inch	
inch	0.0254	0.0833	Inch	
moduet	0.0762	0.250	Palm, 3 inches	

(continued)

Table 4.5 (continued)

Region and Unit	Equivalent meters	Equivalent feet, US	Notes	Era
modfedd	0.0762	0.250	Palm, 3 inches	
palf	0.305	1.00	Foot	
palyw	0.305	1.00	Foot	
troedfedd	0.914	3.00	Pace, 3 feet	
troetued	0.914	3.00	Pace, 3 feet	
uerr yeu	1.219	4.000	Short yoke, 4 feet	
byr iau	1.219	4.000	Short yoke, 4 feet	
veieu	2.438	8.000	Field yoke or 2nd yoke, 8 feet	
eyl yeu	2.438	8.000	Field yoke or 2nd yoke, 8 feet	
cam	2.743	9.000	3 paces, AKA Leap	
cessel-yeu	3.658	12.00	Lateral yoke, 12 feet, 4 paces	
gesseylyeu	3.658	12.00	Lateral yoke, 12 feet, 4 paces	
hyryeu	4.877	16.00	Rod or long yoke, 16 feet	
hir iau	4.877	16.00	Rod or long yoke, 16 feet	
gwyalen	4.877	16.00	Rod or long yoke, 16 feet	
gwialen	4.877	16.00	Rod or long yoke, 16 feet	
neyt	8.230	27.00	Land, 3 leaps	
naid	8.230	27.00	Land, 3 leaps	
tyr	8230	27,000	Mile, 1000 lands	
tir	8230	27,000	Mile, 1000 lands	
mylltyr	8230	27,000	Mile, 1000 lands	
milltir	8230	27,000	Mile, 1000 lands	
West Australia (See Australia)				1891
West Indies				Colonial to 1891
Spanish units used in: Cuba, Puerto Rico, Isle of Pines, Curacao, and Culebra				
French units used in: Martinique, Deseada, Guadeloupe, Marie Galante, Le Saintes, and part of St. Martin				
Swedish units used in St. Bartholomew				

(continued)

Table 4.5 (continued)

Region and Unit	Equivalent meters	Equivalent feet, US	Notes	Era
Dutch (Netherlands) units used in: Part of St. Martin, Buen Ayre, Oruba (Aruba), and Tortuga				
Danish units used in: Santa Cruz, St. Thomas, and St. Jan or St. John, but also use English standards for length				
English units used in: Jamaica, Barbados, Grenada, Santa Lucia, St. Vincent, Trinidad, Tobago, Antigua, Bermuda, Dominica, Nevis, Montserrat, St. Kitt's, Tortola, Bahamas, and minor islands. Units are essentially US Customary				
Independent units used in: Haiti and Santo Domingo				
vara (Spanish areas)	0.848	2.78		
aune (Martinique)	1.190	3.904		
Wurtemberg (See Germany)				1891
Yucatan (See Mexico)				1891
Yugoslavia (Pre-metric units, pre-1873 primarily, 2003 reference)				Pre-metric
linia	0.00218	0.00715	2003 reference	
palaz	0.0363	0.119	16-2/3 linia, 2003 reference	
stopa	0.316	1.04	8.7 palaz, 2003 reference	
archine	0.711	2.33	2.25 stopa, 2003 reference	
kvat	1.90	6.22	6 stopa, 2003 reference	
Zanzibar				1891
ohra	0.571	1.87		
Miscellaneous Old Units				Misc
hand	0.102	0.333	For horses, still in use	
metric foot	0.300	0.984	Not used much	
remen	0.400	1.31	Four-hands, 4 dva	
pank'a dva	0.500	1.64	Cubit, 5 hands, 5 dva	
horse length	2.400	7.874	In horse racing	

Table 4.6 Alphabetical table of historical length measurement conversion factors. Refer to References section for data sources

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
↑	0.7	2.3	Aztec	Colonial to pre-metric	Land	1/2 land rod, possibly distance from shoulder to outstretched hand (like an arrow), “monad” unit
♥	0.6	1.8	Aztec	Colonial to pre-metric	Land	2/5 land rod, “monad” unit
1/3 PHU	0.012	0.039	Maya	Pre-colonial	General	
1/4 PHU	0.009	0.03	Maya	Pre-colonial	General	
1-1/4 PHU	0.045	0.15	Maya	Pre-colonial	General	
2 karams	2.514	8.248	India	Medieval to pre-metric	General	3 gaz
3/4 PHU	0.032	0.10	Maya	Pre-colonial	General	
3 mm	0.113	0.369	Egypt	Ancient to pre-metric	General	“Fist”, 6 fingers
abdat	0.0967	0.317	Egypt	Ancient to pre-metric	General	1/6 dirra, 4 kirat, 1891 value, consistent with 2003 reference
achtel (Hamburg)	0.00307	0.0101	Germany	Medieval to pre-metric	General	1/8 zoll
actus (common)	35.33	115.9	Rome	Ancient to pre-metric	General	120 pedes, consistent with 2003 reference
ady (Madras, Malabar coast)	0.266	0.872	India	Medieval to pre-metric	General	Local unit?, 1891 reference
aiwas	0.0200	0.0656	Persia, Iran	Ancient to pre-metric	General	Finger
akaina	2.777	9.111	Greece	Ancient to pre-metric	General	9 pous, 2003 reference

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
akaina	3.080	10.10	Greece	Ancient to pre-metric	General	10 podes
alen	0.5937	1.948	Sweden	Medieval to pre-metric	General	Forearm, varied, value reported in 2003 reference
alen	0.628	2.06	Norway	Medieval to pre-metric	General	Forearm or ell, cubit?, varied
alen	0.6277	2.059	Denmark	Medieval to pre-metric	General	Ell, 2 fod, 2003 reference
alen	0.6278	2.060	Iceland	Medieval to pre-metric	General	Cubit, 2 fet, 2003 reference, also reported as 0.57 m in 1891
alin	0.6278	2.060	Iceland	Medieval to pre-metric	General	Cubit, 2 fet, 2003 reference, also reported as 0.57 m in 1891
aln	0.5937	1.948	Sweden	Medieval to pre-metric	General	Forearm, varied, value reported in 2003 reference
aln	0.6277	2.059	Denmark	Medieval to pre-metric	General	Ell, 2 fod, 2003 reference
alnar	5.344	17.53	Sweden	Medieval to pre-metric	General	3 famn, 2003 reference
altschin	0.7112	2.333	Turkmenistan	Pre-metric	Linen	Linen goods, 1891 value, consistent with 2003 reference
amah	0.528	1.73	Biblical, Talmudic	Ancient	General	Ell or cubit, 2 spans, avg, Talmudic pace, also reported as 0.518 in Ezekiel 40.5
amm	0.113	0.369	Egypt	Ancient to pre-metric	General	“Fist”, 6 fingers

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
amma	18.51	60.73	Greece	Ancient to pre-metric	General	"Cord", 60 podes, consistent with 2003 reference
ammah	0.528	1.73	Biblical, Talmudic	Ancient	General	Ell or cubit, 2 spans, avg, Talmudic pace, also reported as 0.518 in Ezekiel 40.5
ammatu	0.497	1.63	Mesopotamia, Sumer, Akkadia	Ancient	General	cubit
angula (Bengal, Calcutta)	0.0190	0.0625	India	Medieval to pre-metric	General	Finger, 3 jows, 1891 reference, consistent with 1966 reference
angula (Bombay)	0.01429	0.04687	India	Medieval to pre-metric	General	Finger, 3 jow, 2003 reference
anguli	0.0520	0.171	India	Medieval to pre-metric	General	3 fingers
anne	0.1188	0.3898	Haiti, Hayti	Colonial to pre-metric	General	2003 reference
anukabiet	0.00260	0.00854	Thailand	Medieval to metric	General	2003 reference
arabi draa	0.483	1.59	Libya	Medieval or pre-metric	General	Lesser pik
Arabian canneh	4.267	14.00	Jewish	Medieval to Modern	General	168 inches
Arabic foot	0.320	1.05	Arabia	Ancient to pre-metric	General	Consistent with 2003 reference
arbi dra'a	0.483	1.59	Tripoli, Libya	Medieval to pre-metric	General	1891 value

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
archeen	0.7112	2.333	Russia	Medieval to pre-metric	General	Yard, 4 tchevert, 2003 reference
archin arisch	0.972	3.19	Persia, Iran	Ancient to pre-metric	General	Reported in 1891
archin schah	0.799	2.62	Persia, Iran	Ancient to pre-metric	General	Reported in 1891
archine	0.711	2.33	Serbia, Servia	Pre-metric	General	1891 value
archine	0.711	2.33	Yugoslavia	Pre-metric	General	2.25 stopa, 2003 reference
archine	0.7112	2.333	Russia	Medieval to pre-metric	General	Yard, 4 tchevert, 2003 reference
archine (builders, surveyors)	0.750	2.46	Turkey	Medieval to pre-metric	Builder, Surveyor	24 parmacks, 1891 value
architect's canna	2.233	7.325	Rome	Ancient to pre-metric	Builders	1891 value, 10 arch. palmi
architect's canna (Tuscany)	2.918	9.575	Italy	Medieval to pre-metric	General	5 braccia, reported in 1891
architect's catena	12.84	42.12	Rome	Ancient to pre-metric	Builders	1891 value, 57.5 arch. palmi
architect's decimi	0.00246	0.00807	Rome	Ancient to pre-metric	Builders	1/10 arch. oncie
architect's fuß (Leipsic)	0.283	0.927	Germany	Medieval to pre-metric	Builders	Reported in Liebsic 1891
architect's oncie	0.0177	0.0580	Rome	Ancient to pre-metric	Builders	1/12 architect's palmi, reported in 1891

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
architect's palmo	0.223	0.732	Italy	Medieval to pre-metric	Builders	Roman, buildings
architect's palmo	0.223	0.732	Rome	Ancient to pre-metric	Builders	1891 value
architect's pié	0.298	0.977	Rome	Ancient to pre-metric	Builders	1891 value
architect's stjoli	1.284	4.212	Rome	Ancient to pre-metric	Builders	1891 value, 1/10 arch. catena
arm			Aztec	Colonial to pre-metric	General	Unknown value
arpent	71.46	234.4	France	Medieval to pre-metric	General	Varied
arpent ordinaire	64.97	213.2	France	Medieval to pre-metric	General	Local use
arrow	0.7	2.3	Aztec	Colonial to pre-metric	Land	1/2 land rod, possibly distance from shoulder to outstretched hand (like an arrow), "monad" unit
arsheen	0.7112	2.333	Russia	Medieval to pre-metric	General	Yard, 4 tchevert, 2003 reference
arshin	0.7112	2.333	Russia	Medieval to pre-metric	General	Yard, 4 tchevert, 2003 reference
arshine	1.659	5.444	Estonia	Medieval to pre-metric	General	7/3 foute, 2003 reference
arsin	0.584	1.92	Hungary	Medieval to pre-metric	General	Like a cubit

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
arşın	0.680	2.23	Ottoman Empire, Turkey	Ancient to medieval	General	Ell or cubit
arşın	0.711	2.33	Tatar	Medieval to pre-metric	General	4 çirek, 16 qariş, 28 duym, essentially a cubit
askel	1.00	3.28	Finland	Medieval to pre-metric	General	“Pace”, approx value for adult male
aslu	60.00	196.8	Mesopotamia, Sumer, Akkadia	Ancient	General	cord, 120 cubits
asparsa	191.0	626.6	Persia, Iran	Ancient to pre-metric	General	Varied, avg
assbā	0.0225	0.0738	Arabia	Ancient to pre-metric	General	1/16 Ar ft, reported as 0.0200 m in 2003
assbaa	0.0225	0.0738	Arabia	Ancient to pre-metric	General	1/16 Ar ft, reported as 0.0200 m in 2003
atmı tuqtawsız yurıyu	20,000	65,616	Tatar	Medieval to pre-metric	General	Dist horse travels between stops, 15-25 km, used avg
atmñ könlek yulı	45,000	147,636	Tatar	Medieval to pre-metric	General	Distance horse travels in one day, 40-50 km, avg used
atomo (Parma)	0.000314	0.00103	Italy	Medieval to pre-metric	General	1/12 Punto, reported in 1891
atomo (typical)	0.000297	0.000975	Italy	Medieval to pre-metric	General	1/12 Punto
atomo (Venice)	0.000402	0.00132	Italy	Medieval to pre-metric	General	Reported in 1891

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
atour	5.235	17.175	Egypt	Ancient to pre-metric	General	3 mille, 2003 reference
atur	11.000	36.089	Egypt	Ancient to pre-metric	General	21,000 Royal cubits
aune	0.6496	2.131	France	Medieval to pre-metric	Cloth	"Ell", varied greatly, used for cloth measure, estd, also reported as length from right elbow to left middle finger tip with arms outstretched (~1.4 m), 2003 reference
aune	1.200	3.937	Switzerland	Medieval to pre-metric	General	2 braches, 1891 value
aune (Martinique)	1.190	3.904	West Indies	Colonial to pre-metric	General	
ayak	0.379	1.24	Ottoman Empire, Turkey	Ancient to Medieval	General	Foot, 12 parmak
bââh	1.847	6.060	Egypt	Ancient to pre-metric	General	5/2 derah, road measure
bamba	1.900	6.234	Sri Lanka	Medieval to pre-metric	General	Dist between finger tips, arms outstretched (estimate)
bamboo	3.912	12.83	Burma, Rangoon, Myanmar	Pre-metric	General	7 sandong, 2003 reference
bambou	3.912	12.83	Burma, Rangoon, Myanmar	Pre-metric	General	7 sandong, 2003 reference
bara	0.836	2.74	Chile	Colonial to pre-metric	General	Yard, 3 pie, 2003 reference, also reported as 0.847 m in 1891

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
barid	23,040	75,590	Arabia	Ancient to pre-metric	General	4 parasang, also reported as 19,300 m in 1891, consistent with 2003 reference
baride	22,164	72,716	Egypt	Ancient to pre-metric	Roads	4 farsakh, road measure
barleycorn	0.00847	0.0278	United Kingdom	Medieval to pre-metric	General	1/3 inch
baryd	19,320	63,385	Saudi Arabia	Pre-metric	General	4 farsakh, 2003 reference
baryd	23,040	75,590	Arabia	Ancient to pre-metric	General	4 parasang, also reported as 19,300 m in 1891, consistent with 2003 reference
bas	0.0840	0.276	Ireland	Medieval to pre-metric	General	Palm, 1/3 troighid
begah	977.7	3208	India	Medieval to pre-metric	General	20 pand
bema	0.7714	2.531	Greece	Ancient to pre-metric	General	“Pace”, 2003 reference
bēma	1.540	5,052	Greece	Ancient to pre-metric	General	5 podes
berid	227.0	744.7	Ottoman Empire, Turkey	Ancient to medieval	General	Range, 600 ayak
berri	1690	5545	Ethiopia	Medieval to pre-metric	General	1/3 farsang
berri	1690	5545	Abyssinia	Pre-metric	General	2464 pic, 2003 reference
bēru	10,800	35,433	Mesopotamia, Sumer, Akkadia	Ancient	General	league, 30 cable

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
bolt	36.58	120.0	United States	Colonial to Modern	General	
bolt (cloth)	13.00	42.65	China	Ancient to pre-metric	Cloth	Traditional measure
bone			Aztec	Colonial to pre-metric	General	Unknown value
border versta	2134	7000	Russia	Medieval to pre-metric	Land, Distance	For land and distances between settlements, 2 versta
bowshot	314.8	1033	Byzantine Empire	Ancient	General	
brabucco (Milan)	0.595	1.95	Italy	Medieval to pre-metric	General	12 once, typical, 2003 reference
braca	2.200	7.218	Brazil	Colonial to pre-metric	General	Fathom, 6-2/3 pés, also reported as 2.222 m in 2003 reference
braça	2.200	7.218	Portugal	Medieval to pre-metric	General	Fathom, 2 varas
braça	2.200	7.218	Brazil	Colonial to pre-metric	General	Fathom, 6-2/3 pés, also reported as 2.222 m in 2003 reference
braccio	0.680	2.23	Italy	Medieval to pre-metric	General	Like a large foot, varied, appx value
braccio (Ancona)	0.643	2.11	Rome	Ancient to pre-metric	General	1891 value reported for Ancona
braccio (Milan)	0.595	1.95	Italy	Medieval to pre-metric	General	12 once, typical, 2003 reference

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
braccio (Modena)	0.578	1.90	Italy	Medieval to pre-metric	General	Reported at Modena 1891
braccio (Rome)	0.781	2.56	Rome	Ancient to pre-metric	General	1891 value reported for Rome
braccio (Tuscany)	0.584	1.91	Italy	Medieval to pre-metric	General	2 palmi, reported in 1891
braccio (Venice)	0.695	2.28	Italy	Medieval to pre-metric	General	12 oncia, 2 piede, reported in 1891, reported as 0.683 m in 2003 reference
braccio di legno (Parma)	0.542	1.78	Italy	Medieval to pre-metric	General	Reported in 1891
brache	0.600	1.97	Switzerland	Medieval to pre-metric	General	2 pied, depending on source, 1891 value, consistent with 2003 reference
brasse (nautical)	1.624	5.328	France	Medieval to pre-metric	Nautical	“Fathom”, 5 pied, nautical, 2003 reference
brazo	1.733	5.686	Argentina	Colonial to pre-metric	General	2 vara, 2003 reference
brazo (typical)	1.672	5.485	Spain	Medieval to pre-metric	General	Fathom, 2 vara, pre-1860, 2003 reference
bu	0.00303	0.00994	Japan	Ancient to pre-metric	General	10 rin, 2003 reference
bu	1.341	4.398	China	Ancient to Pre-metric	General	varied, 5–6 chī, roughly a fathom
bw	0.300	0.984	Egypt	Ancient to pre-metric	General	foot, 4 palms = 16 fingers

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
canna	2.088	6.850	Malta	Medieval or pre-metric	General	8 palmo, reported in 2003 reference
canna	2.096	6.877	Malta	Medieval or pre-metric	General	Fathom essentially, reported 1891, 8 palmi
canna (Naples)	2.109	6.921	Italy	Medieval to pre-metric	General	8 palmo, reported in 1891
canna (Sicily)	1.936	6.353	Italy	Medieval to pre-metric	General	8 palmo, reported in 1891
canna (Tuscany)	2.335	7.660	Italy	Medieval to pre-metric	General	4 braccia, reported in 1891
canna (typical)	2.055	6.742	Italy	Medieval to pre-metric	General	4 piede liprando, 8-10 palmi, varied, pre-1861, 2003 reference
canne	4.072	13.36	Egypt	Ancient to pre-metric	General	2003 reference
çaqm	1.067	3.500	Tatar	Medieval to pre-metric	General	500 sajin
cassaba	3.695	12.12	Egypt	Ancient pre-metric	Roads	(1891), 5 derah, road measure
cassaba	38.4	126	Saudi Arabia	Pre-metric	General	7.97 covid, 2003 reference
Castilian foot	0.283	0.927	Canary Islands	Pre-metric	General	Local variation, 1891 reference
catena	5.693	18.68	Italy	Medieval to pre-metric	Buildings	Architect, 10 stajoli, 25.5 palmi
cavezzo (Modena)	3.138	10.30	Italy	Medieval to pre-metric	General	6 piede (Modena)

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
cavezzo (typical)	3.083	10.11	Italy	Medieval to pre-metric	General	6 picde liprando, pre-1861, 2003 reference, regional variations
cāyāwleneñ aylıq yulı	1,120,140	3,674,955	Tatar	Medieval to pre-metric	General	Month of riding, 1050 çaqırım
cāyāwleneñ köñlek yulı	37,338	122,499	Tatar	Medieval to pre-metric	General	A day of riding, 35 çaqırım
ceim	0.625	2.05	Ireland	Medieval to pre-metric	General	Step, 2.5 troighid
cessel-yeu	3.658	12.00	Wales	Medieval to pre-metric	General	Lateral yoke, 12 feet, 4 paces
cha	0.303	0.994	Korea, Korea	Medieval or pre-metric	General	
chai vai	12.75	41.83	Vietnam, Annam	Medieval to metric	General	2 sao, 2003 reference
chai vai	14.63	48.00	Vietnam, Annam	Medieval to metric	General	Alternate source data
chain	20.12	66.00	United States	Colonial to modern	General	4 rods, 66 ft, also reported as 100 ft in some references, believe 66 ft is correct
chain	22.68	74.40	Scotland	Medieval to pre-metric	General	4 fall, 2003 reference
chain	25.60	84.00	Ireland	Medieval to pre-metric	General	4 perch, pre-1824 value, 2003 reference
chain	42.67	140.0	Jewish	Medieval to modern	General	1680 inches

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
charak	0.2286	0.7500	Persia, Iran	Ancient to pre-metric	General	2 urub, 2003 reference
chebel	24.00	78.74	Persia, Iran	Ancient to pre-metric	General	Hundred foot, 8 daga trayas
chebel	25.60	83.99	Persia, Iran	Ancient to pre-metric	General	40 cubits, 2003 reference
chetvert	0.1778	0.5833	Russia	Medieval to pre-metric	General	Palm or quarter, 1/4 arshin, 4 vershok, 2003 reference
cheung (official)	3.334	10.94	China	Ancient to pre-metric	General	Value in 1891, 1/10 yan
chhioh	0.303	0.994	Taiwan, Formosa	Medieval to pre-metric	General	Foot, same as Japanese shaku
chhün	0.0303	0.0994	Taiwan, Formosa	Medieval to pre-metric	General	Same as Japanese sun
chi	0.0330	0.108	Korea, Korea	Medieval or pre-metric	General	
chī	0.251	0.823	China	Ancient to pre-metric	General	varied, roughly a foot, length of a forearm (not including hand)
chik (commercial)	0.375	1.23	China	Ancient to pre-metric	General	Value in 1891
chik (itinerary)	0.309	1.01	China	Ancient to pre-metric	General	Value in 1891
chik (official, average)	0.333	1.09	China	Ancient to pre-metric	General	Value in 1891, 1/100 yan, 10 cun, similar in 1966
chik (surveyors, engineers)	0.323	1.06	China	Ancient to pre-metric	Engrs, Surveyors	Value in 1891

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
chō	109.1	357.9	Japan	Ancient to pre-metric	General	360 shaku, 60 ken, 2003 reference
chō	109.1	357.9	Japan	Ancient to pre-metric	General	360 shaku, 60 ken, 2003 reference
choryos	0.08725	0.2862	Egypt	Ancient to pre-metric	General	"Palm", 4 fingers, 2003 reference
Cicéro	0.00451	0.0148	France	Medieval to pre-metric	Typographic	Typographic, 12 Didot pts, French pica
çirek, qarış	0.178	0.583	Tatar	Medieval to pre-metric	General	4 qarış
cobido	0.483	1.58	Arabia	Ancient to pre-metric	General	In 1891 reference, reported as 0.480 m in 2003
codo	0.531	1.74	Morocco	Medieval to pre-metric	General	Varied greatly (0.504 to 0.571), best estimate of typical value
codo (typical)	0.4180	1.371	Spain	Medieval to pre-metric	General	Cubit, 2 palma, pre-1860, 2003 reference
codo de ribera	0.557	1.83	Spain	Medieval to pre-metric	General	
codos (typical)	0.4180	1.371	Spain	Medieval to pre-metric	General	Cubit, 2 palma, pre-1860, 2003 reference
commercial palmo	0.223	0.733	Italy	Medieval to pre-metric	General	Roman
commercial palmo	0.223	0.733	Rome	Ancient to pre-metric	General	1891 value

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
condylos	0.03857	0.1265	Greece	Ancient to pre-metric	General	2 daktyloi, consistent with 2003 reference
cong ly	1000	3281	Vietnam, Annam	Medieval to metric	General	3125 xich
cord—Gemara	2.112	6.929	Biblical, Talmudic	Ancient	General	4 ells
cord—Mishnah	26.40	86.61	Biblical, Talmudic	Ancient	General	50 ells
cordel (10 varas)	8.359	27.42	Spain	Medieval to pre-metric	General	Variant
cordel (50 varas)	41.80	137.1	Spain	Medieval to pre-metric	General	Variant
cordel (69 varas)	57.68	189.2	Spain	Medieval to pre-metric	General	Variant
Cornish fathom	1.5	5.0	Cornwall	Medieval to pre-metric	General	5 feet, estd
Cornish mile	2400	7874	Cornwall	Medieval to pre-metric	General	1.5 miles, est
coss (Bengal)	1828	5997	India	Medieval to pre-metric	General	1000 fathoms, 1891 reference
coss (Bombay)	1372	4500	India	Medieval to pre-metric	General	200 niranga, 2003 reference
coss (Seringapatam)	5866	19,245	India	Medieval to pre-metric	General	Local unit?, 1891 reference

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
covada	0.660	2.17	Portugal	Medieval to pre-metric	General	Cubit, 3 palmos, 2 pes, reported as 0.6570 m in 2003 reference
covado	0.531	1.74	Morocco	Medieval to pre-metric	General	Varied greatly (0.504 to 0.571), best estimate of typical value
côvado	0.660	2.17	Portugal	Medieval to pre-metric	General	Cubit, 3 palmos, 2 pes, reported as 0.6570 m in 2003 reference
covid	0.381	1.25	Cochin China	Pre-metric	General	1891 Value
covid	0.457	1.50	Malacca	Pre-metric	General	1891 value, also reported as 0.459
covid	0.457	1.50	Singapore	Colonial to pre-metric	General	Cubit
covid	0.464	1.52	Sri Lanka	Medieval to pre-metric	General	Cubit?
covid	0.483	1.58	Arabia	Ancient to pre-metric	General	In 1891 reference, reported as 0.480 m in 2003
covid	0.531	1.74	Morocco	Medieval to pre-metric	General	Varied greatly (0.504 to 0.571), best estimate of typical value
covid	0.686	2.25	Indonesia	Colonial to pre-metric	General	Java, appx 3/4 yard, roughly a cubit
covid	0.686	2.25	Java	Pre-colonial	General	
covid	0.994	3.26	Muscat	Pre-metric	General	1891 value
covid	0.994	3.26	Oman	Medieval to pre-metric	General	Yard
covid	4.82	15.8	Saudi Arabia	Pre-metric	General	2003 reference
covid (Ahmednuggur)	0.356	1.17	India	Medieval to pre-metric	General	Local value, 1891 reference

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
covid (Bengal, Calcutta)	0.457	1.50	India	Medieval to pre-metric	General	2 spans, 1891 reference
covid (Bombay)	0.3429	1.125	India	Medieval to pre-metric	General	2 span, 2003 reference
covid (Ceylon)	0.464	1.52	Ceylon, Sri Lanka	Pre-metric	General	2003 reference
covid (Madras)	0.472	1.55	Ceylon, Sri Lanka	Pre-metric	General	2003 reference
covid (Madras)	0.472	1.55	India	Medieval to pre-metric	General	2 spans, varied significantly by location, value shown is for Madras, 1891 reference
covid (Surat)	0.531	1.74	India	Medieval to pre-metric	General	Local value, 1891 reference
crosta	3,656	11,995	India	Medieval to pre-metric	General	2000 dhanush, 1966 value
cuadra	84.00	275.6	Colombia	Colonial to pre-metric	General	100 vara, also reported as 80.0 m in 2003 reference
cuadra	125.4	411.4	Chile	Colonial to pre-metric	General	150 bara, 2003 reference
cuadra	130.0	426.5	Argentina	Colonial to pre-metric	General	150 vara, 75 braza, 2003 reference
cuadra (new)	86.60	284.1	Paraguay	Colonial to pre-metric	General	100 vara (new), 2003 reference
cuadra (old)	83.86	275.1	Paraguay	Colonial to pre-metric	General	100 vara (old), 2003 reference

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
cuarta	0.200	0.656	Venezuela	Colonial to pre-metric	General	1/4 vara, 9 pulgada, 2003 reference
cuarta	0.2032	0.6667	Honduras	Colonial to pre-metric	General	1/4 vara, 9 pulgada, 2003 reference
cuarta	0.21	0.68	El Salvador	Colonial to pre-metric	General	1/4 vara, 9 pulgada, 2003 reference
cuarta	0.21	0.68	Nicaragua	Colonial to pre-metric	General	1/4 vara, 9 pulgada, 2003 reference
cuarta	0.209	0.685	Central America	Colonial to pre-metric	General	1/4 vara, 9 pulgada, 2003 & 1891 references
cuarta	0.2090	0.6856	Guatemala	Colonial to pre-metric	General	1/4 vara, 9 pulgada, 2003 reference
cuarta	0.2098	0.6884	Costa Rica	Colonial to pre-metric	General	1/4 vara, 9 pulgada, 2003 reference
cuarta	0.210	0.689	Colombia	Colonial to pre-metric	General	1/4 vara, 9 pulgada, also reported as 0.200 m in 2003 reference
cubi	0.320	1.05	Eritrea	Medieval to pre-metric	General	Varied by location, 2003 reference
cubit	0.4572	1.500	Burma, Rangoon, Myanmar	Pre-metric	General	4.5 palgat, 2003 reference
cubit	0.4572	1.500	Ireland	Medieval to pre-metric	General	18 inches, pre-1824 value, 2003 reference
cubit	0.457	1.50	United Kingdom	Medieval to pre-metric	General	3 shaftment or 1/2 yard, elbow to tip of middle finger

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
cubit	0.500	1.64	Inca	Ancient to pre-colonial	General	Est'd
cubit	0.533	1.75	Jewish	Medieval to modern	General	21 inches
cubit	0.534	1.75	Morocco	Medieval to pre-metric	General	7 tonni, 2003 reference
cubit	0.560	1.84	Arabia	Ancient to pre-metric	General	1.5-2 Ar ft
cubit	0.640	2.10	Persia, Iran	Ancient to pre-metric	General	Reported 2003
cubit (Bengal, Calcutta)	0.457	1.50	India	Medieval to pre-metric	General	2 spans, 1891 reference
cubit (Bombay)	0.460	1.51	India	Medieval to Pre-Metric	General	16 tussoos, 1891 reference
cubit (common)	0.555	1.82	Hebrew	Ancient to pre-metric	General	Long cubit, 2 feet, 2003 reference
cubit (Madras)	0.472	1.55	India	Medieval to pre-metric	General	2 spans, varied significantly by location, value shown is for Madras, 1891 reference
cubit (new)	0.483	1.58	Arabia	Ancient to pre-metric	General, New	In 1891 reference, reported as 0.480 m in 2003
cubit (old)	0.635	2.08	Arabia	Ancient to pre-metric	General, Old	Old cubit (hashemic), in 1891 reference, reported as 0.640 m in 2003
cubit (sacred)	0.640	2.10	Hebrew	Ancient to pre-metric	General	Long cubit, 2 feet, 2003 reference

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
cubito	0.560	1.84	Somalia	Medieval to pre-metric	General	cubit, 1/7 top, 2003 reference
cubitus (common)	0.4416	1.449	Rome	Ancient to pre-metric	General	cubit, 1–1/2 pedes, distance from elbow to wrist, consistent with 2003 reference
cuerda (new)	24.06	78.92	Paraguay	Colonial to pre-metric	General	1000 pulgada (new), 2003 reference
cuerda (old)	23.29	76.42	Paraguay	Colonial to pre-metric	General	1000 pulgada (old), 2003 reference
cùn	0.089	0.29	China	Ancient to pre-metric	General	Length of a finger, est at 3.5 inches
cun (official)	0.033	0.11	China	Ancient to pre-metric	General	1/1000 yan, 10 Fen, value reported 1891, similar in 1966
ćwierć	0.149	0.488	Poland	Medieval to pre-metric	General	Quarter łokieć, 2 palms
daca trayas	3.000	9.842	Persia, Iran	Ancient to pre-metric	General	Ten-foot, 2 pank'a
dain	3912	12.833	Burma, Rangoon, Myanmar	Pre-metric	General	50 oke thapal, 1000 bambous, 2003 reference
daktylos	0.01929	0.06329	Greece	Ancient to pre-metric	General	"Finger", consistent with 2003 reference
dam	444.4	1458	Vietnam, Annam	Medieval to metric	General	Reported as 444 or 576 meters, used 444
dam	885	2903	Annam	Pre-metric	Roads	2 ly road measure, 0.55 mi

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
da-na	10.800	35.433	Mesopotamia, Sumer, Akkadia	Ancient	General	league, 30 cable
danda (Bombay)	1.372	4.500	India	Medieval to pre-metric	General	2 guz, 2003 reference
day's journey	47.220	154.919	Byzantine Empire	Ancient	General	
db	0.0188	0.0615	Egypt	Ancient to pre-metric	General	"Finger", 1/4 palm
decempeda (common)	2.944	9.659	Rome	Ancient to pre-metric	General	"Perch", 10 pedes, consistent with 2003 reference
decimal fuss	0.316	1.04	Austrian Empire	Pre-metric	Engrs, Surveyors	10 decimal zoll (Used this as base)
decimal fuß	0.316	1.04	Austrian Empire	Pre-metric	Engrs, Surveyors	10 decimal zoll (Used this as base)
decimal fuss (Surveyors)	0.377	1.24	Prussia	Pre-metric	Surveyor	1891 value
decimal linie	0.00316	0.0104	Austrian Empire	Pre-metric	Engrs, Surveyors	
decimal linie (Surveyors)	0.00377	0.0124	Prussia	Pre-metric	Surveyor	1891 value
decimal zoll	0.0316	0.104	Austrian Empire	Pre-metric	Engrs, Surveyors	10 decimal linie
decimal zoll (Surveyors)	0.0377	0.124	Prussia	Pre-metric	General	1891 value

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
derah Istambuli	0.669	2.20	Egypt	Ancient to pre-metric	General	Constantinople pic
derah meimari	0.750	2.46	Egypt	Ancient to pre-metric	Builders	Builder's pic
derekh yom	42,240	138,581	Biblical, Talmudic	Ancient	General	Day's journey, Talmudic, 10 parasangs
dha	3.912	12.83	Burma, Rangoon, Myanmar	Pre-metric	General	7 sandong, 2003 reference
dhanush	1.83	6.00	India	Medieval to pre-metric	General	4 hasta, 1966 value
dhr'a	0.531	1.74	Morocco	Medieval to pre-metric	General	Varied greatly (0.504 to 0.571), best estimate of typical value
dhra	0.531	1.74	Morocco	Medieval to pre-metric	General	Varied greatly (0.504 to 0.571), best estimate of typical value
dialulos	370.2	1215	Greece	Ancient to pre-metric	General	2 stadia, consistent with 2003 reference
dichas	0.1543	0.5062	Greece	Ancient to pre-metric	General	Half foot, 8 dak., consistent with 2003 reference
dichas	0.1745	0.5725	Egypt	Ancient to pre-metric	General	2 palms
Didot point	0.000376	0.00123	France	Medieval to pre-metric	Typographic	Typographic measure, 1/72 inch
diedo (typical)	0.01741	0.05713	Spain	Medieval to pre-metric	General	Finger, 12 linea, pre-1860, 2003 reference

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
dien xich	0.470	1.54	Vietnam, Annam	Medieval to metric	General	2003 and other references
dien xich	4.250	13.94	Vietnam, Annam	Medieval to metric	General	2 ngũ or 10 thước, also defined as 10 Chinese chi (3.33 m) or 4 thước mộc (1.7 m), 2003 reference
digit	0.0191	0.0625	United Kingdom	Medieval to pre-metric	General	1/4 palm or 3/4 inch
digit	0.0195	0.0640	Byzantine Empire	Ancient	General	Finger, monas, daktylos
digit	0.0222	0.0729	Jewish	Medieval to modern	General	0.875 inches
digits	0.01091	0.03579	Egypt	Ancient to pre-metric	General	2003 reference
digitu (common)	0.01840	0.06037	Rome	Ancient to pre-metric	General	finger, 1/16 pes, consistent with 2003 reference
digitus (common)	0.01840	0.06037	Rome	Ancient to pre-metric	General	finger, 1/16 pes, consistent with 2003 reference
diploun bēma	1.540	5.052	Greece	Ancient to pre-metric	General	5 podes
diraa	0.580	1.90	Egypt	Ancient to pre-metric	General	2 kadam, 1891 value, consistent with 2003 reference
dirra baladi	0.580	1.90	Egypt	Ancient to pre-metric	General	2 kadam, 1891 value, consistent with 2003 reference
djeba	0.0188	0.0615	Egypt	Ancient to pre-metric	General	“Finger”, 1/4 palm

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
djeser	0.300	0.984	Egypt	Ancient to pre-metric	General	foot, 4 palms = 16 fingers
dloñ	0.0744	0.244	Poland	Medieval to pre-metric	General	Palm, 3 inches
dolichos	2.221	7.287	Greece	Ancient to pre-metric	General	12 stadia, consistent with 2003 reference
dorn	0.125	0.410	Ireland	Medieval to pre-metric	General	Fist, 5/12 or 1/2 troighid
dōron	0.07714	0.2531	Greece	Ancient to pre-metric	General	“Palm”, 4 dak, consistent with 2003 reference
double pace	1.574	5.164	Byzantine Empire	Ancient	General	(= Roman pace), 2 steps
double remen	0.741	2.43	Egypt	Ancient to pre-metric	General	Diag of square royal cubit
double versta	2.134	7,000	Russia	Medieval to pre-metric	Land, Distance	For land and distances between settlements, 2 versta
draa	0.453	1.49	Libya	Medieval or pre-metric	General	Basic, 2 palmo, 2003 reference
dra’a	0.671	2.20	Tripoli, Libya	Medieval to pre-metric	General	1891 value
dra’a hendaseh	0.673	2.21	Tunisia	Ancient to pre-metric	Wool	For woollen goods
drt	0.0938	0.308	Egypt	Ancient to pre-metric	General	“Hand”, 5 fingers

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
duïne	0.02540	0.08333	Russia	Medieval to pre-metric	General	Inch, 1/28 arshin, 2 pal' ets, 2003 reference
duimen	0.02359	0.07739	Netherlands, Holland	Medieval to metric	General	12 lyne, thumb or inch, varied 10-14 per Voet, 2003 reference
duimen	0.0263	0.0862	Netherlands, Holland	Medieval to metric	General	Thumb or Inch, varied 10-14 per Voet, avg, alternate reference
duym	0.0254	0.0833	Tatar	Medieval to pre-metric	General	Thumb or inch
dva	0.100	0.328	Persia, Iran	Ancient to pre-metric	General	Hand, 5 aiwas
dyuim	0.02540	0.08333	Russia	Medieval to pre-metric	General	Inch, 1/28 arshin, 2 pal' ets, 2003 reference
dzera a rabry	0.467	1.53	Algeria	Medieval to pre-met	General	Arabic pic with different basis, varied, 2 nus, also reported as 0.482 m, value from 2003 reference
dzera a torlky	0.623	2.04	Algeria	Medieval to pre-met	General	Turkish pic, 2 nus, varied, 2003 reference
el	0.672	2.21	Netherlands, Holland	Medieval to metric	General	Length of arm from armpit to tip of fingers, avg, alternate references
el	0.7076	2.321	Netherlands, Holland	Medieval to metric	General	30 duime, 2003 reference
el (Amsterdam)	0.688	2.26	Netherlands, Holland	Medieval to metric	General	Reported for Amsterdam in 1891
ell	0.381	1.25	United Kingdom	Medieval to pre-metric	General	5 span, in other references = distance from right armpit to end of left middle finger on outstretched arm (~1.2 yds or ~1.1 m)

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
ell	0.9449	3.100	Scotland	Medieval to pre-metric	General	37 inches, 2003 reference
ell	5.344	17.53	Sweden	Medieval to pre-metric	General	3 famn, 2003 reference
elle	0.5334	1.750	Estonia	Medieval to pre-metric	General	2003 reference
elle	0.537	1.76	Latvia	Medieval or pre-metric	General	4 quartier, 2003 reference
elle	0.600	1.97	Switzerland	Medieval to pre-metric	General	2 pied, depending on source, 1891 value, consistent with 2003 reference
elle	0.667	2.19	Prussia	Pre-metric	General	1891 value
elle	0.672	2.21	Netherlands, Holland	Medieval to metric	General	Length of arm from armpit to tip of fingers, avg, alternate references
elle	0.685	2.25	South Africa	Medieval to pre-metric	General	Pre-1922
elle	0.7076	2.321	Netherlands, Holland	Medieval to metric	General	30 duime, 2003 reference
elle (Amsterdam)	0.688	2.26	Netherlands, Holland	Medieval to metric	General	Reported for Amsterdam in 1891
elle (average)	0.600	1.97	Germany	Medieval to pre-metric	General	Cubit, Elbow to fingertip, varied 0.4-0.8 m
elle (Average)	0.779	2.56	Austrian Empire	Pre-metric	Common	2.465 fuss, 2003 reference
elle (Bohemia)	0.589	1.93	Austrian Empire	Pre-metric	Common	Reported in Bohemia 1891

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
elle (Frankfort)	0.547	1.80	Germany	Medieval to pre-metric	General	Reported in Frankfort 1891
elle (Hesse-Cassel)	0.570	1.87	Germany	Medieval to pre-metric	General	Reported in Hesse-Cassel 1891, 2 landfuß
elle (Hesse-Darmstadt)	0.800	2.62	Germany	Medieval to pre-metric	General	Reported in Hesse-Darmstadt 1821
elle (Lubeck)	0.576	1.89	Germany	Medieval to pre-metric	General	Reported in Lubeck 1821
elle (Prussian system)	0.6669	2.188	Germany	Medieval to pre-metric	General	17/8 fuss, 2003 reference
elle (Stuttgart)	0.614	2.01	Germany	Medieval to pre-metric	General	Reported in 1891
emmet	0.460	1.51	Eritrea	Medieval to pre-metric	General	Essentially pic, 23/16 cubi, 2003 reference
encablure (nautical)	194.9	639.4	France	Medieval to pre-metric	Nautical	"Cable length", 100 toise, nautical, 2003 reference
endasch (cloth)	0.653	2.14	Turkey	Medieval to pre-metric	Cloth	8 ouroubs, 1891 value
endasch (cloth, Smyrna)	0.626	2.05	Turkey	Medieval to pre-metric	Cloth	Reported at Smyrna, 1891 value
endasch (common)	0.662	2.17	Romania	Pre-metric	General	2003 reference
endaze	0.650	2.13	Ottoman Empire, Turkey	Ancient to medieval	General	Ell or cubit
endere (common)	0.662	2.17	Romania	Pre-metric	General	2003 reference

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
English ell	1.143	3.750	United Kingdom	Medieval to pre-metric	General	Reported value in 1891
eše2	60.00	196.8	Mesopotamia, Sumer, Akkadia	Ancient	General	cord, 120 cubits
eski mil	1894	6215	Ottoman Empire, Turkey	Ancient to medieval	General	Old mile, 5000 ayak
estada	257.2	843.7	Portugal	Medieval to pre-metric	General	Stade, 236 varas, reported in 1891, reported as 258.4 m in 2003 reference
estadal (typical)	3.344	10.97	Spain	Medieval to pre-metric	General	Perch, 2 estado, 4 varas, pre-1860, 2003 reference
estadio	257.2	843.7	Portugal	Medieval to pre-metric	General	Stade, 236 varas, reported in 1891, reported as 258.4 m in 2003 reference
estadjo	174.1	571.2	Spain	Medieval to pre-metric	General	
estado (typical)	1.672	5.485	Spain	Medieval to Pre-Metric	General	Fathom, 2 vara, pre-1860, 2003 reference
etsba	0.0222	0.0729	Biblical, Talmudic	Ancient	General	Thumb breadth, inch
etto	0.457	1.50	Indonesia	Colonial to pre-metric	General	Sumatra, 2 jankel
etto	0.457	1.50	Sumatra	Pre-metric	General	2 jankal, 1891 value
etzba	0.0222	0.0729	Biblical, Talmudic	Ancient	General	Thumb breadth, inch
						(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
eyl yeu	2.438	8.000	Wales	Medieval to pre-metric	General	Field yoke or 2nd yoke, 8 feet
Ezekiel's canneh	3.200	10.50	Jewish	Medieval to modern	General	126 inches
faden	1.883	6.178	Germany	Medieval to pre-metric	General	fathom, 6 fuss, 2003 reference
faden	2.134	7.000	Estonia	Medieval to pre-metric	General	Fathom, 3 archine, 2003 reference
fall	5.669	18.60	Scotland	Medieval to pre-metric	General	6 ells, 222 inches, like a rod, 2003 reference
famn	1.781	5.843	Sweden	Medieval to pre-metric	General	Fathom, 3 aln, 2003 reference
fan (official)	0.0033	0.011	China	Ancient pre-metric	General	1/10000 yan, 10 li, value reported in 1891, similar in 1966
fanen	1.781	5.843	Sweden	Medieval to pre-metric	General	Fathom, 3 aln, 2003 reference
faðmur	1.883	6.179	Iceland	Medieval to pre-metric	General	Fathom, 6 fet, 3 alin, 2003 reference
farsakh	1740	5709	Egypt	Ancient to pre-metric	General	3000 dirra, 1891 value, consistent with 2003 reference
farsakh	4830	15,846	Saudi Arabia	Pre-metric	General	125.8 cassaba, 2003 reference
farsakh	5486	18,000	Persia, Iran	Ancient to pre-metric	General	5275 zar, 2003 reference
farsakh	5541	18,179	Egypt	Ancient to pre-metric	General	3 mili, road measure, league

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
farsakh	5760	18,897	Arabia	Ancient to pre-metric	General	18000 Ar ft, consistent with 2003 reference
farsang	5070	16,634	Ethiopia	Medieval to pre-metric	General	Roughly
farsang	5070	16,634	Abyssinia	Pre-metric	General	3 berri, 2003 reference
färsäx	6934	22,747	Tatar	Medieval to pre-metric	General	6–7 çaqım, used average
fathom	1.781	5.843	Sweden	Medieval to pre-metric	General	Fathom, 3 aln, 2003 reference
fathom	1.829	6.000	United Kingdom	Medieval to pre-metric	General	2 yards, width of outstretched arms between tips of middle fingers, 18 handbreadths, 6 feet
fathom	2.134	7.000	Jewish	Medieval to modern	General	84 inches
fathom	4.267	14.00	Ireland	Medieval to pre-metric	General	14 feet, pre-1824 value, 2003 reference
fathom (Bengal)	1.828	5.997	India	Medieval to pre-metric	General	2 guz, 1891 reference
fathom (nautical)	1.829	6.000	United States	Colonial to modern	Nautical	2 yards
faust	0.1054	0.3457	Hungary	Medieval to Pre-Metric	General	2003 reference
favn	1.882	6.174	Norway	Medieval to pre-metric	General	Fathom, 3 alen, Naut = 1.85 m
favn	1.883	6.178	Denmark	Medieval to pre-metric	General	3 aln, 2003 reference

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
feldfuß (surveyors)	0.356	1.17	Germany	Medieval to pre-metric	General	Reported in Frankfort 1891
fen	0.0032	0.010	China	Ancient to pre-metric	General	10 li
fen	38.4	126	China	Ancient to pre-metric	General	12 zhang, 1966 value
fen (official)	0.0033	0.011	China	Ancient to pre-metric	General	1/10000 yan, 10 li, value reported in 1891, similar in 1966
fersah	5685	18,651	Ottoman Empire, Turkey	Ancient to medieval	General	League, 3 eski mil
fertach	3.000	9.842	Ireland	Medieval to pre-metric	General	Rod, 12 troighid, AKA inntrít?
fet	0.3139	1.030	Iceland	Medieval to pre-metric	General	Foot, 12 pumlungur, 2003 reference
finger	0.0180	0.0591	Inca	Ancient to pre-colonial	General	Est'd
finger	0.0222	0.0729	United Kingdom	Medieval to pre-metric	General	63 points or 7/8 inch
finger (common)	0.0231	0.0759	Hebrew	Ancient to pre-metric	General	2003 Reference
finger (sacred)	0.0267	0.0875	Hebrew	Ancient to pre-metric	General	2003 Reference
fingerbredd	0.01856	0.06088	Sweden	Medieval to pre-metric	General	3/4 tum, 2003 reference

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
finger's breadth	0.0222	0.0729	Jewish	Medieval to modern	General	0.875 inches
fitel	0.142	0.465	Malta	Medieval or pre-metric	General	1/2 xiber, half foot
fjårdingsväg	2,673	8,768	Sweden	Medieval to pre-metric	General	1/4 mil, 500 alnar, 2003 reference
fjerdingsvei	2,820	9,252	Norway	Medieval to pre-metric	General	1/4 mil, quarter mile
Flemish ell	0.700	2.30	Flanders	Medieval to pre-metric	General	Arm pit to tip of middle finger outstretched
fod	0.3137	1.029	Norway	Medieval to pre-metric	General	Foot, 1/2 alen, 2003 reference, also reported as 0.297 m in 1891
fod	0.3139	1.030	Denmark	Medieval to pre-metric	General	Foot, Varied, 2003 reference
foot	0.284	0.931	Malta	Medieval or pre-metric	General	Reported 1891
foot	0.3048	1.000	Cyprus	Colonial to pre-metric	General	2003 reference
foot	0.3048	1.000	Ireland	Medieval to pre-metric	General	12 inches, pre-1824 value, 2003 reference
foot	0.305	1.00	United Kingdom	Medieval to pre-metric	General	1/3 yard—base unit, starting 13th century—12 inches or 10/11 Anglo-Saxon foot, originally Roman foot of 11.65 inches, N. German foot of 13.2 inches also used in parallel after Anglo-Saxon Invasion

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
foot	0.3048	1.000	United States	Colonial to modern	General	12 inches
foot	0.3064	1.005	Scotland	Medieval to pre-metric	General	12 inches, 2003 reference
forrach	36.00	118.1	Ireland	Medieval to pre-metric	General	144 troighid
fot	0.2969	0.9741	Sweden	Medieval to pre-metric	General	Foot, 1/2 aln, same value in 1891, consistent with 2003 reference
fot	0.3137	1.029	Norway	Medieval to pre-metric	General	Foot, 1/2 alen, 2003 reference, also reported as 0.297 m in 1891
foute	0.3048	1.000	Russia	Medieval to pre-metric	General	Foot, 3/7 arshin, 12 duime, 2003 reference
foute	0.7112	2.333	Estonia	Medieval to pre-metric	General	Russian, foot, 4/3 elle, 2003 reference
furlong	201.2	660.0	United Kingdom	Medieval to pre-metric	General	10 Gunter's chains
furlong	226.8	744.0	Scotland	Medieval to pre-metric	General	10 chain, 2003 reference
furlong	256.0	840.0	Ireland	Medieval to pre-metric	General	10 chains, pre-1824 value, 2003 reference
furlong	2.134	7,000	Jewish	Medieval to modern	General	84000 inches
furlong (survey)	201.2	660.0	United States	Colonial to modern	Surveyor	10 chains
fuss	0.300	0.984	Switzerland	Medieval to pre-metric	General	Foot, consistent with value reported in 1891 and 2003 reference

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
fuss (Average)	0.3161	1.037	Austrian Empire	Pre-metric	Common	Foot, 12 zoll, 2003 reference
fuß (Average)	0.3161	1.037	Austrian Empire	Pre-metric	Common	Foot, 12 zoll, 2003 reference
fuß (average, typical)	0.295	0.968	Germany	Medieval to pre-metric	General	Foot, varied a lot, typical average
fuß (Baden)	0.300	0.984	Germany	Medieval to pre-metric	General	Reported in Baden 1891
fuß (Bavaria)	0.292	0.957	Germany	Medieval to pre-metric	General	Reported in Bavaria 1891
fuß (Bremen)	0.289	0.949	Germany	Medieval to pre-metric	General	Reported in Bremen 1891
fuss (Bohemia)	0.302	0.990	Austrian Empire	Pre-metric	Common	Reported in Bohemia 1891
fuß (Bohemia)	0.302	0.990	Austrian Empire	Pre-metric	Common	Reported in Bohemia 1891
fuß (Frankfort)	0.285	0.934	Germany	Medieval to pre-metric	General	Reported in Frankfort 1891
fuß (Hamburg)	0.286	0.939	Germany	Medieval to pre-metric	General	Reported in Hamburg 1891
fuß (Hanover)	0.292	0.958	Germany	Medieval to pre-metric	General	Reported in Hanover 1891
fuß (Hesse-Cassel)	0.288	0.944	Germany	Medieval to pre-metric	General	Reported in Hesse-Cassel 1891
fuß (Hesse-Darmstadt)	0.250	0.820	Germany	Medieval to pre-metric	General	Reported in Hesse-Darmstadt 1821

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
fuß (Lubeck)	0.288	0.945	Germany	Medieval to pre-metric	General	Reported in Lubeck 1891
fuß (Prussian system)	0.3139	1.030	Germany	Medieval to pre-metric	General	12 zoll, 2003 reference
fuss (Prussian system)	0.3139	1.030	Germany	Medieval to pre-metric	General	12 zoll, 2003 reference
fuß (Saxony)	0.283	0.929	Germany	Medieval to pre-metric	General	Reported in Saxony 1891
fuss (Wurtemberg)	0.286	0.939	Germany	Medieval to pre-metric	General	10 zoll, reported in 1891
fuß (Wurtemberg)	0.286	0.939	Germany	Medieval to pre-metric	General	10 zoll, reported in 1891
fut	0.3048	1.000	Russia	Medieval to pre-metric	General	Foot, 3/7 arshin, 12 duime, 2003 reference
fut	0.305	1.00	Tatar	Medieval to pre-metric	General	Foot, 12 duym
gasab	2.320	7.611	Egypt	Ancient to pre-metric	General	4 dirra, 1891 value, consistent with 2003 reference
gat	0.080	0.26	Ethiopia	Medieval to pre-metric	General	16/5 tat, 2003 reference
gavada (Mysore)	23,465	76,982	India	Medieval to pre-metric	General	Local unit?, 1891 reference
gavva			Sri Lanka	Medieval to pre-metric	Roads	Distance on roads

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
gavyuti	7312	23,989	India	Medieval to pre-metric	General	2 crosa, 1966 value
gaz	0.838	2.75	India	Medieval to pre-metric	General	2 hath
geografisk mil	7421	24,347	Norway	Medieval to pre-metric	General	1/15 equatorial degree, 4 min arc
geometric cubit	0.625	2.05	Byzantine Empire	Ancient	General	
geometric fathom	2.100	6.890	Byzantine Empire	Ancient	General	9 spithamai = 108 daktyloi, varied by land value
gesseylyeu	3.658	12.00	Wales	Medieval to pre-metric	General	Lateral yoke, 12 feet, 4 paces
gez	0.635	2.08	Arabia	Ancient to pre-metric	General	Old cubit (hashemic), in 1891 reference, reported as 0.640 m in 2003
gez	0.9144	3.000	Persia, Iran	Ancient to pre-metric	General	4 charak, 2003 reference
gez (Bengal)	0.914	3.00	India	Medieval to pre-metric	General	2 covids, also reported as 1.08 m in Patna, 1891 reference
ghalva	230.4	755.9	Arabia	Ancient to pre-metric	General	720 Ar ft, consistent with 2003 reference
ghalva	230.4	755.9	Persia, Iran	Ancient to pre-metric	General	9 chebel, 2003 reference
gheria (Bengal, Calcutta)	0.0571	0.187	India	Medieval to pre-metric	General	3 fingers, 1/8 covid, alternate units, 1891 reference

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
gi	3.000	9.842	Mesopotamia, Sumer, Akkadia	Ancient	General	reed, 6 cubits
girah	0.0520	0.171	India	Medieval to pre-metric	General	3 fingers
gireh	0.05715	0.1875	Persia, Iran	Ancient to pre-metric	General	2003 reference
gini3	1.000	3.281	Mesopotamia, Sumer, Akkadia	Ancient	General	step, 2 cubits
goess	0.635	2.08	Arabia	Ancient to pre-metric	General	Old cubit (hashemic), in 1891 reference, reported as 0.640 m in 2003
goess	1.160	3.806	Afghanistan	Pre-metric	General	
gon	127.6	418.6	Vietnam, Annam	Medieval to metric	General	2 mao, 2003 reference
gon	195	639	Annam	Pre-metric	Cloth	10 that
grade	1.524	5.000	United Kingdom	Medieval to pre-metric	General	2 paces
gradus (common)	0.736	2.41	Rome	Ancient to pre-metric	General	One step or simple pace, 2.5 pedes, consistent with 2003 reference
gradus pes sestertius	0.736	2.41	Rome	Ancient to pre-metric	General	One step or simple pace, 2.5 pedes, consistent with 2003 reference
grain	0.0070	0.023	Ireland	Medieval to pre-metric	General	Grain, 1/36 troighid

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
grano	0.00458	0.0150	Portugal	Medieval to pre-metric	General	2 linhas in 1891
grenzmül	25.099	82,345	Norway	Medieval to pre-metric	General	80000 fot in 1891
gronyn heyd	0.00847	0.0278	Wales	Medieval to pre-metric	General	Barleycorn, 1/3 inch
grote palm	0.0980	0.322	Netherlands, Holland	Medieval to metric	General	Large Palm, varied, avg
guerze	0.9144	3.000	Persia, Iran	Ancient to pre-metric	General	4 charak, 2003 reference
guerze (Ispahan)	0.949	3.11	Persia, Iran	Ancient to pre-metric	General	Reported in 1891
gueza (Ispahan)	0.949	3.11	Persia, Iran	Ancient to pre-metric	General	Reported in 1891
guiah (cloth)	0.0408	0.134	Turkey	Medieval to pre-metric	Cloth	1891 value
gujah (Madras)	0.945	3.10	India	Medieval to pre-metric	General	2 covids, 1891 reference
Gunter's chain	20.12	66.00	United Kingdom	Medieval to pre-metric	General	4 rods
gus (Bengal)	0.914	3.00	India	Medieval to pre-metric	General	2 covids, also reported as 1.08 m in Patna, 1891 reference
guz	0.635	2.08	Arabia	Ancient to pre-metric	General	Old cubit (hashemic), in 1891 reference, reported as 0.640 m in 2003
guz	6.35	20.8	Saudi Arabia	Pre-metric	General	1.32 covid, 2003 reference

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
guz (Bombay)	0.6858	2.250	India	Medieval to pre-metric	General	2 covid, 2003 reference
guz (Bombay)	0.690	2.26	India	Medieval to pre-metric	General	24 tussoos, 1891 reference
guz (Calcutta)	0.915	3.00	India	Medieval to pre-metric	General	Variation, buildup of other units same as Bombay, 2003 reference
guz (Guzerat)	0.593	1.94	India	Medieval to pre-metric	General	Local value, 1891 reference
gwialen	4.877	16.00	Wales	Medieval to pre-metric	General	Rod or long yoke, 16 feet
gwyalen	4.877	16.00	Wales	Medieval to pre-metric	General	Rod or long yoke, 16 feet
h3yt	5.250	17.22	Egypt	Ancient to pre-metric	General	
hailoh	0.914	3.00	Indonesia	Colonial to pre-metric	General	Sumatra, 2 etto
hailoh	0.914	3.00	Sumatra	pre-metric	General	2 etto, 1891 value
half-pous	0.157	0.516	Byzantine Empire	Ancient	General	1/2 foot
halibiu (common)	0.701	2.30	Romania	Pre-metric	General	1.06 endere, 2003 reference
hamma	18.51	60.73	Greece	Ancient to pre-metric	General	"Cord", 60 podes, consistent with 2003 reference
hand	0.1	0.3	Shoshone	Pre-colonial	General	Very rough estimate of typical value, like a palm width

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
hand	0.102	0.333	Miscellaneous	Medieval to modern	Horses	For horses, still in use
hand	0.1016	0.3333	United States	Colonial to modern	General	4 inches
hand	0.102	0.333	United Kingdom	Medieval to pre-metric	General	2 sticks or 1/3 foot
hand	0.8	2.6	Aztec	Colonial to pre-metric	Land	3/5 land rod, “monad” unit
handaze	0.680	2.23	Libya	Medieval or pre-metric	General	3 palmo, 2003 reference
handbreadth	0.102	0.333	United Kingdom	Medieval to pre-metric	General	2 sticks or 1/3 foot
hand’s breadth	0.0889	0.292	Jewish	Medieval to modern	General	3.5 inches
hao	0.000032	0.00010	China	Ancient to pre-metric	General	10 su
hào	0.0000425	0.000139	Vietnam, Annam	Medieval to metric	General	
haploun bēma	0.770	2.53	Greece	Ancient to pre-metric	General	2.5 podes
hardary (Mysore)	4,400	14,434	India	Medieval to pre-metric	General	Local unit?, 1891 reference
hasch	0.7112	2.333	Turkmenistan	Pre-metric	Linen	Linen goods, 1891 value, consistent with 2003 reference

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
hasit	0.176	0.577	Biblical, Talmudic	Ancient	General	Double palm, Talmudic
hasta	0.425	1.39	Indonesia	Colonial to pre-metric	General	1/4 depa, 2 kilan, 2003 reference
hasta	0.457	1.50	India	Medieval to pre-metric	General	2 vistati, "cubit", 1966 value
hasta	0.457	1.50	Malacca	Pre-metric	General	1891 value, also reported as 0.459
hasta	0.457	1.50	Singapore	Colonial to pre-metric	General	Cubit
hat	0.00263	0.00863	Ottoman Empire, Turkey	Ancient to medieval	General	Line, 12 Nokta
hath	0.419	1.37	India	Medieval to pre-metric	General	8 girah (like cubit)
hath (Ahmednuggur)	0.356	1.17	India	Medieval to pre-metric	General	Local value, 1891 reference
hath (Bombay)	0.460	1.51	India	Medieval to pre-metric	General	16 tussoos, 1891 reference
hath (Surat)	0.531	1.74	India	Medieval to pre-metric	General	Local value, 1891 reference
hatt (builders, surveyors)	0.00260	0.00854	Turkey	Medieval to pre-metric	Builder, Surveyor	12 nocktats, 1891 value
hatt (common)	0.002623	0.008605	Turkey	Medieval to pre-metric	General	12 nocktat, 2003 reference
haut (Ahmednuggur)	0.356	1.17	India	Medieval to pre-metric	General	Local value, 1891 reference

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
haut (Bengal, Calcutta)	0.457	1.50	India	Medieval to pre-metric	General	2 spans, 1891 reference
haut (Madras)	0.472	1.55	India	Medieval to pre-metric	General	2 spans, varied significantly by location, value shown is for Madras, 1891 reference
haut (Surat)	0.531	1.74	India	Medieval to pre-metric	General	Local value, 1891 reference
heart	0.6	1.8	Aztec	Colonial to pre-metric	Land	2/5 land rod, "monad" unit
heidden	0.00847	0.0278	Wales	Medieval to pre-metric	General	Barleycorn, 1/3 inch
hēmipodion	0.1543	0.5062	Greece	Ancient to pre-metric	General	Half foot, 8 dak., consistent with 2003 reference
hippikon	739.7	2,427	Greece	Ancient to pre-metric	General	4 stadia
hir iau	4.877	16.00	Wales	Medieval to pre-metric	General	Rod or long yoke, 16 feet
hiro	1.515	4.970	Japan	Ancient to pre-metric	General	2 yabiki, 2003 reference
hoé	0.00000032	0.0000010	China	Ancient to pre-metric	General	
Hollandse mijl	5000	16,404	Netherlands, Holland	Medieval to metric	General	Mile, Varied, an hour's walk
Hollandse myl	5000	16,404	Netherlands, Holland	Medieval to metric	General	Mile, Varied, an hour's walk

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
hoo kiyana dura			Sri Lanka	Medieval to pre-metric	General	No reference
horse length	2.400	7.874	Miscellaneous	Medieval to modern	Racing	In horse racing
hour of march	11,000	36,089	Egypt	Ancient to pre-metric	General	21,000 Royal cubits
ht	52.50	172.2	Egypt	Ancient to pre-metric	General	"Rod of cord", 100 cubits
ht n nhw	52.50	172.2	Egypt	Ancient to pre-metric	General	"Rod of cord", 100 cubits
hunab	1.048	3.437	Maya	Pre-colonial	General	Reported in literature
hyreyu	4.877	16.00	Wales	Medieval to pre-metric	General	Rod or long yoke, 16 feet
ꜥ	0.8	2.6	Aztec	Colonial to pre-metric	Land	3/5 land rod, "monad" unit
imperial cubit	0.625	2.05	Byzantine Empire	Ancient	General	
imperial fathom	2.100	6.890	Byzantine Empire	Ancient	General	9 spithamai = 108 daktyloi, varied by land value
inc	1.906	6.253	Japan	Ancient to pre-metric	General	1891 value
inch	0.02540	0.08333	United States	Colonial to modern	General	6 picas
inch	0.0254	0.0833	Wales	Medieval to pre-metric	General	Inch

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
inch	0.02540	0.08333	Ireland	Medieval to pre-metric	General	Pre-1824 value, 2003 reference
inch	0.025	0.0833	United Kingdom	Medieval to pre-metric	General	1/12 foot or 3 barleycorns, also 1/10 foot at times
inch	0.02554	0.08378	Scotland	Medieval to pre-metric	General	2003 reference
inch	0.0295	0.0967	Jewish	Medieval to modern	General	1.16 inches
inch (clothes)	0.02540	0.08333	United Kingdom	Medieval to pre-metric	Clothing	
innrit	3.000	9.842	Ireland	Medieval to pre-metric	General	Uncertain value, possibly equal to 1 fertach
Irish mile	2048	6718	Ireland	Medieval to pre-metric	General	1-3/11 English mile, 8 furlongs, pre-1824 value, 2003 reference
iteru	10,500	34,448	Egypt	Ancient to pre-metric	General	“River measure”, 20,000 cubits
itinerary derah	0.739	2.42	Egypt	Ancient to pre-metric	Roads	“Road measure pic”, also reported as 0.7889 m in 1891
itinerary pic	0.739	2.42	Egypt	Ancient to pre-metric	Roads	“Road measure pic”, also reported as 0.7889 m in 1891
itrw	11,000	36,089	Egypt	Ancient to pre-metric	General	21,000 Royal cubits
jacktan	3.658	12.00	Guinea	Medieval to pre-metric	General	6.329 pic, 2003 reference

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
jalka	0.297	0.974	Finland	Medieval to pre-metric	General	Foot
jankal	0.229	0.750	Indonesia	Colonial to pre-metric	General	Sumatra, 1/2 etto
jankal	0.229	0.750	Sumatra	Pre-metric	General	1891 value
jaob (Bengal, Calcutta)	0.0508	0.167	India	Medieval to pre-metric	General	1/9 covid, alternate units, 1891 reference
jaob (Bombay)	0.004763	0.01562	India	Medieval to pre-metric	General	2003 reference
jarda Ionia	0.914	3.00	Ionian Islands	Pre-metric	General	1 yard, 1891 value
jeme (typical)	0.1393	0.4571	Spain	Medieval to pre-metric	General	6 pulgada, pre-1860, 2003 reference
Jewish mile	2134	7000	Jewish	Medieval to modern	General	84000 inches
jō	3.030	9.941	Japan	Ancient to pre-metric	General	10 shaku, 2003 reference
jō	3.030	9.941	Japan	Ancient to pre-metric	General	10 shaku, 2003 reference
jow (Bengal, Calcutta)	0.00635	0.0208	India	Medieval to pre-metric	General	Barleycorns, 1891 reference
jow (Bombay)	0.004763	0.01562	India	Medieval to pre-metric	General	2003 reference
jumba	0.366	1.20	Malacca	Pre-metric	General	1891 value
kaapelimitta	185.2	607.6	Finland	Medieval to pre-metric	General	1/10 Naut mile

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
kabellengde	185.2	607.6	Norway	Medieval to pre-metric	General	Cable- length, Naut, 100 favner
kabiet	0.00521	0.0171	Thailand	Medieval to metric	General	2 anukabiet, 2003 reference
kadam	0.290	0.951	Egypt	Ancient to pre-metric	General	1/2 dirra, 3 abdat, 1891 value, consistent with 2003 reference
kadem	0.379	1.24	Ottoman Empire, Turkey	Ancient to medieval	General	Foot, 12 parmak
kalamos	3.080	10.10	Greece	Ancient to pre-metric	General	10 podes
kan	1.818	5.965	Korea, Korea	Medieval or pre-metric	General	6 cha
kan	3.771	12.37	India	Medieval to pre-metric	General	3 karams
kassaba	3.84	12.6	Arabia	Ancient to pre-metric	General	12 Ar ft, also reported as 3.75 m in 1891, 2003 reference value
kassabah	3.480	11.42	Egypt	Ancient to pre-metric	General	6 dirra, 2003 reference, also reported as 3,550 m in 1891
kathi	2.440	8.005	India	Medieval to pre-metric	General	5-5/6 hath
ken	0.961	3.15	Siam, Thailand	Pre-metric	General	2 soks, 1891 value
ken	1.00	3.28	Thailand	Medieval to metric	General	2 sawk, 2003 reference
ken	1.818	5.964	Japan	Ancient to pre-metric	General	6 shaku, distance between support poles in homes or length of tatami mat, 2003 reference

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
kend	0.490	1.61	Ethiopia	Medieval to pre-metric	General	49/16 sinzer, 2003 reference
kérat	0.0242	0.0793	Egypt	Ancient to pre-metric	General	1/24 dirra, 1891 value, consistent with 2003 reference, pre-metric
kerrab	0.0425	0.139	Ottoman Empire, Turkey	Ancient to medieval	General	
keup	0.250	0.820	Thailand	Medieval to metric	General	Span, 12 niou, variable, 2003 reference
khalebi (wool)	0.671	2.20	Romania	Pre-metric	General	1891 value
khet	52.50	172.2	Egypt	Ancient to pre-metric	General	"Rod of cord", 100 cubits
khuep	0.250	0.820	Thailand	Medieval to metric	General	Span, 12 niou, variable, 2003 reference
kilan	0.2125	0.6972	Indonesia	Colonial to pre-metric	General	1/8 depa, 2003 reference
kirab	0.0425	0.139	Ottoman Empire, Turkey	Ancient to medieval	General	
kirat	0.0242	0.0793	Egypt	Ancient to pre-metric	General	1/24 dirra, 1891 value, consistent with 2003 reference, pre-metric
kivenheitto	59.38	194.8	Finland	Medieval to pre-metric	General	"Throw of a rock", used to describe something near
klaffer	1.800	5.905	Germany	Medieval to pre-metric	General	Fathom, 6 ft before metric, varied 1.75 to 3 m
klaffer	1.896	6.222	Austrian Empire	Pre-metric	Common	6 fuss, 2003 reference

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
klafter (Wurtemberg)	1.717	5.633	Germany	Medieval to pre-metric	General	6 fuss, reported in 1891
kleine palm	0.0300	0.0984	Netherlands, Holland	Medieval to metric	General	small palm
kole (Travancore)	0.738	2.42	India	Medieval to pre-metric	General	Local unit?, 1891 reference
kondylos	0.03857	0.1265	Greece	Ancient to pre-metric	General	2 daktyloi, consistent with 2003 reference
kot (silk, linen)	0.631	2.07	Romania	Pre-metric	General	1891 value
krabiat	0.00521	0.0171	Thailand	Medieval to metric	General	2 anukabiet, 2003 reference
krok (or piędź?)	2.233	7.327	Poland	Medieval to pre-metric	General	Step, 3.75 ell, agrarian
kswacsh dva	0.642	2.11	Persia, Iran	Ancient to pre-metric	General	Great cubit, 6 Hands, 6 dva
kulaç	1.829	6.000	Ottoman Empire, Turkey	Ancient to medieval	General	Fathom
kuš3	0.497	1.63	Mesopotamia, Sumer, Akkadia	Ancient	General	cubit
kuunar	0.5334	1.750	Estonia	Medieval to pre-metric	General	2003 reference
kvarter	0.1484	0.4870	Sweden	Medieval to pre-metric	General	Quarter, 6 tum, 2003 reference

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
kvarter	0.157	0.515	Norway	Medieval to pre-metric	General	Quarter, 1/4 Alen
kvarter	0.157	0.515	Denmark	Medieval to pre-metric	General	Quarter, 1/4 alen
kvat	1.90	6.22	Yugoslavia	Pre-metric	General	6 stopa, 2003 reference
kyndemil	16,000	52,493	Sweden	Medieval to pre-metric	General	Distance torch will last
kyo	96.0	315	China	Ancient to pre-metric	General	3 yin, 1966 value
kyynärä	0.594	1.95	Finland	Medieval to pre-metric	General	2 ft. Cubit, everyday measure
lachter	2.000	6.562	Germany	Medieval to pre-metric	General	Mining, varied 1.9 to 2.1 m
lait	6.000	19.68	Ireland	Medieval to pre-metric	General	Unknown, perhaps 2 fertach
lan	2.235	7.333	Burma, Rangoon, Myanmar	Pre-metric	General	4 sandong, 2003 reference
land	1609	5280	United States	Colonial to modern	General	8 furlongs
land fuß (Hesse-Cassel)	0.285	0.935	Germany	Medieval to pre-metric	General	Reported in Hesse-Cassel 1891
land rod	1.4	4.6	Aztec	Colonial to pre-metric	Land	Basic unit

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
landmil	11,295	37,057	Norway	Medieval to pre-metric	General	Norwegian mile, 17600 to 18000 alen, per 1862 defn, 36000 fot in 1891
lanmil	10,686	35,059	Sweden	Medieval to pre-metric	General	Mile, 18000 aln, distance between inns, 2003 reference
large span	0.267	0.875	Jewish	Medieval to modern	General	10.5 inches
lås	28.20	92.52	Norway	Medieval to pre-metric	General	15 favner
laska	8.933	29.31	Poland	Medieval to pre-metric	General	Stick, 2 rods, agrarian
latro	1.917	6.289	Czechoslovakia	Pre-metric	General	
latro	1.917	6.289	Latvia	Medieval or pre-metric	General	
latro	1.917	6.289	Slovakia	Medieval to pre-metric	General	Pre-1876
latro (Bohemian)	1.909	6.264	Czechoslovakia	Pre-metric	General	6.45 stopa, 2003 reference
league	5548	18,202	Greece	Ancient to pre-metric	General	30 stadia, Persian origin
league	5560	18,240	United Kingdom	Medieval to pre-metric	General	3 Nautic miles or 3 Statute miles, used nautic mile
league (nautical)	5560	18,240	United States	Colonial to modern	Nautical	3 nautical miles
league (survey)	4828	15,840	United States	Colonial to modern	Surveyor	3 miles

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
legoa	6173	20,252	Portugal	Medieval to pre-metric	General	League of 18 degrees, consistent with value reported in 1891, = 3 milha
legoa	6202	20,348	Portugal	Medieval to pre-metric	General	League, 2 millha, 2003 reference
legoa	6600	21,653	Brazil	Colonial to pre-metric	General	League, 20000 pés, also reported as 6667 m in 2003 reference
legoa (nautical)	5555	18,225	Portugal	Medieval to pre-metric	General	League of 20 degrees, 3 milhas geo., consistent with value reported in 2003 reference
legua	0.0677	0.222	Cuba	Colonial to pre-metric	General	2-2/3 in, questionable value
legua	4190	13,747	Mexico	Colonial to pre-metric	General	League, 3 milla, 2003 reference
legua	4514	14,811	Chile	Colonial to pre-metric	General	League, 5400 vara, 2003 reference
legua	5024	16,483	Venezuela	Colonial to pre-metric	General	Mile or league, 6280 vara, 2003 reference
legua	5200	17,059	Argentina	Colonial to pre-metric	General	League, 6000 vara, 40 cuadra, 2003 reference
legua	5250	17,224	Colombia	Colonial to pre-metric	General	League, 6250 vara, also reported as 5000 m in 2003 reference
légua	6600	21,653	Brazil	Colonial to pre-metric	General	League, 20000 pés, also reported as 6667 m in 2003 reference
legua (common)	2208	7,244	Rome	Ancient to pre-metric	General	Gallic league, 7500 pedes, consistent with 2003 reference

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
legua (new)	4330	14,206	Paraguay	Colonial to pre-metric	General	League, 5000 vara (new), 2003 reference
legua (old)	4193	13,756	Paraguay	Colonial to pre-metric	General	League, 5000 vara (old), 2003 reference
legua (railroad)	520	1706	Argentina	Colonial to pre-metric	Railroad	Railroad distance only, 600 vara
legua (typical)	4180	13,712	Spain	Medieval to pre-metric	General	League, 3 milla, pre-1860, 2003 reference, also reported as 8000 varas or 6782 m in 1891
légua de 18 ao grau	6173	20,252	Portugal	Medieval to pre-metric	General	League of 18 degrees, consistent with value reported in 1891, =3 milha
légua de 20 ao grau	5555	18,225	Portugal	Medieval to pre-metric	General	League of 20 degrees, 3 milhas geo., consistent with value reported in 2003 reference
legua royal (typical)	6687	21,939	Spain	Medieval to pre-metric	General	Royal league, 24000 pie, pre-1860, 2003 reference
lesser pie	0.483	1.59	Tripoli, Libya	Medieval to pre-metric	General	1891 value
leuga	2208	7244	Rome	Ancient to pre-metric	General	Gallie league, 7500 pedes, consistent with 2003 reference
li	0.000425	0.00139	Vietnam, Annam	Medieval to metric	General	10 hào, 2003 reference
li	393.0	1289	Korea, Korea	Medieval or pre-metric	General	
li	576.0	1890	China	Ancient to pre-metric	General	6 kyo, reported in 1966

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
lǐ	0.00032	0.0010	China	Ancient to pre-metric	General	10 hao
lǐ	452.5	1485	China	Ancient to pre-metric	General	Chinese mile, 300–360 bu, varied, usually about 1/3 English mile
lǐ (itinerary)	556.4	1825	China	Ancient to pre-metric	General	Value in 1891
lichas	0.193	0.632	Greece	Ancient to pre-metric	General	10 dak
lieu marine	5555	18,225	Netherlands, Holland	Medieval to metric	Nautical	French unit
lieue	4800	15,748	Switzerland	Medieval to pre-metric	General	Road measure, 16,000 pied, 1000 perch, 2003 reference
lieue (de Paris)	4443	14,577	France	Medieval to pre-metric	General	“League”, 2003 reference, 1737-1794
lieue (Gauloise)	2222	7,290	France	Medieval to pre-metric	General	
lieue (metric)	4000	13,122	France	1812–1846	General	3 mille (metric), 2003 reference
lieue (new)	4330	14,206	Paraguay	Colonial to pre-metric	General	League, 5000 vara (new), 2003 reference
lieue (old)	4193	13,756	Paraguay	Colonial to pre-metric	General	League, 5000 vara (old), 2003 reference
lieue ancienne	3247	10,653	France	Medieval to pre-metric	General	league, old French - 10,000 feet, used until 1674
lieue de 25 au degré	4448	14,593	France	Medieval to pre-metric	General	2282 toises, represents 1/25 of an equatorial degree

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
lieue de Paris	3898	12,789	France	Medieval to pre-metric	Roads	Paris league, defined as 2000 toises, 1674-1737, AKA league of bridges and roads (des Ponts et des Chaussées)
lieue des Postes	4288	14,068	France	Medieval to pre-metric	General	2200 toises, created in 1737
lieue marine (nautical)	5846	19,180	France	Medieval to pre-metric	Nautical	"Nautical League", 3 mille marin, 2003 reference
lieue tarifaire	4678	15,348	France	Medieval to pre-metric	General	2400 toises, created 1737
ligne	0.002256	0.007401	France	Medieval to pre-metric	General	Line
ligne (metric)	0.002315	0.007594	France	1812-1841	General	
ligne (new)	0.002005	0.006577	Paraguay	Colonial to pre-metric	General	1/432 vara (new), 2003 reference
ligne (new)	0.00208	0.00684	Switzerland	Medieval to pre-metric	General	Line, 1/144 pied, 2003 reference
ligne (old)	0.001941	0.006368	Paraguay	Colonial to pre-metric	General	1/432 vara (old), 2003 reference
ligne (old)	0.00300	0.00984	Switzerland	Medieval to pre-metric	General	Line, 1/10 pounce, 1891 value
lina	0.002180	0.007152	Iceland	Medieval to pre-metric	General	
line	0.0006350	0.002083	United States	Colonial to modern	General	1/40 inch
line	0.00212	0.00694	United Kingdom	Medieval to pre-metric	General	1/12 inch or 1/4 barleycorn

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
line	0.002540	0.008333	Russia	Medieval to Pre-Metric	General	Line, 1/280 arshin, 10 tochka, 2003 reference
linea	0.00194	0.00635	Spain	Medieval to pre-metric	General	Line, 1/144 pie, 12 puntos, alternate reference
linea	0.00194	0.00635	Chile	Colonial to pre-metric	General	Line, 1/432 vara, 2003 reference
linea	0.00194	0.00636	Mexico	Colonial to pre-metric	General	1/432 vara, 2003 reference
linea	0.002006	0.006581	Argentina	Colonial to pre-metric	General	1/432 vara, 2003 reference
linéa	0.002006	0.006581	Argentina	Colonial to pre-metric	General	1/432 vara, 2003 reference
linea (new)	0.002005	0.006577	Paraguay	Colonial to pre-metric	General	1/432 vara (new), 2003 reference
linea (old)	0.001941	0.006368	Paraguay	Colonial to pre-metric	General	1/432 vara (old), 2003 reference
linea (typical)	0.001451	0.004761	Spain	Medieval to pre-metric	General	Line, 12 punto, pre-1860, 2003 reference
linha	0.00229	0.00751	Portugal	Medieval to pre-metric	General	Line, 1/480 varos, 12 pontos, reported as 0.002281 m in 2003 reference
linia	0.00218	0.00715	Yugoslavia	Pre-metric	General	2003 reference
linie	0.00218	0.00715	Prussia	Pre-metric	General	12 scrupel, 1891 value
linie	0.002180	0.007152	Denmark	Medieval to pre-metric	General	Line, 1/12 tomme, 2003 reference

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
linie	0.002195	0.007201	Austrian Empire	Pre-metric	Common	12 punkt, 2003 reference
linie	0.002540	0.008333	Russia	Medieval to pre-metric	General	Line, 1/280 arshin, 10 tochka, 2003 reference
linie (Lubeck)	0.00400	0.0131	Germany	Medieval to pre-metric	General	1/6 zoll, 1891
linie (new)	0.00208	0.00684	Switzerland	Medieval to pre-metric	General	Line, 1/144 pied, 2003 reference
linie (old)	0.00300	0.00984	Switzerland	Medieval to pre-metric	General	Line, 1/10 pounce, 1891 value
linie (Prussian system)	0.002180	0.007151	Germany	Medieval to pre-metric	General	2003 reference
linie (typical average)	0.00205	0.00672	Germany	Medieval to pre-metric	General	1/6 to 1/12 inch, usually 1/12 inch
linie (Wurtemberg)	0.00286	0.00939	Germany	Medieval to pre-metric	General	10 punkte, reported in 1891
liniya	0.002540	0.008333	Russia	Medieval to pre-metric	General	Line, 1/280 arshin, 10 tochka, 2003 reference
linja	0.002000	0.006562	Poland	Medieval to pre-metric	General	2003 reference
linja	0.00206	0.00676	Finland	Medieval to pre-metric	General	1/144 ft, width of a barleycorn
linje	0.00218	0.00715	Norway	Medieval to pre-metric	General	Line, 1/12 tomme

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
linje (after 1855)	0.00297	0.00974	Sweden	Medieval to pre-metric	General	Line, 1/10 tum after 1855
linje (pre-1855)	0.002062	0.006765	Sweden	Medieval to pre-metric	General	Line, 1/12 tum, consistent with 2003 reference
link	0.201	0.660	Mesopotamia, Sumer, Akkadia	Ancient	General	7.92"
link	0.201	0.660	United Kingdom	Medieval to pre-metric	General	1/25 rod or 7.92 inches or 1/100 chain
link	2.560	8.400	Ireland	Medieval to pre-metric	General	8.4 feet, pre-1824 value, 2003 reference
link (survey)	0.2012	0.6601	United States	Colonial to modern	Surveyor	33/50 ft
Lithuanian meile	8040	26,377	Russia	Medieval to pre-metric	General	1891 value
loket (Bohemian)	0.592	1.94	Czechoslovakia	Pre-metric	General	2 stopa, 2003 reference
lokice	0.1440	0.4724	Poland	Medieval to pre-metric	General	6 cal, 2003 reference
łokice	0.596	1.95	Poland	Medieval to pre-metric	General	Ell or cubit, see alternate value
long cubit	0.6171	2.025	Greece	Ancient to pre-metric	General	2 pous, 2003 reference
long cubit	0.6980	2.290	Egypt	Ancient to pre-metric	General	2 zereth, 2003 reference

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
ly	0.000425	0.00139	Vietnam, Annam	Medieval to metric	General	10 hào, 2003 reference
ly	0.000487	0.00160	Annam	Pre-metric	Buildings	
ly	0.000650	0.00213	Annam	Pre-metric	Cloth	
ly	442	1,452	Annam	Pre-metric	Roads	
lyne	0.001966	0.006450	Netherlands, Holland	Medieval to metric	General	2003 reference
magh-space			Ireland	Medieval to pre-metric	General	Unknown, similar to mile, based on how far a cock's crow or a bell can be heard
mansion	25,600	83,988	Persia, Iran	Ancient to pre-metric	General	4 parasang, 2003 reference
mao	63.80	209.3	Vietnam, Annam	Medieval to metric	General	5 that, 2003 reference
marca	2.403	7.882	Spain	Medieval to pre-metric	General	
marhala	38,640	126,770	Saudi Arabia	Pre-metric	General	2 baryd, 2003 reference
marhala	46,080	151,179	Arabia	Ancient to pre-metric	General	8 paras, village-length, consistent with 2003 reference
marok	0.1054	0.3457	Hungary	Medieval to pre-metric	General	2003 reference
mau	73.1	240	Annam	Pre-metric	Buildings	10 sao
mecate	19.51	64.00	Honduras	Colonial to pre-metric	General	24 vara, 2003 reference
mecate	19.9	65.4	El Salvador	Colonial to pre-metric	General	24 vara, 2003 reference

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
mecate	19.9	65.4	Nicaragua	Colonial to pre-metric	General	24 vara, 2003 reference
mecate	20.0	65.7	Central America	Colonial to pre-metric	General	24 vara, 2003 & 1891 references
mecate	20.06	65.82	Guatemala	Colonial to pre-metric	General	24 vara, 2003 reference
mecate	20.14	66.09	Costa Rica	Colonial to pre-metric	General	24 vara, 2003 reference
meh nedjes	0.450	1.48	Egypt	Ancient to pre-metric	General	Short (Greek) or ordinary cubit, 6 palms = 24 fingers, also called natural cubit in 1891
meh niswt	0.525	1.72	Egypt	Ancient to pre-metric	General	"Royal cubit", 7 palms - 28 fingers
meile	5024	16,483	Venezuela	Colonial to pre-metric	General	Mile or league, 6280 vara, 2003 reference
meile	7468	24,501	Latvia	Medieval or pre-metric	General	Mile, 7 verste (Russian), 2003 reference
meile	7586	24,888	Austrian Empire	Pre-metric	Common	2000 ruthe, 2003 reference
meile	8354	27,406	Hungary	Medieval to pre-metric	General	2003 reference
meile (Anspach)	8633	28,322	Germany	Medieval to pre-metric	General	Reported in Bavaria 1891
meile (Average, typical)	7500	24,606	Germany	Medieval to pre-metric	General	Varied from 1000 to over 11000 m locally, 1/15 equatorial deg

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
meile (Baden)	8887	29,157	Germany	Medieval to pre-metric	General	Reported in Baden 1891
meile (Bavaria)	7424	24,358	Germany	Medieval to pre-metric	General	Reported in Bavaria 1891
meile (Braunschweig or Brunswick)	10,802	35,440	Germany	Medieval to pre-metric	General	Reported in Brunswick 1891, 34,424 Rheinisch feet
meile (Bremen)	6280	20,603	Germany	Medieval to pre-metric	General	Reported in Bremen 1891
meile (Hamburg)	7530	24,705	Germany	Medieval to pre-metric	General	Reported in Hamburg 1891, 24,000 Rheinisch fuß
meile (Hanover)	7415	24,328	Germany	Medieval to pre-metric	General	Reported in Hanover 1891, 25,400 fuß
meile (Prussian system)	7533	24,713	Germany	Medieval to pre-metric	General	2000 ruthe, 2003 reference
menzil	227.0	744.7	Ottoman Empire, Turkey	Ancient to medieval	General	Range, 600 ayak
mercier's palmo	0.212	0.696	Italy	Medieval to pre-metric	Cloth	Roman, fabric
mercier's palmo	0.212	0.696	Rome	Ancient to pre-metric	Cloth	1891 value
merthale	45,480	149,211	Ottoman Empire, Turkey	Ancient to medieval	General	Stage or phase, 200 berid
meripeninkulma	1852	6076	Finland	Medieval to pre-metric	Nautical	Maritime distance, Naut mil, 1 angular minute at equator

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
merisekunti	30.87	101.3	Finland	Medieval to pre-metric	Nautical	1/60 Naut Mile
meritertia	0.514	1.69	Finland	Medieval to pre-metric	Nautical	1/3600 Naut mile
mertföld	8354	27,406	Hungary	Medieval to pre-metric	General	2003 reference
metric foot	0.300	0.984	Miscellaneous	Medieval to modern	General	Not used much
mh	0.450	1.48	Egypt	Ancient to pre-metric	General	Short (Greek) or ordinary cubit, 6 palms = 24 fingers, also called natural cubit in 1891
mh	0.525	1.72	Egypt	Ancient to pre-metric	General	“Royal cubit”, 7 palms—28 fingers
miglio (Naples)	1846	6056	Italy	Medieval to pre-metric	General	Mile, 7000 palmi
miglio (Tuscany)	1654	5425	Italy	Medieval to pre-metric	General	2833-1/3 braccia, reported in 1891
miglio (typical)	2226	7304	Italy	Medieval to pre-metric	General	Mile, 4333.33 piede liprando, 7000 palmi, consistent with reported value in Sardinia in 1891 and 2003 reference for pre-1861 value
miglio (Venice)	1000	3280	Italy	Medieval to pre-metric	General	Reported in 1891
mil	7533	24,714	Denmark	Medieval to pre-metric	General	Mile, reported in 1891, consistent with value reported in 2003 reference
miil (alt)	11,130	36,515	Denmark	Medieval to pre-metric	General	Danish mile, 12,000-17,600 alen, see alternate values

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
mil	0.00002540	0.00008333	United States	Colonial to modern	General	1/1000 inch
mil	1056	3465	Biblical, Talmudic	Ancient	General	Mile, 2000 ells, avg
mil	7467	24,498	Tatar	Medieval to pre-metric	General	Mile, geographic, 7 қағым
mil	7533	24,714	Denmark	Medieval to pre-metric	General	Mile, reported in 1891, consistent with value reported in 2003 reference
mil	10,686	35,059	Sweden	Medieval to pre-metric	General	Mile, 18000 aln, distance between inns, 2003 reference
mil	11,295	37,057	Norway	Medieval to pre-metric	General	Norwegian mile, 17600 to 18000 alen, per 1862 defn, 36000 fot in 1891
mil (alt)	11,130	36,515	Denmark	Medieval to pre-metric	General	Danish mile, 12,000–17,600 alen, see alternate values
mil hachmi	580.0	1903	Egypt	Ancient to pre-metric	General	1000 dirra, 1891 value, consistent with 2003 reference
mila a landi	7534	24,716	Iceland	Medieval to pre-metric	General	Mile on land, 4000 faðmur, 2003 reference
mile	1389	4555	Greece	Ancient to pre-metric	General	45 plethron, 2003 value
mile	1574	5164	Byzantine Empire	Ancient	General	Milion, Roman mile
mile	1609	5280	United States	Colonial to modern	General	5280 ft, 80 chains

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
mile	1728	5669	Persia, Iran	Ancient to pre-metric	General	2003 reference
mile (Bohemian)	6988	22,925	Czechoslovakia	Pre-metric	General	3660 latro, 2003 reference
mile (nautical)	1853	6080	United States	Colonial to modern	Nautical	8,439 cables, 1,151 miles
milha	2057	6749	Portugal	Medieval to pre-metric	General	Mile, reported in 1891, 8 estadios, reported as 2067 m in 2003 reference
milha (nautical)	1851	6073	Portugal	Medieval to pre-metric	General	Geographic mile, 1/3 League, reported as 1852 m in 2003 reference
milha geográfica	1851	6073	Portugal	Medieval to pre-metric	General	Geographic mile, 1/3 League, reported as 1852 m in 2003 reference
mili	1847	6060	Egypt	Ancient to pre-metric	General	500 cassabas
milja	7468	24,500	Russia	Medieval to pre-metric	General	Mile, 10500 arshin
milion	1479	4852	Greece	Ancient to pre-metric	General	8 stadia, Roman mile
milla	1397	4582	Mexico	Colonial to pre-metric	General	Mile, 5000 pie, 2003 reference
milla (railroad)	1850	6069	Argentina	Colonial to pre-metric	Railroad	Railroad measure
milla (typical)	1393	4571	Spain	Medieval to pre-metric	General	Mile, 1000 passo, 5000 pies, pre-1860, 2003 reference
mille	1728	5,669	Persia, Iran	Ancient to pre-metric	General	2003 reference

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
mille	1745	5725	Egypt	Ancient to pre-metric	General	"Mile", 2500 long cubits, 2003 reference
mille (metric)	1333	4374	France	1812–1845	General	4000 pied (metric), 2003 reference
mille marin (nautical)	1949	6394	France	Medieval to pre-metric	General	"Nautical Mile", 20 encablure, 2003 reference
mille passus	1480	4856	Rome	Ancient to pre-metric	General	Roman mile, 5000 pedes
mille passuum	1480	4856	Rome	Ancient to pre-metric	General	Roman mile, 5000 pedes
milliarum (common)	1472	4829	Rome	Ancient to pre-metric	General	"Mile", consistent with 2003 reference
milltir	8230	27,000	Wales	Medieval to pre-metric	General	Mile, 1000 lands
minute of march	183.8	602.8	Egypt	Ancient to pre-metric	General	
minuti	0.00856	0.0281	Italy	Medieval to pre-metric	General	1/5 oncia
minuti (Naples)	0.00439	0.0144	Italy	Medieval to pre-metric	General	1/5 oncia. Reported in 1891
mō	0.0000303	0.0000994	Japan	Ancient to pre-metric	General	10 shi, 2003 reference
mō	0.0000303	0.0000994	Japan	Ancient to pre-metric	General	10 shi, 2003 reference
modfedd	0.0762	0.250	Wales	Medieval to pre-metric	General	Palm, 3 inches

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
moduet	0.0762	0.250	Wales	Medieval to pre-metric	General	Palm, 3 inches
moons			Shoshone	Pre-colonial	Distance	Similar to use of suns, indeterminate.
moot (Bengal, Calcutta)	0.0762	0.250	India	Medieval to pre-metric	General	Hand, 4 unglees, 1891 reference
moot (Bombay)	0.05715	0.1875	India	Medieval to pre-metric	General	Hand, 2 tassooos, 2003 reference
mot thuoc	1	3	Cambodia	Post-metric	General	2003 reference
möl	11,295	37,057	Norway	Medieval to pre-metric	General	Norwegian mile, 17600 to 18000 alen, per 1862 defn, 36000 fot in 1891
muoi	1	3	Cambodia	Post-Metric	General	2003 reference
myl	1000	3281	Netherlands, Holland	Medieval to metric	General	3533 voeten, 2003 reference, post-metric?
mylltyr	8230	27,000	Wales	Medieval to pre-metric	General	Mile, 1000 lands
naid	8,230	27.00	Wales	Medieval to pre-metric	General	Land, 3 leaps
nail (cloth measure)	0.0572	0.187	United Kingdom	Medieval to pre-metric	General	3 digits or 2.5 inches or 1/16 yard, also reported as 2.25 inches in 1891
nail (clothes)	0.05715	0.1875	United Kingdom	Medieval to pre-metric	Clothing	2-1/4 inches
nautic mile	1853	6080	United Kingdom	Medieval to pre-metric	General	6080 feet
neyt	8,230	27.00	Wales	Medieval to pre-metric	General	Land, 3 leaps

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
ngu	2.44	7.99	Annam	Pre-metric	Buildings	5 thuc
ngũ	2.125	6.972	Vietnam, Annam	Medieval to metric	General	5 thước, 2003 reference
nibw	0.600	1.97	Egypt	Ancient to pre-metric	General	Pole, 6 hands, 8 palms, 32 fingers
Nile derah	0.255	0.835	Egypt	Ancient to pre-metric	General	"Nile pic"
Nile dirra	0.255	0.835	Egypt	Ancient to pre-metric	General	"Nile pic"
nindan	6.000	19.68	Mesopotamia, Sumer, Akkadia	Ancient	General	rod, 12 cubits, also reported as 16.5 ft or ~5 meters as a "pole"
nindanu	6.000	19.68	Mesopotamia, Sumer, Akkadia	Ancient	General	rod, 12 cubits, also reported as 16.5 ft or ~5 meters as a "pole"
nio	0.0208	0.0684	Thailand	Medieval to metric	General	Inch, 4 kabiet, varied, 2003 reference
niou	0.0208	0.0684	Thailand	Medieval to metric	General	Inch, 4 kabiet, varied, 2003 reference
niranga (Bombay)	6.858	22.50	India	Medieval to pre-metric	General	5 danda, 2003 reference
nocttat (builders, surveyors)	0.000217	0.000712	Turkey	Medieval to pre-metric	Builder, Surveyor	1891 value
nocttat (common)	0.0002186	0.0007171	Turkey	Medieval to pre-metric	General	2003 reference

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
nokta	0.000219	0.000718	Ottoman Empire, Turkey	Ancient to medieval	General	Dot
nul (common)	1007	3304	Turkey	Medieval to pre-metric	General	1333.3 pics, 2003 reference
nus	0.312	1.02	Algeria	Medieval to pre-metric	General	1/2 pic, 2 rebia, using dzera a torky basis, 2003 reference
nymil	10,000	32,808	Sweden	Medieval to pre-metric	General	New mile after 1889
oblique sazhen	2.480	8.136	Russia	Medieval to pre-metric	General	Tip of raised arm to opp. Leg slightly bent
ohra	0.571	1.87	Zanzibar	Pre-metric	General	1891 value
ohra	0.571	1.87	Tanzania	Pre-metric	General	
oke thapal	78.23	256.7	Burma, Rangoon, Myanmar	Pre-metric	General	20 dha, 2003 reference
oncia (Naples)	0.0220	0.0721	Italy	Medieval to pre-metric	General	1/12 palmo, reported in 1891
oncia (typical)	0.04281	0.1405	Italy	Medieval to pre-metric	General	Inch, 1/12 piede liprando, 12 punto, pre-1861, 2003 reference
oncia (Venice)	0.0580	0.190	Italy	Medieval to pre-metric	General	12 punti, reported in 1891
oncie (Parma)	0.0452	0.148	Italy	Medieval to pre-metric	General	1/12 braccio di legno, reported in 1891
ordlach	0.0210	0.0689	Ireland	Medieval to pre-metric	General	Thumb length, 1/12 troighid

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
orguia	1.851	6.073	Greece	Ancient to pre-metric	General	6 podes, 3 long cubits, consistent with 2003 reference
orgye	1.92	6.30	Arabia	Ancient to pre-metric	General	"Pace", 6 Ar ft, consistent with 2003 reference
orgye	2.094	6.870	Egypt	Ancient pre-metric	General	"Fathom", 3 long cubits, 2003 reference
orgyia	1.851	6.073	Greece	Ancient to pre-metric	General	6 podes, 3 long cubits, consistent with 2003 reference
orgyia	2.134	7.000	Jewish	Medieval to modern	General	84 inches
orgyla	1.83	6.00	India	Medieval to pre-metric	General	4 hasta, 1966 value
orthodōron	0.212	0.695	Greece	Ancient to pre-metric	General	11 dak
ouroub (cloth)	0.0816	0.268	Turkey	Medieval to pre-metric	Cloth	2 guirahs, 1891 value
outstretched arm	0.8	2.6	Shoshone	Pre-colonial	General	Very rough estimate of typical value
pace	0.762	2.50	United Kingdom	Medieval to pre-metric	General	5 shaftments
pace	0.787	2.58	Byzantine Empire	Ancient	General	Single step
pace	0.9144	3.000	Cyprus	Colonial to pre-metric	General	2003 reference
pace	1.524	5.000	Ireland	Medieval to pre-metric	General	5 feet, pre-1824 value, 2003 reference

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
pace	1.920	6.299	Persia, Iran	Ancient to pre-metric	General	Reported 2003
paces	1.0	3.3	Shoshone	Pre-colonial	General	Very rough estimate of typical value
päivämätka	20,000	65,616	Finland	Medieval to pre-metric	General	One day's travel
pal' ets	0.01270	0.04167	Russia	Medieval to pre-metric	General	5 line, 2003 reference
palaistiē	0.07714	0.2531	Greece	Ancient to pre-metric	General	"Palm", 4 dak, consistent with 2003 reference
palaz	0.0363	0.119	Yugoslavia	Pre-metric	General	16-2/3 linia, 2003 reference
palestra	0.07714	0.2531	Greece	Ancient to pre-metric	General	"Palm", 4 dak, consistent with 2003 reference
palf	0.305	1.00	Wales	Medieval to pre-metric	General	Foot
palgat	0.0254	0.0833	Burma, Rangoon, Myanmar	Pre-metric	General	Inch, alternate reference
palgat	0.1016	0.3333	Burma, Rangoon, Myanmar	Pre-metric	General	2003 reference
palm	0.0750	0.246	Inca	Ancient to pre-colonial	General	Est'd
palm	0.07620	0.2500	Ireland	Medieval to pre-metric	General	3 inches, pre-1824 value, 2003 reference

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
palm	0.0762	0.250	United Kingdom	Medieval to pre-metric	General	3 inches
palm	0.0787	0.258	Byzantine Empire	Ancient	General	
palm	0.0800	0.262	Persia, Iran	Ancient to pre-metric	General	4 fingers, 2003 values
palm	0.0889	0.292	Jewish	Medieval to modern	General	3.5 inches
palm	0.224	0.734	Tripoli, Libya	Medieval to pre-metric	General	1891 value
palm (common)	0.0925	0.303	Hebrew	Ancient to pre-metric	General	4 fingers, 2003 reference
palm (sacred)	0.107	0.350	Hebrew	Ancient to pre-metric	General	4 fingers, 2003 reference
palm width	0.0762	0.250	United Kingdom	Medieval to pre-metric	General	3 inches
palma	0.277	0.907	Romania	Pre-metric	General	1891 value
palma (typical)	0.2090	0.6856	Spain	Medieval to pre-metric	General	Palm length, 9 pulgada, pre-1860, 2003 reference
palmas	0.2167	0.7108	Argentina	Colonial to pre-metric	General	Palm, 1/4 vara
palme	0.0886	0.291	Denmark	Medieval to pre-metric	General	Palm, Circumfer.
palmi	0.262	0.859	Malta	Medieval or pre-metric	General	

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
palmipes	0.368	1.21	Rome	Ancient to pre-metric	General	1-1/4 pedes, consistent with 2003 reference
palmu	0.2190	0.7185	Portugal	Medieval to pre-metric	General	8 pollegadas, 2003 reference
palmu	0.220	0.722	Brazil	Colonial to pre-metric	General	Palm, 2/3 pés, 8 pulgadó, also reported as 0.2222 m in 2003 reference
palmu	0.227	0.744	Libya	Medieval or pre-metric	General	1/3 pik, 2003 reference
palmu	0.260	0.853	Italy	Medieval to pre-metric	General	Palm, varied by area
palmu	0.261	0.856	Malta	Medieval or pre-metric	General	2003 reference
palmu (Naples)	0.264	0.865	Italy	Medieval to pre-metric	General	Palm, 12 oncia, reported in 1891
palmu (Sicily)	0.242	0.794	Italy	Medieval to pre-metric	General	Palm, 12 oncia, reported in 1891
palmu (Tuscany)	0.292	0.957	Italy	Medieval to pre-metric	General	10 soldi, reported in 1891
palmu de craveira	0.220	0.722	Portugal	Medieval to pre-metric	General	Span, 8 polegadas, 1/5 varos
palmu mayor (typical)	0.2090	0.6856	Spain	Medieval to pre-metric	General	Palm length, 9 pulgada, pre-1860, 2003 reference
palmu menor	0.0697	0.229	Spain	Medieval to pre-metric	General	(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
palmos	0.1955	0.6414	Balearic Islands	Pre-metric	General	2003 reference
palmus (common)	0.0736	0.241	Rome	Ancient to pre-metric	General	palm, 1/4 pes, consistent with 2003 reference
palmus major	0.222	0.728	Rome	Ancient to pre-metric	General	palm length, 3/4 pes
palyw	0.305	1.00	Wales	Medieval to pre-metric	General	Foot
pand	48.88	160.38	India	Medieval to pre-metric	General	20 kathi
pank'a	1.500	4.921	Persia, Iran	Ancient to pre-metric	General	Pace, 5 trayas
pank'a dva	0.500	1.64	Miscellaneous	Medieval to Modern	General	Cubit, 5 hands, 5 dva
pank'a dva	0.500	1.64	Persia, Iran	Ancient to pre-metric	General	Cubit, 5 hands, 5 dva
parasa	4224	13,858	Biblical, Talmudic	Ancient	General	Parasang, 4 mills, avg
parasang	5486	18,000	Persia, Iran	Ancient to pre-metric	General	5275 zar, 2003 reference
parasang	5760	18,897	Arabia	Ancient to pre-metric	General	18000 Ar ft, consistent with 2003 reference
parasang	6000	19,685	Persia, Iran	Ancient to pre-metric	General	League, dist for horse over 1 h walking, 250 chebel

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
parasang	6400	20,997	Persia, Iran	Ancient to pre-metric	General	20000 zereth, 2003 vreference
parasang	6401	21,000	Jewish	Medieval to modern	General	252000 inches
parasang	6934	22,747	Tatar	Medieval to pre-metric	General	6-7 caqrum, used average
parasange	6980	22,900	Egypt	Ancient to pre-metric	General	4 mille, 2003 reference
parasanges	5548	18,202	Greece	Ancient to pre-metric	General	30 stadia, Persian origin
parmack (builders, surveyors)	0.0313	0.103	Turkey	Medieval to pre-metric	Builder, Surveyor	12 hatts, 1891 value
parmack (common)	0.03147	0.1033	Turkey	Medieval to pre-metric	General	12 hatt, 2003 reference
parmark	0.0316	0.104	Ottoman Empire, Turkey	Ancient to medieval	General	Finger, 12 Hat
paso (typical)	1.393	4.571	Spain	Medieval to pre-metric	General	Pace, 5 pie, pre-1860, 2003 reference
paso geométrico (typical)	1.393	4.571	Spain	Medieval to pre-metric	General	Pace, 5 pie, pre-1860, 2003 reference
paso ordinario	0.697	2.29	Spain	Medieval to pre-metric	General	
pass geométrico	1.650	5.413	Portugal	Medieval to pre-metric	General	Geometric pace, 5 pes, 1.5 varas

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
passo	1.950	6.398	Italy	Medieval to pre-metric	General	7.5 palmi
passo (Naples)	1.978	6.488	Italy	Medieval to pre-metric	General	7.5 palmi, reported in 1891
passo (Parma)	3.253	10.67	Italy	Medieval to pre-metric	General	6 braccia, reported in 1891
passo geométrico	1.650	5.413	Brazil	Colonial to pre-metric	General	5 pés, also reported as 1.667 m in 2003 reference
passus (common)	1.472	4.829	Rome	Ancient to pre-metric	General	Double pace, 5 pedes, consistent with 2003 reference
paulgaut	0.0254	0.0833	Burma, Rangoon, Myanmar	Pre-metric	General	Inch, alternate reference
paulgaut	0.1016	0.3333	Burma, Rangoon, Myanmar	Pre-metric	General	2003 reference
pe	0.330	1.08	Brazil	Colonial to pre-metric	General	Foot, 1/3 vara, 12 pulgado, also reported as 0.3333 m in 2003 reference
pé	0.330	1.08	Brazil	Colonial to pre-metric	General	Foot, 1/3 vara, 12 pulgado, also reported as 0.3333 m in 2003 reference
pé or pe	0.330	1.08	Portugal	Medieval to pre-metric	General	Foot, 12 polegadas, 3/10 varos, reported as 0.3285 m in 2003 reference
pechya	0.4628	1.518	Greece	Ancient to pre-metric	General	“Cubit”, 24 dak, consistent with 2003 reference

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
pēchys	0.4628	1.518	Greece	Ancient to pre-metric	General	"Cubit", 24 dak, consistent with 2003 reference
pedj-aa	0.260	0.853	Egypt	Ancient to pre-metric	General	"Large span", 3.5 palms = 14 fingers
pedj-sheser	0.225	0.738	Egypt	Ancient to pre-metric	General	"Small span", 3 palms = 12 fingers
peninkulma (new)	10.688	35.067	Finland	Medieval to pre-metric	General	Dist a dog barking can be heard, after 1600 = 10 virsta
peninkulma (old)	5344	17,533	Finland	Medieval to pre-metric	General	Dist a dog barking can be heard, before 1600 = 5 virsta
perch	3.000	9.842	Switzerland	Medieval to pre-metric	General	Reported as 10 pieds, 1891 value
perch	3.148	10.33	Byzantine Empire	Ancient	General	deca-foot
perch	5.029	16.50	United States	Colonial to modern	General	25 links, 16.5 ft
perch	5.846	19.181	France	Medieval to pre-metric	General	3 toise, 2003 reference
perch	6.401	21.00	Ireland	Medieval to pre-metric	General	7 yards, pre-1824 value, 2003 reference
perch (eaux & forêts)	7.146	23.44	France	Medieval to pre-metric	General	"Perch" or "rood", 2003 reference
perche	3.000	9.842	Switzerland	Medieval to pre-metric	General	Reported as 10 pieds, 1891 value
perche	6.498	21.32	Belgium	Pre-metric	General	20 pied, 2003 reference

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
perche d'arpent	7.146	23.44	France	Medieval to pre-metric	General	"Perch" or "rood", 2003 reference
perche ordinaire	6.496	21.31	France	Medieval to pre-metric	General	Local use, 20 peds, 2003 reference
pertica	1.950	6.398	Italy	Medieval to pre-metric	General	7.5 palmi
pertica (Naples)	1.978	6.488	Italy	Medieval to pre-metric	General	7.5 palmi, reported in 1891
pertica (Parma)	3.253	10.67	Italy	Medieval to pre-metric	General	6 braccia, reported in 1891
pes	0.296	0.971	Rome	Ancient to pre-metric	General	Roman foot
pes (common)	0.2944	0.9659	Rome	Ancient to pre-metric	General	Foot, variation, 2003 reference
pes (Druisian)	0.3196	1.049	Rome	Ancient to pre-metric	General	Foot, variation, 2003 reference
pes (legal, 1st)	0.2962	0.9718	Rome	Ancient to pre-metric	General	Foot, variation, 2003 reference
pes (legal, 2nd)	0.2967	0.9734	Rome	Ancient to pre-metric	General	Foot, variation, 2003 reference
pes pedis	0.296	0.971	Rome	Ancient to pre-metric	General	Roman foot
pesiah	0.528	1.73	Biblical, Talmudic	Ancient	General	Ell or cubit, 2 spans, avg, Talmudic pace, also reported as 0.518 in Ezekiel 40.5
phan	0.00487	0.0160	Annam	Pre-metric	Buildings	10 ly

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
phan	0.00650	0.0213	Annam	Pre-metric	Cloth	10 ly
phân	0.00425	0.0139	Vietnam, Annam	Medieval to metric	General	10 ly, 2003 reference
PHU	0.036	0.12	Maya	Pre-colonial	General	Base size, unknown name
phyeam	2	7	Cambodia	Post-metric	General	2 muoi, 2003 reference
piad	0.1778	0.5833	Russia	Medieval to pre-metric	General	Palm or quarter, 1/4 arshin, 4 vershok, 2003 reference
pic	0.578	1.90	Guinea	Medieval to pre-metric	General	2003 reference
pic	0.580	1.90	Egypt	Ancient to pre-metric	General	2 kadam, 1891 value, consistent with 2003 reference
pic	0.582	1.91	Syria	Medieval to pre-metric	General	Cubit, 2003 reference
pic	0.6096	2.000	Cyprus	Colonial to pre-metric	General	2 feet, also reported as 0.672 m in 1891, 2003 reference
pic	0.610	2.00	Morocco	Medieval to pre-metric	General	8 tonni, 2003 reference, also reported as 0.660 m in 1891
pic	0.637	2.09	Crete or Candia	Pre-metric	General	1891 Value
pic	0.671	2.20	Tripoli, Libya	Medieval to pre-metric	General	1891 value
pic	0.680	2.23	Libya	Medieval or pre-metric	General	3 palmo, 2003 reference
pic	0.686	2.25	Abyssinia	Pre-metric	General	2003 reference
pic	0.686	2.25	Ethiopia	Medieval to pre-metric	General	Roughly

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
pic (Aleppo)	0.676	2.22	Turkey	Medieval to pre-metric	General	Reported at Aleppo, 1891 value
pic (average, common)	0.655	2.15	Greece	Ancient to pre-metric	General	piki, average, varied
pic (common)	0.7554	2.478	Turkey	Medieval to pre-metric	General	8 urumb, 2003 reference
pic (Damascus)	0.580	1.90	Turkey	Medieval to pre-metric	General	Reported at Damascus, 1891 value
pic (linen, wool)	0.686	2.25	Greece	Ancient to pre-metric	Linen, Wool	Reported in 1891
pic (silks)	0.635	2.08	Greece	Ancient to pre-metric	Silk	Reported in 1891
pic (typical)	0.668	2.19	Turkey	Medieval to pre-metric	General	1891 value
pic Arabic	0.488	1.60	Tunisia	Ancient to pre-metric	General	2003 reference
pic endazé	0.673	2.21	Tunisia	Ancient to pre-metric	General	2003 reference
pic Endežian	0.673	2.21	Tunisia	Ancient to pre-metric	General	2003 reference
pic Turkish	0.637	2.09	Tunisia	Ancient to pre-metric	General	
pica	0.004233	0.01389	United States	Colonial to modern	General	12 points

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
pica	0.00423	0.0139	United Kingdom	Medieval to pre-metric	General	1/6 inch
pie	0.267	0.875	Venezuela	Colonial to pre-metric	General	Foot, 1/3 vara, 12 pulgada, 2003 reference
pie	0.2787	0.9142	Peru	Colonial to pre-metric	General	Foot, 2003 reference
pie	0.279	0.916	Mexico	Colonial to pre-metric	General	Foot, 1/3 vara, 12 pulgada, 2003 reference
pie	0.280	0.919	Colombia	Colonial to pre-metric	General	Foot, 1/3 vara, 12 pulgada, also reported as 0.267 m in 2003 reference
pie	0.2889	0.9477	Argentina	Colonial to pre-metric	General	Foot, 1/3 vara, 12 pulgada, 2003 reference
pié	0.279	0.914	Chile	Colonial to pre-metric	General	Foot, 1/3 vara, 12 pulgada, 2003 reference
pié	0.283	0.927	Canary Islands	Pre-metric	General	Local variation, 1891 reference
pié	0.2889	0.9477	Argentina	Colonial to pre-metric	General	Foot, 1/3 vara, 12 pulgada, 2003 reference
pié	0.294	0.966	Rome	Ancient to pre-metric	General	1891 value
pié (Ancona)	0.391	1.28	Rome	Ancient to pre-metric	General	1891 value reported for Ancona
piè (Milan)	0.396	1.30	Italy	Medieval to pre-metric	General	Reported in 1891
pié (Modena)	0.523	1.72	Italy	Medieval to pre-metric	General	Reported in 1891

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
pié (Parma)	0.570	1.87	Italy	Medieval to pre-metric	General	Reported in 1891
pié (Sadinia)	0.515	1.69	Italy	Medieval to pre-metric	General	Reported in 1891
pie (typical)	0.2786	0.9141	Spain	Medieval to pre-metric	General	Foot, 2 sesma, pre-1860, 2003 reference, also reported as 0.283 m in 1891
piè (typical)	0.2786	0.9141	Spain	Medieval to pre-metric	General	Foot, 2 sesma, pre-1860, 2003 reference, also reported as 0.283 m in 1891
piè (Venice)	0.348	1.14	Italy	Medieval to pre-metric	General	Reported in 1891, consistent with 2003 reference
pié liprando (typical)	0.5138	1.686	Italy	Medieval to pre-metric	General	Basic unit, foot, varied, 12 onci, pre-1861, 2003 reference
pié manuale (Genoa)	0.343	1.13	Italy	Medieval to pre-metric	General	Reported in 1891
pied	0.300	0.984	Switzerland	Medieval to pre-metric	General	Foot, consistent with value reported in 1891 and 2003 reference
pied	0.3249	1.066	Belgium	Pre-metric	General	Foot, 2003 reference
pied	0.326	1.07	France	Medieval to pre-metric	General	790 AD by Charlemagne
pied (metric)	0.3333	1.093	France	1812–1843	General	12 pouche (metric), 2003 reference
pied du roi	0.3248	1.066	France	Medieval to pre-metric	General	Royal foot, also known as “pié de Paris”, 2003 reference
piede (Modena)	0.523	1.72	Italy	Medieval to pre-metric	General	Reported in 1891

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
piede (new)	0.2887	0.9471	Paraguay	Colonial to pre-metric	General	Foot, 12 pulgada (new), 2003 reference
piede (old)	0.2795	0.9170	Paraguay	Colonial to pre-metric	General	Foot, 12 pulgada (old), 2003 reference
piede (typical)	0.348	1.14	Italy	Medieval to pre-metric	General	Used in some areas, varied
piede (typical)	0.5138	1.686	Italy	Medieval to pre-metric	General	Basic unit, foot, varied, 12 onci, pre-1861, 2003 reference
piede (Venice)	0.348	1.14	Italy	Medieval to pre-metric	General	Reported in 1891, consistent with 2003 reference
pigon	0.4363	1.431	Egypt	Ancient to pre-metric	General	1.25 zereth, 2003 reference
pik	0.578	1.90	Guinea	Medieval to pre-metric	General	2003 reference
pik	0.680	2.23	Libya	Medieval or pre-metric	General	3 palmo, 2003 reference
pik - linen	0.473	1.55	Tunisia	Ancient to pre-metric	Linen	Linen goods
pik—silk	0.631	2.07	Tunisia	Ancient to pre-metric	Silk	For silk goods
piki (long)	0.669	2.19	Greece	Ancient to pre-metric	General	2003 reference, pre-1836
piki (masonry)	0.750	2.46	Greece	Ancient to pre-metric	Masonry	2003 reference, pre-1836

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
piki (short)	0.648	2.13	Greece	Ancient to pre-metric	General	2003 reference, pre-1836
plethron	30.86	101.2	Greece	Ancient to pre-metric	General	100 podes, 2003 value
plethron	31.48	103.3	Byzantine Empire	Ancient	General	Greek furlong
point	0.0001880	0.0006168	France	Medieval to pre-metric	General	Called Truchet point in English
point	0.000353	0.00116	United Kingdom	Medieval to pre-metric	General	1/12 pica or 1/6 line
point	0.0003528	0.001157	United States	Colonial to modern	General	
pole	4.267	14.00	Jewish	Medieval to modern	General	168 inches
pole	6.401	21.00	Ireland	Medieval to pre-metric	General	7 yards, pre-1824 value, 2003 reference
pole (survey)	5.029	16.50	United States	Colonial to modern	Surveyor	25 links, 16.5 ft
polegada	0.0275	0.0902	Brazil	Colonial to pre-metric	General	Inch or thumb, 1/12 pé, also reported as 0.02778 m in 2003 reference
polegada	0.0275	0.0902	Portugal	Medieval to pre-metric	General	Inch, 12 linhas, 1/40 varos, reported as 0.02738 m in 2003 reference
Polish mile	7144	23,438	Poland	Medieval to pre-metric	General	8 staję
	9,059	29,721	Germany		General	Reported in Saxony 1891, 32,000 fuß

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
polizei-meile (Saxony)				Medieval to pre-metric		
pollegada	0.0275	0.0902	Portugal	Medieval to pre-metric	General	Inch, 12 linhas, 1/40 varos, reported as 0.02738 m in 2003 reference
ponto	0.000190	0.000623	Portugal	Medieval to pre-metric	General	Point, 1/5760 varos
poppyseed	0.00212	0.00694	United Kingdom	Medieval to pre-metric	General	1/4 or 1/5 barleycorn
poronkusema	7500	24,606	Finland	Medieval to pre-metric	General	Sami measure, distance reindeer can travel before urinating, used to describe obscure distance
postmeile	7533	24,714	Prussia	Pre-metric	General	24,000 Rhein fuss, 1891 value
postmeile (Saxony)	6795	22,292	Germany	Medieval to pre-metric	General	Reported in Saxony 1891, 24,000 fuß
pou	1.6	5.2	China	Ancient to pre-metric	General	5 tchi
potù	5760	18,897	China	Ancient to Pre-metric	General	10 Li, reported in 1966
pouche (metric)	0.02778	0.09112	France	1812–1842	General	12 ligne (metric), 2003 reference
pounce	0.02707	0.08881	France	Medieval to pre-metric	General	inch
pounce (new)	0.02406	0.07892	Paraguay	Colonial to pre-metric	General	Inch or thumb, 12 linea (new), 2003 reference
pounce (new)	0.0250	0.0820	Switzerland	Medieval to pre-metric	General	Inch, 1/12 pied, 2003 reference

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
pounce (old)	0.02329	0.07642	Paraguay	Colonial to pre-metric	General	Inch or thumb, 12 linea (old), 2003 reference
pounce (old)	0.0300	0.0984	Switzerland	Medieval to pre-metric	General	1/10 pied, 1891 value
pous	0.212	0.697	Byzantine Empire	Ancient	General	Foot
pous	0.3086	1.012	Greece	Ancient to pre-metric	General	"Foot", 16 dak, also reported as 0.300 m (1891), consistent with 2003 reference
pret	4.320	14.17	Poland	Medieval to pre-metric	General	15 stopa, 2003 reference
pret	4.467	14.65	Poland	Medieval to pre-metric	General	Rod, agrarian, 2 steps, alternate value
public cubit	0.469	1.54	Byzantine Empire	Ancient	General	AKA lithikos, pxihtikos, tektonikos
pulgada	0.00974	0.0320	Mexico	Colonial to pre-metric	General	1/86 vara, 12 linea, 2003 reference
pulgada	0.0222	0.0729	Venezuela	Colonial to pre-metric	General	Inch, 1/36 vara, 2003 reference
pulgada	0.02258	0.07407	Honduras	Colonial to pre-metric	General	Inch, 2003 reference
pulgada	0.023	0.076	El Salvador	Colonial to pre-metric	General	Inch, 2003 reference
pulgada	0.023	0.076	Nicaragua	Colonial to pre-metric	General	Inch, 2003 reference
pulgada	0.0232	0.0761	Central America	Colonial to pre-metric	General	Inch, 2003 & 1891 references

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
pulgada	0.02322	0.07618	Guatemala	Colonial to pre-metric	General	Inch, 2003 reference
pulgada	0.0232	0.0762	Chile	Colonial to pre-metric	General	Inch or thumb, 1/36 vara, 12 linea, 2003 reference
pulgada	0.02331	0.07648	Costa Rica	Colonial to pre-metric	General	Inch, 2003 reference
pulgada	0.02407	0.07898	Argentina	Colonial to pre-metric	General	Inch or thumb, 1/86 vara, 12 linea, 2003 reference
pulgada	0.0263	0.0861	Colombia	Colonial to pre-metric	General	Inch or thumb, 1/32 vara, also reported as 0.0222 m in 2003 reference
pulgada (new)	0.02406	0.07892	Paraguay	Colonial to pre-metric	General	Inch or thumb, 12 linea (new), 2003 reference
pulgada (old)	0.02329	0.07642	Paraguay	Colonial to pre-metric	General	Inch or thumb, 12 linea (old), 2003 reference
pulgada (typical)	0.02322	0.07618	Spain	Medieval to pre-metric	General	Inch, 16 linea, pre-1860, 2003 reference
pulzier	0.0118	0.0388	Malta	Medieval or pre-metric	General	1/12 Xiber, inch
pumlungur	0.02616	0.08582	Iceland	Medieval to pre-metric	General	Thumb, 12 lina, 2003 reference
p'un	0.00300	0.00984	Korea, Korea	Medieval or pre-metric	General	
punkt	0.0001829	0.0006001	Austrian Empire	Pre-metric	Common	2003 reference

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
punkte	0.0001829	0.0006001	Austrian Empire	Pre-metric	Common	2003 reference
punkte (Lubeck)	0.000333	0.00109	Germany	Medieval to pre-metric	General	1/12 linie, 1891
punkte (Wurtemberg)	0.000286	0.000939	Germany	Medieval to pre-metric	General	Reported in 1891
punto	0.000158	0.000519	Spain	Medieval to pre-metric	General	Point, 1/1728 pie, alternate reference
punto (Parma)	0.00376	0.0124	Italy	Medieval to pre-metric	General	Point, 1/12 oncie, reported in 1891
punto (typical)	0.0001209	0.0003968	Spain	Medieval to pre-metric	General	Point, pre-1860, 2003 reference
punto (typical)	0.003568	0.01171	Italy	Medieval to pre-metric	General	Point, 1/144 piede liprando, pre-1861, 2003 reference
punto (Venice)	0.00483	0.0158	Italy	Medieval to pre-metric	General	12 atomi, reported in 1891
pygmē	0.347	1.14	Greece	Ancient to pre-metric	General	forearm, 18 dak
pygōn	0.3858	1.266	Greece	Ancient to pre-metric	General	20 dak, consistent with 2003 reference
qanū	3.000	9.842	Mesopotamia, Sumer, Akkadia	Ancient	General	reed, 6 cubits
qariş	0.0445	0.146	Tatar	Medieval to pre-metric	General	

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
qasab	3.84	12.6	Arabia	Ancient to pre-metric	General	12 Ar ft, also reported as 3.75 m in 1891, 2003 reference value
qasab	3.840	12.60	Persia, Iran	Ancient to pre-metric	General	Reported 2003
qasba	2.096	6.877	Malta	Medieval or pre-metric	General	Fathom essentially, reported 1891, 8 palmi
qolaç	2.133	6.998	Tatar	Medieval to pre-metric	General	3 arşın, 7 fut
quarter yard (clothes)	0.2286	0.7500	United Kingdom	Medieval to pre-metric	Clothing	9 inches, 4 nails
quartier	0.134	0.440	Latvia	Medieval or pre-metric	General	1/4 elle, 2003 reference
rahf—northern	2.360	7.743	Madagascar	Pre-metric	General	Northern Madagascar, 1891 value
rahf—southern	1.180	3.871	Madagascar	Pre-metric	General	Southern Madagascar, 1891 value
Ramsden chain	30.48	100.0	United Kingdom	Medieval to pre-metric	General	5 ropes
Ramsden's chain (survey)	20.12	66.00	United States	Colonial to modern	Surveyor	4 rods, 66 ft, also reported as 100 ft in some references, believe 66 ft is correct
raso	0.600	1.97	Italy	Medieval to pre-metric	General	Some areas
rast	5000	16,404	Sweden	Medieval to pre-metric	General	Distance between rests in woods
rast	9000	29,527	Norway	Medieval to pre-metric	General	"Rest", Distance between rests, old name for mile pre 1541

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
rebia	0.156	0.511	Algeria	Medieval to pre-met	General	1/4 pic, 2 termin, using dzera a torky basis, 2003 reference
reed	3.200	10.50	Jewish	Medieval to modern	General	126 inches
ref (after 1855)	29.69	97.41	Sweden	Medieval to pre-metric	Land	Land measure, reduced to 100 fot after 1855
ref (pre-1855)	47.50	155.9	Sweden	Medieval to pre-metric	Land	160 fot, land measure, 2003 reference
remen	0.375	1.23	Egypt	Ancient to pre-metric	General	remen, 5 palms = 20 fingers
remen	0.400	1.31	Miscellaneous	Medieval to modern	General	Four-hands, 4 dva
remen	0.400	1.31	Persia, Iran	Ancient to pre-metric	General	Four-hands, 4 dva
Rheinfuß	0.314	1.03	Germany	Medieval to pre-metric	General	Reported in Hamburg 1891
Rheinfuss	0.314	1.03	Prussia	Pre-metric	General	12 zoll, 1891 value
Rheinfuß	0.314	1.03	Prussia	Pre-metric	General	12 zoll, 1891 value
ri	3927	12.884	Japan	Ancient to pre-metric	General	12,960 shaku, 36 chō, 2003 reference
ri (ancient)	600	1968	Japan	Ancient to pre-metric	General	
rin	0.000303	0.000994	Japan	Ancient to pre-metric	General	10 mō, 2003 reference

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
ris	104.8	343.8	Biblical, Talmudic	Ancient	General	Stadium, avg
ris - Talmudic	140.8	461.9	Biblical, Talmudic	Ancient	General	1600 palms
rmn	0.375	1.23	Egypt	Ancient to pre-metric	General	remen, 5 palms = 20 fingers
roby	0.0779	0.255	Algeria	Medieval to pre-met	General	1/8 pic, using dzera a torky basis, 2003 reference
rod	5.029	16.50	United Kingdom	Medieval to pre-metric	General	11 cubits
rod	5.029	16.50	United States	Colonial to modern	General	25 links, 16.5 ft
rod	5.250	17.22	Egypt	Ancient to pre-metric	General	
rode	5.026	16.49	Denmark	Medieval to pre-metric	General	16 fod, also reported as 5 alen = 10 fod or 3.14 m in 1891
roede	3.680	12.07	Netherlands, Holland	Medieval to metric	General	13 voeten, 2003 reference
roede	3.970	13.03	Netherlands, Holland	Medieval to metric	General	Rod, varied, average value, alternate references
roeden	3.680	12.07	Netherlands, Holland	Medieval to metric	General	13 voeten, 2003 reference
roeden	3.970	13.03	Netherlands, Holland	Medieval to metric	General	Rod, varied, average value, alternate references

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
roeneung	4000	13,123	Thailand	Medieval to metric	General	100 sen, 2003 reference
röenung	3844	12,611	Siam, Thailand	Pre-metric	General	2,000 vouahs, 1891 value
Roman mile	1524	5000	United Kingdom	Medieval to pre-metric	General	50 Ramsden chains
rope	6.096	20.00	United Kingdom	Medieval to pre-metric	General	4 grades
royal atour	10,470	34,350	Egypt	Ancient to pre-metric	General	2 atour, 2003 reference
rubu	0.0850	0.279	Ottoman Empire, Turkey	Ancient to medieval	General	2 kerrab
rut	5.026	16.49	Denmark	Medieval to pre-metric	General	16 fod, also reported as 5 alen = 10 fod or 3.14 m in 1891
rute	4.191	13.75	Germany	Medieval to pre-metric	Surveyor	Rod, land measure, varied 2.9-5.9 m
ruthe	1.800	5.905	Switzerland	Medieval to pre-metric	General	6 pied, 3 braches, 2003 reference
ruthe	3.16	10.4	Austrian Empire	Pre-metric	Engrs, Surveyors	10 decimal fuss
ruthe	3.766	12.36	Denmark	Medieval to pre-metric	General	2 favn, 2003 reference
ruthe	3.766	12.36	Prussia	Pre-metric	General	1891 value
ruthe	3.793	12.44	Austrian Empire	Pre-metric	Common	2 klafter, 2003 reference

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
ruthe	4.191	13.75	Germany	Medieval to pre-metric	Surveyor	Rod, land measure, varied 2.9-5.9 m
ruthe (Baden)	3.000	9.842	Germany	Medieval to pre-metric	General	Rod, reported in 1891
ruthe (Bremen)	4.627	15.18	Germany	Medieval to pre-metric	General	Rod, reported in 1891
ruthe (Brunswick)	4.560	14.96	Germany	Medieval to pre-metric	General	8 ellen or 16 schuh, reported in Brunswick 1891
ruthe (Hesse-Cassel)	3.989	13.09	Germany	Medieval to pre-metric	General	Reported in Hesse-Cassel 1891, 7 ellen
ruthe (Prussian system)	3.766	12.36	Germany	Medieval to pre-metric	General	12 fuss, 2003 reference
ruthe (Wurtemberg)	2.862	9.388	Germany	Medieval to pre-metric	General	10 fuss, reported in 1891
saaschen	2.134	7.000	Russia	Medieval to pre-metric	General	Fathom, 3 yards, 7 fut, 2003 reference
Sabbath-day's journey	1.067	3,500	Jewish	Medieval to modern	General	42,000 inches
sachin	2.134	7.000	Russia	Medieval to pre-metric	General	Fathom, 3 yards, 7 fut, 2003 reference
safar yome	44,328	145,431	Egypt	Ancient to pre-metric	General	2.5 safar yome = 1° meridian = 60 mili, 2 baride
sagéne	2.134	7.000	Russia	Medieval to pre-metric	General	Fathom, 3 yards, 7 fut, 2003 reference
sah (Bohemian)	1.776	5.827	Czechoslovakia	Pre-metric	General	3 loket, 2003 reference

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
sajm	2.133	6.998	Tatar	Medieval to pre-metric	General	3 arşın, 7 fut
sals	0.3030	0.9941	Japan	Ancient to pre-metric	General	Foot, 10 sun, 100 bu, 2003 reference
sandong	0.5588	1.833	Burma, Rangoon, Myanmar	Pre-metric	General	11/9 taim, 2003 reference
sao	6.375	20.92	Vietnam, Annam	Medieval to metric	General	3 tam, 2003 reference
sao	7.31	24.0	Annam	Pre-metric	Buildings	3 ngu
sashen	2.134	7.000	Russia	Medieval to pre-metric	General	Fathom, 3 yards, 7 fut, 2003 reference
sawk	0.500	1.64	Thailand	Medieval to metric	General	Cubit, 2 keup, 2003 reference
sazen	1.728	5.669	Poland	Medieval to pre-metric	General	6 stopa, 2003 reference
sążeń	1.787	5.863	Poland	Medieval to pre-metric	General	Fathom, 3 ells, alternate value
sazhen	2.134	7.000	Russia	Medieval to pre-metric	General	Fathom, 3 yards, 7 fut, 2003 reference
Schaenus line	42.67	140.0	Jewish	Medieval to modern	General	1680 inches
schoëme	6912	22.677	Persia, Iran	Ancient to pre-metric	General	4 mille, 2003 reference

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
schoenus	6296	20,656	Byzantine Empire	Ancient	General	Reed rope, 33,333 stades
schoenus (common)	5888	19,317	Rome	Ancient to pre-metric	General	20000 pes, consistent with 2003 reference
schoinion	21.30	69.88	Byzantine Empire	Ancient	General	Little schoenus, tax basis 10-12 fathoms, 25.3 m also
schoinos	7397	24,268	Greece	Ancient to pre-metric	General	40 stadia, Egypt origin
schuh (Braunschweig, Brunswick)	0.285	0.935	Germany	Medieval to pre-metric	General	Reported in Brunswick 1891
Scots mile	1814	5952	Scotland	Medieval to pre-metric	General	320 falls, 8 furlongs, but varied, 1-1/8 English mile in 1891, 2003 reference
Scottish inch	0.0224	0.0734	Scotland	Medieval to pre-metric	General	Fraudulent inch, 1/42 ell, 2003 reference
scrupel	0.000182	0.000596	Prussia	Pre-metric	General	1891 value
še	0.00250	0.00820	Mesopotamia, Sumer, Akkadia	Ancient	General	grain, 1/180th cubit
seir	192.0	629.9	Arabia	Ancient to pre-metric	General	600 Ar ft, consistent with 2003 reference
sen	40	131	Cambodia	Post-metric	General	40 muoi, 20 phyeam, 2003 reference
sen	40.0	131	Thailand	Medieval to metric	General	Rope or line of rope, 20 wah, 2003 reference

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
šēpu	1.000	3.281	Mesopotamia, Sumer, Akkadia	Ancient	General	step, 2 cubits
serveyor's fuß (Hesse-Cassel)	0.285	0.935	Germany	Medieval to pre-metric	General	Reported in Hesse-Cassel 1891
sesma (typical)	0.1393	0.4571	Spain	Medieval to pre-metric	General	6 pulgada, pre-1860, 2003 reference
Shackle	27.43	90.00	United Kingdom	Medieval to pre-metric	General	15 fathoms
shaftment	0.152	0.500	United Kingdom	Medieval to pre-metric	General	2 palms or 1/2 foot, 6.5 inches before 1066, 6" after
shakkanho (ancient)	0.180	0.591	Japan	Ancient to pre-metric	General	Origin: length from thumb to middle finger
shaku	0.3030	0.9941	Japan	Ancient to pre-metric	General	Foot, 10 sun, 100 bu, 2003 reference
shesep	0.0750	0.246	Egypt	Ancient to pre-metric	General	"Palm", 4 fingers
shi	0.00000303	0.00000994	Japan	Ancient to pre-metric	General	2003 reference
shoëme	6282	20,610	Egypt	Ancient to pre-metric	General	30 stade, 2003 reference
shusi	0.0150	0.0492	Mesopotamia, Sumer, Akkadia	Ancient	General	finger, 1/30 cubit

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
simple fathom	1.870	6.135	Byzantine Empire	Ancient	General	AKA kanna, varied, Greek basis
sinzer	0.160	0.525	Ethiopia	Medieval to pre-metric	General	2 gat, 2003 reference
šizu	0.333	1.09	Mesopotamia, Sumer, Akkadia	Ancient	General	foot, 2/3 cubit
sjomil	1852	6076	Norway	Medieval to pre-metric	General	Sea mile, 3950 fathoms
sjomila	1855	6086	Iceland	Medieval to pre-metric	General	
skein	36.58	120.0	United Kingdom	Medieval to pre-metric	General	96 ells
skewed sazhen	2.480	8.136	Russia	Medieval to pre-metric	General	Tip of raised arm to opp. Leg slightly bent
skogsmil	5000	16,404	Sweden	Medieval to pre-metric	General	Distance between rests in woods
skrupel	0.000180	0.000591	Norway	Medieval to pre-metric	General	1/12 Ligne
skrupel	0.000182	0.000596	Denmark	Medieval to pre-metric	General	Scruple, 1/12 Linie
small span	0.178	0.583	Jewish	Medieval to modern	General	7 inches
sok	0.481	1.58	Siam, Thailand	Pre-metric	General	1891 value

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
sok	0.500	1.64	Thailand	Medieval to metric	General	Cubit, 2 keup, 2003 reference
soldo (Tuscany)	0.0292	0.0957	Italy	Medieval to pre-metric	General	12 denari, reported in 1891
sofka	0.02134	0.07000	Russia	Medieval to pre-metric	General	84 totchka, 2003 reference
söyäm	0.178	0.583	Tatar	Medieval to pre-metric	General	4 qaris
span	0.2286	0.7500	Ireland	Medieval to pre-metric	General	3 palm, pre-1824 value, 2003 reference
span	0.2286	0.7500	United Kingdom	Medieval to pre-metric	General	3 palms, width of outstretched hand from tip of thumb to tip of little finger, 9 inches
span	0.2286	0.7500	United States	Colonial to modern	General	9 inches
span	0.236	0.775	Byzantine Empire	Ancient	General	
span (Bengal, Calcutta)	0.229	0.750	India	Medieval to pre-metric	General	3 moot, 1891 reference
span (Bombay)	0.1715	0.5625	India	Medieval to pre-metric	General	3 moot, 2003 reference
spd	0.225	0.738	Egypt	Ancient to pre-metric	General	"Small span", 3 palms = 12 fingers
spindle	4389	14,400	United Kingdom	Medieval to pre-metric	General	120 skeins

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
spithame	0.2618	0.8589	Egypt	Ancient to pre-metric	General	"Span", 2003 reference
spithamē	0.2314	0.7592	Greece	Ancient to pre-metric	General	"Span", 12 dak, consistent with 2003 reference
ssp	0.0750	0.246	Egypt	Ancient to pre-metric	General	"Palm", 4 fingers
stab	1.581	5.186	Hungary	Medieval to pre-metric	General	Like a rod or fathom
stade	188.8	619.4	Byzantine Empire	Ancient	General	Stadion, Stadium, English furlong
stade	201.2	660.0	United Kingdom	Medieval to pre-metric	General	10 Gunter's chains
stade	209.4	687.0	Egypt	Ancient to pre-metric	General	"Stadium", 4 senus, 2003 reference
stadion	20.12	66.00	Ionian Islands	Pre-metric	General	22 yards, 1891 value
stadion	185.1	607.3	Greece	Ancient to pre-metric	General	600 podes, ~ 1/8 Roman mile, 2003 value
stadion	192.0	629.9	Arabia	Ancient to pre-metric	General	600 Ar ft, consistent with 2003 reference
stadion	230.4	755.9	Persia, Iran	Ancient to pre-metric	General	9 chebel, 2003 reference
stadium	185.1	607.3	Greece	Ancient to pre-metric	General	600 podes, ~ 1/8 Roman mile, 2003 value
stadium	2134	7000	Jewish	Medieval to modern	General	84,000 inches

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
stadium (common)	184.0	603.7	Rome	Ancient to pre-metric	General	stade, 625 pedes, 600 Greek ft, =furlong, consistent with 2003 reference
stage	29,800	97,768	Greece	Ancient to pre-metric	General	160 stadia
staje	134.0	439.6	Poland	Medieval to pre-metric	General	Furlong, 3 cables, agrarian
staje	893.0	2930	Poland	Medieval to pre-metric	General	Stage, Distances between points
stajoli	0.569	1.87	Italy	Medieval to pre-metric	Buildings	Architect
stang	3.137	10.29	Norway	Medieval to pre-metric	General	Rod, 5 alen
stång (after 1855)	2.969	9.741	Sweden	Medieval to pre-metric	General	For land measure, reduced to 10 fot after 1855
stång (pre-1855)	4.750	15.59	Sweden	Medieval to pre-metric	General	16 fot, for land measure, 2003 reference
stathmos	24,685	80,987	Greece	Ancient to pre-metric	General	80,000 pous, 2003 reference
stathmos	25,600	83,988	Persia, Iran	Ancient to pre-metric	General	4 parasang, 2003 reference
stathmos (Greek)	27,000	88,582	Persia, Iran	Ancient to pre-metric	General	Mansion, a day march on Royal Road, 4–5 parasang, avg
statute mile	1609	5280	United Kingdom	Medieval to pre-metric	General	1760 yards

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
statute mile	1609	5280	United States	Colonial to modern	General	8 furlongs
steg	0.8905	2.922	Sweden	Medieval to pre-metric	General	1/2 famn, 2003 reference
steinkast	47.05	154.4	Norway	Medieval to pre-metric	General	Stone's throw, 25 favner—still used
stenkast	50.00	164.0	Sweden	Medieval to pre-metric	General	Stone's throw, still used
step	0.762	2.50	United Kingdom	Medieval to pre-metric	General	5 shaftments
stick	0.0508	0.167	United Kingdom	Medieval to pre-metric	General	2 inches
stopa	0.316	1.04	Yugoslavia	Pre-metric	General	8.7 palaz, 2003 reference
stopa (Bohemian)	0.296	0.971	Czechoslovakia	Pre-metric	General	2003 reference
stopa (Krakow)	0.2356	0.7731	Poland	Medieval to pre-metric	General	2 lokiec, 2003 reference
stopa (Moravian)	0.284	0.932	Czechoslovakia	Pre-metric	General	Regional variation, 2003 reference
stopa (new)	0.2880	0.9449	Poland	Medieval to pre-metric	General	2 lokiec, 2003 reference
stopa (Praha)	0.297	0.973	Czechoslovakia	Pre-Metric	General	Regional variation, 2003 reference
stopa (Silesian)	0.290	0.950	Czechoslovakia	Pre-metric	General	Regional variation, 2003 reference
stopa (Warsaw)	0.2978	0.9770	Poland	Medieval to pre-metric	General	Foot, 1.5 szytych, also reported as 0.356 m in 1891, alternate references, consistent with 2003 reference for Warsaw

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
strevic (Bohemian)	0.296	0.971	Czechoslovakia	Pre-metric	General	2003 reference
stringene (common)	1.96	6.43	Romania	Pre-metric	General	2.8 halibiu, 2003 reference
su	0.0000032	0.000010	China	Ancient to pre-metric	General	10 hoé
šu-du3-a	0.333	1.09	Mesopotamia, Sumer, Akkadia	Ancient	General	foot, 2/3 cubit
sun	0.0303	0.0994	Japan	Ancient to pre-metric	General	10 bu, 2003 reference
suns			Shoshone	Pre-colonial	Distance	Indeterminate, used for long distances, roughly number of days required, depended on mode of transportation
survey foot	0.3048	1.000	United States	Colonial to modern	Surveyor	1200/3937 meter
survey mile	1609	5280	United States	Colonial to modern	General	8 furlongs
šu-si	0.0150	0.0492	Mesopotamia, Sumer, Akkadia	Ancient	General	finger, 1/30 cubit
swaesh dva	0.642	2.11	Persia, Iran	Ancient to pre-metric	General	Great cubit, 6 Hands, 6 dva
swung sazhen	1.760	5.774	Russia	Medieval to pre-metric	General	Tips of arms outstretched

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
syli	1.80	5.91	Finland	Medieval to pre-metric	General	6 ft, fathom, fingertip to fingertip with arms spread
syli	1.85	6.08	Finland	Medieval to pre-metric	Nautical	1/1000 Naut mile, seldom used
sznur	44.67	146.5	Poland	Medieval to pre-metric	General	Cable, agrarian, 5 sticks
sztych	0.198	0.651	Poland	Medieval to pre-metric	General	1.33 Qtrs
tac	0.0487	0.160	Annam	Pre-metric	Buildings	10 phan
tac	0.0650	0.213	Annam	Pre-metric	Cloth	10 phan
tác	0.0425	0.139	Vietnam, Annam	Medieval to metric	General	10 phán, in some areas = 0.047 m, 2003 reference
taim	0.4572	1.500	Burma, Rangoon, Myanmar	Pre-metric	General	4.5 palgat, 2003 reference
taing	3912	12,833	Burma, Rangoon, Myanmar	Pre-metric	General	50 oke thapal, 1000 bambous, 2003 reference
tam	2.125	6.972	Vietnam, Annam	Medieval to metric	General	5 thước, 2003 reference
tassoo (Bombay)	0.02858	0.09375	India	Medieval to pre-metric	General	2 unglee, 2003 reference
tat	0.025	0.082	Ethiopia	Medieval to pre-metric	General	2003 reference
tat	0.0425	0.139	Vietnam, Annam	Medieval to metric	General	10 phán, in some areas = 0.047 m, 2003 reference

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
tayaq	2.133	6.998	Tatar	Medieval to pre-metric	General	3 arşın, 7 fut
tchetverk	0.1778	0.5833	Russia	Medieval to pre-metric	General	Palm or quarter, 1/4 arshin, 4 vershok, 2003 reference
tchi (official, average)	0.333	1.09	China	Ancient to pre-metric	General	Value in 1891, 1/100 yan, 10 cun, similar in 1966
tefach	0.0880	0.289	Biblical, Talmudic	Ancient	General	Palm or hand breadth, 4 finger-breadths, avg, also reported as 0.74 m
tepah	0.0880	0.289	Biblical, Talmudic	Ancient	General	Palm or hand breadth, 4 finger-breadths, avg, also reported as 0.74 m
tercia	0.2709	0.8889	Honduras	Colonial to pre-metric	General	Foot, 1/3 vara, 12 pulgada, 2003 reference
tercia	0.28	0.91	El Salvador	Colonial to pre-metric	General	Foot, 1/3 vara, 12 pulgada, 2003 reference
tercia	0.28	0.91	Nicaragua	Colonial to pre-metric	General	Foot, 1/3 vara, 12 pulgada, 2003 reference
tercia	0.278	0.913	Central America	Colonial to pre-metric	General	Foot, 1/3 vara, 12 pulgada, 2003 & 1891 references
tercia	0.2786	0.9141	Guatemala	Colonial to pre-metric	General	Foot, 1/3 vara, 12 pulgada, 2003 reference
tercia	0.2798	0.9179	Costa Rica	Colonial to pre-metric	General	Foot, 1/3 vara, 12 pulgada, 2003 reference
termin	0.0779	0.255	Algeria	Medieval to pre-met	General	1/8 pic, using dzera a torky basis, 2003 reference

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
that	12.75	41.83	Vietnam, Annam	Medieval to metric	General	2 sao, 2003 reference
that	14.63	48.00	Vietnam, Annam	Medieval to metric	General	Alternate source data
that	19.5	63.9	Annam	Pre-metric	Cloth	3 truông
thatkiy	1.283	4.210	Inca	Ancient to pre-colonial	General	basic distance, one pace
thebs	0.02181	0.07155	Egypt	Ancient to pre-metric	General	"Finger", 2003 reference, 2 digits
thi ly	500.0	1,640	Vietnam, Annam	Medieval to metric	General	1562.55 xich
thsan	46.080	151,179	China	Ancient to pre-metric	General	8 pòu, reported in 1966
thumb to forefinger	0.0540	0.177	Inca	Ancient to pre-colonial	General	Est'd
thumb's breadth	0.0295	0.0967	Jewish	Medieval to modern	General	1.16 inches
thuoc	0.487	1.60	Annam	Pre-metric	Buildings	10 tac
thuoc	0.650	2.13	Annam	Pre-metric	Cloth	10 tac
thuoc de ruong	0.470	1.54	Vietnam, Annam	Medieval to metric	General	2003 and other references
thước đo vai	0.644	2.11	Vietnam, Annam	Medieval to metric	Cloth	Cloth measure, 2003 reference
thước mộc	0.425	1.39	Vietnam, Annam	Medieval to metric	General	Varied 0.28–0.5 m, 2003 reference used

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
thước ta	0.425	1.39	Vietnam, Annam	Medieval to metric	General	Varied based on purpose, 10 tấc
thước vai	0.644	2.11	Vietnam, Annam	Medieval to metric	Cloth	Cloth measure, 2003 reference
tir	8230	27,000	Wales	Medieval to pre-metric	General	Mile, 1000 lands
tlalquahuitl	1.4	4.6	Aztec	Colonial to pre-metric	Land	Basic unit
tochka	0.0002540	0.0008333	Russia	Medieval to pre-metric	General	Point, 1/2800 arshin, 2003 reference
toesa	1.944	6.377	Spain	Medieval to pre-metric	General	
toesa	1.980	6.496	Portugal	Medieval to pre-metric	General	Toise, 6 pes, 1 4/5 varas
toise	1.800	5.905	Switzerland	Medieval to pre-metric	General	6 pied, 3 braches, 2003 reference
toise	1.949	6.394	France	Medieval to pre-metric	General	"Fathom", 3 long cubits, 2003 reference
toise	1.949	6.394	Haiti, Hayti	Colonial to pre-metric	General	1624/99 aune, 2003 reference
toise	3.600	11.81	Switzerland	Medieval to pre-metric	General	3 aunes, 1891 value
toise (metric)	2.000	6.561	France	1812-1844	General	6 pied (metric), 2003 reference
toise (nautical)	1.949	6.394	France	Medieval to pre-metric	Nautical	6 pied, nautical, 2003 reference

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
toise de l'Écritoire	1.956	6.417	France	Medieval to pre-metric	General	6 pied, fathom
toise du Châtelet or du Pérou	1.945	6.381	France	Medieval to pre-metric	General	Introduced 1668 as a correction, fathom
tonne	0.0261	0.0856	Norway	Medieval to pre-metric	General	Thumb or inch, Basic unit
tonne	0.02615	0.08579	Denmark	Medieval to pre-metric	General	Thumb, 1/12 fod, 2003 reference
tonni	0.0763	0.250	Morocco	Medieval to pre-metric	General	1/8 pic, 2003 reference
top	3.920	12.86	Somalia	Medieval to pre-metric	General	7 cubito, 2003 reference
topah	0.0880	0.289	Biblical, Talmudic	Ancient	General	Palm or hand breadth, 4 finger-breadths, avg, also reported as 0.74 m
topo	7.700	25.262	Inca	Ancient to pre-colonial	General	6000 thatkiys
totchka	0.0002540	0.0008333	Russia	Medieval to pre-metric	General	Point, 1/2800 arshin, 2003 reference
tou	144,000	472,435	China	Ancient to pre-metric	General	25 pou, reported in 1966
trabucco (typical)	3.083	10.11	Italy	Medieval to pre-metric	General	6 piede liprando, pre-1861, 2003 reference, regional variations
trabucco (typical)	3.083	10.11	Italy	Medieval to pre-metric	General	6 piede liprando, pre-1861, 2003 reference, regional variations

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
trait	0.000300	0.000984	Switzerland	Medieval to pre-metric	General	1/10 ligne, 1891 value
trayas	0.300	0.984	Persia, Iran	Ancient to pre-metric	General	Foot, 3 dva
Tripoli draa	0.671	2.20	Libya	Medieval or pre-metric	General	
troedfedd	0.914	3.00	Wales	Medieval to pre-metric	General	Pace, 3 feet
troetued	0.914	3.00	Wales	Medieval to pre-metric	General	Pace, 3 feet
troighid	0.250	0.820	Ireland	Medieval to pre-metric	General	Foot, basic unit
truong	4.250	13.94	Vietnam, Annam	Medieval to metric	General	2 ngũ or 10 thước, also defined as 10 Chinese chi (3.33 m) or 4 thước mộc (1.7 m), 2003 reference
truong	6.50	21.3	Annam	Pre-metric	Cloth	10 thucuc
trường xích	0.470	1.54	Vietnam, Annam	Medieval to metric	General	2003 and other references
trường xích	4.250	13.94	Vietnam, Annam	Medieval to metric	General	2 ngũ or 10 thước, also defined as 10 Chinese chi (3.33 m) or 4 thước mộc (1.7 m), 2003 reference
tsouen (official)	0.033	0.11	China	Ancient to pre-metric	General	1/1000 yan, 10 Fen, value reported 1891, similar in 1966
tsun (official)	0.033	0.11	China	Ancient to pre-metric	General	1/1000 yan, 10 Fen, value reported 1891, similar in 1966

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
túc	0.0425	0.139	Vietnam, Annam	Medieval to metric	General	10 phán, in some areas = 0.047 m, 2003 reference
tum (after 1855)	0.0297	0.0974	Sweden	Medieval to pre-metric	General	Thumb or inch, 1/10 fot after 1855
tum (pre-1855)	0.02474	0.08117	Sweden	Medieval to pre-metric	General	Thumb or inch, 12 linje before 1855, 2003 reference
tung	3.658	12.00	Indonesia	Colonial to Pre-Metric	General	Sumatra, 4 hailoh, appx 12 ft
tung	3.658	12.00	Sumatra	Pre-metric	General	4 hailoh, 1891 value
tupu	7700	25,262	Inca	Ancient to pre-colonial	General	6000 thatkiys
tussoo (Bombay)	0.0288	0.0944	India	Medieval to pre-metric	General	1891 reference
tuuma	0.0247	0.0812	Finland	Medieval to pre-metric	General	1/12 ft, width of thumb
tvärhand	0.09896	0.3247	Sweden	Medieval to pre-metric	General	Hand, 4 tum, 2003 reference
tvärhand	0.102	0.333	Sweden	Medieval to pre-metric	General	Hand, 4 inches
twip	0.0000176	0.0000579	United Kingdom	Medieval to pre-metric	General	1/20 point
tyr	8230	27,000	Wales	Medieval to pre-metric	General	Mile, 1000 lands
ubānu	0.0150	0.0492	Mesopotamia, Sumer, Akkadia	Ancient	General	finger, 1/30 cubit

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
uerr yeu	1.219	4.000	Wales	Medieval to pre-metric	General	Short yoke, 4 feet
uncia (common)	0.0245	0.0805	Rome	Ancient to pre-metric	General	inch, thumb, 1/2 pes, consistent with 2003 reference
uncia pollex (common)	0.0245	0.0805	Rome	Ancient to pre-metric	General	inch, thumb, 1/2 pes, consistent with 2003 reference
unglee (Bengal, Calcutta)	0.0190	0.0625	India	Medieval to pre-metric	General	Finger, 3 jows, 1891 reference, consistent with 1966 reference
unglee (Bombay)	0.01429	0.04687	India	Medieval to pre-metric	General	Finger, 3 jow, 2003 reference
uren	5000	16,404	Netherlands, Holland	Medieval to metric	General	5 myl, 2003 reference, post-metric?
urub	0.1143	0.3750	Persia, Iran	Ancient to pre-metric	General	2 gireh, 2003 reference
urumb (common)	0.09442	0.3098	Turkey	Medieval to pre-metric	General	3 parmack, 2003 reference
urup	0.0850	0.279	Ottoman Empire, Turkey	Ancient to medieval	General	2 kerrab
uš	360.0	1,181	Mesopotamia, Sumer, Akkadia	Ancient	General	cable
uŧtatu	0.00250	0.00820	Mesopotamia, Sumer, Akkadia	Ancient	General	grain, 1/180th cubit

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
vaaksa	0.148	0.487	Finland	Medieval to pre-metric	General	Span: tips of little finger to thumb extended
vakomitta	213.6	700.8	Finland	Medieval to pre-metric	General	Furrow's length in field, furlong
vara	0.800	2.62	Venezuela	Colonial to pre-metric	General	Yard, 3 pie, also reported as 0.835 m, 2003 reference
vara	0.8128	2.667	Honduras	Colonial to pre-metric	General	Yard, 3 terciá, 2003 reference
vara	0.83	2.7	El Salvador	Colonial to pre-metric	General	Yard, 3 terciá, 2003 reference
vara	0.83	2.7	Nicaragua	Colonial to Pre-Metric	General	Yard, 3 terciá, 2003 reference
vara	0.835	2.74	Central America	Colonial to pre-metric	General	Yard, 3 terciá, 2003 & 1891 references
vara	0.8359	2.742	Guatemala	Colonial to pre-metric	General	Yard, 3 terciá, 2003 reference
vara	0.8360	2.743	Peru	Colonial to pre-metric	General	Yard, 12 pie, 2003 reference, also reported as 0.847 m in 1891
vara	0.836	2.74	Chile	Colonial to pre-metric	General	Yard, 3 pie, 2003 reference, also reported as 0.847 m in 1891
vara	0.838	2.75	Mexico	Colonial to pre-metric	General	3 pie, 2003 reference, also reported as 0.836 m in 1891
vara	0.8393	2.754	Costa Rica	Colonial to pre-metric	General	Yard, 3 terciá, 2003 reference

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
vara	0.840	2.76	Colombia	Colonial to pre-metric	General	Yard, 3 pie, also reported as 0.800 m in 2003 reference
vara	0.848	2.78	Cuba	Colonial to pre-metric	General	
vara	0.8666	2.843	Argentina	Colonial to pre-metric	General	Yard, 3 pie, 2003 reference
vara	1.100	3.609	Brazil	Colonial to pre-metric	General	Yard, 3-1/3 pés, 40 pulgado, also reported as 1.111 m in 2003 reference
vara	1.100	3.609	Portugal	Medieval to pre-metric	General	Yard, 5 palmos, basic unit, reported as 1.099 m in 1891 (consistent), reported as 1.095 m in 2003 reference
vara (new)	0.8660	2.841	Paraguay	Colonial to pre-metric	General	Yard, 3 piede (new), 2003 reference
vara (old)	0.8386	2.751	Paraguay	Colonial to pre-metric	General	Yard, 3 piede (old), 2003 reference
vara (Spanish areas)	0.848	2.78	West Indies	Colonial to pre-metric	General	
vara (typical)	0.8359	2.742	Spain	Medieval to pre-metric	General	Yard, 2 codos, 3 pies, pre-1860, 2003 reference, literally rod or pole
veieu	2.438	8.000	Wales	Medieval to pre-metric	General	Field yoke or 2nd yoke, 8 feet
veredus	23.040	75,590	Arabia	Ancient to pre-metric	General	4 parasang, also reported as 19,300 m in 1891, consistent with 2003 reference
verschok	0.04445	0.1458	Russia	Medieval to pre-metric	General	Tip or top, 1/16 arshin, 1/4 chetvert, 1-3/4 duine, 2003 reference

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
vershok	0.04445	0.1458	Russia	Medieval to pre-metric	General	Tip or top, 1/16 arshin, 1/4 chetvert, 1-3/4 duime, 2003 reference
verst	1.067	3500	Russia	Medieval to pre-metric	General	Turn of a plough, 1500 arshin, 2003 reference
versta	1067	3500	Russia	Medieval to pre-metric	General	Turn of a plough, 1500 arshin, 2003 reference
verste	1067	3500	Latvia	Medieval or pre-metric	General	2003 reference
virsta	1069	3507	Finland	Medieval to pre-metric	General	Varied
vistati	0.229	0.751	India	Medieval to pre-metric	General	12 angula, "span", 1966 value
voet	0.296	0.972	Netherlands, Holland	Medieval to metric	General	Foot, Varied, avg from alternate references
voeten (Amsterdam)	0.2831	0.9288	Netherlands, Holland	Medieval to metric	General	Foot, 12 duime, 2003 reference, consistent with 1891 reference
vouah	1.922	6.306	Siam, Thailand	Pre-metric	General	2 kens, 1891 value
vyorst	1.067	3,500	Russia	Medieval to pre-metric	General	Turn of a plough, 1500 arshin, 2003 reference
wa	2.00	6.56	Thailand	Medieval to metric	General	Fathom, 2 ken, outstretched arms, 4 sok, 2003 reference
wah	2.00	6.56	Thailand	Medieval to metric	General	Fathom, 2 ken, outstretched arms, 4 sok, 2003 reference
wamani	232,000	761,146	Inca	Ancient to pre-colonial	General	30 topos

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
week's journey	330,540	1,084,436	Byzantine Empire	Ancient	General	
wegstunde	3710	12,172	Germany	Medieval to pre-metric	Roads	1 h travel, 1/2 meile, Swiss = 4880 m
werst	1067	3,500	Russia	Medieval to pre-metric	General	Turn of a plough, 1500 arshin, 2003 reference
wingspan	1620	5,315	Inca	Ancient to pre-colonial	General	Est'd
workshuh (Frankfort)	0.285	0.934	Germany	Medieval to pre-metric	General	Reported in Frankfort 1891
xiber	0.262	0.859	Malta	Medieval or pre-metric	General	
xilon	1.571	5.154	Egypt	Ancient to pre-metric	General	3 derah, 2003 reference
xylon	1.389	4.557	Greece	Ancient to pre-metric	General	4.5 pous, 2003 reference
yabiki	0.7575	2.485	Japan	Ancient to pre-metric	General	25 sun, 2003 reference
yan	32.0	105	China	Ancient to pre-metric	General	10 zhang, reported in 1966
yan (official)	33.34	109.4	China	Ancient to pre-metric	General	Base value fixed as of 1891
yard	0.9144	3.000	United States	Colonial to modern	General	3 ft

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
yard	0.9144	3.000	Ireland	Medieval to pre-metric	General	36 inches, pre-1824 value, 2003 reference
yard	0.914	3.00	United Kingdom	Medieval to pre-metric	General	3 feet, from nose to tip middle finger on outstretched arm
yard	0.9193	3.016	Scotland	Medieval to pre-metric	General	36 inches, 2003 reference
yard (Bengal)	0.914	3.00	India	Medieval to pre-metric	General	2 covids, also reported as 1.08 m in Patna, 1891 reference
yard (Bombay)	0.690	2.26	India	Medieval to pre-metric	General	24 tussoos, 1891 reference
yin	32.0	105	China	Ancient to pre-metric	General	10 zhang, reported in 1966
yoch	800	2625	Cambodia	Post-metric	General	20 sen, 2003 reference
yodjana	14,624	47,978	India	Medieval to pre-metric	General	2 gavyuti, 1966 value
yoduna			Sri Lanka	Medieval to pre-metric	Roads	Distance on roads, 4 gavu
yot	16,000	52,493	Thailand	Medieval to metric	General	League, 4 roeneng, 2003 reference
yote	16,000	52,493	Thailand	Medieval to metric	General	League, 4 roeneng, 2003 reference
zar	1.040	3.412	Persia, Iran	Ancient to pre-metric	General	1.137 gez, 2003 reference
zeret	0.264	0.866	Biblical, Talmudic	Ancient	General	Span, 3 palms, avg

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
zereth	0.267	0.875	Jewish	Medieval to Modern	General	10.5 inches
zereth	0.320	1.05	Persia, Iran	Ancient to pre-metric	General	Foot, 4 palms, reported 2003
zereth	0.3490	1.145	Egypt	Ancient to pre-metric	General	“Royal foot”, 2003 reference
zereth (common)	0.278	0.910	Hebrew	Ancient to pre-metric	General	“Foot”, 3 palms, 2003 reference
zereth (sacred)	0.320	1.05	Hebrew	Ancient to pre-metric	General	“Foot”, 3 palms, 2003 reference
zhāng	2.510	8.235	China	Ancient to pre-metric	General	10 chǐ, old value
zhāng	3.2	10.5	China	Ancient to pre-metric	General	2 pou, reported in 1966
zirai	0.758	2.49	Ottoman Empire, Turkey	Ancient to medieval	General	Agriculture, 2 ayak
zoll	0.0262	0.0858	Prussia	Pre-metric	General	12 linin, 1891 value
zoll	0.02634	0.08642	Austrian Empire	Pre-metric	Common	Inch, 12 linin, 2003 reference
zoll (Lubeck)	0.0240	0.0787	Germany	Medieval to pre-metric	General	1/12 fuss, 1891
zoll (new)	0.0250	0.0820	Switzerland	Medieval to pre-metric	General	Inch, 1/12 pied, 2003 reference
zoll (old)	0.0300	0.0984	Switzerland	Medieval to pre-metric	General	1/10 pied, 1891 value

(continued)

Table 4.6 (continued)

Unit (Qualifiers)	Equivalent meters	Equivalent feet, US	Region	Era	Common application	Notes
zoll (Prussian system)	0.02615	0.08581	Germany	Medieval to pre-metric	General	12 linien, 2003 reference
zoll (typical average)	0.0246	0.0807	Germany	Medieval to pre-metric	General	Inch, 1/10 through 1/12 ft, common 1/12
zoll (Wurtemberg)	0.0286	0.0939	Germany	Medieval to pre-metric	General	10 linien, reported in 1891

Conclusion

Length is one of the oldest (if not the oldest) measures used by humans. It is a measure of the physical size or extent of something along a line, which may be straight or curved. Length measurement has evolved from the simple use of the size of body parts or paces to gauge a distance to sophisticated methods based on light and time which enable measurements on both sub-atomic or astronomical scales. An extensive compilation of conversion factors for many ancient and historical length measurements has been provided.

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measurement" tt. "Old Irish units of measurement" uu. "Italian units of measurement" vv. "Japanese units of measurement" ww. "Latvian units of measurement" xx. "Libyan units of measurement" yy. "Luxembourgian units of measurement" zz. "Maltese units of measurement" aaa. "Malagasy units of measurement" bbb. "Mauritian units of measurement" ccc. "Ancient Mesopotamian units of measurement" ddd. "Mexican units of measurement" eee. "Moroccan units of measurement" fff. "Nicaraguan units of measurement" ggg. "Norwegian units of measurement" hhh. "Omani units of measurement" iii. "Ottoman units of measurement" jjj. "Paraguayan units of measurement" kkk. "Persian units of measurement" lll. "Peruvian units of measurement" mmm. "Philippine units of measurement" nnn. "Obsolete Polish units of measurement" ooo. "Portuguese customary units" ppp. "Puerto Rican units of measurement" qq. "Ancient Roman units of measurement" rrr. "Obsolete Russian units of measurement" sss. "Scottish units" tt. "Serbian units of measurement" uuu. "Seychellois units of measurement" vvv. "Singaporean units of measurement" www. "Slovak units of measurement" xxx. "Somalian units of measurement" yyy. "South African units of measurement" zzz. "Spanish customary units" aaaa. "Sri Lankan units of measurement" bbbb. "Swedish units of measurement" cccc. "Swiss units of measurement" dddd. "Syrian units of measurement" eeee. "Taiwanese units of measurement" ffff. "Tanzanian units of measurement" gggg. "Obsolete Tatar units of measurement" hhhh. "Thai units of measurement" iiii. "Tunisian units of measurement" jjjj. "Uruguayan units of measurement" kkkk. "Venezuelan units of measurement" llll. "Vietnamese units of measurement" mmmm. "Welsh units"

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Chapter 5

Historical Area



Abstract Area has been an historical, base measurement unit. Area units appropriate for everyday use were most commonly squares of linear measurement units, but have also been separately defined and had their own, unique unit names. This chapter describes the roots and approaches to area measurement and calculation which have been applied over the centuries. The development of the concepts of land ownership and agriculture that drove the definitions of larger area units is discussed. At the other end of the spectrum, the impact of science in driving other units of area measurement—from the very tiny to the very large—is reviewed. The development of methods for calculating areas through history from simple concepts involving circles, rectangles, and triangles to the integral calculus applied to complex areas is described. Extensive listings of conversion factors for historical units to modern area units are provided for various locales and eras in world history.

Introduction

Following length, one of the first types of measurements you might think of is area. For our purposes here, area is a quantity that describes the physical extent of a planar figure or surface extent of a three-dimensional shape. In its simplest forms, area is the surface encompassed in a rectangle or a circle. It can also describe the more complex areas encompassed by irregular shapes or three-dimensional surfaces, such as a cylinder. Some examples of areas are illustrated in Fig. 5.1.

Technically, area is just a linear combination or derivation of length or distance measurements. In the modern SI metric system, area is not considered a base unit; but in the historical context of this chapter, we will treat it as a fundamental or base unit. The justification for this is that throughout most of history, area was defined and treated separately as a unit, with its own set of unit names and relationships.

We will review a little history highlighting the importance of area measurement, along with a brief discussion of the methods for determining areas mathematically and by measurement. Tables of area conversion factors are provided by region/era and alphabetically.

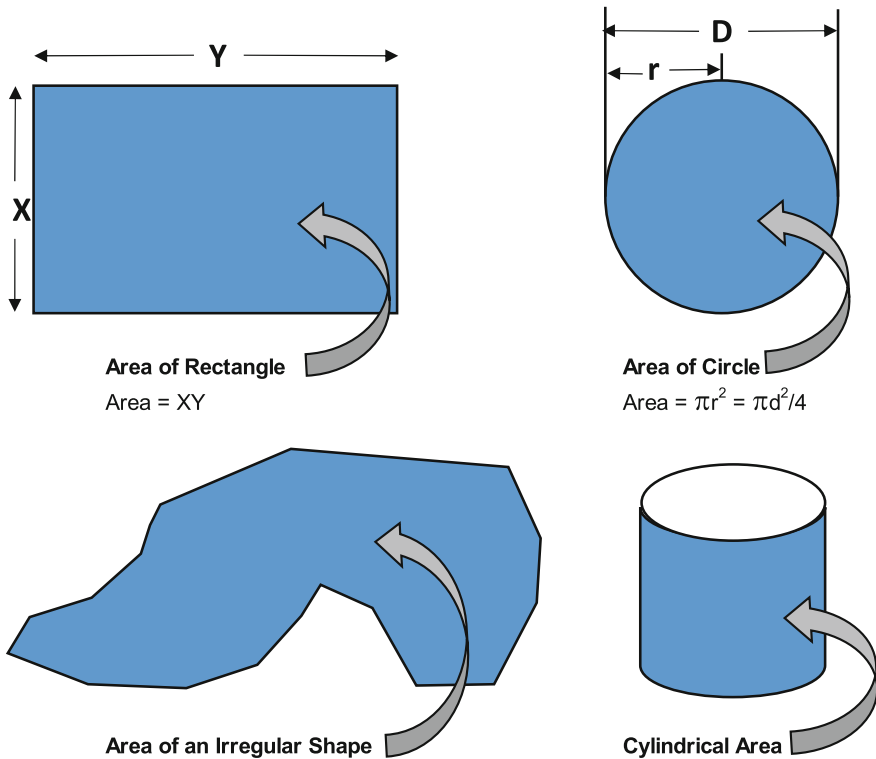


Fig. 5.1 Examples of areas for various shapes

Historical Development [1, 2, 6–8, 10, 11, 14–17, 19–23, 28–30, 32–35]

Historical Units [1, 2, 6–12, 14, 18–20, 26–31, 33, 34]

The determination of larger areas was probably not really important for early mankind with a largely nomadic lifestyle, but small areas would have had some importance. When agriculture and the concept of land ownership developed, however, the measurement of land area assumed a pivotal role. Area measurement units have been focused largely on land area for the purposes of rents, taxation, and administration. Land must be bought, sold, rented, and used in place and the units of area reflect this. Trading of land between civilizations is not conducted in the same way as other commodities.

Many early definitions of large areas were based on agricultural activities. For instance, in old England, an “acre” was originally the approximate amount of land a team of oxen could plow in one day. This varied considerably by location. Other land areas were defined by similar factors such as the amount of land tillable by one ox in a ploughing season (an oxgang, about $60.7 \times 10^4 \text{ m}^2/6.53 \times 10^5 \text{ sq ft}$) or

land tillable by a team of oxen in a ploughing season (a virgate, about $1.2 \times 10^5 \text{ m}^2/1.31 \times 10^6 \text{ sq ft}$) or land tillable by eight oxen in a ploughing season (a carucate, about $4.9 \times 10^5 \text{ m}^2/5.22 \times 10^6 \text{ sq ft}$). Figure 5.2 illustrates the old English definitions of area. Similar definitions for land areas were developed in many regions of the world.

In Scotland, in the Middle Ages, some land area measurements were related to rent and taxation [20]. The basic unit of land valuation was a dabach (with spelling variances, about $1.75 \times 10^6 \text{ m}^2/1.88 \times 10^7 \text{ sq ft}$, but varied greatly), which was approximately equal to four ploughgates. The dabach was also called an “ounce-land” when discussing values. At one time, this was the rent charged by the local ruler for use of the land in a period when all land was held by governing authorities. There were also farthinglands, pennylands, and so on, based on their rental value.

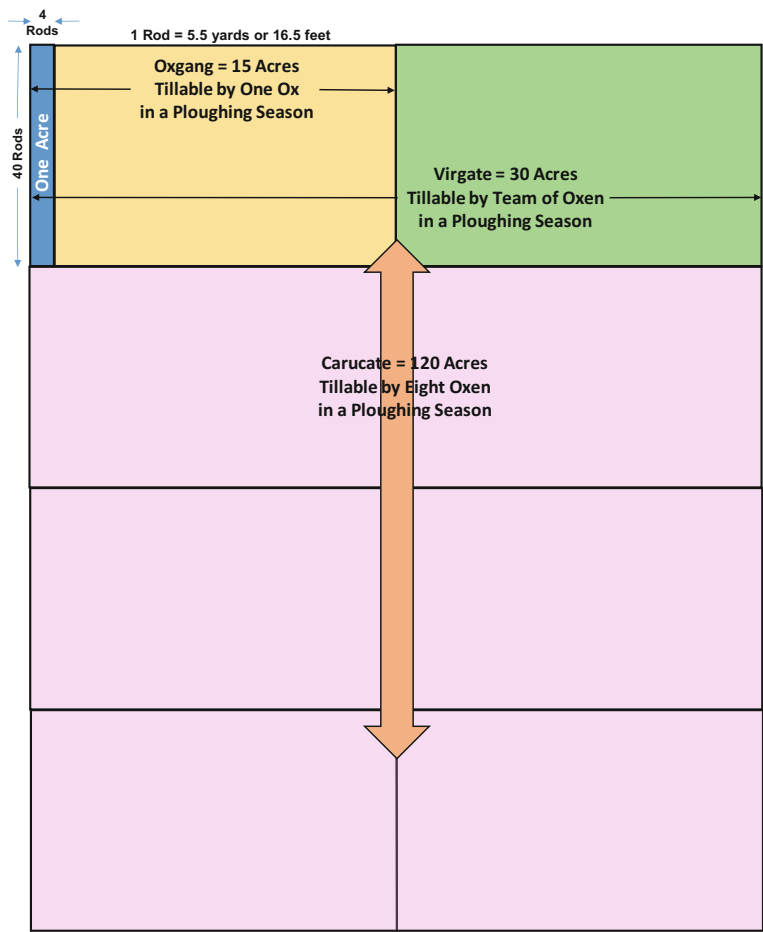


Fig. 5.2 English definitions of land areas beginning before 1300 AD [30, 33]

The actual rental or tax, however, varied considerably [20]. The quantity of land described by the terms varied widely also until the values were standardized.

In addition to the determination of rents, taxes, and values, it was important to rulers to know the extents or their realms. The same units were primarily used for this purpose as for agriculture and taxation.

Other area measures from the Middle Ages were related to fielding a fighting force. From this type of definition, we see the English unit of area called a “knight’s fee” ($1.82 \times 10^5 \text{ m}^2$ /about 0.7 square miles) [30]. This was the area of land (assumed to be under cultivation) that was required to field a fully-equipped knight in battle.

But this discussion has been centered around large areas of land, how about smaller areas like living areas or structures or cloth? In most instances, the smaller areas were quantified by the equivalents of simple squares of linear measures, such as square feet (English, $0.0929 \text{ m}^2/0.999 \text{ sq ft}$) or *pes quadratus* (Roman, $0.0876 \text{ m}^2/0.933 \text{ sq ft}$). A few societies had historically named units in the smaller range, such as *akaina* (Greek, $9.5 \text{ m}^2/102 \text{ sq ft}$), *brass* (India, $9.29 \text{ m}^2/100 \text{ sq ft}$), *go* (Japan, $0.331 \text{ m}^2/3.58 \text{ sq ft}$), *brick* (Mesopotamia, $0.05 \text{ m}^2/0.54 \text{ sq ft}$), or *phan* (Vietnam, $0.24 \text{ m}^2/2.54 \text{ sq ft}$).

Some societies, largely nomadic, did not really have a strong land ownership concept. This was true of many the Native American tribes. For these societies, the smaller units were more the norm and the areas were based on personal needs and individual measurements. There are few records of what these units were called, if they had names at all. An example of this approach can be found in the North American Shoshone tribe, where an individual might have a rawhide strap or rope that was knotted appropriately for that individual [21]. The rope or hide strap could be used, for example, to scribe a circle of the diameter needed to erect that person’s tepee. We would expect this sort of practical approach to be true of pre-agricultural times in many areas of the world.

Prior to the development of the metric system in France, large areas were measured in arpents, really shorthand for square arpents (about 5100 square meters/1.3 acres). The remnants of this system can still be seen along the lower Mississippi River in the old plantation locations of the southern United States [17]. The plantations were built on land granted by the French Crown in the 1700s with a standard parcel being 1 arpent by 10 arpents. Many people were granted more area and shapes might vary, but the general unit for the sizes of the grants was the arpent. In old plantation ownership maps of the lower Mississippi, you can still see the results of this system—many long narrow strips that were the plantations. The plantation homes that still exist are roughly 1, 2, 3, or another whole number multiple of an arpent apart bordering the river.

When the metric system was developed in France in the late 1700s, the developers followed previous precedent and used area as a named base measurement unit. The unit was the “are”, defined as 100 square meters (1076 sq ft). The “are” itself has since fallen out of use, but many areas are still measured in hectares (100 ares, about 2.5 acres) [11].

Now what about even smaller areas? One of the smallest named areas is the “barn” which is 10^{-28} square meters (1.5×10^{-25} sq in) [7]. This unit was originally used in nuclear physics to define the approximate area of a uranium nucleus when attempting to hit the nucleus with a particle. The term began in World War II as an attempt to hide secret nuclear research and is derived from the colloquial expression describing poor marksmanship: “you couldn’t hit the broad side of a barn”. As if this wasn’t colloquial enough, there are terms for even smaller areas that are seldom used today:

- Outhouse, 10^{-34} m² (1.5×10^{-31} sq in)
- Shed, 10^{-52} m² (1.5×10^{-49} sq in)

Who says physicists don’t have a sense of humor?

Comparison of Historical Unit Magnitudes

Figure 5.3 provides a comparison of the relative magnitudes of several traditional units in terms of square meters for selected civilizations through history. The named area units tend to concentrate in the larger sizes, above one square meter (10.76 sq ft) from an historical perspective.

The data used in developing this comparison were derived from multiple sources listed in the “References” section; hence, the reference numbers are not repeated here.

Development of Area Calculation [15, 16, 19]

Naming and defining an area unit can be relatively easy compared to actually calculating the area. These calculations have their own history, which is interesting in its own right.

Among the earliest area calculations understood by mathematicians is the area inside a circle. Hippocrates of Chios demonstrated that the area of a circle was proportional to the square of the diameter in the 5th century BC. Eudoxus of Cnidus recognized that the area was also proportional to the square of the radius. Neither mathematician defined the constant of proportionality, which we now call “pi” ($\pi = 3.14159\dots$). Archimedes, in the 3rd century BC, used Euclidean geometry to relate the area of a circle to the area of a right triangle with a height equal to the radius and base equal to the circumference. He was able to estimate the value of π . The nature of π itself waited until the 18th century to be better understood.

The calculations of the areas for a triangle and a rectangle were discovered independently in several civilizations, including Mesopotamian, Greek, Indian, and Chinese, dating before the third millennium BC. The mathematics were well understood by the time Euclid wrote his “Elements” around the beginning of the 3rd century BC.

Calculation of areas for polygons and irregular shapes was furthered by the development and understanding of Cartesian coordinates in the 17th century by René Descartes. This enabled surveyors to accurately calculate land areas knowing the vertex locations of any polygon using the surveyors' or shoelace formula.

Using the surveyors' formula for calculating an area involves:

1. Plotting the vertices of the desired area on a Cartesian ($x - y$) grid and numbering the vertices in order around the shape starting with zero.
2. Starting at one of the vertices and proceeding either clockwise or counter-clockwise, the area formula is:

$$A = \frac{1}{2} \sum_{i=0}^{n-1} (x_i y_{i+1} - x_{i+1} y_i) \quad (5.1)$$

where

- n = number of vertices enclosing area (counting starting vertex twice)
- x, y = Cartesian coordinates for each of the vertices
- i = number assigned to each vertex

A simple example can serve to illustrate the surveyors' formula. Suppose we have Fig. 5.4 plotted on a Cartesian grid. In this case, the measurement units are arbitrary for purposes of illustration. What is the area?

We assign each vertex a number using the coordinate system. We will start at the origin, $(0,0)$, for the calculation and proceed counter-clockwise around the figure. The number of sides, n , is 6.

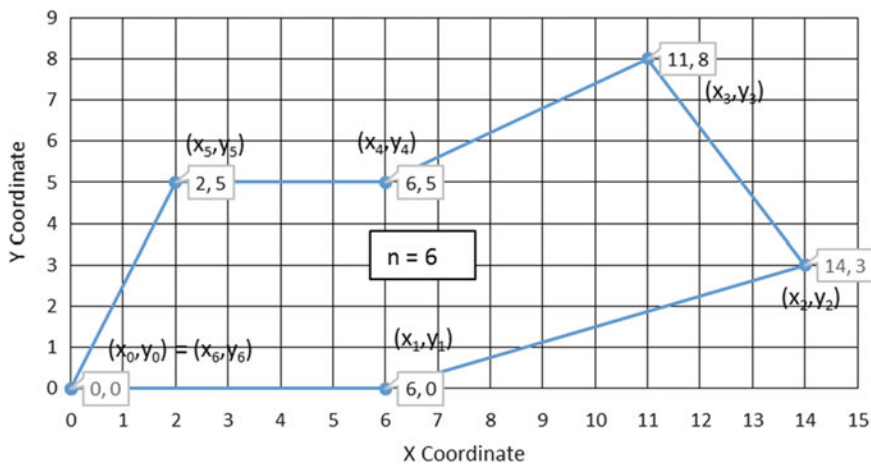


Fig. 5.4 An example application of the surveyors' formula

The x_iy_{i+1} and $x_{i+1}y_i$ are calculated for $i = 0$ to $n - 1$ of this irregular polygon. We then calculate the differences $(x_iy_{i+1} - x_{i+1}y_i)$ and add them up. The area is half the sum. Table 5.1 shows the calculation in a spreadsheet format. Modern spreadsheet software makes this a simple and fast procedure once you know the coordinates of the vertices. The total area is 62 units. This is much faster than breaking the area up into simple polygons and calculating the area of each. It is still used for surveying.

The late 17th century saw the development of integral calculus, which enabled the calculation of more complicated types of areas, like elliptical and complex surface areas. Calculations were no longer restricted to linear forms or simple curves. This would be a useful for land surveying along a river, for instance, where the banks are not straight lines or line segments.

In the calculus, area is defined by the integral:

$$A = \int_a^b f(x)dx$$

where

$f(x)$ is the function describing the shape
 a and b are the boundaries of the area

For an example of area calculation using calculus, consider Fig. 5.5.

We could break the area up into small pieces, calculate the areas for all the pieces and then add them together, but suppose we can determine an equation that describes the upper and lower limits for the area. In our case here, the equation for the upper boundary is $y = 0.0125x^3 - 0.4081x^2 + 3.8669x - 0.242$ and for the lower bound the equation is $y = -0.0344x^2 + 0.673x + 0.1161$. The difference between these two boundaries from $a = 4$ to $b = 16$ is the area of interest.

Table 5.1 An example calculation using the surveyors’ formula

i	x_iy_{i+1}	$x_{i+1}y_i$	Difference
0	0	0	0
1	18	0	18
2	112	33	79
3	55	48	7
4	30	10	20
5	0	0	0
		Sum	124
Area = 1/2 Sum			62

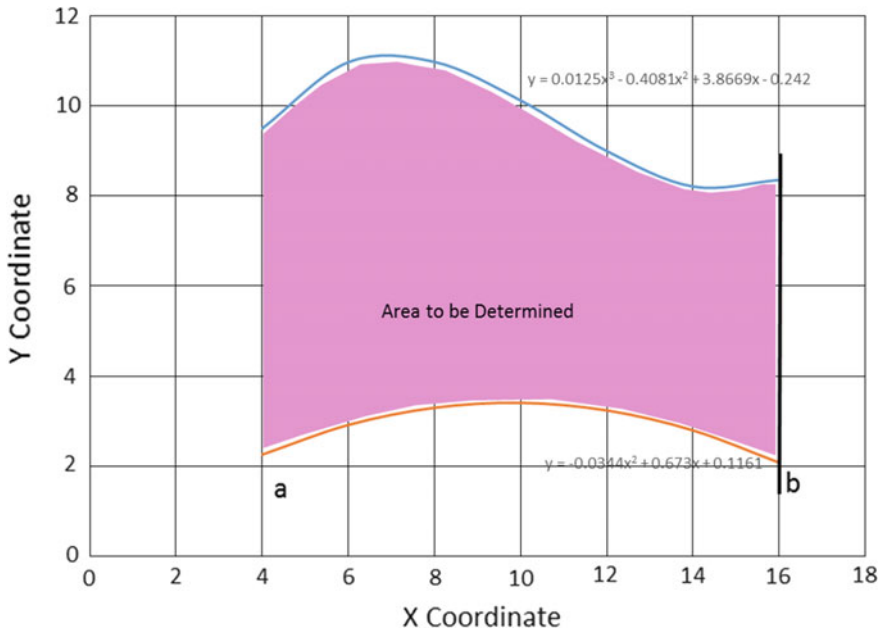


Fig. 5.5 Example of area calculation by integration

So the integral of the upper boundary between a and b is:

$$\begin{aligned}
 A_{\text{upper}} &= \int_4^{16} [0.0125x^3 - 0.4081x^2 + 3.8669x - 0.242] dx \\
 &= \left[\left(\frac{0.0125}{4} \right) x^4 - \left(\frac{0.4081}{3} \right) x^3 + \left(\frac{3.8669}{2} \right) x^2 - 0.242x + C \right]_4^{16} \\
 &= 116.6
 \end{aligned}$$

The integral of the lower boundary between a and b is:

$$\begin{aligned}
 A_{\text{lower}} &= \int_4^{16} [-0.0344x^2 + 0.673x - 0.1161] dx \\
 &= \left[-\left(\frac{0.0344}{3} \right) x^3 + \left(\frac{0.673}{2} \right) x^2 - 0.1161x + C \right]_4^{16} \\
 &= 33.1
 \end{aligned}$$

The desired area is the difference between a and b.

$$A = 116.6 - 33.1 = 83.5 \text{ units.}$$

Note that we can neglect the constant that comes from integration because each of the integrals is relative to $y = 0$ or the x -axis.

Additional calculation tools allow the calculation of 3-dimensional surfaces and so on. The ability to calculate these more complex areas has developed primarily in the past three centuries.

The calculations discussed so far can all be applied when the dimensions of a two or three dimensional area or object are known; but what about three dimensional objects which cannot be simply measured, like the convoluted surface area of a solid catalyst or activated carbon particle, at the atomic or molecular level. These types of measurements have become important in the past several decades as knowledge and applications of surface chemistry have developed.

It is not feasible (or at least not easy) to take measurements of the complicated, convoluted surfaces within a particle or surface. To accomplish this type of measurement, special techniques are employed. For instance, these methods may include determining the amount of a specific gas with a known-sized atom or molecule that can be adsorbed as a monoatomic layer onto the surface per gram of material, say. Many materials that appear otherwise monolithic actually have huge surface areas on an atomic scale. A zeolyte (silica) may have a surface area of 300–450 square meters per gram ($1.4\text{--}2.2 \times 10^6$ sq ft/lb), for instance.

We won't discuss the history of the measurement of surface at the atomic or molecular level, except to note that it is another realm in the range of area measurements applied today.

So the tools developed over the centuries allow us to accurately calculate or determine all kinds of areas. When we need to convert units within the full range of areas measurements, we can still apply the same conversion factors and approaches applied for other types of units.

Historical Area Conversion Factors [1–14, 16, 18, 21–34]

We offer here two types of area conversion tables:

- Table 5.2 provides area conversions for different locations, regions, eras, and historical civilizations listed alphabetically by location in both metric and U.S. Customary units.
- Table 5.3 provides the same area conversion options as Table 5.2, except that the conversions are all listed alphabetically, without regard to location or era.

The data used in compiling these tables included virtually all of the sources listed in the “References” section; hence, the reference numbers are not repeated here.

Table 5.2 Historical area measurement conversion factors by location and era. Refer to references section for data sources

Region and unit	Equivalent square meters	Equivalent square feet, US	Notes	Era
Afghanistan				Colonial to modern times
biswa	100	1076	1/20 jerib	
jerib	400	4304	1/5 ha	
ha	2000	21,520	Approx	
American (See United States)				
Annam (See Vietnam)				Pre-metric
Arabia (Local variations, changes over time, ancient values)				Ancient
square cubit (hachemic)	0.4096	4.407	2003 reference	
qasaba (Achir)	14.75	158.7	36 sq cubits, 2003 reference	
qamha	61.44	661.1	150 sq cubits, 2003 reference	
habbah	81.92	881.5	200 sq cubits, 2003 reference	
cafiz	147.5	1587	10 qasaba, 2003 reference	
qirat	245.8	2645	3 habbah, 2003 reference	
daneq	983.0	10,580	4 qirat, 2003 reference	
djarib	1475	15,870	6 qirat, 2003 reference	
feddan	5898	63,460	4 djarib, 2003 reference	
Argentina				Colonial to pre-metric
square bara	0.699	7.52		
Austrian Empire (Squares of linear measure commonly used)				Pre-metric
square klafter	3.597	38.70	2003 reference	
metze	1918	20,640	2003 reference	
strich	2878	30,970	1/2 Austrian joch	
joch	5755	61,920	3 metzen, 1600 sq klafter, 57,600 sq fuss, 2003 reference	
Belgium (Used units of France, early metric system adoption, pre-metric)				1816
arpent	42.21	454.2	100 square perches, 2003 reference	
Biblical and Talmudic (approx)				Ancient
searah	0.00000873	0.0000939	Hair, 1/36 geris	
adashah	0.0000349	0.000376	Lentils, 1/9 geris	
geris	0.000314	0.00338	Split bean, circle of 20 mm dia	

(continued)

Table 5.2 (continued)

Region and unit	Equivalent square meters	Equivalent square feet, US	Notes	Era
amah al amah	0.281	3.02	Sq cubit, 2304 to 3318 sq cm, avg	
beit rova	29.30	315.3	Space for sowing, 1/4 kav, avg	
beit seah	703	7560	Space for sowing a seah, avg	
semed	1822	19,600	Area ploughed by 2 oxen in 1 day, 6480 sq cubits	
yoke	1822	19,600	Area ploughed by 2 oxen in 1 day, 6480 sq cubits	
beit kor	21,082	226,800	Space for sowing a kor, avg	
Brazil (pre 1862, varied)				Colonial to pre-metric
tarefa	3500	37,660	3000 to 4000 sq meters, avg	
salamis	4538	48,820	1/8 alqueire	
alqueire	36,300	390,600	Varied, 2.42 e4 to 4.84 e4, avg	
Byzantine Empire				Ancient
pous	0.095	1.0	1 square Greek foot	
square pous	0.095	1.0	1 square Greek foot	
square plethron	991.0	10,660	10,000 square pous, lit. turning, varied from 900 to 1900 sq meters, effectively an acre	
stremma	991.0	10,660	10,000 square pous, lit. turning, varied from 900 to 1900 sq meters, effectively an acre	
modios zeugarion	2973	31,990	Varied greatly, 30,000 square pous, modios also smaller units of 100–250 per zeugarion.	
Canada				Pre-metric
General: pre-metric conversion (1970s), Canada used English Imperial system. Occasionally some French units used as noted below				
arpent (land)	3419	36,790		
Central America (See also individual countries, generally Spanish Castilian units used, average values)				Colonial to pre-metric
square vara	0.6879	7.402		
manzana	6879	74,020	10,000 sq vara, 2003 reference	
caballiera	440,256	4,737,000	64 manzana, 2003 reference	
China				Ancient to pre-metric
hao	0.6144	6.611		
kung	2.560	27.55	4.17 hao	
square pou	2.560	27.55	4.17 hao	
lyi	6.144	66.11	10 hao	
fen	61.44	661.1	10 lyi	

(continued)

Table 5.2 (continued)

Region and unit	Equivalent square meters	Equivalent square feet, US	Notes	Era
kish	153.6	1653	25 lyi	
meou	614.4	6611	Chinese acre, 4 kish	
mū	614.4	6611	Chinese acre, 4 kish	
king	6144	66,110	10 mū	
ching	61,440	661,100	100 mū	
qūn	61,440	661,100	100 mū	
Colombia (pre 1854)				Colonial to pre-metric
square vara	0.640	6.89	1920s	
fanegada	6400	68,900	10,000 sq vara	
Cornwall (Pre-metric, some available data are contradictory)				Medieval or pre-metric
Cornish stick	7.5	81	3 square yards	
Cornish land rod	15.1	162	1/2 lace	
Cornish lorgh	15.1	162	1/2 lace	
Cornish lease	30.1	324	4 sticks	
Cornish lace	30.1	324	18 ft square	
Cornish rod	4818	51,840	160 lace	
Cornish farthing	121,400	1,307,000	1/4 Cornish acre, 16 or <u>30</u> statute acres	
Cornish ferling	121,400	1,307,000	1/4 Cornish acre, 16 or <u>30</u> statute acres	
Cornish acre	485,700	5,226,000	120 statute acres or could be 64, 8 score lease per other references	
Cornish Knight's fee	1,943,000	20,900,000	4 Cornish acres	
Costa Rica (See also Central America, generally Spanish Castilian units used)				Colonial to pre-metric
square vara	0.7044	7.580	2003 reference	
manzana	7044	75,800	10,000 sq vara, 2003 reference	
caballera	450,800	4,851,000	64 manzana, 2003 reference	
Cuba (mostly Spanish basis)				Colonial to pre-metric
cordele	414.2	4457	1/324 caballeria, 2003 reference	
fanega	11,180	120,330	27 cordele, 1/12 caballeria, 2003 reference	
caballeria	134,200	1,444,000	12 fanega, 1920s value, consistent with 2003 reference	
caballeria Cubana	134,200	1,444,000	12 fanega, 1920s value, consistent with 2003 reference	

(continued)

Table 5.2 (continued)

Region and unit	Equivalent square meters	Equivalent square feet, US	Notes	Era
Cypress (pre 1972, mostly English units used)				Medieval or pre-metric
square pace	0.836	9.00	2003 reference	
donum	1338	14,400	Turkish acre, 1600 square Turkish paces, 2003 reference	
scala	1338	14,400	Turkish acre, 1600 square Turkish paces, 2003 reference	
Czechoslovakia (pre 1876, some carried into 20th Century)				Medieval or pre-metric
merice	2000	21,520	Bohemia, 2003 reference	
korec	2878	30,970	1.439 merice, 2003 reference	
mira	2878	30,970	1.439 merice, 2003 reference	
strych	2878	30,970	1.439 merice, 2003 reference	
jitro	5756	61,940	2 korec, 2003 reference	
lan	172,700	1,858,000	60 korec, 2003 reference	
Denmark				Pre-metric
sq aln	0.394	4.241		
square ruthe	14.18	152.6	144 sq fod, 2003 reference	
penge	81.49	876.9	5.75 square ruthe, 2003 reference	
album	295.4	3179	3-5/8 penge, 2003 reference	
fjerdingar	886.3	9536	3 album, 2003 reference	
skiepper	3545	38,140	4 fjerdingar, 2003 reference	
töndeland	5516	59,350	14,000 sq aln, consistent with 2003 reference	
tonde	28,360	305,200	8 skiepper, 2003 reference	
pflug	907,500	9,765,000	32 tonde, 2003 reference	
Egypt (Ancient and pre-metric, local variations, different values reported by various sources)				Ancient to pre-metric
square derah	0.2741	2.949	1966 value	
square derah	0.323	3.47	Pre 1891	
square derah meimari	0.563	6.05		
heseb	6.900	74.24	1/2 remen, 25 sq cubits	
sahme	7.293	78.47	1/576 feddan, pre 1891, consistent with 2003 reference	
square cassaba	12.60	135.6	Pre-1891	
remen	13.70	147.4	Shoulder, 1/4 ta, 50 sq cubits	
pekeis	27.41	294.9	100 sq derah, 1966 value	
ta	27.60	297.0	100 sq cubits = 1/100 setat	
khet	52.50	564.9	100 sq cubits	
sû	171.3	1843	625 sq derah, 1966 value	

(continued)

Table 5.2 (continued)

Region and unit	Equivalent square meters	Equivalent square feet, US	Notes	Era
kérat	175.0	1883	1/24 feddan, 24 sahme, pre 1891, consistent with 2003 reference	
kirat kamel	175.0	1883	1/24 feddan, 24 sahme, pre 1891, consistent with 2003 reference	
ten	274.1	2949	10 pekeis, 1966 value	
S3	345.0	3712	1/8 st3t, 1250 sq cubits	
hsb	689.0	7414	1/4 st3t, 2500 sq cubits	
rema	1370	14,740	5 ten, 1966 value	
rmn	1378	14,830	1/2 st3t, 5000 sq cubits	
aurure	2741	29,490	2 rema, 1966 value	
aroura	2756	29,660	10,000 sq cubits	
setat	2756	29,660	10,000 sq cubits	
setjat	2756	29,660	10,000 sq cubits	
feddan	4201	45,200	Pre 1891, 333-1/3 sq cassabas, 24 kirat kamel, consistent with 2003 reference	
feddan masri	4201	45,200	Pre 1891, 333-1/3 sq cassabas, 24 kirat kamel, consistent with 2003 reference	
setta	27,410	294,900	10 aurure, 1966 value	
h3-t3	27,560	296,600	1000 of land, 10 arouras, 100,000 sq cubits	
kha	27,560	296,600	1000 of land, 10 arouras, 100,000 sq cubits	
El Salvador (See also Central America, generally Spanish Castilian units used)				Colonial to pre-metric
square vara	0.6879	7.402	2003 reference	
manzana	6879	74,020	10,000 sq vara, 2003 reference	
caballiera	440,300	4,737,000	64 manzana, 2003 reference	
Estonia				
lofstelle (Reval/Tallinn region)	1855	19,960		
lofstelle (Livonian region)	3710	39,920		
tonnland (Livonian region)	5194	55,890		
tonnland (Reval/Tallinn region)	5463	58,780		
Finland (pre 1861)				Medieval or pre-metric
square jalka	0.0882	0.948		
square kyynärä	0.353	3.79	basic unit for taxation areas	
kannunala	88.15	948.5	1000 square jalka	

(continued)

Table 5.2 (continued)

Region and unit	Equivalent square meters	Equivalent square feet, US	Notes	Era
kapanala	154.0	1657	1/32 tynnyrinala, area of a field that could be sown with one bushel grain	
äyrytisenmaa	1384	14,890	3926 square kyynärä, area that grows grain worth one äyrytinen for taxation	
panninala	2464	26,510	16 kapanala or 1/2 tynnyrinala, area that could be sown with one pannin grain	
äyrimaa	4152	44,680	3 äyrytisenmaa, 11,777 square kyynärä, area growing grain worth one äyri for taxation	
tynnyrinala	4937	53,120	Area that could be sown with one barrel of grain	
penninginmaa	173,000	1,861,000	490,790 square kyynärä, area growing grain worth one penninki for taxation	
France (pre-1795 plus values reported in 1891, many variations with sample of ranges provided, Paris basis where applicable)				Medieval to pre-metric
pied carré (de Paris)	0.1055	1.135	Square foot, pre-1795, 2003 reference	
centare	1.000	10.76	1891 value, metric basis	
sq meter	1.000	10.76	1891 value, metric basis	
toise carrée (de Paris)	3.798	40.87	36 pied carré, pre-1795, 2003 reference	
perche (de Paris)	34.18	367.8	9 toise carrée (de Paris), pre-1795, 2003 reference	
perche (Eaux et Forêts)	51.06	549.4	484 pied carré, pre-1795, 2003 reference	
are	100.0	1076	=Square 10 meters on a side, metric basis, 1891 value	
vergé (de Paris)	855	9200	1/4 arpent (de Paris), 25 perches, old, 2003 reference	
vergé (Eaux et Forêts)	1277	13,740	1/4 arpent (Eaux et Forêts), 25 perches, old, 2003 reference	
journal (Bordeaux)	3190	34,320	31.9 ares, variation, 2003 reference	
arpent (de Paris)	3418	36,780	100 perche (de Paris), pre-1795, 2003 reference	
journal	4000	43,040	Typical value, old, 2003 reference	
journal (Saint-Brieuc)	4000	43,040	40 ares, variation, 2003 reference	
journal (Mamers)	4400	47,340	44 ares, variation, 2003 reference	
journal (Nord de la Mayenne)	5000	53,800	50 ares, variation, 2003 reference	
journal (Domfront)	5000	53,800	50 ares, variation, 2003 reference	

(continued)

Table 5.2 (continued)

Region and unit	Equivalent square meters	Equivalent square feet, US	Notes	Era
arpent (Eaux et Forêts)	5106	54,940	100 perche (Eaux et Forêts), pre-1795, 2003 reference	
acre (de Paris)	5469	58,850	160 perches (de Paris), old, 2003 reference	
acre (Eaux et Forêts)	8170	87,910	160 perches (Eaux et Forêts), old, 2003 reference	
hectare	10,000	107,600	100 are, 10,000 sq m, 1891 value, metric basis	
Germany (Squares of linear measure used primarily, other units indicated, significant local variation)				Medieval to Metric
sq fuss (Hesse-Darmstadt)	0.0625	0.673	Reported in 1891	
sq fuss (Saxony)	0.0802	0.863	Reported in 1891	
sq landfuss (Hesse-Cassel)	0.0812	0.873	Reported in 1891	
sq fuss (Hamburg)	0.0821	0.883	Reported in 1891	
sq fuss (Württemberg)	0.0821	0.883	1891 value	
sq feldfuss (Frankfort)	0.127	1.36	Reported in 1891	
sq ruthen (Baden)	9.0	97	Reported in 1891	
sq ruthen (Hanover)	14.6	157	Reported in 1891	
sq ruthen (Brunswick)	20.9	225	Reported in 1891	
sq ruthen (Bremen)	21.4	230	Reported in 1891	
ar (post Metric)	100.0	1076	Same as French, 1891	
viertel (Hesse-Darmstadt)	625	6730	Reported in 1891	
vorling (Hanover)	873	9390	60 sq ruthen, 1891	
vierte (Baden)	900	9690	100 sq ruthen, reported 1891	
drohn (Hanover)	1746	18,790	Reported in 1891	
morgen (Frankfort)	2025	21,790	16,000 sq feldfuss, 1891	
acker (Hesse-Cassel)	2387	25,680	29,400 sq landfuss, 1891	
morgen (Hesse-Darmstadt)	2500	26,900	4 viertel, 40,000 sq fuss, 1891 value	
morgen (Brunswick)	2512	27,030	120 sq ruthen, 30,720 sq fuss, 1891	
morgen (Bremen)	2567	27,620	120 sq ruthen, 30,720 sq fuss, 1891	
morgen of Calenberg (Hanover)	2619	28,180	2 vorling, 1.5 drohn, 1891	

(continued)

Table 5.2 (continued)

Region and unit	Equivalent square meters	Equivalent square feet, US	Notes	Era
morgen (Werttemberg)	3152	33,920	38,400 sq fuss, 1891 value	
morgen, juchart, tagewerk (Bavaria)	3406	36,650	Reported in 1891, 40,000 sq fuss, divided into tenths for smaller units	
morgen (Baden)	3601	38,740	4 virtel, reported 1891	
morgen (Saxony)	6158	66,260	Reported in 1891, 76,800 sq fuss	
morgen (Hamburg)	9653	103,900	117,600 sq fuss, 1891	
hectar (post metric)	10,000	107,600	Same as French, 1891	
Greece (Ancient)				Ancient
pous	0.0950	1.02	sq foot	
hexapodes	3.420	36.80	36 podes	
akaina	9.500	102.2	100 podes	
hemiektos	79.20	852.2	833-1/3 podes	
hektos	158.3	1703	1666-2/3 podes, 1/6 plethron	
aroura	237.5	2556	2500 podes	
plethron	950.0	10,220	10,000 podes	
Greece (pre 1836, sizes varied by region)				Medieval or pre-metric
stemma	1000	10,760	Greek acre, 10,000 square Greek feet	
hectare	1700	18,290	varied by region from 900 to 2500 sq m	
Guatemala (See also Central America, generally Spanish Castilian units used)				Colonial to pre-metric
square vara	0.6987	7.518	2003 reference	
manzana	6987	75,180	10,000 sq vara, 2003 reference	
caballiera	447,200	4,812,000	64 manzana, 2003 reference	
Haiti (mixed heritages)				Colonial to pre-metric
carreau	1292	13,910	Pre-metric conversion, 2003 reference	
Honduras (See also Central America, generally Spanish Castilian units used)				Colonial to pre-metric
square vara	0.6606	7.109	2003 reference	
manzana	6606	71,090	10,000 sq vara, 2003 reference	
caballiera	422,800	4,549,000	64 manzana, 2003 reference	
Hungary (several units used, pre-1876)				Medieval or pre-metric
hold	431.6	4644	2003 reference	

(continued)

Table 5.2 (continued)

Region and unit	Equivalent square meters	Equivalent square feet, US	Notes	Era
joch	431.6	4644	2003 reference	
square meile	6,978,000	75,090,000	2003 reference	
Iceland (many units used, pre 1907)				Medieval or pre-metric
ferpumlungur	0.0006841	0.007361	1/5184 ferfaðmur, 2003 reference	
ferfet	0.09851	1.060	1/36 ferfaðmur, 2003 reference	
feralin	0.3940	4.239	1/9 ferfaðmur, 2003 reference	
ferfaðmur	3.546	38.15	9 feralin, 2003 reference	
tundagslatla	3192	34,350	900 ferfaðmur, 2003 reference	
engjateigur	5674	61,050	1600 ferfaðmur, 2003 reference	
fermila	56,740	610,500	10,000 engjateigur, 2003 reference	
India (pre Akbar Systems—avg)				Medieval or pre-metric
chahar	0.02962	0.3187	2003 reference	
sq covid (Bengal)	0.209	2.25	Reported 1891 value	
square guz (Bombay)	0.4703	5.060	2003 reference	
square guz (Calcutta)	0.8372	9.009	Variation, unit buildup same proportions as Bombay, 2003 reference	
chattack (Bombay)	2.352	25.30	5 sq guz, 2003 reference	
Sq karam	2.81	30.2		
chattack (Bengal)	4.18	45.0	20 sq covid, 1891	
Sq kan	8.43	90.7	1/3 marla	
brass	9.290	100.0	100 sq ft for building work	
ground	20.3	218	2003 reference	
sq covid (Madras)	22.3	240	Reported 1891 value	
marla	25.3	272	3 sq kans, also reported as 9 sq karams, different sources report different values	
cottah (Bombay)	37.62	404.8	16 chattack, 2003 reference	
biswa	42.2	454		
cottah (Bengal)	66.9	720	16 chattack, 1891	
katha	67.2	723		
guntha	101.2	1089	33 ft × 33 ft	
nalli	202	2170		
maoney (Madras)	223	2400	Reported 1891 value	
kani	307.5	3309	2003 reference	

(continued)

Table 5.2 (continued)

Region and unit	Equivalent square meters	Equivalent square feet, US	Notes	Era
kanal	506.0	5445	20 marlas	
cawnie	540	5810	2003 reference	
biggah (Bombay)	752.5	8097	20 cottah, 2003 reference	
biga	843	9070	Different source	
tenab (Bombay)	1176	12,650	500 chattack, 2003 reference	
biggah (Bengal)	1338	14,400	20 cottah, 1891	
bhigha	1345	14,470		
begah	2024	21,780	4 kanals	
biggah (Bombay)	2458	26,450	Reported 1891 value	
ghamaon	4048	43,560	"Acre", 8 kanals, also reported as 9 kanals + 12 marlas = 4858 sq m	
ghumaon	4048	43,560	"Acre", 8 kanals, also reported as 9 kanals + 12 marlas = 4858 sq m	
quilla	4048	43,560	"Acre", 8 kanals, also reported as 9 kanals + 12 marlas = 4858 sq m	
cassenev (Carnatic)	4066	43,750	Reported 1891 value	
cawney (Carnatic)	4066	43,750	Reported 1891 value	
cassenev (Madras)	5351	57,580	24 maoney, 240 sq covid, 1891 value	
cawney (Madras)	5351	57,580	24 maoney, 240 sq covid, 1891 value	
Indonesia (Local Units, Normally Dutch)				pre-metric
bahoe	7097	76,360		
bouw	7097	76,360		
Ireland (pre 1800, some later units)				Medieval or pre-metric
square forraigh	1296	13,950		
achar	4047	43,550	acre, adopted from Norman invasions	
Irish acre	6555	70,530	7840 square yards	
tir-cumaile	93,310	1,004,000	23 Imperial acres, land of 3 cows	
seisrech	485,600	5,225,000	plough-land, 120 achar	
baile	5,828,000	62,710,000	townland, 1440 achar, still used	
tuath	17,480,000	188,100,000	4320 achar, originally designated a petty kingdom	
cow's grass			Pre 1800, land reqd by 1 cow	
Italy				Medieval or pre-metric
sq palma (Naples)	0.0686	0.738	1891 value	
sq piede (Modena)	0.274	2.94	1891 value	

(continued)

Table 5.2 (continued)

Region and unit	Equivalent square meters	Equivalent square feet, US	Notes	Era
sq braccio (Tuscany)	0.341	3.67	1891 value	
sq palmi (Venice)	1.00	10.8	1891 value	
sq cavezzo (Modena)	9.85	106	36 sq piede, 1891 value	
sq pertica (Parma)	10.6	114	1891 value	
sq pertica (Piedmont)	38.0	409	In Sardinia, 1891 value	
tavola (Modena)	39.4	424	4 sq cavezzi, 1891 value	
tavola (Parma)	42.3	455	1891 value	
are (Venetian Lombardy)	100	1080	100 sq palmi, 1891 value	
tornatura (Venetian Lombardy)	100	1080	100 sq palmi, 1891 value	
staro (Parma)	508	5460	12 tavola, 1891 value	
campo (Venetian Lombardy)	2785	29,960	1891 value	
biolea (Modena)	2837	30,520	72 tavole, 1891 value	
biolca (Parma)	3047	32,780	6 stari, 288 sq pertica, 1891 value	
moggio (Naples)	3474	37,380	50,625 sq palmi, 1891 value	
giornata (Piedmont)	3801	40,900	In Sardinia, 1891 value, 100 sq pertica	
saccato (Tuscany)	5621	60,490	16,500 braccia, 1891 value	
Japan				Medieval or pre-metric
shaku	0.0331	0.356	1/100 tsubo	
go	0.3306	3.557	1/10 tsubo, 2003 reference	
gō	0.3306	3.557	1/10 tsubo, 2003 reference	
jo	1.653	17.79	1/2 tsubo, size of one tatami mat for room size	
bu (agriculture)	3.306	35.57	One square ken, 2003 reference	
tsubo (construction)	3.306	35.57	One square ken, 2003 reference	
se	99.17	1067	30 tsubo, 2003 reference	
tan	991.7	10,670	300 tsubo, 10 se, 2003 reference	
chō	9917	106,700	3000 tsubo, 10 tan, 2003 reference	
chō	9917	106,700	3000 tsubo, 10 tan, 2003 reference	
square ri	15,420,000	165,900,000	15,552 tan, 2003 reference	

(continued)

Table 5.2 (continued)

Region and unit	Equivalent square meters	Equivalent square feet, US	Notes	Era
Korea				Medieval or pre-metric
pyeong	3.306	35.57		
Latvia				Medieval or pre-metric
kapp	148.6	1599	2003 reference	
loofstelle	3716	39,980	25 kapp, 2003 reference	
pourvete	92,900	39,980	25 kapp, 2003 reference	
pourvette	2,322,500	39,980	25 kapp, 2003 reference	
tonnestelle	5202	55,980	35 kapp, 2003 reference	
Libya				Medieval or pre-metric
square pic	0.4624	4.975	2003 reference	
square pik	0.4624	4.975	2003 reference	
denum	739.8	7961	1600 sq pik, 2003 reference	
jabia	832.3	8956	1800 sq pik, 2003 reference	
Malacca (See also Singapore)				1891
orlong	5351	57,580		
Malta				Medieval or pre-metric
pulzier kwadru	0.000477	0.00513	1/144 xiber kwadru	
fitel kwadru	0.0172	0.185	1/4 xiber kwadru	
xiber kwadru	0.0686	0.738		
qasba kwadru	4.391	47.25	64 xiber kwadru	
Mesopotamia (Sumerian/Akkadian—Mesopotamian designations used)				Ancient
brick	0.0500	0.538	brick, basic unit	
gin ₂	1.000	10.76	shekel, 1/60 garden	
siqlu	1.000	10.76	shekel, 1/60 garden	
musaru	36.00	387.4	garden or brick garden, 720 bricks	
sar	36.00	387.4	garden or brick garden, 720 bricks	
uzalak	900.0	9684	quarter-field, 5 gardens	
ubu	1800	19,370	half-field, 10 gardens	
upu	1800	19,370	half-field, 10 gardens	
iku	3600	38,740	field, 100 gardens	
bur	64,800	697,200	estate, 1800 gardens	
buru	64,800	697,200	estate, 1800 gardens	
Mexico				Colonial to pre-metric
square vara	0.7022	7.556	2003 reference	

(continued)

Table 5.2 (continued)

Region and unit	Equivalent square meters	Equivalent square feet, US	Notes	Era
fanega	35,700	384,000	50,784 sq vara, 2003 reference	
caballeria	428,000	4,610,000	12 fanega, 2003 reference	
labor	642,000	6,910,000	18 fanega, 2003 reference	
sitio	17,560,000	188,900,000	27.35 labor, 2003 reference	
Native America (Shoshone tribe, many other similar measures)				pre-metric
General: Areas were defined by function. Teepee ring area was based on length of poles used to build it				
Netherlands (Holland, Dutch)				Medieval to Metric
square Rijnlandse feet	0.0986	1.06		
Rijnlandse voet	0.0986	1.06	AKA square voet, square foot, local variation	
Rijnlandse roede	14.19	152.7	AKA square roede, 144 Rijnland square feet	
roede (average)	22.40	241.0	varied from 11.7 to 33.1 square meters	
are	100.0	1076	Reported in 1891, post Metric	
vierkante roede	100.0	1076	Reported in 1891, post Metric	
Rijnlandse hont	1419	15,270	100 square Rijnland rods	
morgen	8516	91,630	amount of land that could be ploughed in a morning (hence "morgen"), varied considerably by location (8516 to 10,700 sq meters), 150 to 900 roede in a morgen	
Rijnlandse morgen	8516	91,630	6 Rijnland honts	
bunder	10,000	107,600	Reported in 1891, post Metric	
hectare	10,000	107,600	Reported in 1891, post Metric	
Nicaragua (Pre-1910, see also Central America, generally Spanish Castilian units used)				Colonial to pre-metric
square vara	0.6987	7.518	2003 reference	
manzana	6987	75,180	10,000 sq vara, 2003 reference	
caballiera	447,200	4,812,000	64 manzana, 2003 reference	
Norway				Medieval or pre-metric
sq fot	0.0877	0.943	1891 value	
kvadrat rode	9.840	105.9	square stang	

(continued)

Table 5.2 (continued)

Region and unit	Equivalent square meters	Equivalent square feet, US	Notes	Era
kappland	153	1650	1891 value	
fjerdings	614	6600	4 kappland, 1891 value	
mal	984.0	10,590	100 kvartrat rode, also reported as 1000 sq meters in 2003 reference—probably post-metric value	
spannland	2455	26,420	4 fjerding, 1891 value	
tonneland	3936	42,350	Barrel of land, 4 mal	
tøndeland	4910	52,830	2 spannland, 56,000 sq fot, 1891 value	
tunna	4910	52,830	2 spannland, 56,000 sq fot, 1891 value	
Ottoman Empire (See also Turkey)				Ancient
eski donum	919.0	9888	dunam (old)	
buyuk donum	2720	29,270	dunam (big)	
Paraguay (Mostly Spanish, pre 1890)				Colonial to pre-metric
lifio (old)	70.32	756.6	100 sq vara, 2003 reference	
lino (old)	70.32	756.6	100 sq vara, 2003 reference	
lifio (new)	75.00	807.0	100 sq vara, 2003 reference	
lino (new)	75.00	807.0	100 sq vara, 2003 reference	
Persia or Iran (Assyrio-Chaldean-Persian system, local variations, 2003 reference)				2003
square zereth	0.1024	1.102	2003 reference	
gar	14.75	158.7	144 square zereth, 1 square qasab, 2003 reference	
ten	147.5	1587	10 gar, 2003 reference	
gan	1475	15,870	10 ten, 2003 reference	
gur	14,750	158,700	10 gan, 2003 reference	
Peru (Orig Spanish Castilian, pre 1869)				Colonial to pre-metric
topo	2706	29,120	3872 sq vara, 2003 reference	
fanegada	3145	33,840	4500 sq vara, 2003 reference	
Philippines				pre-metric
loan	279.5	3007	1/10 belita, pre 1860, consistent with 2003 reference	
balita	2795	30,070	Pre 1860, consistent with 2003 reference	
belita	2795	30,070	Pre 1860, consistent with 2003 reference	

(continued)

Table 5.2 (continued)

Region and unit	Equivalent square meters	Equivalent square feet, US	Notes	Era
quignon	27,950	300,700	10 balita, pre 1860, consistent with 2003 reference	
Poland				Medieval or pre-metric
square stopa	0.08294	0.8924	2003 reference	
lokiec	0.355	3.82	1/506,250 wloka	
square pret	18.66	200.8	2003 reference	
kopanka	19.95	214.7	1/9000 wloka	
pret	199.5	2147	1/900 wloka	
sznur	1995	21,470	1/90 wloka	
morga	5985	64,400	1/30 wloka, 300 sq pret, also reported as 5599 sq meters in 2003	
staje	13,500	145,300	Appx 1.2–1.5 hectares, used avg	
lan	179,500	1,932,000	Lesser lan, 30 morga	
wloka	179,500	1,932,000	Also reported as 167,962 sq meters in 2003, 30 morga	
lan	258,600	2,782,000	Greater lan, 43.2 morgs, used avg	
zreb	275,000	2,959,000	Appx 20–35 hectares	
Portugal				1891
sq vara	1.19	12.9	1891 value, reported as 1.199 sq m in 2003 reference	
ferrado	725.4	7805	2003 reference	
geira	5782	62,210	4840 sq varas, 1891 value, reported as 5803 in 2003 reference	
Prussia (See also Germany)				1891
sq ruthe	14.2	153		
morgen	2553	27,470	180 sq ruten	
Puerto Rico or Porto Rico (several units used, pre-1860, see also West Indies)				Colonial to pre-metric
cuerdo	1572	16,920	2250 sq vara	
Roman Empire or Roman States (Ancient to 1891)				Ancient to 1891
sq architect's palmi	0.0499	0.537	1891 value	
pes quadratus (common)	0.08667	0.933	Square foot, 1 sq pes, consistent with 2003 reference	
quadratus pes (common)	0.08667	0.933	Square foot, 1 sq pes, consistent with 2003 reference	

(continued)

Table 5.2 (continued)

Region and unit	Equivalent square meters	Equivalent square feet, US	Notes	Era
quadratus pes (legal, 1st)	0.08773	0.944	2003 reference	
dimidium scrupulum	4.380	47.13	50 sq pedes	
scrupulum (common)	8.667	93.26	100 sq pedes, consistent with 2003 reference	
decempedia quadrata (common)	8.667	93.26	100 sq pedes, consistent with 2003 reference	
duo scrupula	17.50	188.3	200 sq pedes	
short actus (common)	34.67	373.0	400 quadrus pes, consistent with 2003 reference	
sextula	35.00	376.6	400 sq pedes	
actus simplex	42.10	453.0	4 × 120 sq pedes	
sicilicus	52.60	566.0	600 sq pedes	
semiuncia	105.0	1130	1200 sq pedes	
uncia	210.0	2260	2400 sq pedes	
clima (common)	312.0	3357	3600 sq pedes, consistent with 2003 reference	
sextans	421.0	4530	4800 sq pedes	
porca	473.0	5089	180 × 30 Roman feet	
quadrans	631.0	6790	7200 sq pedes	
triens	841.0	9049	9600 sq pedes	
versum (common)	866.7	9326	10,000 quadratus pes, consistent with 2003 reference	
quincunx	1051	11,310	12,000 sq pedes	
actus (common)	1248	13,430	14,400 quadratus pes, “Roman acre”, consistent with 2003 reference	
actus quadratus	1262	13,580	14,400 sq pedes (or sq Roman feet), Roman acre	
semis	1262	13,580	14,400 sq pedes (or sq Roman feet), Roman acre	
acnua	1262	13,580	14,400 sq pedes (or sq Roman feet), Roman acre	
arpennis	1262	13,580	14,400 sq pedes (or sq Roman feet), Roman acre	
septunx	1472	15,840	16,800 sq pedes	
bes	1682	18,100	19,200 sq pedes	
dodrans	1893	20,370	21,600 sq pedes	
dextans	2103	22,630	24,000 sq pedes	
deunx	2313	24,890	26,400 sq pedes	

(continued)

Table 5.2 (continued)

Region and unit	Equivalent square meters	Equivalent square feet, US	Notes	Era
jugerum (common)	2496	26,860	28,800 quadratus pes, consistent with 2003 reference	
jugerum	2523	27,150	28,800 sq pedes	
heredium (common)	4992	53,710	2 jugera, consistent with 2003 reference	
heredium	5047	54,310	2 jugera	
rubbio	18,480	198,800	1891 value, 370,300 sq architect's palmi	
centurium (common)	499,200	5,371,000	200 jugera, consistent with 2003 reference	
centuria	504,600	5,429,000	200 jugera, formerly 100 jugera	
saltus (common)	1,996,800	21,490,000	800 jugera, consistent with 2003 reference	
saltus	2,018,400	21,720,000	800 jugera	
Russia				Medieval to pre-metric
sazhen	4.55	49.0	1891 value	
sq sachine	4.55	49.0	1891 value	
kazionnaya desiatina (official)	10,930	117,600	2400 sq sazhen, 1891 value	
deciatine (official)	10,930	117,600	2400 sq sazhen, 1891 value	
vladelcheskaya desiatina (proprietor's)	14,570	156,700	3200 sq sazhen, 4/3 official desiatina	
Salvador (See El Salvador)				Colonial to pre-metric
San Salvador (See El Salvador)				Colonial to pre-metric
Scotland (many conflicting systems, different names for similar units)				Medieval to pre-metric
square inch	0.00,068	0.0073		
square foot	0.09391	1.010	2003 reference	
square ell	0.884	9.51		
square fall	32.14	345.8	2003 reference	
square faw	32.14	345.8	2003 reference	
farthing-land	230	2480	1/4 pennyland, western region, taxes & rents, estimated at 1/480 daugh, value based on 1886 reference	
half penny-land	460	4950	1/2 pennyland, western region, taxes & rents, estimated at 1/960 daugh, value based on 1886 reference	

(continued)

Table 5.2 (continued)

Region and unit	Equivalent square meters	Equivalent square feet, US	Notes	Era
peighinn	910	9800	Basic unit, western region, taxes & rents, estimated at 1/1920 daugh, value based on 1886 reference	
pennyland	910	9800	Basic unit, western region, taxes & rents, estimated at 1/1920 daugh, value based on 1886 reference	
rod	1286	13,830	2003 reference	
rood	1286	13,830	2003 reference	
cota ban	3600	38,740	Estimate based on 1886 reference	
fourpennyland	3600	38,740	Estimate based on 1886 reference	
groatland	3600	38,740	Estimate based on 1886 reference	
acre	5142	55,330	Scottish acre, 2003 reference	
tir-unga	18,000	193,700	Ounceland, 20 pennylands, western region, taxes & rents	
ceathramh	29,000	312,000	Quarterland, variable value, supposed to be 8 fourpennylands, estimate based on 1886 reference	
damh-imir	55,000	592,000	Oxgang, appx, area an ox could plough in one year, agriculture, eastern region, 1886 value range estimate 6-19 acres, recent estimate was about 20 acres	
nook	103,000	1,110,000	2003 reference	
marg-fhearann	144,000	1,550,000	Markland, 8 ouncelands, western region, taxes & rents, varied	
ploughgate	437,000	4,700,000	Appx, 8 oxgangs, agriculture, eastern region, 1886 value estimate	
dabhach or dabach	1,748,000	18,810,000	Daugh, appx, 4 ploughgates, agriculture, eastern region, 1886 value estimate	
davach	1,748,000	18,810,000	Daugh, appx, 4 ploughgates, agriculture, eastern region, 1886 value estimate	
daach	1,748,000	18,810,000	Daugh, appx, 4 ploughgates, agriculture, eastern region, 1886 value estimate	
davoch	1,748,000	18,810,000	Daugh, appx, 4 ploughgates, agriculture, eastern region, 1886 value estimate	
Somalia (varied)				Medieval or pre-metric
darat	8000	86,000		
South Africa (Used Dutch, English)				pre-metric
morgen	85,000	915,000		

(continued)

Table 5.2 (continued)

Region and unit	Equivalent square meters	Equivalent square feet, US	Notes	Era
Spain				Medieval or pre-metric
square vara	0.6987	7.518	Pre-1860, 2003 reference	
cuartilla	17.47	188.0	25 sq vara, pre-1860, 2003 reference	
calemin	536.6	5774	768 sq vara, pre-1860, 2003 reference	
cahizada	2059	22,150	Pre-1860, 2003 reference	
aranzada	4472	48,120	256 cuartilla, pre-1860, 2003 reference	
fanegada	6440	69,290	12 calemin, pre-1860, 2003 reference	
yugada	322,000	3,465,000	50 fanegada, pre-1860, 2003 reference	
labor	698,700	7,518,000	1 million sq varas	
league	17,470,000	188,000,000	25 million sq vara	
Sweden				Medieval or pre-metric
kvardrattum	0.0006122	0.006587	Square inch, 2003 reference	
kvardrafot	0.08815	0.9485	Square foot, 144 kvardrattum, 1891 value, consistent with 2003 reference	
square fot	0.08815	0.9485	Square foot, 144 kvardrattum, 1891 value, consistent with 2003 reference	
kannaland	88.15	948.5	1000 sq fot	
kappland	154.3	1660	1750 kvardrafot, 2003 reference	
sq ref	880	9470	1891 value, 10,000 sq fot	
fjärdingsland	2468	26,560	16 kappland, 2003 reference	
tunnland	4936	53,120	2 fjärdingsland, 2003 reference	
spannland	9873	106,200	2 tunnland, 2003 reference	
pundland	19,750	212,500	2 spannland, 2003 reference	
kvadratmil	114,200,000	1,229,000,000	Sq mil, 36 million sq favnar (1739 value)	
Switzerland				Medieval or pre-metric
pieds square	36.0	387	1891 value	
arpent	14,400	154,900	400 square pied, 1891 value	
Taiwan (Formosa)				pre-metric
pheng	3.306	35.57		
bo	99.20	1067	30 pheng	
kah	9699	104,400	2934 pheng	
le	48,500	521,800	5 kah, 14,670 pheng	

(continued)

Table 5.2 (continued)

Region and unit	Equivalent square meters	Equivalent square feet, US	Notes	Era
Tatar				Medieval or pre-metric
quadrat sajın	4.552	48.98	1 sajın square	
carib	1821	19,590	3600 square arsin	
cirek	5463	58,780	1/2 disatina	
disatina	10,930	117,600	2400 quadrat sajın	
quarat caqrim	1,138,000	12,240,000	1 square caqrim	
Thailand				pre-metric
tarang wa	4.0	43	square wa, 2003 reference	
ngan	400	4300	100 tarang wa, 2003 reference	
rai	1600	17,200	4 ngan, 2003 reference	
Turkey (Old units, 2003 reference)				pre- and post-metric
square pic	0.5706	6.140	2003 reference	
donum (old)	913.0	9824	1600 sq pics, pre-1933, original Ottoman unit, area a team of oxen could plow in one day, standardized at 1210 sq yards, 2003 reference	
dunum (old)	913.0	9824	1600 sq pics, pre-1933, original Ottoman unit, area a team of oxen could plow in one day, standardized at 1210 sq yards, 2003 reference	
donum (new)	1000	10,760	Defined 1939, post-metric-metric, 2003 reference	
dunum (new)	1000	10,760	Defined 1939, post-metric-metric, 2003 reference	
djeril	10,000	107,600	Post metric, 2003 reference	
United Kingdom (Includes England, Great Britain, and former possessions, customary units, major local variations and changes over time, smaller areas measured as squares of linear measure)				Medieval to pre-metric
sq inch	0.000645	0.00694		
sq foot	0.0929	0.999	144 sq inches	
sq yard	0.836	9.00	9 sq feet	
sq rod	25.3	272	30.25 sq yards	
perch	25.3	272	1 sq rod	
sq chain	405	4350	16 sq rods	
rood	1011	10,880	1/4 acre, sometimes called an acre in ancient times, 1 furlong $\times$ 1 rod = 40 sq rods	

(continued)

Table 5.2 (continued)

Region and unit	Equivalent square meters	Equivalent square feet, US	Notes	Era
acre	4047	43,550	1 chain $\times$ 1 furlong, varied by country, England = 4840 sq yds, Scotland = 6150 sq yds, Ireland = 7840 sq yds, Saxon unit for “field”, as much area as could be plowed in 1 day, 4 roods	
bovate	60,650	652,600	land one ox can plow in a year, $\sim$ 15 acres or 1/8 carucate	
oxgang	60,650	652,600	land one ox can plow in a year, $\sim$ 15 acres or 1/8 carucate	
virgate	121,300	1,305,000	Land two oxen can plow in a year, $\sim$ 30 acres	
yard land	121,300	1,305,000	Land two oxen can plow in a year, $\sim$ 30 acres	
hide	363,900	3,916,000	4 to 8 bovates, based on yield, land able to support one household for ag or taxes, used 6 as basis	
carucate	485,200	5,221,000	Area that can be plowed by an 8 oxen team in 1 year, $\sim$ 120 acres	
carve	485,200	5,221,000	Area that can be plowed by an 8 oxen team in 1 year, $\sim$ 120 acres	
plough	485,200	5,221,000	Area that can be plowed by an 8 oxen team in 1 year, $\sim$ 120 acres	
knight’s fee	1,820,000	19,580,000	5 hides, land required to field one fully-equipped soldier	
sq mile	2,590,000	27,870,000	640 acres	
hundred	36,390,000	391,600,000	100 hides, administration grouping, $\sim$ 9000 acres or 14 sq miles	
wapentake	36,390,000	391,600,000	100 hides, administration grouping, $\sim$ 9000 acres or 14 sq miles	
United States (Customary units, based on English units before 1824)				Colonial to Modern
circular mil	5.067E-10	5.452E-09		
square inch	0.0006451	0.006942		
square foot	0.09290	1.000	144 square inches	
sq yard	0.8361	9.000	1891 value, still current	
square rod	25.29	272.2		
are	100.0	1076	1891 value, metric unit	
square chain	404.7	4354	4356 sq survey ft	
square surveyor’s chain (Old)	929.0	9996	Old value, obsolete	
Ramsden’s chain (Old)	929.0	9996	Old value, obsolete	

(continued)

Table 5.2 (continued)

Region and unit	Equivalent square meters	Equivalent square feet, US	Notes	Era
acre	4047.0	43,540	43,560 sq survey ft, 10 sq chains	
hectare	10,000	107,600	1891 value, metric unit	
section	2,590,000	27,870,000	640 acres, 1 sq mile	
survey township	93,240,000	1,003,000,000	36 sections, 4 square leagues	
Vietnam (Also known as Annam 1891, many units based on squares of builder's long measures)				pre-metric
khau	0.0160	0.172	1891 reference	
ghe	0.160	1.72	1891 reference	
o	0.160	1.72	1891 reference	
phan	0.240	2.58	1891 reference	
tac	2.400	25.82	10 phan, traditional, 3.3135 m ² Annamite, 1891 value	
thon	2.400	25.82	10 phan, traditional, 3.3135 m ² Annamite, 1891 value	
than	4.000	43.04	1 ngu square, 1891 value	
square ngu	5.523	59.42	2003 reference	
thuroc	24.00	258.2	10 tac, traditional, 33 m ² Annamite, 1891 value	
xich	24.00	258.2	10 tac, traditional, 33 m ² Annamite, 1891 value	
thuoc	33.14	356.5	6 sq ngu, 2003 reference	
mieng	36.00	387.4	3 ngu squared, 1891 value	
cao (old)	360.0	3874	10 mieng, traditional, 497 m ² Annamite, 1891 value	
sao (old)	360.0	3874	10 mieng, traditional, 497 m ² Annamite, 1891 value	
cao (new)	497.0	5348	15 thuoc, 2003 reference	
sao (new)	497.0	5348	15 thuoc, 2003 reference	
mau (old)	3600	38,740	10 sao, traditional, 4970 m ² Annamite, 1891 value	
mau (new)	4970	53,480	10 sao, 2003 reference	
quo	9941	107,000	2 mau, 2003 reference	
Wales (Appx, ignores southern measures, see also England)				Medieval or pre-metric
erw	1715	18,450	Welsh acre, ambiguous, used avg	
homestead	6860	73,810	4 acres	

(continued)

Table 5.2 (continued)

Region and unit	Equivalent square meters	Equivalent square feet, US	Notes	Era
shareland	27,440	295,300	4 homesteads	
holding	109,760	1,181,000	4 sharelands	
township	439,040	4,724,000	4 holdings	
manor	1,756,160	18,900,000	4 townships	
commote	21,950,000	236,200,000	12.5 manors, varied by region	
cantref	43,900,000	472,400,000	2 commotes, varied by region	
West Indies				Colonial to 1891
Spanish units used in: Cuba, Puerto Rico, Isle of Pines, Curacao, and Culebra				
French units used in: Martinique, Deseada, Guadeloupe, Marie Galante, Le Saintes, and part of St. Martin				
Swedish units used in St. Bartholomew				
Dutch (Netherlands) units used in: Part of St. Martin, Buen Ayre, Oruba (Aruba), and Tortuga				
Danish units used in: Santa Cruz, St. Thomas, and St. Jan or St. John, but also use English standards for length				
English units used in: Jamaica, Barbados, Grenada, Santa Lucia, St. Vincent, Trinidad, Tobago, Antigua, Bermuda, Dominica, Nevis, Montserrat, St. Kitt's, Tortola, Bahamas, and minor islands. Units are essentially US Customary				
Independent units used in: Haiti and Santo Domingo				
Yugoslavia (Pre-metric units, pre-1873 primarily, 2003 reference)				Pre-metric
square stopa	0.09986	1.074	2003 reference	
square kvat	3.595	38.68	36 sq stopa, 2003 reference	
donum	699.0	7521	7000 sq stopa, 2003 reference	
dunum	699.0	7521	7000 sq stopa, 2003 reference	
motyka	798.8	8596	8000 sq stopa, 2003 reference	
raliza	2496	26,860	25,000 sq stopa, 2003 reference	
dan oranja	3592	38,650	35,970 sq stopa, 2003 reference	
lanatz	5752	61,890	1600 sq kvat, 2003 reference	
Miscellaneous Old Units				pre-metric
square	9.290	100.0	100 sq feet	

Table 5.3 Alphabetical table of historical area measurement conversion factors. Refer to References section for data sources

Unit	Equivalent sq. meters	Equivalent sq. feet, US	Region	Era	Common application	Notes
achar	4047	43,550	Ireland	Medieval to pre-metric	Land	acre, adopted from Norman invasions
acker (Hesse-Cassel)	2387	25,680	Germany	Medieval to metric	Land	29,400 sq landfuss, 1891
acuna	1262	13,580	Roman Empire	Ancient	Land	14,400 sq pedes (or sq Roman feet), Roman acre
acre	4047	43,550	United Kingdom	Medieval to pre-metric	Land	1 chain $\times$ 1 furlong, varied by country, England = 4840 sq yds, Scotland = 6150 sq yds, Ireland = 7840 sq yds, Saxon unit for "field", as much area as could be plowed in 1 day, 4 roods
acre	4047.0	43,540	United States	Colonial to modern	Land	43,560 sq survey ft, 10 sq chains
acre	5142	55,330	Scotland	Medieval to pre-metric	Land	Scottish acre, 2003 reference
acre (de Paris)	5469	58,850	France	Medieval to pre-metric	Land	160 perches (de Paris), old, 2003 reference
acre (Eaux et Forêts)	8170	87,910	France	Medieval to pre-metric	Land	160 perches (Eaux et Forêts), old, 2003 reference
actus (common)	1248	13,430	Roman Empire	Ancient	Land	14,400 quadratus pes, "Roman acre", consistent with 2003 reference
actus quadratus	1262	13,580	Roman Empire	Ancient	Land	14,400 sq pedes (or sq Roman feet), Roman acre
actus simplex	42.10	453.0	Roman Empire	Ancient	General	4 $\times$ 120 sq pedes

(continued)

Table 5.3 (continued)

Unit	Equivalent sq. meters	Equivalent sq. feet, US	Region	Era	Common application	Notes
adashah	3.491E-05	3.76E-04	Biblical, Talmudic	Ancient	General	Lentils, 1/9 girls
akaina	9.500	102.2	Greece	Ancient	General	100 podes
album	295.4	3179	Denmark	Pre-metric	Land	3-5/8 penge, 2003 reference
alqueire	36,300	390,600	Brazil	Colonial to pre-metric	Land	Varied, 2.42e4 to 4.84 e4, avg
amah al amah	0.281	3.02	Biblical, Talmudic	Ancient	General	Sq cubit, 2304 to 3318 sq cm, avg
ar (post Metric)	100.0	1076	Germany	Medieval to metric	General	Same as French, 1891
aranzada	4472	48,120	Spain	Medieval to pre-metric	Land	256 cuartilla, pre-1860, 2003 reference
are	100.0	1076	United States	Colonial to modern	Land	1891 value, metric unit
are	100.0	1076	France	Medieval to pre-metric	General	=Square 10 meters on a side, metric basis, 1891 value
are	100.0	1076	Netherlands, Holland	Medieval to metric	Land	Reported in 1891, post Metric
are (Venetian Lombardy)	100	1080	Italy	Medieval to pre-metric	General	100 sq palmi, 1891 value
aroura	237.5	2556	Greece	Ancient	Land	2500 podes

(continued)

Table 5.3 (continued)

Unit	Equivalent sq. meters	Equivalent sq. feet, US	Region	Era	Common application	Notes
aroura	2756	29,660	Egypt	Ancient to pre-metric	Land	10,000 sq cubits
arpennis	1262	13,580	Roman Empire	Ancient	Land	14,400 sq pedes (or sq Roman feet), Roman acre
arpent	42.21	454.2	Belgium	Pre-metric	General	100 square perches, 2003 reference
arpent	14,400	154,900	Switzerland	Medieval to pre-metric	Land	400 square pied, 1891 value
arpent (de Paris)	3418	36,780	France	Medieval to pre-metric	Land	100 perche (de Paris), pre-1795, 2003 reference
arpent (Eaux et Forêts)	5106	54,940	France	Medieval to pre-metric	Land	100 perche (Eaux et Forêts), pre-1795, 2003 reference
arpent (land)	3419	36,790	Canada	Pre-metric	Land	English Imperial & French Units also
aure	2741	29,490	Egypt	Ancient to pre-metric	Land	2 rema, 1966 value
äyrinmaa	4152	44,680	Finland	Medieval to pre-metric	Land	3 äyrityisenmaa, 11,777 square kynnärä, area growing grain worth one äyri for taxation
äyrityisenmaa	1384	14,890	Finland	Medieval to pre-metric	Land	3926 square kynnärä, area that grows grain worth one äyritynen for taxation
bahoe	7097	76,360	Indonesia	Pre-metric	Land	
baile	5,828,000	6.271E+07	Ireland	Medieval to pre-metric	Land	townland, 1440 achar, still used

(continued)

Table 5.3 (continued)

Unit	Equivalent sq. meters	Equivalent sq. feet, US	Region	Era	Common application	Notes
balita	2795	30,070	Philippines	Pre-metric	Land	Pre 1860, consistent with 2003 reference
begah	2024	21,780	India	Medieval to pre-metric	Land	4 kanals
beit kor	21,082	226,800	Biblical, Talmudic	Ancient	Land	Space for sowing a kor, avg
beit rova	29.30	315.3	Biblical, Talmudic	Ancient	Land	Space for sowing, 1/4 kav, avg
beit seah	703	7560	Biblical, Talmudic	Ancient	Land	Space for sowing a seah, avg
belita	2795	30,070	Philippines	Pre-metric	Land	Pre 1860, consistent with 2003 reference
bes	1682	18,100	Roman Empire	Ancient	Land	19,200 sq pedes
bhigah	1345	14,470	India	Medieval to pre-metric	Land	
biga	843	9070	India	Medieval to pre-metric	Land	Different source
biggah (Bengal)	1338	14,400	India	Medieval to pre-metric	Land	20 cottah, 1891
biggah (Bombay)	752.5	8097	India	Medieval to pre-metric	Land	20 cottah, 2003 reference

(continued)

Table 5.3 (continued)

Unit	Equivalent sq. meters	Equivalent sq. feet, US	Region	Era	Common application	Notes
biggah (Bombay)	2458	26,450	India	Medieval to pre-metric	Land	Reported 1891 value
biolca (Parma)	3047	32,780	Italy	Medieval to pre-metric	Land	6 stari, 288 sq pertica, 1891 value
biolea (Modena)	2837	30,520	Italy	Medieval to pre-metric	Land	72 tavole, 1891 value
biswa	42.2	454	India	Medieval to pre-metric	General	
biswa	100	1076	Afghanistan	Colonial to Modern	Land	1/20 jerib
bo	99.20	1067	Taiwan, Formosa	Pre-metric	Land	30 pheng
bouw	7097	76,360	Indonesia	Pre-metric	Land	
bovate	60,650	652,600	United Kingdom	Medieval to pre-metric	Land	land one ox can plow in a year, ~15 acres or 1/8 carucate
brass	9,290	100.0	India	Medieval to pre-metric	General	100 sq ft for building work

(continued)

Table 5.3 (continued)

Unit	Equivalent sq. meters	Equivalent sq. feet, US	Region	Era	Common application	Notes
brick	0.0500	0.538	Mesopotamia, Sumer, Akkadia	Ancient	General	brick, basic unit
bu (agriculture)	3.306	35.57	Japan	Medieval to pre-metric	General	One square ken, 2003 reference
bunder	10,000	107,600	Netherlands, Holland	Medieval to Metric	Land	Reported in 1891, post Metric
bur	64,800	697,200	Mesopotamia, Sumer, Akkadia	Ancient	Land	estate, 1800 gardens
buru	64,800	697,200	Mesopotamia, Sumer, Akkadia	Ancient	Land	estate, 1800 gardens
buyuk donum	2720	29,270	Ottoman Empire, Turkey	Medieval to pre-metric	Land	dunam (big)
caballeria	134,200	1,444,000	Cuba	Colonial to pre-metric	Land	12 fanega, 1920s value, consistent with 2003 reference
caballeria	428,000	4,610,000	Mexico	Colonial to pre-metric	Land	12 fanega, 2003 reference
caballeria Cubana	134,200	1,444,000	Cuba	Colonial to pre-metric	Land	12 fanega, 1920s value, consistent with 2003 reference

(continued)

Table 5.3 (continued)

Unit	Equivalent sq. meters	Equivalent sq. feet, US	Region	Era	Common application	Notes
campo (Venetian Lombardy)	2785	29,960	Italy	Medieval to pre-metric	Land	1891 value
cantref	4.390E+07	4.724E+08	Wales	Medieval to pre-metric	Land	2 commotes, varied by region
cao (new)	497.0	5348	Vietnam, Annam	Colonial to pre-metric	Land	15 thuoc, 2003 reference
cao (old)	360.0	3874	Vietnam, Annam	Colonial to pre-metric	Land	10 mieng, traditional, 497 m ² Annamite, 1891 value
carib	1821	19,590	Tatar	Medieval to pre-metric	Land	3600 square arsin
carreau	1292	13,910	Haiti	Colonial to pre-metric	Land	Pre-metric conversion, 2003 reference
carucate	485,200	5,221,000	United Kingdom	Medieval to pre-metric	Land	Area that can be plowed by an 8 oxen team in 1 year, ~ 120 acres
carve	485,200	5,221,000	United Kingdom	Medieval to pre-metric	Land	Area that can be plowed by an 8 oxen team in 1 year, ~ 120 acres
cassenny (Carnatic)	4066	43,750	India	Medieval to pre-metric	Land	Reported 1891 value

(continued)

Table 5.3 (continued)

Unit	Equivalent sq. meters	Equivalent sq. feet, US	Region	Era	Common application	Notes
cassenev (Madras)	5351	57,580	India	Medieval to pre-metric	Land	24 maoney, 240 sq covid, 1891 value
cawney (Camatic)	4066	43,750	India	Medieval to pre-metric	Land	Reported 1891 value
cawney (Madras)	5351	57,580	India	Medieval to pre-metric	Land	24 maoney, 240 sq covid, 1891 value
cawnie	540	5810	India	Medieval to pre-metric	Land	2003 reference
ceathramh	29,000	312,000	Scotland	Medieval to pre-metric	Land	Quarterland, variable value, supposed to be 8 fourpennylands, estimate based on 1886 reference
centare	1,000	10.76	France	Medieval to pre-metric	General	1891 value, metric basis
centuria	504,600	5,429,000	Roman Empire	Ancient	Land	200 jugera, formerly 100 jugera
centurium (common)	499,200	5,371,000	Roman Empire	Ancient	Land	200 jugera, consistent with 2003 reference
chahar	0.02,962	0.3187	India	Medieval to pre-metric	General	2003 reference
chattack (Bengal)	4.18	45.0	India	Medieval to pre-metric	General	20 sq covid, 1891

(continued)

Table 5.3 (continued)

Unit	Equivalent sq. meters	Equivalent sq. feet, US	Region	Era	Common application	Notes
chattack (Bombay)	2.352	25.30	India	Medieval to pre-metric	General	5 sq guz, 2003 reference
ching	61,440	661,100	China	Ancient to pre-metric	Land	100 mǔ
chō	9917	106,700	Japan	Medieval to pre-metric	Land	3000 tsubo, 10 tan, 2003 reference
chō	9917	106,700	Japan	Medieval to pre-metric	Land	3000 tsubo, 10 tan, 2003 reference
circular mil	5.067E-10	5.452E-09	United States	Colonial to Modern	General	
cirek	5463	58,780	Tatar	Medieval to pre-metric	Land	1/2 disatina
clima (common)	312.0	3357	Roman Empire	Ancient	Land	3600 sq pedes, consistent with 2003 reference
commote	2.195E+07	2.362E+08	Wales	Medieval to pre-metric	Land	12.5 manors, varied by region
cordele	414.2	4457	Cuba	Colonial to pre-metric	Land	1/324 caballeria, 2003 reference
Cornish acre	485,700	5,226,000	Cornwall	Medieval or pre-metric	Land	120 statute acres or could be 64, 8 score lease

(continued)

Table 5.3 (continued)

Unit	Equivalent sq. meters	Equivalent sq. feet, US	Region	Era	Common application	Notes
Cornish farthing	121,400	1,307,000	Cornwall	Medieval or pre-metric	Land	1/4 Cornish acre
Cornish ferling	121,400	1,307,000	Cornwall	Medieval or pre-metric	Land	1/4 Cornish acre
Cornish Knight's fee	1.943E+06	2.090E+07	Cornwall	Medieval or pre-metric	Land	4 Cornish acres
Cornish lace	30	324	Cornwall	Medieval or pre-metric	General	18 ft square
Cornish land rod	15	162	Cornwall	Medieval or pre-metric	General	1/2 lace
Cornish lease	30	324	Cornwall	Medieval or pre-metric	General	4 sticks
Cornish lorgh	15	162	Cornwall	Medieval or pre-metric	General	1/2 lace
Cornish rod	4818	51,840	Cornwall	Medieval or pre-metric	Land	160 lace
Cornish stick	7.5	81	Cornwall	Medieval or pre-metric	General	

(continued)

Table 5.3 (continued)

Unit	Equivalent sq. meters	Equivalent sq. feet, US	Region	Era	Common application	Notes
cota ban	3600	38,740	Scotland	Medieval to pre-metric	Land	Estimate based on 1886 reference
cottah (Bengal)	66.9	720	India	Medieval to pre-metric	General	16 chatack, 1891
cottah (Bombay)	37.62	404.8	India	Medieval to pre-metric	General	16 chatack, 2003 reference
cow's grass			Ireland	Medieval to pre-metric	General	Pre 1800, land reqd by 1 cow
cuartilla	17.47	188.0	Spain	Medieval to pre-metric	General	25 sq vara, pre-1860, 2003 reference
cuerdo	1572	16,920	Puerto Rico	Colonial to pre-metric	Land	2250 sq vara
daach	1,748,000	1.881E+07	Scotland	Medieval to pre-metric	Land	Daugh, appx. 4 ploughgates, agriculture, eastern region, 1886 value estimate
dabach or dabach	1,748,000	1.881E+07	Scotland	Medieval to pre-metric	Land	Daugh, appx. 4 ploughgates, agriculture, eastern region, 1886 value estimate

(continued)

Table 5.3 (continued)

Unit	Equivalent sq. meters	Equivalent sq. feet, US	Region	Era	Common application	Notes
danh-imir	55,000	592,000	Scotland	Medieval to pre-metric	Land	Oxgang, appx. area an ox could plough in one year, agriculture, eastern region, 1886 value range estimate 6–19 acres, recent estimate was about 20 acres
dan oranja	3592	38,650	Yugoslavia	Pre-metric	Land	35,970 sq stopa, 2003 reference
daneq	983.0	10,580	Arabia	Ancient	Land	4 qirat, 2003 reference
darat	8000	86,000	Somalia	Medieval to pre-metric	Land	
davach	1,748,000	1.881E+07	Scotland	Medieval to pre-metric	Land	Daugh, appx. 4 ploughgates, agriculture, eastern region, 1886 value estimate
davoch	1,748,000	1.881E+07	Scotland	Medieval to pre-metric	Land	Daugh, appx. 4 ploughgates, agriculture, eastern region, 1886 value estimate
decempedia quadrata (common)	8,667	93.26	Roman Empire	Ancient	General	100 sq pedes, consistent with 2003 reference
deciatine (official)	10,930	117,600	Russia	Medieval to pre-metric	Land	2400 sq sazhen, 1891 value
denum	739.8	7961	Libya	Medieval to pre-metric	Land	1600 sq pik, 2003 reference
deunx	2313	24,890	Roman Empire	Ancient	Land	26,400 sq pedes
dexians	2103	22,630	Roman Empire	Ancient	Land	24,000 sq pedes

(continued)

Table 5.3 (continued)

Unit	Equivalent sq. meters	Equivalent sq. feet, US	Region	Era	Common application	Notes
dimidium scrupulum	4.380	47.13	Roman Empire	Ancient	General	50 sq pedes
disatina	10,930	117,600	Tatar	Medieval to pre-metric	Land	2400 quadrat sajın
djarib	1475	15,870	Arabia	Ancient	Land	6 qirat, 2003 reference
djeril	10,000	107,600	Turkey	Medieval to Metric	Land	Post metric, 2003 reference
dodrans	1893	20,370	Roman Empire	Ancient	Land	21,600 sq pedes
donum	699.0	7521	Yugoslavia	Pre-metric	Land	7000 sq stopa, 2003 reference
donum	1338	14,400	Cyprus	Medieval or pre-metric	Land	Turkish acre, 1600 square Turkish paces, 2003 reference
donum (new)	1000	10,760	Turkey	Medieval to Metric	Land	Defined 1939, post-metric-metric, 2003 reference
donum (old)	913.0	9824	Turkey	Medieval to Metric	Land	1600 sq pics, pre-1933, original Ottoman unit, area a team of oxen could plow in one day, standardized at 1210 sq yards, 2003 reference
drohn (Hanover)	1746	18,790	Germany	Medieval to Metric	Land	Reported in 1891
dunum	699.0	7521	Yugoslavia	Pre-metric	Land	7000 sq stopa, 2003 reference
dunum (new)	1000	10,760	Turkey	Medieval to Metric	Land	Defined 1939, post-metric-metric, 2003 reference
dunum (old)	913.0	9824	Turkey	Medieval to Metric	Land	1600 sq pics, pre-1933, original Ottoman unit, area a team of oxen could plow in one day, standardized at 1210 sq yards, 2003 reference

(continued)

Table 5.3 (continued)

Unit	Equivalent sq. meters	Equivalent sq. feet, US	Region	Era	Common application	Notes
duo scrupula	17.50	188.3	Roman Empire	Ancient	General	200 sq pedes
engjateigur	5674	61,050	Iceland	Medieval to pre-metric	Land	1600 ferðadmur, 2003 reference
erw	1715	18,450	Wales	Medieval to pre-metric	Land	Welsh acre, ambiguous, used avg
eski donum	919.0	9888	Ottoman Empire, Turkey	Medieval to pre-metric	Land	dunam (old)
fanega	11,180	120,330	Cuba	Colonial to pre-metric	Land	27 cordele, 1/12 caballeria, 2003 reference
fanega	35,700	384,000	Mexico	Colonial to pre-metric	Land	50,784 sq vara, 2003 reference
fanegada	3145	33,840	Peru	Colonial to pre-metric	Land	4500 sq vara, 2003 reference
fanegada	6400	68,900	Colombia	Colonial to pre-metric	Land	10,000 sq vara
fanegada	6440	69,290	Spain	Medieval to pre-metric	Land	12 calemin, pre-1860, 2003 reference

(continued)

Table 5.3 (continued)

Unit	Equivalent sq. meters	Equivalent sq. feet, US	Region	Era	Common application	Notes
farthing-land	230	2480	Scotland	Medieval to pre-metric	Land	1/4 pennyland, western region, taxes & rents, estimated at 1/480 daugh, value based on 1886 reference
feddan	4201	45,200	Egypt	Ancient to pre-metric	Land	Pre 1891, 333-1/3 sq cassabas, 24 kirat kamel, consistent with 2003 reference
feddan	5898	63,460	Arabia	Ancient	Land	4 djarib, 2003 reference
feddan masri	4201	45,200	Egypt	Ancient to pre-metric	Land	Pre 1891, 333-1/3 sq cassabas, 24 kirat kamel, consistent with 2003 reference
fen	61.44	661.1	China	Ancient to pre-metric	General	10 lyi
feralin	0.3940	4.239	Iceland	Medieval to pre-metric	General	1/9 ferfaðmur, 2003 reference
ferfaðmur	3.546	38.15	Iceland	Medieval to pre-metric	General	9 feralin, 2003 reference
ferfet	0.09851	1.060	Iceland	Medieval to pre-metric	General	1/36 ferfaðmur, 2003 reference
fermila	56,740	610,500	Iceland	Medieval to pre-metric	Land	10,000 engjateigur, 2003 reference
ferpumlungur	0.0006841	0.007361	Iceland	Medieval to pre-metric	General	1/5184 ferfaðmur, 2003 reference

(continued)

Table 5.3 (continued)

Unit	Equivalent sq. meters	Equivalent sq. feet, US	Region	Era	Common application	Notes
ferrado	725.4	7805	Portugal	Medieval to pre-metric	Land	2003 reference
fitel kwadru	0.0172	0.185	Malta	Medieval to pre-metric	General	1/4 xiber kwadru
fjårdingsland	2468	26,560	Sweden	Medieval to pre-metric	Land	16 kappland, 2003 reference
fjerdings	614	6600	Norway	Medieval to pre-metric	Land	4 kappland, 1891 value
fjerdingsar	886.3	9536	Denmark	Pre-metric	Land	3 album, 2003 reference
fourpennyland	3600	38,740	Scotland	Medieval to pre-metric	Land	Estimate based on 1886 reference
gan	1475	15,870	Persia, Iran	Medieval to pre-metric	Land	10 ten, 2003 reference
gar	14.75	158.7	Persia, Iran	Medieval to pre-metric	General	144 square zereth, 1 square qasab, 2003 reference
geira	5782	62,210	Portugal	Medieval to pre-metric	Land	4840 sq varas, 1891 value, reported as 5803 in 2003 reference

(continued)

Table 5.3 (continued)

Unit	Equivalent sq. meters	Equivalent sq. feet, US	Region	Era	Common application	Notes
geris	3.14E-04	3.38E-03	Biblical, Talmudic	Ancient	General	Split bean, circle of 20 mm dia
ghamaon	4048	43,560	India	Medieval to pre-metric	Land	“Acre”, 8 kanals, also reported as 9 kanals + 12 marlas = 4858 sq m
ghe	0.160	1.72	Vietnam, Annam	Colonial to pre-metric	General	1891 reference
ghumaon	4048	43,560	India	Medieval to pre-metric	Land	“Acre”, 8 kanals, also reported as 9 kanals + 12 marlas = 4858 sq m
gin ₂	1.000	10.76	Mesopotamia, Sumer, Akkadia	Ancient	General	shekel, 1/60 garden
giornata (Piedmont)	3801	40,900	Italy	Medieval to pre-metric	Land	In Sardinia, 1891 value, 100 sq pertica
go	0.3306	3.557	Japan	Medieval to pre-metric	General	1/10 tsubo, 2003 reference
gô	0.3306	3.557	Japan	Medieval to pre-metric	General	1/10 tsubo, 2003 reference
groatland	3600	38,740	Scotland	Medieval to pre-metric	Land	Estimate based on 1886 reference

(continued)

Table 5.3 (continued)

Unit	Equivalent sq. meters	Equivalent sq. feet, US	Region	Era	Common application	Notes
hectare	10,000	107,600	France	Medieval to pre-metric	Land	100 are, 10,000 sq m, 1891 value, metric basis
hectare	10,000	107,600	Netherlands, Holland	Medieval to Metric	Land	Reported in 1891, post Metric
hectare	10,000	107,600	United States	Colonial to Modern	Land	1891 value, metric unit
hektos	158.3	1703	Greece	Ancient	Land	1666-2/3 podes, 1/6 plethron
hemiektos	79.20	852.2	Greece	Ancient	General	833-1/3 podes
heredium	5047	54,310	Roman Empire	Ancient	Land	2 jugera
heredium (common)	4992	53,710	Roman Empire	Ancient	Land	2 jugera, consistent with 2003 reference
heseb	6.900	74.24	Egypt	Ancient to pre-metric	General	1/2 remen, 25 sq cubits
hexapodes	3.420	36.80	Greece	Ancient	General	36 podes
hide	363,900	3,916,000	United Kingdom	Medieval to pre-metric	Land	4 to 8 bovates, based on yield, land able to support one household for ag or taxes, used 6 as basis
hold	431.6	4644	Hungary	Medieval to pre-metric	Land	2003 reference
holding	109,760	1,181,000	Wales	Medieval to pre-metric	Land	4 sharelands

(continued)

Table 5.3 (continued)

Unit	Equivalent sq. meters	Equivalent sq. feet, US	Region	Era	Common application	Notes
homestead	6860	73,810	Wales	Medieval to pre-metric	Land	4 acres
hsb	689.0	7414	Egypt	Ancient to pre-metric	Land	1/4 st3t, 2500 sq cubits
hundred	3.639E+07	3.916E+08	United Kingdom	Medieval to pre-metric	Land	100 hides, administration grouping, ~ 9000 acres or 14 sq miles
iku	3600	38,740	Mesopotamia, Sumer, Akkadia	Ancient	Land	field, 100 gardens
Irish acre	6555	70,530	Ireland	Medieval to pre-metric	Land	7840 square yards
jabia	832.3	8956	Libya	Medieval to pre-metric	Land	1800 sq pik, 2003 reference
jerib	400	4304	Afghanistan	Colonial to Modern	Land	1/5 ha
jítő	5756	61,940	Czechoslovakia	Medieval or pre-metric	Land	2 korec, 2003 reference
jo	1.653	17.79	Japan	Medieval to pre-metric	General	1/2 tsubo, size of one tatami mat for room size

(continued)

Table 5.3 (continued)

Unit	Equivalent sq. meters	Equivalent sq. feet, US	Region	Era	Common application	Notes
joch	431.6	4644	Hungary	Medieval to pre-metric	Land	2003 reference
joch	5755	61,920	Austrian Empire	Pre-metric	Land	3 metzen, 1600 sq klafter, 57,600 sq fuss, 2003 reference
journal	4000	43,040	France	Medieval to pre-metric	Land	Typical value, old, 2003 reference
journal (Bordeaux)	3190	34,320	France	Medieval to pre-metric	Land	31.9 ares, variation, 2003 reference
journal (Domfront)	5000	53,800	France	Medieval to pre-metric	Land	50 ares, variation, 2003 reference
journal (Mamers)	4400	47,340	France	Medieval to pre-metric	Land	44 ares, variation, 2003 reference
journal (Nord de la Mayenne)	5000	53,800	France	Medieval to pre-metric	Land	50 ares, variation, 2003 reference
journal (Saint-Brieuc)	4000	43,040	France	Medieval to pre-metric	Land	40 ares, variation, 2003 reference
jugerum	2523	27,150	Roman Empire	Ancient	Land	28,800 sq pedes
jugerum (common)	2496	26,860	Roman Empire	Ancient	Land	28,800 quadratus pes, consistent with 2003 reference

(continued)

Table 5.3 (continued)

Unit	Equivalent sq. meters	Equivalent sq. feet, US	Region	Era	Common application	Notes
kah	9699	104,400	Taiwan, Formosa	Pre-metric	Land	2934 pheng
kanal	506.0	5445	India	Medieval to pre-metric	Land	20 marlas
kani	307.5	3309	India	Medieval to pre-metric	Land	2003 reference
kannaland	88.15	948.5	Sweden	Medieval to pre-metric	Land	1000 sq fot
kannunala	88.15	948.5	Finland	Medieval to pre-metric	General	1000 square jalka
kapanala	154.0	1657	Finland	Medieval to pre-metric	Land	1/32 tynmyrinala, area of a field that could be sown with one bushel grain
kapp	148.6	1599	Latvia	Medieval to pre-metric	Land	2003 reference
kappland	153	1650	Norway	Medieval to pre-metric	Land	1891 value
kappland	154.3	1660	Sweden	Medieval to pre-metric	Land	1750 kvadratfot, 2003 reference

(continued)

Table 5.3 (continued)

Unit	Equivalent sq. meters	Equivalent sq. feet, US	Region	Era	Common application	Notes
katha	67.2	723	India	Medieval to pre-metric	General	
kazionnaya desiatina (official)	10,930	117,600	Russia	Medieval to pre-metric	Land	2400 sq sazhen, 1891 value
kérat	175.0	1883	Egypt	Ancient to pre-metric	Land	1/24 feddan, 24 sahne, pre 1891, consistent with 2003 reference
kha	27,560	296,600	Egypt	Ancient to pre-metric	Land	1000 of land, 10 arouras, 100,000 sq cubits
khau	0.0160	0.172	Vietnam, Annam	Colonial to pre-metric	General	1891 reference
khet	52.50	564.9	Egypt	Ancient to pre-metric	General	100 sq cubits
king	6144	66,110	China	Ancient to pre-metric	Land	10 mǔ
kirat kamel	175.0	1883	Egypt	Ancient to pre-metric	Land	1/24 feddan, 24 sahne, pre 1891, consistent with 2003 reference
kish	153.6	1653	China	Ancient to pre-metric	Land	25 lyi
knight's fee	1,820,000	1.958E+07	United Kingdom	Medieval to pre-metric	Land	5 hides, land required to field one fully-equipped soldier
kopanka	19.95	214.7	Poland	Medieval to pre-metric	General	1/9000 wloka

(continued)

Table 5.3 (continued)

Unit	Equivalent sq. meters	Equivalent sq. feet, US	Region	Era	Common application	Notes
korec	2878	30,970	Czechoslovakia	Medieval or pre-metric	Land	1.439 merice, 2003 reference
kung	2,560	27.55	China	Ancient to pre-metric	General	4.17 hao
kvadrat rode	9,840	105.9	Norway	Medieval to pre-metric	General	square stang
kvadratmil	1.142E+08	1.229E+09	Sweden	Medieval to pre-metric	Land	Sq mil, 36 million sq favnar (1739 value)
kvardrafot	0.08815	0.9485	Sweden	Medieval to pre-metric	General	Square foot, 144 kvardratum, 1891 value, consistent with 2003 reference
kvardrattum	0.0006122	0.006587	Sweden	Medieval to pre-metric	General	Square inch, 2003 reference
labor	642,000	6,910,000	Mexico	Colonial to pre-metric	Land	18 fanega, 2003 reference
labor	698,700	7,518,000	Spain	Medieval to pre-metric	Land	1 million sq varas
lan	172,700	1,858,000	Czechoslovakia	Medieval or pre-metric	Land	60 korec, 2003 reference

(continued)

Table 5.3 (continued)

Unit	Equivalent sq. meters	Equivalent sq. feet, US	Region	Era	Common application	Notes
lan	179,500	1,932,000	Poland	Medieval to pre-metric	Land	Lesser lan, 30 morgs
lan	258,600	2,782,000	Poland	Medieval to pre-metric	Land	Greater lan, 43.2 morgs, used avg
lanatz	5752	61,890	Yugoslavia	Pre-metric	Land	1600 sq kvat, 2003 reference
le	48,500	521,800	Taiwan, Formosa	pre-metric	Land	5 kah, 14,670 pheng
league	1.747E+07	1.880E+08	Spain	Medieval to pre-metric	Land	25 million sq vara
lifo (new)	75.00	807.0	Paraguay	Colonial to pre-metric	General	100 sq vara, 2003 reference
lifo (old)	70.32	756.6	Paraguay	Colonial to pre-metric	General	100 sq vara, 2003 reference
lino (new)	75.00	807.0	Paraguay	Colonial to pre-metric	General	100 sq vara, 2003 reference
lino (old)	70.32	756.6	Paraguay	Colonial to pre-metric	General	100 sq vara, 2003 reference
loan	279.5	3007	Philippines	Pre-metric	Land	1/10 belita, pre 1860, consistent with 2003 reference

(continued)

Table 5.3 (continued)

Unit	Equivalent sq. meters	Equivalent sq. feet, US	Region	Era	Common application	Notes
lofstelle (Livonian region)	3710	39,920	Estonia	Medieval to pre-metric	Land	
lofstelle (Reval/ Tallinn region)	1855	19,960	Estonia	Medieval to pre-metric	Land	
lokiec	0.355	3.82	Poland	Medieval to pre-metric	General	1/506,250 włoka
loofstelle	9	39,980	Latvia	Medieval to pre-metric	Land	25 kapp, 2003 reference
lyi	6.144	66.11	China	Ancient to pre-metric	General	10 hao
mal	984.0	10,590	Norway	Medieval to pre-metric	Land	100 kvartrat rode, also reported as 1000 sq meters in 2003 reference—probably post-metric value
manor	1,756,160	1.890E+07	Wales	Medieval to pre-metric	Land	4 townships
manzana	6606	71,090	Honduras	Colonial to pre-metric	Land	10,000 sq vara, 2003 reference
manzana	6879	74,020	Central America	Colonial to pre-metric	Land	10,000 sq vara, 2003 reference

(continued)

Table 5.3 (continued)

Unit	Equivalent sq. meters	Equivalent sq. feet, US	Region	Era	Common application	Notes
manzana	6879	74,020	El Salvador	Colonial to pre-metric	Land	10,000 sq vara, 2003 reference
manzana	6987	75,180	Nicaragua	Colonial to pre-metric	Land	10,000 sq vara, 2003 reference
manzana	6987	75,180	Guatemala	Colonial to pre-metric	Land	10,000 sq vara, 2003 reference
manzana	7044	75,800	Costa Rica	Colonial to pre-metric	Land	10,000 sq vara, 2003 reference
maoney (Madras)	223	2400	India	Medieval to pre-metric	Land	Reported 1891 value
marg-fhearann	144,000	1,550,000	Scotland	Medieval to pre-metric	Land	Markland, 8 ouncelands, western region, taxes & rents, varied
marla	25.3	272	India	Medieval to pre-metric	General	3 sq kans, also reported as 9 sq karams, different sources report different values
mau (new)	4970	53,480	Vietnam, Annam	Colonial to pre-metric	Land	10 sao, 2003 reference
mau (old)	3600	38,740	Vietnam, Annam	Colonial to pre-metric	Land	10 sao, traditional, 4970 m ² Annamite, 1891 value

(continued)

Table 5.3 (continued)

Unit	Equivalent sq. meters	Equivalent sq. feet, US	Region	Era	Common application	Notes
meou	614.4	6611	China	Ancient to pre-metric	Land	Chinese acre, 4 kish
merice	2000	21,520	Czechoslovakia	Medieval or pre-metric	Land	Bohemia, 2003 reference
metze	1918	20,640	Austrian Empire	Pre-metric	Land	2003 reference
mieng	36.00	387.4	Vietnam, Annam	Colonial to pre-metric	General	3 ngu squared, 1891 value
mira	2878	30,970	Czechoslovakia	Medieval or pre-metric	Land	1.439 merice, 2003 reference
modios zeugarton	2973	31,990	Byzantine Empire	Ancient	Land	Varied greatly, 30,000 square pous, modios also smaller units of 100–250 per zeugarton.
moggio (Naples)	3474	37,380	Italy	Medieval to pre-metric	Land	50,625 sq palmi, 1891 value
morga	5985	64,400	Poland	Medieval to pre-metric	Land	1/30 włoka, 300 sq pret, also reported as 5599 sq meters in 2003
morgen	2553	27,470	Prussia	Pre-metric	Land	180 sq ruthen, 1891 value
morgen	8516	91,630	Netherlands, Holland	Medieval to Metric	Land	amount of land that could be ploughed in a morning (hence “morgen”), varied considerably by location (8516 to 10,700 sq meters), 150 to 900 roede in a morgen

(continued)

Table 5.3 (continued)

Unit	Equivalent sq. meters	Equivalent sq. feet, US	Region	Era	Common application	Notes
morgen	85,000	915,000	South Africa	Colonial to pre-metric	Land	
morgen (Baden)	3601	38,740	Germany	Medieval to Metric	Land	4 viertel, reported 1891
morgen (Bremen)	2567	27,620	Germany	Medieval to Metric	Land	120 sq ruthen, 30,720 sq fuss, 1891
morgen (Brunswick)	2512	27,030	Germany	Medieval to Metric	Land	120 sq ruthen, 30,720 sq fuss, 1891
morgen (Frankfort)	2025	21,790	Germany	Medieval to Metric	Land	16,000 sq feldfuss, 1891
morgen (Hamburg)	9653	103,900	Germany	Medieval to Metric	Land	117,600 sq fuss, 1891
morgen (Hesse-Darmstadt)	2500	26,900	Germany	Medieval to Metric	Land	4 viertel, 40,000 sq fuss, 1891 value
morgen (Saxony)	6158	66,260	Germany	Medieval to Metric	Land	Reported in 1891, 76,800 sq fuss
morgen (Wertenberg)	3152	33,920	Germany	Medieval to Metric	Land	38,400 sq fuss, 1891 value
morgen of Calenberg (Hanover)	2619	28,180	Germany	Medieval to Metric	Land	2 vorling, 1.5 drohn, 1891
morgen, juchart, tagewerk (Bavaria)	3406	36,650	Germany	Medieval to Metric	Land	Reported in 1891, 40,000 sq fuss, divided into tenths for smaller units
motyka	798.8	8596	Yugoslavia	pre-metric	Land	8000 sq stopa, 2003 reference

(continued)

Table 5.3 (continued)

Unit	Equivalent sq. meters	Equivalent sq. feet, US	Region	Era	Common application	Notes
mǔ	614.4	6611	China	Ancient to pre-metric	Land	Chinese acre, 4 kish
musaru	36.00	387.4	Mesopotamia, Sumer, Akkadia	Ancient	General	garden or brick garden, 720 bricks
nalli	202	2170	India	Medieval to pre-metric	Land	
ngan	400	4300	Thailand	Pre-metric	Land	100 tarang wa, 2003 reference
nook	103,000	1,110,000	Scotland	Medieval to pre-metric	Land	2003 reference
o	0.160	1.72	Vietnam, Annam	Colonial to pre-metric	General	1891 reference
orlong	5351	57,580	Malacca	Pre-metric	Land	1891 value
oxgang	60,650	652,600	United Kingdom	Medieval to pre-metric	Land	land one ox can plow in a year, ~ 15 acres or 1/8 carucate
panninala	2464	26,510	Finland	Medieval to pre-metric	Land	16 kapanala or 1/2 tynmyrinala, area that could be sown with one panni grain
peighinn	910	9800	Scotland	Medieval to pre-metric	Land	Basic unit, western region, taxes & rents, estimated at 1/1920 daugh, value based on 1886 reference
pekeis	27.41	294.9	Egypt	Ancient to pre-metric	General	100 sq derah, 1966 value

(continued)

Table 5.3 (continued)

Unit	Equivalent sq. meters	Equivalent sq. feet, US	Region	Era	Common application	Notes
penge	81.49	876.9	Denmark	pre-metric	General	5.75 square ruthe, 2003 reference
penninginmaa	173,000	1,861,000	Finland	Medieval to pre-metric	Land	490,790 square kynnäri, area growing grain worth one penninki for taxation
pennyland	910	9800	Scotland	Medieval to pre-metric	Land	Basic unit, western region, taxes & rents, estimated at 1/1920 daugh, value based on 1886 reference
perch	25.3	272	United Kingdom	Medieval to pre-metric	Land	1 sq rod
perche (de Paris)	34.18	367.8	France	Medieval to pre-metric	General	9 toise carrée (de Paris), pre-1795, 2003 reference
perche (Eaux et Forêts)	51.06	549.4	France	Medieval to pre-metric	General	484 pied carré, pre-1795, 2003 reference
pes quadratus (common)	0.08,667	0.933	Roman Empire	Ancient	General	Square foot, 1 sq pes, consistent with 2003 reference
pflug	907,500	9,765,000	Denmark	Pre-metric	Land	32 tonde, 2003 reference
phan	0.240	2.58	Vietnam, Annam	Colonial to pre-metric	General	1891 reference
pheng	3.306	35.57	Taiwan, Formosa	Pre-metric	General	
pied carré (de Paris)	0.1055	1.135	France	Medieval to pre-metric	General	Square foot, pre-1795, 2003 reference

(continued)

Table 5.3 (continued)

Unit	Equivalent sq. meters	Equivalent sq. feet, US	Region	Era	Common application	Notes
pieds square	36.0	387	Switzerland	Medieval to pre-metric	General	1891 value
plethron	950.0	10,220	Greece	Ancient	Land	10,000 podes
plough	485,200	5,221,000	United Kingdom	Medieval to pre-metric	Land	Area that can be plowed by an 8 oxen team in 1 year, ~ 120 acres
ploughgate	437,000	4,700,000	Scotland	Medieval to pre-metric	Land	Appx, 8 oxgangs, agriculture, eastern region, 1886 value estimate
porca	473.0	5089	Roman Empire	Ancient	Land	180 × 30 Roman feet
pourvete	11,825	39,980	Latvia	Medieval to pre-metric	Land	25 kapp, 2003 reference
pourvette	295,625	39,980	Latvia	Medieval to pre-metric	Land	25 kapp, 2003 reference
pous	0.095	1.0	Byzantine Empire	Ancient	General	1 square Greek foot
pous	0.0950	1.02	Greece	Ancient	General	sq foot
pret	199.5	2147	Poland	Medieval to pre-metric	Land	1/900 wloka
pulzier kwadru	0.000,477	0.00513	Malta	Medieval to pre-metric	General	1/144 xiber kwadru

(continued)

Table 5.3 (continued)

Unit	Equivalent sq. meters	Equivalent sq. feet, US	Region	Era	Common application	Notes
pundland	19,750	212,500	Sweden	Medieval to pre-metric	Land	2 spamland, 2003 reference
pyeong	3,306	35.57	Korea	Medieval to pre-metric	General	
qamha	61.44	661.1	Arabia	Ancient	General	150 sq cubits, 2003 reference
qasaba (Achir)	14.75	158.7	Arabia	Ancient	General	36 sq cubits, 2003 reference
qasba kwadru	4,391	47.25	Malta	Medieval to pre-metric	General	64 xiber kwadru
qirat	245.8	2645	Arabia	Ancient	Land	3 habbah, 2003 reference
quadrans	631.0	6790	Roman Empire	Ancient	Land	7200 sq pedes
quadrat sajjin	4,552	48.98	Tatar	Medieval to pre-metric	General	1 sajjin square
quadratus pes (common)	0.08667	0.933	Roman Empire	Ancient	General	Square foot, 1 sq pes, consistent with 2003 reference
quadratus pes (legal, 1st)	0.08773	0.944	Roman Empire	Ancient	General	2003 reference
quarat caqrim	1,138,000	1.224E+07	Tatar	Medieval to pre-metric	Land	1 square caqrim
quignon	27,950	300,700	Philippines	Pre-metric	Land	10 balita, pre 1860, consistent with 2003 reference (continued)

Table 5.3 (continued)

Unit	Equivalent sq. meters	Equivalent sq. feet, US	Region	Era	Common application	Notes
quilla	4048	43,560	India	Medieval to pre-metric	Land	"Acre", 8 kanals, also reported as 9 kanals + 12 marlas = 4858 sq m
qūin	61,440	661,100	China	Ancient to pre-metric	Land	100 mǔ
quincunx	1051	11,310	Roman Empire	Ancient	Land	12,000 sq pedes
quo	9941	107,000	Vietnam, Annam	Colonial to pre-metric	Land	2 mau, 2003 reference
rai	1600	17,200	Thailand	Pre-metric	Land	4 ngan, 2003 reference
raliza	2496	26,860	Yugoslavia	Pre-metric	Land	25,000 sq stopa, 2003 reference
Ramsden's chain (Old)	929.0	9996	United States	Colonial to Modern	Land	Old value, obsolete
rema	1370	14,740	Egypt	Ancient to pre-metric	Land	5 ten, 1966 value
remen	13.70	147.4	Egypt	Ancient to pre-metric	General	Shoulder, 1/4 ta, 50 sq cubits
Rijnlandse hont	1419	15,270	Netherlands, Holland	Medieval to Metric	Land	100 square Rijnland rods
Rijnlandse morgen	8516	91,630	Netherlands, Holland	Medieval to Metric	Land	6 Rijnland honts
Rijnlandse voet	0.0986	1.06	Netherlands, Holland	Medieval to Metric	General	AKA square voet, square foot, local variation
Rijnlandse roede	14.19	152.7	Netherlands, Holland	Medieval to Metric	General	AKA square roede, 144 Rijnland square feet

(continued)

Table 5.3 (continued)

Unit	Equivalent sq. meters	Equivalent sq. feet, US	Region	Era	Common application	Notes
mn	1378	14,830	Egypt	Ancient to pre-metric	Land	1/2 st3t, 5000 sq cubits
rod	1286	13,830	Scotland	Medieval to pre-metric	Land	2003 reference
roede (average)	22.40	241.0	Netherlands, Holland	Medieval to Metric	General	varied from 11.7 to 33.1 square meters
rood	1011	10,880	United Kingdom	Medieval to pre-metric	Land	1/4 acre, sometimes called an acre in ancient times, 1 furlong $\times$ 1 rod = 40 sq rods
rood	1286	13,830	Scotland	Medieval to pre-metric	Land	2003 reference
rubbio	18,480	198,800	Roman Empire	Ancient	Land	1891 value, 370,300 sq architect's palmi
S3	345.0	3712	Egypt	Ancient to pre-metric	Land	1/8 st3t, 1250 sq cubits
saccato (Tuscany)	5621	60,490	Italy	Medieval to pre-metric	Land	16,500 braccia, 1891 value
sahne	7.293	78.47	Egypt	Ancient to pre-metric	General	1/576 feddan, pre 1891, consistent with 2003 reference
salamis	4538	48,820	Brazil	Colonial to pre-metric	Land	1/8 alqueire
salus	2,018,400	2.172E+07	Roman Empire	Ancient	Land	800 jugera
salus (common)	1,996,800	2.149E+07	Roman Empire	Ancient	Land	800 jugera, consistent with 2003 reference

(continued)

Table 5.3 (continued)

Unit	Equivalent sq. meters	Equivalent sq. feet, US	Region	Era	Common application	Notes
sao (new)	497.0	5348	Vietnam, Annam	Colonial to pre-metric	Land	15 thuoc, 2003 reference
sao (old)	360.0	3874	Vietnam, Annam	Colonial to pre-metric	Land	10 mieng, traditional, 497 m ² Annamite, 1891 value
sar	36.00	387.4	Mesopotamia, Sumer, Akkadia	Ancient	General	garden or brick garden, 720 bricks
sazhen	4.55	49.0	Russia	Medieval to pre-metric	General	1891 value
scala	1338	14,400	Cyprus	Medieval or pre-metric	Land	Turkish acre, 1600 square Turkish paces, 2003 reference
scrupulum (common) se	8.667	93.26	Roman Empire	Ancient	General	100 sq pedes, consistent with 2003 reference
	99.17	1067	Japan	Medieval to pre-metric	General	30 tsubo, 2003 reference
searah	8.727E-06	9.390E-05	Biblical, Talmudic	Ancient	General	Hair, 1/36 giris
section	2,590,000	2.787E+07	United States	Colonial to Modern	Land	640 acres, 1 sq mile
						(continued)

Table 5.3 (continued)

Unit	Equivalent sq. meters	Equivalent sq. feet, US	Region	Era	Common application	Notes
seisrech	485,600	5,225,000	Ireland	Medieval to pre-metric	Land	plough-land, 120 achar
semed	1822	19,600	Biblical, Talmudic	Ancient	Land	Area ploughed by 2 oxen in 1 day, 6480 sq cubits
semis	1262	13,580	Roman Empire	Ancient	Land	14,400 sq pedes (or sq Roman feet), Roman acre
semiuncia	105.0	1130	Roman Empire	Ancient	Land	1200 sq pedes
septunx	1472	15,840	Roman Empire	Ancient	Land	16,800 sq pedes
setat	2756	29,660	Egypt	Ancient to pre-metric	Land	10,000 sq cubits
setjat	2756	29,660	Egypt	Ancient to pre-metric	Land	10,000 sq cubits
setta	27,410	294,900	Egypt	Ancient to pre-metric	Land	10 aureure, 1966 value
sextans	421.0	4530	Roman Empire	Ancient	Land	4800 sq pedes
sextula	35.00	376.6	Roman Empire	Ancient	General	400 sq pedes
shaku	0.0331	0.356	Japan	Medieval to pre-metric	General	1/100 tsubo
shareland	27,440	295,300	Wales	Medieval to pre-metric	Land	4 homesteads
short actus (common)	34.67	373.0	Roman Empire	Ancient	General	400 quadrus pes, consistent with 2003 reference
sicilicus	52.60	566.0	Roman Empire	Ancient	General	600 sq pedes

(continued)

Table 5.3 (continued)

Unit	Equivalent sq. meters	Equivalent sq. feet, US	Region	Era	Common application	Notes
siqlu	1.000	10.76	Mesopotamia, Sumer, Akkadia	Ancient	General	shekel, 1/60 garden
sitio	1.756E+07	1.889E+08	Mexico	Colonial to pre-metric	Land	27.35 labor, 2003 reference
skiepper	3545	38,140	Denmark	Pre-metric	Land	4 fjerdingar, 2003 reference
spannland	2455	26,420	Norway	Medieval to pre-metric	Land	4 fjerding, 1891 value
spannland	9873	106,200	Sweden	Medieval to pre-metric	Land	2 tunnland, 2003 reference
sq aln	0.394	4.241	Denmark	Pre-metric	General	
sq architect's palmi	0.0499	0.537	Roman Empire	Ancient	General	1891 value
sq braccio (Tuscany)	0.341	3.67	Italy	Medieval to pre-metric	General	1891 value
sq cavezzo (Modena)	9.85	106	Italy	Medieval to pre-metric	General	36 sq piede, 1891 value
sq chain	405	4350	United Kingdom	Medieval to pre-metric	Land	16 sq rods

(continued)

Table 5.3 (continued)

Unit	Equivalent sq. meters	Equivalent sq. feet, US	Region	Era	Common application	Notes
sq covid (Bengal)	0.209	2.25	India	Medieval to pre-metric	General	Reported 1891 value
sq covid (Madras)	22.3	240	India	Medieval to pre-metric	General	Reported 1891 value
sq feldfuss (Frankfort)	0.127	1.36	Germany	Medieval to Metric	General	Reported in 1891
sq foot	0.0929	0.999	United Kingdom	Medieval to pre-metric	General	144 sq inches
sq fot	0.0877	0.943	Norway	Medieval to pre-metric	General	1891 value
sq fuss (Hamburg)	0.0821	0.883	Germany	Medieval to Metric	General	Reported in 1891
sq fuss (Hesse-Darmstadt)	0.0625	0.673	Germany	Medieval to Metric	General	Reported in 1891
sq fuss (Saxony)	0.0802	0.863	Germany	Medieval to Metric	General	Reported in 1891
sq fuss (Wertemberg)	0.0821	0.883	Germany	Medieval to Metric	General	1891 value
sq inch	0.000645	0.00694	United Kingdom	Medieval to pre-metric	General	

(continued)

Table 5.3 (continued)

Unit	Equivalent sq. meters	Equivalent sq. feet, US	Region	Era	Common application	Notes
Sq kan	8.43	90.7	India	Medieval to pre-metric	General	1/3 marla
Sq karam	2.81	30.2	India	Medieval to pre-metric	General	
sq landfuss (Hesse-Cassel)	0.0812	0.873	Germany	Medieval to Metric	General	Reported in 1891
sq meter	1.000	10.76	France	Medieval to pre-metric	General	1891 value, metric basis
sq mile	2,590,000	2.787E+07	United Kingdom	Medieval to pre-metric	Land	640 acres
sq palma (Naples)	0.0686	0.738	Italy	Medieval to pre-metric	General	1891 value
sq palmi (Venice)	1.00	10.8	Italy	Medieval to pre-metric	General	1891 value
sq pertica (Parma)	10.6	114	Italy	Medieval to pre-metric	General	1891 value
sq pertica (Piedmont)	38.0	409	Italy	Medieval to pre-metric	General	In Sardinia, 1891 value

(continued)

Table 5.3 (continued)

Unit	Equivalent sq. meters	Equivalent sq. feet, US	Region	Era	Common application	Notes
sq piede (Modena)	0.274	2.94	Italy	Medieval to pre-metric	General	1891 value
sq ref	880	9470	Sweden	Medieval to pre-metric	Land	1891 value, 10,000 sq fot
sq rod	25.3	272	United Kingdom	Medieval to pre-metric	Land	30.25 sq yards
sq ruthe	14.2	153	Prussia	Pre-metric	General	1891 value
sq ruthe (Hanover)	14.6	157	Germany	Medieval to Metric	General	Reported in 1891
sq ruthen (Baden)	9.0	97	Germany	Medieval to Metric	General	Reported in 1891
sq ruthen (Bremen)	21.4	230	Germany	Medieval to Metric	General	Reported in 1891
sq ruthen (Brunswick)	20.9	225	Germany	Medieval to Metric	General	Reported in 1891
sq sachine	4.55	49.0	Russia	Medieval to pre-metric	General	1891 value
sq vara	1.19	12.9	Portugal	Medieval to pre-metric	General	1891 value, reported as 1.199 sq m in 2003 reference
sq yard	0.836	9.00	United Kingdom	Medieval to pre-metric	General	9 sq feet

(continued)

Table 5.3 (continued)

Unit	Equivalent sq. meters	Equivalent sq. feet, US	Region	Era	Common application	Notes
sq yard	0.8361	9.000	United States	Colonial to Modern	General	1891 value, still current
square	9.290	100.0	Miscellaneous	Pre-metric	General	100 sq feet
square bara	0.699	7.52	Argentina	Colonial to pre-metric	General	1891 value
square cassaba	12.60	135.6	Egypt	Ancient to pre-metric	General	Pre-1891
square chain	404.7	4354	United States	Colonial to Modern	Land	4356 sq survey ft
square cubit (hachemic)	0.4096	4.407	Arabia	Ancient	General	2003 reference
square derah	0.2741	2.949	Egypt	Ancient to pre-metric	General	1966 value
square derah	0.323	3.47	Egypt	Ancient to pre-metric	General	Pre 1891
square derah meimari	0.563	6.05	Egypt	Ancient to pre-metric	General	
square ell	0.884	9.51	Scotland	Medieval to pre-metric	General	
square fall	32.14	345.8	Scotland	Medieval to pre-metric	General	2003 reference

(continued)

Table 5.3 (continued)

Unit	Equivalent sq. meters	Equivalent sq. feet, US	Region	Era	Common application	Notes
square faw	32.14	345.8	Scotland	Medieval to pre-metric	General	2003 reference
square foot	0.09290	1.000	United States	Colonial to Modern	General	144 square inches
square foot	0.09391	1.010	Scotland	Medieval to pre-metric	General	2003 reference
square forraigh	1296	13,950	Ireland	Medieval to pre-metric	Land	
square fot	0.08815	0.9485	Sweden	Medieval to pre-metric	General	Square foot, 144 kvadrattum, 1891 value, consistent with 2003 reference
square guz (Bombay)	0.4703	5.060	India	Medieval to pre-metric	General	2003 reference
square guz (Calcutta)	0.8372	9.009	India	Medieval to pre-metric	General	Variation, unit buildup same proportions as Bombay, 2003 reference
square inch	0.0006451	0.006942	United States	Colonial to Modern	General	
square inch	0.00068	0.0073	Scotland	Medieval to pre-metric	General	

(continued)

Table 5.3 (continued)

Unit	Equivalent sq. meters	Equivalent sq. feet, US	Region	Era	Common application	Notes
square jalka	0.0882	0.948	Finland	Medieval to pre-metric	General	
square klafter	3.597	38.70	Austrian Empire	Pre-metric	General	2003 reference
square kvat	3.595	38.68	Yugoslavia	Pre-metric	General	36 sq stopa, 2003 reference
square kynnäri	0.353	3.79	Finland	Medieval to pre-metric	General	basic unit for taxation areas
square meile	6,978,000	7.509E+07	Hungary	Medieval to pre-metric	Land	2003 reference
square ngu	5.523	59.42	Vietnam, Annam	Colonial to pre-metric	General	2003 reference
square pace	0.000	9.00	Cyprus	Medieval or pre-metric	General	2003 reference
square pic	0.4624	4.975	Libya	Medieval to pre-metric	General	2003 reference
square pic	0.5706	6.140	Turkey	Medieval to Metric	General	2003 reference
square pik	0.4624	4.975	Libya	Medieval to pre-metric	General	2003 reference

(continued)

Table 5.3 (continued)

Unit	Equivalent sq. meters	Equivalent sq. feet, US	Region	Era	Common application	Notes
square plethron	991.0	10,660	Byzantine Empire	Ancient	Land	10,000 square pous, lit. turning, varied from 900 to 1900 sq meters, effectively an acre
square pou	2.560	27.55	China	Ancient to pre-metric	General	4.17 hao
square pous	0.095	1.0	Byzantine Empire	Ancient	General	1 square Greek foot
square pret	18.66	200.8	Poland	Medieval to pre-metric	General	2003 reference
square ri	1.542E+07	1.659E+08	Japan	Medieval to pre-metric	Land	15,552 tan, 2003 reference
square Rijnlandse feet	0.0986	1.06	Netherlands, Holland	Medieval to Metric	General	
square rod	25.29	272.2	United States	Colonial to Modern	Land	
square ruthe	14.18	152.6	Denmark	Pre-metric	General	144 sq fod, 2003 reference
square stopa	0.08294	0.8924	Poland	Medieval to pre-metric	General	2003 reference
square stopa	0.09986	1.074	Yugoslavia	Pre-metric	General	2003 reference
square surveyor's chain (Old)	929.0	9996	United States	Colonial to Modern	Land	Old value, obsolete

(continued)

Table 5.3 (continued)

Unit	Equivalent sq. meters	Equivalent sq. feet, US	Region	Era	Common application	Notes
square vara	6.400E-05	7.518	Guatemala	Colonial to pre-metric	General	2003 reference
square vara	0.640	6.89	Colombia	Colonial to pre-metric	General	1920s
square vara	0.6606	7.109	Honduras	Colonial to pre-metric	General	2003 reference
square vara	0.6879	7.402	Central America	Colonial to pre-metric	General	
square vara	0.6879	7.402	El Salvador	Colonial to pre-metric	General	2003 reference
square vara	0.6987	7.518	Nicaragua	Colonial to pre-metric	General	2003 reference
square vara	0.6987	7.518	Spain	Medieval to pre-metric	General	Pre-1860, 2003 reference
square vara	0.7022	7.556	Mexico	Colonial to pre-metric	General	2003 reference
square vara	0.7044	7.580	Costa Rica	Colonial to pre-metric	General	2003 reference

(continued)

Table 5.3 (continued)

Unit	Equivalent sq. meters	Equivalent sq. feet, US	Region	Era	Common application	Notes
square zereh	0.1024	1.102	Persia, Iran	Medieval to pre-metric	General	2003 reference
staje	13,500	145,300	Poland	Medieval to pre-metric	Land	Appx 1.2–1.5 hectares, used avg
staro (Parma)	508	5460	Italy	Medieval to pre-metric	Land	12 tavola, 1891 value
stemma	1000	10,760	Greece	Medieval to pre-metric	Land	Greek acre, 10,000 square Greek feet
stremma	991.0	10,660	Byzantine Empire	Ancient	Land	10,000 square pous, lit. turning, varied from 900 to 1900 sq meters, effectively an acre
strich	2878	30,970	Austrian Empire	Pre-metric	Land	1/2 Austrian joch
strych	2878	30,970	Czechoslovakia	Medieval or pre-metric	Land	1.439 merice, 2003 reference
sù	171.3	1843	Egypt	Ancient to pre-metric	Land	625 sq derah, 1966 value
survey township	9.324E+07	1.003E+09	United States	Colonial to Modern	Land	36 sections, 4 square leagues
sznur	1995	21,470	Poland	Medieval to pre-metric	Land	1/90 włoka

(continued)

Table 5.3 (continued)

Unit	Equivalent sq. meters	Equivalent sq. feet, US	Region	Era	Common application	Notes
ta	27.60	297.0	Egypt	Ancient to pre-metric	General	100 sq cubits = 1/100 setat
tac	2.400	25.82	Vietnam, Annam	Colonial to pre-metric	General	10 phan, traditional, 3.3135 m ² Annamite, 1891 value
tan	991.7	10,670	Japan	Medieval to pre-metric	Land	300 tsubo, 10 se, 2003 reference
tarang wa	4.0	43	Thailand	Pre-metric	General	square wa, 2003 reference
tarefa	3500	37,660	Brazil	Colonial to pre-metric	Land	3000 to 4000 sq meters, avg
tavola (Modena)	39.4	424	Italy	Medieval to pre-metric	General	4 sq cavezzi, 1891 value
tavola (Parma)	42.3	455	Italy	Medieval to pre-metric	General	1891 value
ten	147.5	1587	Persia, Iran	Medieval to pre-metric	Land	10 gar, 2003 reference
ten	274.1	2949	Egypt	Ancient to pre-metric	Land	10 pekeis, 1966 value
tenab (Bombay)	1176	12,650	India	Medieval to pre-metric	Land	500 chattack, 2003 reference

(continued)

Table 5.3 (continued)

Unit	Equivalent sq. meters	Equivalent sq. feet, US	Region	Era	Common application	Notes
than	4,000	43.04	Vietnam, Annam	Colonial to pre-metric	General	1 ngu square, 1891 value
thon	2,400	25.82	Vietnam, Annam	Colonial to pre-metric	General	10 phan, traditional, 3,3135 m ² Annamite, 1891 value
thuoc	33.14	356.5	Vietnam, Annam	Colonial to pre-metric	General	6 sq ngu, 2003 reference
thuroc	24.00	258.2	Vietnam, Annam	Colonial to pre-metric	General	10 tac, traditional, 33 m ² Annamite, 1891 value
tir-cumaile	93,310	1,004,000	Ireland	Medieval to pre-metric	Land	23 Imperial acres, land of 3 cows
tir-unga	18,000	193,700	Scotland	Medieval to pre-metric	Land	Ounceland, 20 pennylands, western region, taxes & rents
toise carrée (de Paris)	3,798	40.87	France	Medieval to pre-metric	General	36 pied carré, pre-1795, 2003 reference
tonde	28,360	305,200	Denmark	Pre-metric	Land	8 skiepper, 2003 reference
tøndeland	5516	59,350	Denmark	Pre-metric	Land	14,000 sq aln, consistent with 2003 reference
tøndeland	4910	52,830	Norway	Medieval to pre-metric	Land	2 spannland, 56,000 sq fot, 1891 value

(continued)

Table 5.3 (continued)

Unit	Equivalent sq. meters	Equivalent sq. feet, US	Region	Era	Common application	Notes
tonneland	3936	42,350	Norway	Medieval to pre-metric	Land	Barrel of land, 4 mal
tonnestelle	992,600	55,980	Latvia	Medieval to pre-metric	Land	35 kapp, 2003 reference
tonnland (Livonian region)	5194	55,890	Estonia	Medieval to pre-metric	Land	
tonnland (Reval/ Tallin region)	5463	58,780	Estonia	Medieval to pre-metric	Land	
topo	2706	29,120	Peru	Colonial to pre-metric	Land	3872 sq vara, 2003 reference
tomatura (Venetian Lombardy)	100	1080	Italy	Medieval to pre-metric	General	100 sq palmi, 1891 value
township	9.324E+07	1.003E+09	United States	Colonial to Modern	Land	36 sections, 4 square leagues
township	439,040	4,724,000	Wales	Medieval to pre-metric	Land	4 holdings
triens	841.0	9049	Roman Empire	Ancient	Land	9600 sq pedes

(continued)

Table 5.3 (continued)

Unit	Equivalent sq. meters	Equivalent sq. feet, US	Region	Era	Common application	Notes
tsubo (construction)	3,306	35,57	Japan	Medieval to pre-metric	General	One square ken, 2003 reference
tuath	1.748E+07	1.881E+08	Ireland	Medieval to pre-metric	Land	4320 achar, originally designated a petty kingdom
tundagslatta	3192	34,350	Iceland	Medieval to pre-metric	Land	900 ferfaðmur, 2003 reference
tunna	4910	52,830	Norway	Medieval to pre-metric	Land	2 spannland, 56,000 sq fot, 1891 value
tunnland	4936	53,120	Sweden	Medieval to pre-metric	Land	2 fjårdingsland, 2003 reference
tynnyrinala	4937	53,120	Finland	Medieval to pre-metric	Land	Area that could be sown with one barrel of grain
ubu	1800	19,370	Mesopotamia, Sumer, Akkadia	Ancient	Land	half-field, 10 gardens
uncia	210.0	2260	Roman Empire	Ancient	Land	2400 sq pedes
upu	1800	19,370	Mesopotamia, Sumer, Akkadia	Ancient	Land	half-field, 10 gardens

(continued)

Table 5.3 (continued)

Unit	Equivalent sq. meters	Equivalent sq. feet, US	Region	Era	Common application	Notes
wapentake	3.639E+07	3.916E+08	United Kingdom	Medieval to pre-metric	Land	100 hides, administration grouping, ~9000 acres or 14 sq miles
wloka	179,500	1,932,000	Poland	Medieval to pre-metric	Land	Also reported as 167,962 sq meters in 2003, 30 morga
xiber kwadru	0.0686	0.738	Malta	Medieval to pre-metric	General	
xich	24.00	258.2	Vietnam, Annam	Colonial to pre-metric	General	10 tac, traditional, 33 m ² Annamite, 1891 value
yard land	121,300	1,305,000	United Kingdom	Medieval to pre-metric	Land	Land two oxen can plow in a year, ~30 acres
yoke	1822	19,600	Biblical, Talmudic	Ancient	Land	Area ploughed by 2 oxen in 1 day, 6480 sq cubits
yugada	322,000	3,465,000	Spain	Medieval to pre-metric	Land	50 fanagada, pre-1860, 2003 reference
zreb	275,000	2,959,000	Poland	Medieval to pre-metric	Land	Appx 20–35 hectares

Conclusion

Area was an historical, fundamental or base measurement unit. Area units appropriate for everyday use were most commonly squares of linear measurement units, but have also been separately defined and had their own, unique unit names. The development of the concepts of land ownership and agriculture drove the definitions of larger area units. At the other end of the spectrum, science has driven other units of area measurement—from the very tiny to the very large. The development of methods for calculating areas has progressed through history from simple concepts involving circles, rectangles, and triangles to the integral calculus applied to complex areas. Extensive listings of conversion factors for historical units to modern area units are provided for various locales and eras in world history.

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Chapter 6

Historical Volume or Capacity



Abstract Volume was an historical base measurement unit for all types of fluids, granular solids, and objects. Capacity is the maximum capability of a tank, vessel, or other container to hold a given volume of material. Capacities are generally measured in the same units as volume. This chapter addresses both volume and capacity units. Units appropriate for everyday use are most commonly cubes of small linear measurement units and/or have their own set of unit definitions and names, such as those for cooking. Larger units are driven by industry, commerce, or science and are normally expressed as cubes of linear or spherical dimensions. Extremely small units are based on cubes of linear or spherical measures as driven by scientific needs. The development of methods for calculating volumes is discussed as it has progressed from simple concepts involving basic shapes to integral calculus applied to complex shapes. Methods for measurement of volume are reviewed, including direct linear measurement of an object with subsequent calculation, use of standardized measuring devices (cups, spoons, tanks, etc.), and integration of volumetric flow rates entering a container over time. Extensive listings of conversion factors for historical units to modern volume units are provided for various locales and eras in world history.

Introduction

Volume and capacity are actually different concepts, but share a common measurement heritage and generally use the same units of measurement.

Volume is a measure of the space occupied by a quantity of a material or an object. This includes gases, liquids, solids, mixtures, or physical objects—essentially anything that can have a three dimensional shape. In modern practice, volume measurement is defined by the space enclosed by a combination of linear/curvilinear lines, but this was not always the case. Throughout most of history, volumes were measured in their own separate, base units.

Capacity is specific to a container for a fluid or granular solid and defines the total capability of a container to hold or contain an amount of a given material.

The volume contained may not necessarily fill the entire capacity of the container. Strictly speaking, the material is considered to assume the shape of the container; like a liquid fills a cup completely up to the top level of the liquid and “wets” or contacts the entire interior surface of the container up to the liquid level (neglecting surface tension effects). For gases and liquids, this is a fairly easy thing to see. For granular materials, like wheat or catalyst, the particles of the material fill the container on a macro scale, but there is significant void space on a micro-scale that is still not occupied. Nevertheless, volume and capacity are applied to granular solids as well as liquids and gases and the overall volume is considered to include the voids (the “bulk” capacity).

Often times, we specify that we want a given weight of material in a given volume of a container. This requires that we know or control how much the material weighs per unit volume (i.e. the density or specific gravity). This is mentioned here because people are often surprised when they put the desired weight into a container and the container is either too full or has too much outage. Sometimes this is just an inconvenience, while other times it is a hazard. Suppose you have a 50,000 barrel storage tank that holds up to 7200 MT of gasoil and you switch services to naphtha, a lower density material. If you try to put 7200 MT of naphtha into the tank, you will have over 1000 MT of naphtha overflowing into your tank dike and creating a fire hazard (and someone is going to lose their job). When you are filling a container with a specific capacity, remember that the container of fixed volume only holds physical volume. The container cannot hold weight. Of course, weight comes along with the volume of material, but the two are really separate measures. You must look at contained volume and level.

For the most part in this chapter, we use the terms volume and capacity interchangeably, but will tend to use volume most often, keeping in mind there is a conceptual difference.

In this chapter, we will explore the history of volume measurement units from the earliest recorded applications and standardization to more modern units. We’ll examine the approaches that have been developed to determine volumes on various scales. Finally, tables of conversion factors are provided for various historical civilizations and eras classified by where and who used the units and alphabetically.

We will begin by looking briefly at how volume measurement developed and why.

Historical Volume/Capacity Measurement

[1, 2, 6–11, 13–15, 17, 18, 20–27, 29]

The need for volumetric measurement dates back before recorded history. The easiest way to proportion materials together for a mixture or divide materials for distribution is by volume. This approach does not require anything like a scale or ruler or measurement device, although some standard volume instrument is helpful for bulk materials.

Human Measures

The simplest measures can be made by using your hands. In fact, measuring ingredients for cooking is often still done by handfuls or pinches. It isn't terribly accurate and there is significant variation; but it is accurate enough for the intended purpose. Measurement of volumes using the hands is exemplified by the Native American Shoshone Tribe [15] where pinches (~ 0.0006 liter/ 2×10^{-5} cft), dashes (~ 0.003 liter/ 1×10^{-4} cft), and handfuls (~ 0.1 liter/0.004 cft) were measures of volume in cooking and these are still used today in the United States. "Ju" (~ 0.1 liter/0.004 cft) was a handful and "yi" (~ 0.2 liter/0.007 cft) was a double-handful in traditional Chinese measurements [23]. In Thailand, we find units for dry measure of "chai meu" (volume held in a closed hand, ~ 0.03 liter/0.001 cft) and "kam meu" (volume in an open hand, ~ 0.125 liter/0.004 cft) [9hhh].

"Natural" Volume Measures

The earliest tools for measuring volumes were most likely naturally occurring containers: gourds, sheep or pig stomachs, bladders, and similar vessels. These "natural containers" were roughly consistent in volume, came in a range of sizes, and could be used for many years. They were easily portable and easily replaced when necessary. Examples of these natural containers or volume "standards" include:

- Buffalo horn (~ 0.4 liters/0.014 cft)—used by Shoshone Tribe in North American as recently as 19th century [15]
- Egg (~ 0.05 liters/0.002 cft)—from the Israeli System [20–22]
- Kanahm (~ 1 liter/0.035 cft)—volume of a coconut shell in Thailand [9hhh]
- Gourd (variable size)—used for containing and measuring materials throughout the world since before 10,000 BC; the Chinese actually developed a method for growing gourds into standard shapes and sizes [23].

Manmade Containers

With the development of pottery and basket making, it became possible to create containers of specific and more consistent volumes. Metal working and glass-making made even more accurate and consistent containers possible. The ability to create containers of more or less consistent capacity has been widely applied for thousands of years with such units as:

- Xestes or pot (0.5–2.5 liters/0.02–0.09 cft)—used in many locations and times: Biblical, Greek, Denmark, Norway, Sweden, Switzerland, France, Portugal, Iceland, Byzantine Empire (multiple sources, esp. [9])

- Hin (0.5–7 liters/0.02–0.25 cft)—standard sized jar from Egypt and Biblical areas [9e, 20–22, 25]
- Amphora (19–35 liters/0.67–1.2 cft)—Roman Empire, France—used for liquids [9dd, ee, qqq]
- Anker (34–75 liters/1.2–2.6 cft)—volume of a small, standard cask used in Sweden, Prussia, Germany, Russia, U.S., Latvia, Iceland, Denmark, Finland (multiple sources, esp. [9])
- Baril, barile, barrel, others (9–170 liters/0.3–6 cft)—sizes have varied greatly, used in many locales and still used for oil and spirits (multiple sources, esp. [9])
- Bowl (~1 liter/0.035 cft)—this was a base unit in ancient Mesopotamia and gave rise to a whole family of measurement units [9ccc].

Commodity Variations and Liquid/Dry/Heaped Measures

Historically, the volume represented by a measurement unit varied not only with time and location, but with the commodity being measured. Many places and times had separate liquid and dry measures, and this is perpetuated today in the U.S. Customary system. The liquid system would also apply to gases.

In many cases, volume units have been defined as the space occupied by a specific weight of a standard commodity or material (multiple sources, esp. [9]). For instance, an English Imperial gallon was defined in 1824 as the volume occupied by 10 pounds of distilled water at 62 °F. This was equivalent to 4.546 liters (0.1605 cft) and was eventually redefined as an exact volume of 277.274 cubic inches, essentially converting it to a length-based measurement. The older English gallon units were commodity-based. An English wine gallon was different from a beer gallon which differed from an ale gallon. A “maris” in Biblical times was the volume occupied by one royal talent (a weight unit) of water, equal to about 30 liters (1.06 cft). An apple gallon, in Cornwall (UK) was 7 pounds of apples or 3.028 liters (0.107 cft), smaller than other types of gallons. The term “tun” (~954 liters/33.7 cft), applied in many locales, represented a volume occupied by one long ton of water (2240 lbs/1,016 kg). Larger and smaller units were then defined proportions of the base units.

Volume unit differences based on commodity were particularly true of grains and alcoholic spirits. The actual volumes of a “bushel” of oats or wheat or barley have been different in the same locations over time. In the case of the Scottish [9sss], wheat, peas, beans, rice, and salt were sold by “level” measure; that is, the commodity was leveled off even with the top of the measurement container. In the case of oats, barley, or malt, the commodity was traded by “heaped” measure; that is the container was piled full above the top rim and not leveled off. Differences in volumes represented by different commodities are also seen in wine, beer, oil, and water. The volume definitions in terms of absolute space occupied by a material have only been more or less standardized in the past couple hundred years, but

differences still persist. Previous examples of volume units with the same names, but which represented differing absolute values for different materials include:

- English liquid barrels [9v,w], where:
 - Beer barrel = 166 liters (=5.86 cft)
 - Oil barrel = 159 liters (=5.61 cft)
 - Wine barrel = 143 liters (=5.05 cft)
- Scottish dry peck [9sss], where:
 - Wheat, peas, beans, rice, salt peck = 9 liters (level measure, = 0.32 cft)
 - Oats, barley, malt peck = 13 liters (heaped measure, = 0.46 cft).

Wood Volume Measurements [1, 9, 16]

There are a few odd volumes that apply to specific commodities. There is a whole family of terms for wood measurement. A cord of wood, for example, is a volume of chopped and stacked wood that is equal to 128 cubic feet (3625 liters) in the United States and England. This value varied by region and time, so that a cord of wood in Austria in 1891 was 241 cubic feet (6830 liters) and in France, before the metric system, it was 135 cubic feet (3820 liters). A board foot in the United States is similarly defined as 1/12 cft (2.254 liters). It is defined as a volume of lumber that is 1 foot long $\times$ 1 foot wide by 1 inch thick ($0.30 \times 0.30 \times 0.0254$ m). In buying firewood or pricing wood lumber today, the cord and the board foot units are still used.

Shipping Volume Units

Some volume units are defined by methods of shipping. For instance, the “cargueiro” used in Brazil was equal to 80 liters (2.8 cft) which constituted a “mule-load” [9f]. A Biblical “ephah” was about 23 liters (0.81 cft) and represented an “ass-load” of a commodity (yeah, that is what it was called) [9e]. Ship volumes have been defined in terms of “Register tons” (100 cft, 2832 liters) and “shipping tons” (40 cft, 1133 liters) [1, 2, 9y, 26].

Cubes of Linear Units

Of course, one of the most common ways to define volumes is by using the equivalent cubic measures. These cubic measures are sometimes given their own unit names. This approach gives rise to cubic feet, cubic yards, cubic centimeters,

cubic decimeters, cubic meters, and so on. The use of cubic volumes for volume standards can be traced back to ancient times, where the Roman “amphora quadrantal” (~ 26 liters/ 0.92 cft) [9qqq] was one cubic Roman foot, the volume of a standard liquid shipping container, and the Egyptian “deny” (~ 143 liters/ 5.0 cft) was one cubic royal cubit [9t,u, 25]. Commonly, cubic decimeters are referred to as liters, although the liter is a vestige of the early metric system. A liter is still a convenient size basis for many common measurements, hence it continues to be used (and we use it here for volume comparisons).

The Apothecaries’ System

Apothecary measures were used for medicines and fine goods and are still applied in some cases. The apothecaries’ system is a separate and ancient system of measurement that parallels, and sometimes coincides, with common measurements. In the apothecaries’ system, the largest unit is the gallon and the smallest unit is usually about a drop, so the volumes measured can be very small. Units in this system, within English measurement since 1824 AD [9y, 27], include:

- minim or drop (0.00006 liter/ 2×10^{-6} cft)
- drachm (~ 0.0036 liter/ 1.3×10^{-4} cft)
- ounce (~ 0.028 liter/ 0.0010×10^{-3} cft)
- pint (~ 0.57 liter/ 0.020 cft)
- Imperial gallon (~ 4.5 liters/ 0.16 cft).

Metric and U.S./English Systems

The two primary systems of volume measurement today are the U.S. Customary system and the metric (SI) system. The common units defined by these systems, along with some historical units, are listed below:

- Metric measurement units (based on cubes of length measurements) [2, 11].
 - cubic millimeter (1×10^{-6} liter/ 3.5×10^{-8} cft)
 - cubic centimeter (milliliter, 1×10^{-3} liter/ 3.5×10^{-5} cft)
 - cubic decimeter (1 liter, 0.035 cft)
 - cubic meter (1×10^3 liters/ 35.31 cft)
 - cubic dekameter (1×10^6 liters/ 3.53×10^4 cft)
- U.S. historical measurement units [2, 10].
 - General Volumes
 - cubic inch (0.01639 liter/ 0.000579 cft)
 - cubic foot (28.32 liters/ 1.000 cft)
 - cubic yard (764.6 liters/ 27 cft)

shipping ton (1133 liters/40 cft)
acre foot (1,233,482 liters/43,554 cft)
register ton (2832 liters/100 cft)
cubic mile (4.169×10^{12} liters/ 1.47×10^{11} cft)

- Dry Measure

pint or chopine (0.5506 liter/0.019 cft)
quart (1.101 liters/0.039 cft)
gallon (4.405 liters/0.1555 cft)
peck (8.810 liters/0.3111 cft)
bushel or Winchester bushel (35.24 liters/1.244 cft)
firkin (39.64 liters/1.400 cft)
barrel (115.6 liters/4.082 cft)
chaldron, for coke or coal (1269 liters/44.81 cft)

- Liquid Measure

minim (6.161×10^{-5} liter/ 2.175×10^{-6} cft)
fluid dram (0.003697 liter/ 1.305×10^{-4} cft)
teaspoon (0.004929 liter/ 1.740×10^{-4} cft)
tablespoon (0.01479 liter/ 5.222×10^{-4} cft)
fluid ounce (0.02957 liter/0.001044 cft)
shot or jigger (0.04436 liter/0.001566 cft)
gill or half-cup (0.1183 liter/0.004177 cft)
cup (0.2366 liter/0.008354 cft)
pint (0.4732 liter/0.01671 cft)
quart (0.9464 liter/0.03342 cft)
gallon (3.785 liters/0.1336 cft)
demijohn (11.4–37.9 liters/0.403–1.34 cft)
runlet (68.14 liters/2.406 cft)
barrel, for beer (117.3 liters/4.142 cft)
barrel, for general use (119.2 liters/4.209 cft)
barrel, for whiskey and kerosene (151.4 liters/5.346 cft)
barrel, for petroleum oil (159.0 liters/5.614 cft)—still international standard

- Wine Measure

- anker (37.85 liters/1.336 cft)
- tierce (159.0 liters/5.614 cft)
- hogshead (238.5 liters/8.421 cft)
- puncheon (317.9 liters/11.23 cft)
- pipe (476.9 liters/16.84 cft)
- tun (953.8 liters/33.68 cft)

- Cooking Measure

drop, drp, gtt (4.929×10^{-4} liter/ 1.740×10^{-5} cft)
pinch (6.161×10^{-4} liter/ 2.175×10^{-5} cft)

salt spoon, ssp ($0.001232 \text{ liter}/4.350 \times 10^{-5} \text{ cft}$)
 coffee spoon, csp ($0.002464 \text{ liter}/8.700 \times 10^{-5} \text{ cft}$)
 dash ($0.002957 \text{ liter}/1.044 \times 10^{-4} \text{ cft}$)
 teaspoon, tsp ($0.004929 \text{ liter}/1.740 \times 10^{-4} \text{ cft}$)
 dessertspoon, dst ($0.009858 \text{ liter}/0.0003480 \text{ cft}$)
 tablespoon, tbsp, tls, Tsp ($0.01479 \text{ liter}/0.0005222 \text{ cft}$)
 coffee measure ($0.02957 \text{ liter}/0.001044 \text{ cft}$)
 fluid ounce ($0.02957 \text{ liter}/0.001044 \text{ cft}$)
 wine glassful ($0.1479 \text{ liter}/0.005222 \text{ cft}$)
 teacupful, tcf ($0.1479 \text{ liter}/0.005222 \text{ cft}$)
 cup ($0.2366 \text{ liter}/0.008354 \text{ cft}$)
 breakfast cup, tumblerful ($0.2957 \text{ liter}/0.01044 \text{ cft}$)
 water glassful ($0.4732 \text{ liter}/0.01671 \text{ cft}$)

- Stacked Firewood

board foot measure, bfm, fbm ($2.254 \text{ liters}/0.07959 \text{ cft}$)
 whole deal ($16.23 \text{ liters}/0.5731 \text{ cft}$)
 faggot, fgt ($27.04 \text{ liters}/0.9548 \text{ cft}$)
 cubic foot or timber foot, cft, cu ft, ft^3 ($28.32 \text{ liters}/1.000 \text{ cft}$)
 deal ($38.94 \text{ liters}/1.375 \text{ cft}$)
 cord-foot, cd-ft ($453.1 \text{ liters}/16.00 \text{ cft}$)
 load, unhewn ($755.2 \text{ liters}/26.67 \text{ cft}$)
 load, squared ($1189 \text{ liters}/41.98 \text{ cft}$)
 house cord, rick ($1208 \text{ liters}/42.65 \text{ cft}$)
 face cord ($1813 \text{ liters}/64.02 \text{ cft}$)
 stack, stk ($3058 \text{ liters}/108.0 \text{ cft}$)
 cord, split deal, cd ($3625 \text{ liters}/128.0 \text{ cft}$)
 standard ($4673 \text{ liters}/165.0 \text{ cft}$).

Comparisons of Historical Unit Magnitudes

Across civilizations and following our practice for other measurement units, the orders of magnitude for various historical volume units are compared in Figs. 6.1 and 6.2. Figure 6.1 compares dry units for several systems. Figure 6.2 provides the comparison for liquid measures. Where a system does not distinguish between liquid and dry measure, the general units are used for the comparison. The liquid units also include columns for apothecaries' and standard cooking measures.

Note that the volume units tended to concentrate in the more common range associated with everyday tasks, like cooking for liquids and tend toward the larger range for dry measures, reflecting the most common applications.

The range and concepts behind volume units over history provides a rich and colorful view of how people have sought to measure volume. Not only have volume

units depended on locale and time, but they have depended on the commodity, the shipping or trade method, the density, and how a container is filled, among other factors.

Note that the data used to develop the Figs. 6.1 and 6.2 comparisons were derived from multiple sources listed in the “References” section; hence, the reference numbers are not repeated here.

Historical Determination of Volumes [4, 5, 7, 8, 16, 19]

The history of volume measurement would not be complete without a discussion of how people have determined volumes over time.

Using a Calibrated Container

From the earliest times until today, volume has been commonly measured using vessels or containers of known or consistent capacity. This is sort of an “experimental” or direct physical approach to volume. This method of measurement is still common today in some household, scientific, and industrial applications. It is more easily applied than, say, weighing ingredients, which requires that you carry a scale. It is not practical for large volumes unless you can build a very large calibrated container, like a tank.

With volumes measured by containers, a given volume of material is simply a multiple or fraction of the capacity of the standard container. Normally, the volume is based on the material to be measured being “leveled off” even with the top of the measuring container, as you would have with a liquid. This is the rule of thumb for cooking measures, for instance. But this is not always the case. Some granular material volumes have occasionally been determined by “heaped” measure—that is the material is loaded above the top of the container until it assumes its natural angle of repose. In a recipe, you might see this called out as a “heaping teaspoon” of sugar—adequate, but not terribly accurate.

Calibrated measuring cups and measuring spoons used for cooking are illustrated in Fig. 6.3. The accuracy of these tools is adequate for cooking, but is normally not good enough for scientific applications.

When higher accuracy is required, we usually measure materials by mass rather than volume; but sometimes volume is what we need. We have graduated cylinders, pipettes, and volumetric flasks for instance used in chemistry that have been more accurately calibrated. Some examples are in Fig. 6.4.

Use of calibrated containers is limited to smaller volumes usually. The largest volumes measured this way are probably those in storage tanks that may hold, say, 1 million barrels of crude oil where the contained tank volume has been determined

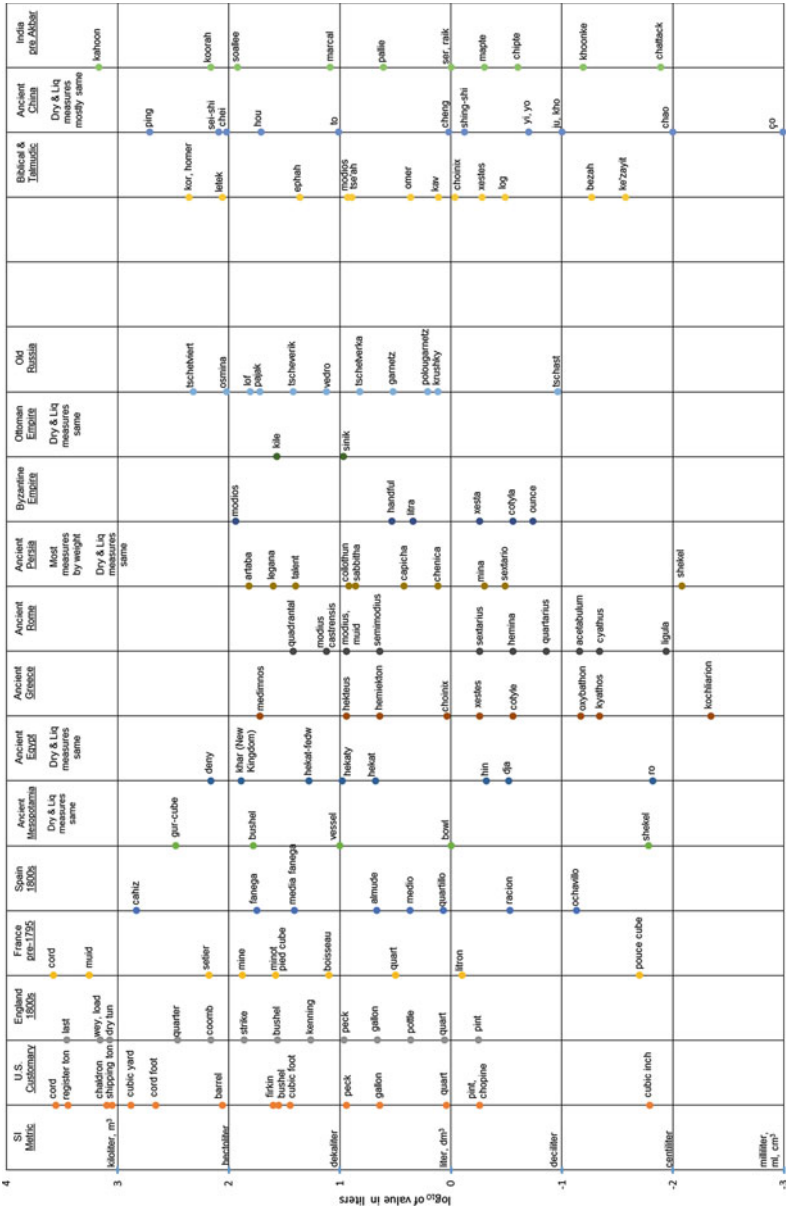


Fig. 6.1 Order of magnitude comparison of significant historical dry volume units by civilization. See references section

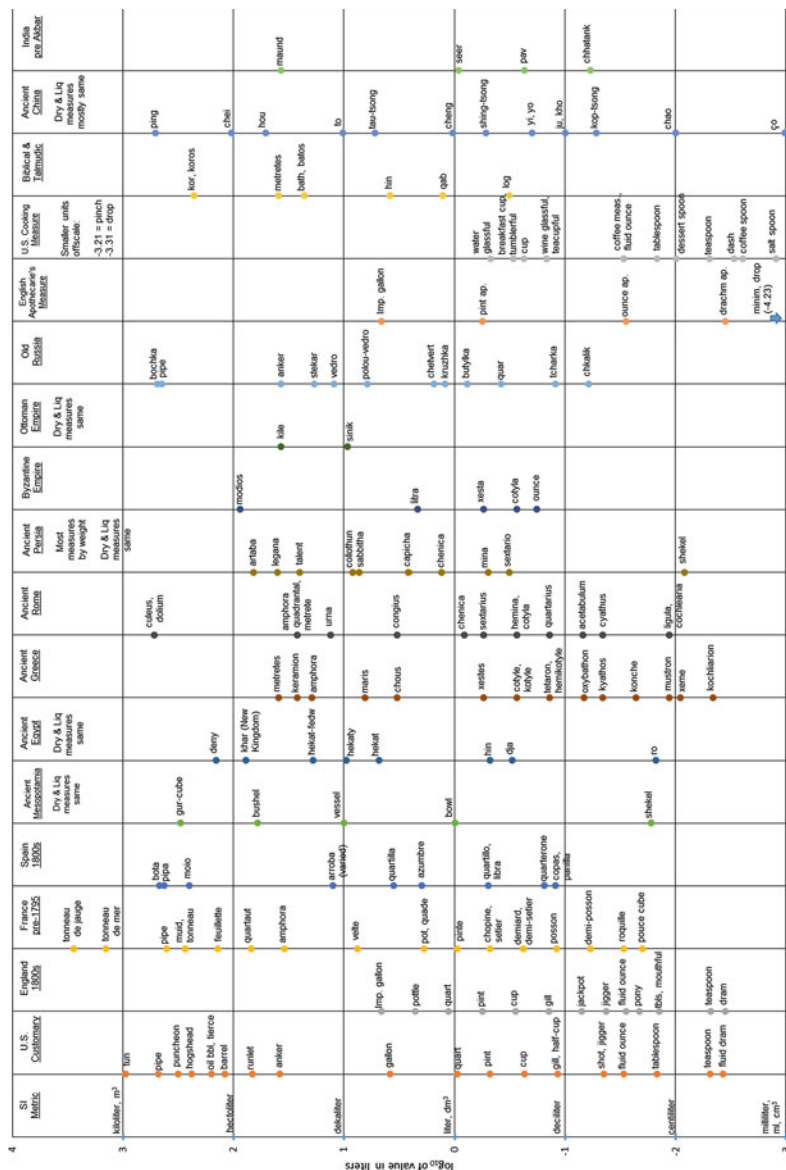


Fig. 6.2 Order of magnitude comparison of significant historical liquid volume units by civilization. See references section



Fig. 6.3 Examples of cooking measurement tools—measuring cups and spoons Calibrated for both metric and U.S. measurements

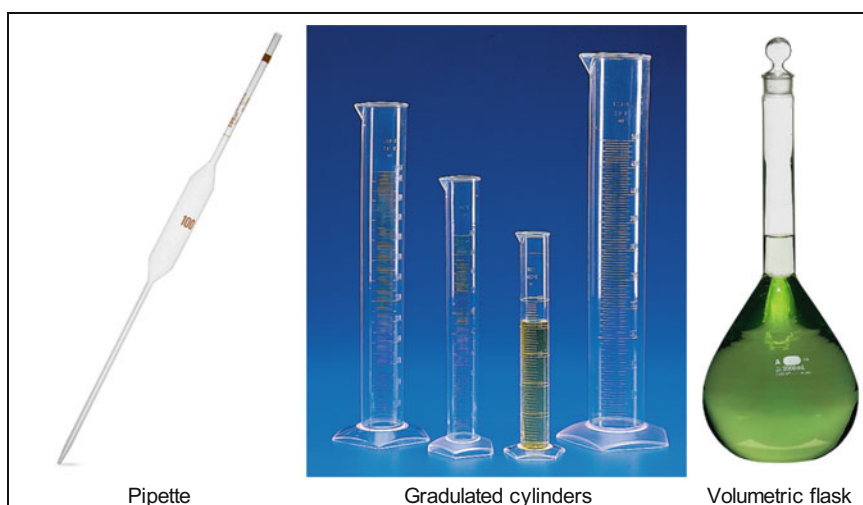


Fig. 6.4 Examples of scientific volume measurement tools Credits Cole Parmer, SKS Science, and Globe Scientific

for every fraction of an inch level at a known temperature. Strapping tables then allow very accurate volume determination using the liquid level in the tank after correction for temperature or density.

Where the use of standard, calibrated containers is not practical, methods have been developed to calculate the volume of a container or a large reservoir with a complex shape mathematically using definitions of the volume units (cubes of linear measures).

For the very large volumes used in commerce and manufacturing, volume is often determined by the total of a flow rate over a period of time. For instance, if you are flowing 2328 barrels per day of oil for 6 h, the total volume would be 582 barrels. If the flow rate varies over time, the instantaneous rates are integrated to get the total volume. Several types of flow meters have been developed with sufficient accuracy for these volume determinations, including custody transfers that involve large product volumes or costs in the millions of dollars, where an error could be very expensive.

Mathematics of Volume Calculation [16, 19]

The use of mathematics to determine volume dates from ancient times. In ancient Mesopotamia and Egypt, there were empirical rules used for determining the volumes of various simple geometric shapes, such as boxes, cylinders, truncated pyramids, and cones. We know this from surviving writings, copied in later times, which described how to determine types of volumes in the form of mathematical problems. Examples of this approach can be found in the Egyptian Moscow papyrus from around 1820 BC. These empirical approaches were not particularly accurate, but they were adequate for the purposes and sizes involved.

The Greeks brought more accurate, general, exact methods for calculating volumes of various simple, three-dimensional shapes or solids. These methods were described by Euclid of Alexandria, around 300 BC, in his treatise “Elements”. This work consisted of 13 books, with the last three books describing calculation of volumes or portions of parallelepipeds (like cubes), cones, pyramids, cylinders, and spheres. His work was a collection, improvement, and extension of much older works. Euclid’s predecessor sources are believed to have included the works of Pythagoras (c. 570–c. 495 BC), Hippocrates of Chios (c. 470–c. 410 BC), Eudoxus of Cnidus (c. 408–c. 355 BC), Theaetetus of Athens (c. 417–369 BC), and other lesser-known mathematicians from around the Mediterranean basin. Translations of the Elements are still available today.

Euclid determined volumes of more complex shapes by using a method for successive approximations, the method of “exhaustion”, to zero in on a value. The method of exhaustion was really pioneered by Eudoxus. Essentially, he broke the volume into simpler pieces for which volume could be calculated and added these together. By using smaller and smaller pieces, more accurate volume could be determined. This is similar to determination of volume by integral calculus, which was not developed until much later.

The determination of volume was extended by the Greek mathematician and inventor Archimedes of Syracuse (c. 287 BC–c. 212 BC). He contributed the idea that the volume of an irregular object could be determined by how much water it displaced when completely immersed. Thus, if you had a calibrated vessel with a known volume of water in it and immersed the object of interest in the vessel, the difference between the final contained volume and the original volume in the vessel would be the volume of the object. This was another experimental approach to volume determination. The volume-related concepts of displacement and buoyancy have been applied extensively over the centuries and are still used today.

Archimedes also developed the heuristic approach, which was similar to the method of exhaustion in some ways. This approach drew parallels between a specific problem and a problem with a known solution. In this case, the volume of an object could be determined approximately by comparison to similar objects.

Some of the Greek methods were independently discovered in China. The method of exhaustion, for instance, was found by Liu Hui in the 3rd century AD. Application of the exhaustion approach to determine the volume of a sphere was made by Zu Chongzhi in the 5th century AD. Similar methods were applied to volume determinations in the Middle East and India, largely independently.

Bonaventura Cavalieri (1598–1647 AD) began the thinking that would result in the modern integral calculus approach to volume calculation. He postulated that the volume an object could be accurately determined by adding the areas of infinitesimally thin cross sections of the object. This was similar to the approach of Archimedes in thinking, but knowledge of that method had been lost in the 13th century and was only rediscovered in the 20th century.

During the 17th and 18th centuries, AD, integral calculus developed along with differential calculus through the contributions of Pierre de Fermat, John Wallis, Isaac Barrow, James Gregory, Isaac Newton, Gottfried Leibniz, and Maria Agnesi. The resulting integral calculus can be used to accurately calculate the volume of any irregularly-shaped solid or space.

From a practical standpoint, it is still easiest to break an object or volume into smaller sections with known equations for volume and then adding these together to get the total wherever practical.

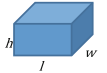
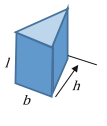
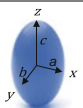
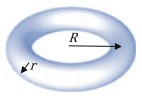
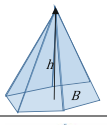
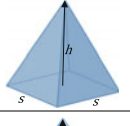
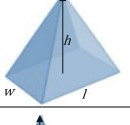
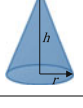
As discussed above, the volumes of large industrial transfers of materials today are often based on flow readings over a periods of time. Essentially, the total volume (V) is the integral of the flow rate ($F(\theta)$) over a time period:

$$V = \int_{\theta=0}^t F(\theta) d\theta \quad (6.1)$$

Formulas for Calculating Volume [4]

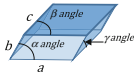
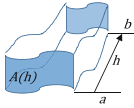
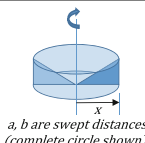
Table 6.1 provides the equations for calculating the volumes of several types of shapes. Additional formulae are available in standard references.

Table 6.1 Formulas for calculating volumes of selected shapes [4]

Shape	Form	Formula	Variables
Cube		a^3	a = length of any side or edge
Cylinder		$\pi r^2 h$	r = radius of the circular face h = height
Prism		$B \cdot h$	B = area of the base h = height
Rectangular prism		$l \cdot w \cdot h$	l = length w = width h = height
Triangular prism		$\frac{1}{2} b h l$	b = base length of triangle h = height of triangle l = length of prism or distance between prism bases
Sphere		$\frac{4}{3} \pi r^3$	r = radius of sphere
Ellipsoid		$\frac{4}{3} \pi a b c$	a, b, c are the semi-axes of the ellipsoid in $x, y,$ and z planes
Torus		$(\pi r^2)(2\pi R) = 2\pi^2 R r^2$	r = minor radius (radius of tube) R = major radius (distance from center of tube to center of torus)
General pyramid		$\frac{1}{3} B h$	B = area of base h = height of pyramid
Square pyramid		$\frac{1}{3} s^2 h$	s = length of a side of the base h = height of pyramid
Rectangular pyramid		$\frac{1}{3} l w h$	l = length of base w = width of base h = height of pyramid
Cone		$\frac{1}{3} \pi r^2 h$	r = radius of circle at base h = height of cone to the tip

(continued)

Table 6.1 (continued)

Shape	Form	Formula	Variables
Tetrahedron		$\frac{\sqrt{2}}{12} a^3$	a = length of each edge
Parallelepiped		$abc\sqrt{K}$ where: $K = 1 + 2 \cos \alpha \cos \beta \cos \gamma - \cos^2 \alpha - \cos^2 \beta - \cos^2 \gamma$	$a, b,$ and c are parallelepiped edge lengths α, β, γ are the interior angles between edges on each side
Any volumetric sweep		$\int_a^b A(h)dh$	h = any dimension of the figure $A(h)$ = area of the cross-sections perpendicular to h as a function of h a, b = limits of integration for the sweep
Any rotated figure		$\pi \int_a^b ([R_o(x)]^2 - [R_I(x)]^2) dx$	R_o and R_I are functions expressing outer and inner radii of the function, respectively

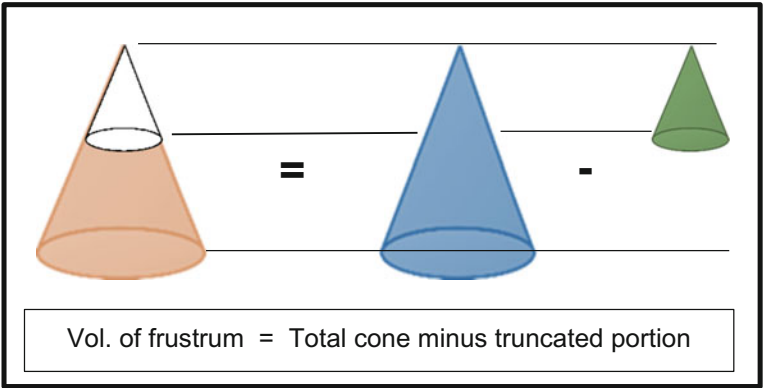


Fig. 6.5 Example calculation of the partial volume (frustum) of a cone

Partial volumes can usually be calculated for these shapes by the difference between two volumes. For instance the volume of a frustum of a cone is equal to the volume of a complete cone minus the volume of a cone representing the volume not occupied. See Fig. 6.5.

Historical Volume Conversion Factors
[1-6, 9, 10, 12–15, 19–28]

Two tables are offered here for volume conversion factors:

- Table 6.2 provides volume conversions for different locations, regions, eras, and historical civilizations listed alphabetically by location in both metric and U.S. Customary units.
- Table 6.3 provides the same volume conversion options as Table 6.2, except that the conversions are all listed alphabetically, without regard to location or era.

Note that the data used to develop Tables 6.2 and 6.3 were compiled from virtually all the sources listed in the “References” section; hence, the reference numbers are not repeated here.

Table 6.2 Historical volume/capacity measurement conversion factors by location and era. Multiple sources, see references section

Region and unit	Equivalent liters (dm ³)	Equivalent cu ft US	Notes	Era
Abyssinia				Pre-metric
madega (Gondar)	0.404	0.0143	1/10 ardeb, for grain, at Gondar, 1891 value	
madega	0.44	0.016	2003 reference	
madega (Massowah)	0.489	0.0173	1/24 ardeb, for grain, at Massowah, 1891 value	
kuba or cuba	1.012	0.03573	23/10 madega, 2003 reference	
kuba or cuba	1.017	0.03590	1891 value	
ardeb (Gondar)	4.039	0.1426	For grain, at Gondar, 1891 value	
ardeb (short)	4.40	0.155	10 madega, 2003 reference	
ardeb (long)	10.6	0.374	24 madega, 2003 reference	
ardeb (Massowah)	11.75	0.4147	For grain, at Massowah, 1891 value	
Algeria (pre-1843)				Medieval to pre-metric
khoull, khoul, kolleh, or khoullé	16.69	0.5892	Consistent with 1891 value and 2003 reference	
metalli (oil)	17.90	0.6321	For oil, 2003 reference	
tarri or tarie	20.02	0.7071	1/12 caffiso, 1.2 khoul, 2003 reference, also reported as 19.84 l in 1891	
saah, ssah, or saâ	48.06	1.697	2.4 tarri, 2003 reference, also reported as 48 l in 1891	
caffiso or calisse	317.5	11.21	Consistent with 1891 value and 2003 reference, ~15.85 tarri	

(continued)

Table 6.2 (continued)

Region and unit	Equivalent liters (dm ³)	Equivalent cu ft US	Notes	Era
America (see United States)				
Annam (little consistency for volume measurement, see Vietnam)				Pre-metric
Arabia (see also weight capacities, volumetric measures varied by region and over time)				Ancient to pre-metric
Dry measure				
mecmeda or kella	3.4	0.12	Estimated, 1891 value	
teman or tomand	136	4.80	For rice = 168 lbs, converted to volume, 40 kellas, 1891 value, rice ~ 35 lb/cft	
Liquid measure				
vakia	0.059	0.0021	1891 value	
noosfia or nusfiah	0.946	0.0334	16 vakias, 1891 value	
gudda or cuddy	7.567	0.2672	1891 value, 8 noosfias	
Argentina (pre-1863, varied by region)				Colonial to pre-metric
Dry measure				
cuartilla	34.30	1.211	1/4 fanega, 2003 reference	
fanega	137.2	4.845	4 quartilla, consistent with 1891 and 2003 references	
tonelada	960.4	33.91	7 fanega, 2003 reference	
lastre	2,058	72.67	15 fanega, also reported as 12 fanegas in some references	
Liquid measure				
octava	0.2969	0.01048	1/8 frasco, 2003 reference	
cuarta	0.5938	0.02097	1/4 frasco, 2 octava, 2003 reference	
frasco	2.375	0.08386	4 cuarta, reported as 0.237 liters in 1891 —may be incorrect, value from 2003 reference	
baril	76.00	2.684	32 frascos, 2003 reference	
cuerta	114.0	4.025	48 frasco, 2003 reference	
pipa	456.0	16.10	192 frasco, 4 cuarta, 2003 reference	
Austrian Empire (1891 information)				Pre-metric
Ordinary dry measure				
probmetze	0.06005	0.002120	2003 reference	
becher	0.4804	0.01696	1891 value, consistent with 2003 reference	
seidel (Bohemia)	0.488	0.0172	1891 value	

(continued)

Table 6.2 (continued)

Region and unit	Equivalent liters (dm ³)	Equivalent cu ft US	Notes	Era
Ordinary dry measure (continued)				
kleines massel	0.961	0.0339	1891 value, 2 becher	
grosses massel or futtermassel	1.922	0.06785	1891 value, 2 kleine massel, consistent with 2003 reference	
müller-massel or muthmassel	3.843	0.1357	1891 value, 2 grosse massel, consistent with 2003 reference	
massel (Bohemia)	5.850	0.2066	12 seidel, 1891 value	
achtel	7.686	0.2714	1891 value, 2 müller massel, consistent with 2003 reference	
viertel	15.37	0.5428	1891 value, 2 achtel, consistent with 2003 reference	
viertel (Bohemia)	23.40	0.8263	4 massel, 1891 value	
metze or metzel	61.49	2.171	1891 value, 4 viertel, consistent with 2003 reference	
strich (Bohemia)	93.60	3.305	4 viertel, 1891 value	
muth	1,844	65.11	1891 value, 30 metzen, consistent with 2003 reference	
Special dry measures				
stübich (coal, coke)	123.0	4.343	2 metzen, 1891 value	
kalkmützel (lime)	153.7	5.428	2.5 metzen, 1891 value	
cord (wood)	6,827	241.1	1/2 cubic klafter, 1891 value	
Liquid measure				
pfiff	0.1769	0.006245	1891 value, consistent with 2003 reference	
seidel	0.3537	0.01249	1891 value, 2 pfiff, consistent with 2003 reference	
seidel (Bohemia)	0.477	0.0169	1891 value	
kanne, halbe mass, or halbe	0.7075	0.02498	1891 value, 2 seidel, consistent with 2003 reference	
mass	1.415	0.04996	1891 value, 2 kannen, consistent with 2003 reference	
pinte (Bohemia)	1.909	0.06741	4 seidel, 1891 value	
viertel	14.15	0.4996	1891 value, 10 mass, consistent with 2003 reference	
eimer	56.60	1.998	1891 value, 4 viertel, consistent with 2003 reference	

(continued)

Table 6.2 (continued)

Region and unit	Equivalent liters (dm ³)	Equivalent cu ft US	Notes	Era
eimer (Bohemia)	61.09	2.157	32 pinten, 1891 value	
fass (Bohemia)	244.4	8.628	4 eimer, 1891 value	
fass	566.0	19.98	10 eimer, 2003 reference	
dreiling	1,358	47.96	1891 value, 24 eimer	
dreiling	1,698	59.95	10 eimer, 2003 reference	
fuder	1,811	63.95	1891 value, 32 eimer, consistent with 2003 reference	
Azores (similar to Portugal)				Pre-metric
Dry measure				
quarto	2.994	0.1057	1891 value	
meio	5.988	0.2115	2 quartos, 1891 value	
alquiere	11.98	0.4229	2 meios, 1891 value	
fanga	47.91	1.692	4 alquires, 1891 value	
Balearic Islands (mostly Spanish units, but many local units used)				
quartés (Majorca)	4.174	0.1474	1891 value	
gerrah (Minorca)	12.06	0.4258	1891 value	
quartin (Majorca)	27.13	0.9580	1891 value	
Dry measure				
almude (common)	1.044	0.0369	2003 reference	
quarte (common)	4.175	0.1474	4 almudes, 2003 reference	
quartin (common)	27.14	0.9583	26 almudes, 2003 reference	
Liquid measure				
almude (common)	1.999	0.07059	2003 reference	
barcella (common)	12.00	0.4237	6 almudes, 2003 reference	
quarta (common)	71.97	2.541	6 barcellas, 2003 reference	
Biblical and Talmudic (approx, used Babylonian system, no agreement on exact values)				Ancient
mina or log	0.505	0.0178	Base unit, 1/60 maris	
maris	30.30	1.070	Vol of water equal to 1 royal talent	
Israeli system				
Dry measure				
ke'zayit	0.0267	0.000942	1/2 or 1/3 bezah or unrelated? Exact value is unclear	
bezah	0.0533	0.00188	Egg, 1/6 log	
log	0.32	0.011	Base unit	

(continued)

Table 6.2 (continued)

Region and unit	Equivalent liters (dm ³)	Equivalent cu ft US	Notes	Era
xestes	0.53	0.019	Pot, dry pint, New Testament	
choinix	1.079	0.03810	Dry quart, New Testament	
kav or qak or kab or qab	1.28	0.0452	4 log	
omer	2.29	0.0809		
tse'ah or saton	7.68	0.271	6 kav	
modios	8.46	0.299	Bushel, New Testament	
ephah or epah	22.9	0.809	3 tse'ah, AKA bath, one "assload"	
letek or lethek	114.8	4.054	5 ephah	
kor, cor, or homer	229.7	8.111	2 letek	
issaron			1/10 ephah, not part of original system, Egyptian or Assyrian influence, undefined	
Liquid measure				
log	0.320	0.0113		
qab or kab	1.276	0.04506		
hin	3.829	0.1352		
bath or batos	22.97	0.8112	Measure, archeologists indicate a bath may have been 22 liters	
metretes	39.00	1.377	New Testament	
kor or koros	229.7	8.112		
Talmudic system			Mostly foreign origin: Persia, Greece, divergent views of exact values	
kab	1.3	0.046	Estimated size	
ukla			Unable to locate definition of size	
tuman			Unable to locate definition of size	
kapiza			Unable to locate definition of size	
modius			Unable to locate definition of size	
geriwa			Unable to locate definition of size	
garab			Unable to locate definition of size	
ardaba			Unable to locate definition of size	
kuna			Unable to locate definition of size	
qometz			Unable to locate definition of size	

(continued)

Table 6.2 (continued)

Region and unit	Equivalent liters (dm ³)	Equivalent cu ft US	Notes	Era
Borneo (English and Dutch units used locally in many areas)				Pre-metric
gantang	26.0	0.918	1891 value	
Brazil (pre-1862, many wide local variations and vastly different values from different sources)				Colonial to pre-metric
Canada	2.662	0.09399	1/12 almude	
alquiera (Bahia)	3.524	0.1244	2003 reference	
alquiera (Common)	3.626	0.1280	2003 reference	
alquiera (Salt)	4.076	0.1439	2003 reference	
alqueire orquiera	5.324	0.1880	2 Canada, but reported as 40–320 liters in some references, range actually appears to have been 3.5–5.3 liters in other references, used 2003 reference value	
almude	31.94	1.128	6quiera, 2003 reference	
cargueiro	80.00	2.825	Mule-load, 2 barrels of 40 liters each	
moio	319.4	11.28	10 almude, 2003 reference	
pipa	383.3	13.53	12 almude, also reported as 15 almude or 479.2 liters in 2003 reference	
tonel	958.2	33.83	30 almude, 2003 reference	
Burma or Birmah (AKA Rangoon, now Republic of the Union of Myanmar)				Pre-metric
lamany	0.126	0.00446	2003 reference	
zalay	0.253	0.00892	2 lamany, 2003 reference	
byee	0.505	0.0178	4 zalay, 2003 reference	
zayoot	1.01	0.0357	2 byee, 2003 reference	
seit	2.02	0.0713	2 zayoot, 2003 reference	
kwai	4.04	0.143	2 seit, 2003 reference	
Byzantine Empire (ancient units, local variations, includes some from Turkey)				Ancient
ounce	0.182	0.00644	1/12 litra, Liquid measure	
cotyla or half-xesta	0.276	0.0097	1/8 litra	
xesta	0.548	0.0194	1/4 litra	
litra or liter	2.189	0.07729	Base unit, liquid measure	
handful	3.367	0.1189	1–13/24 litra	
modios	87.55	3.092	Liquid measure	
Cambodia (see also Annam and Vietnam, appear to be pre-metric names and post metric values)				Post-metric
muoi or vuong mot bat tay	1.0	0.035	1/40 sesep, 2003 reference	
kantang	7.5	0.26	3/16 sesep, 7.5 muoi, 2003 reference	

(continued)

Table 6.2 (continued)

Region and unit	Equivalent liters (dm ³)	Equivalent cu ft US	Notes	Era
tao	15	0.53	3/8 sesepe, 2 kantang, 2003 reference	
thang	30	1.1	3/4 sesepe, 2 tao, 2003 reference	
sesepe or vuong mot gia	40	1.4	40 muoi, 2003 reference	
Canada				Pre-metric
General: pre-metric conversion (1970s), Canada used English Imperial system. Occasionally some French units used as noted below				
minot (wheat)	39.2	1.38	Used for wheat in southern regions, 1891 value	
Central America (see also individual countries, generally Spanish Castilian units used, significant conflicts among references)				Colonial to pre-metric
Dry measure				
cuartilla	13.87	0.4898	1891 reference	
fanega	55.48	1.959	4 cuartillas, 1891 reference	
Liquid measure				
cuartilla	4.03	0.142	1891 reference	
cantara	16.14	0.5698	4 cuartillas, 1891 reference	
General measures				
cuartillo or quartillo	0.51	0.018	2003 reference	
botella	0.65	0.023	32/25 cuartillo, varied from 0.63 to 0.67 liters, used average, 2003 reference	
cajuella	16.3	0.574	25 botella, 2003 reference	
Ceylon (see Sri Lanka)				
Dry measure				
chundoo	0.240	0.00847	~ 1.2 pint US, 1891 value	
amomam	204	7.19	1891 value	
Liquid measure				
seer	1.14	0.0401	1891 value	
parrah	25.5	0.902	1891 value	
Chile (pre-1848, local variations)				Colonial to pre-metric
Dry measure				
almude	8.083	0.2854	8 cuartillo, 2003 reference	
fanega	97.00	3.425	12 almude, 2003 reference, also reported as 90.7 liters in 1891	

(continued)

Table 6.2 (continued)

Region and unit	Equivalent liters (dm ³)	Equivalent cu ft US	Notes	Era
Liquid measure				
cuartillo or quartillo	1.111	0.03923	Also reported as 1.1 liters in 1891 and 1.010 liters in 2003 reference	
arroba	35.55	1.255	32 cuartillo, also reported as 32.33 liters in 2003 reference	
China (1915-1929, local variations, materials primarily traded by weight)				Medieval to pre-metric
quei	1.0350E -04	3.6547E -06	1966 value	
ço	0.001035	0.00003655	10 quei, 1966 value	
sháo or chao	0.01035	0.0003655	1/100 shēng, 10 ço, 1966 value	
ju	0.1	0.004	Handful, traditional, very rough estimate	
gě or khô	0.1035	0.003655	1/10 shēng, 10 chao, 1966 value	
yì	0.2	0.007	Double handful, traditional, very rough estimate	
yo	0.2071	0.007313	2 khô, 1966 value	
shēng or cheng	1.035	0.03656	5 yo, 1966 value	
to or dōu	10.35	0.3655	10 shēng, 1966 value	
hú or hou	51.77	1.828	50 shēng, 5 to, 1966 value	
dàn or chei	103.5	3.656	100 shēng, “picul”, 2 hou, 1966 value	
ping	517.7	18.28	5 chei, 1966 value	
Dry measure (shi series, for grains)				
shing-shi	0.77	0.027	Alternate system, 1891 value	
sei-shi	122	4.32	Alternate system, 1891 value	
Liquid measure (tsong series)				
kop-tsong	0.052	0.0018	Alternate system, 1891 value	
shing-tsong	0.52	0.018	10 kop, alternate system, 1891 value	
tau-tsong	5.2	0.18	10 shing, alternate system, 1891 value	

(continued)

Table 6.2 (continued)

Region and unit	Equivalent liters (dm ³)	Equivalent cu ft US	Notes	Era
Cornwall (pre-metric, varied locally and with commodity, see also English units)				Medieval to pre-metric
apple gallon	3.028	0.1069	Based on weight of 7 lbs	
gallon	4.534	0.1601	Based on weight of material, 10 lbs water	
bushel	105.5	3.726	3 Winchester bushels barley, wheat, or potatoes; value shown is from 1696	
Corsica (generally French units, but some liquid measures from Italian or Spanish)				
Costa Rica (pre-1910, local variations, see also Central America, generally Spanish Castilian units used, significant conflicts among references)				Colonial to pre-metric
cuartillo or quartillo	0.51	0.018	2003 reference	
botella	0.65	0.023	32/25 cuartillo, varied from 0.63 to 0.67 liters, used average, 2003 reference	
cajuella	16.3	0.574	25 botella, 2003 reference	
Crete (or Candia)				
Dry measure				
carga	152	5.38	1891 value	
Liquid measure				
oke	1.31	0.0462	1891 value	
mistate (oil)	11.2	0.394	1891 value	
Cuba (pre-1858, local variations, 1920s values)				Colonial to pre-metric
barrile	22.71	0.8020	2003 reference	
bocoy	136.3	4.812	6 barrile, 2003 reference	
Liquid measure				
arroba	16.14	0.5698	4.263 gallons	
fanega	60.56	2.138	16 gallons	
Dry measure				
fanega	56.35	1.990	1.599 bushels	
Cypress (pre-1972, primarily used British system, varied locally)				Colonial to pre-metric
oke	1.279	0.04515	2003 reference	
cass (liquids)	4.732	0.1671	Used for liquids, 1891 value, consistent with 2003 reference	
kartos	5.116	0.1806	4 oke, 2003 reference	
kouza	10.23	0.3612	8 oke, 2003 reference	
kile	35.81	1.264	7 kartos, 2003 reference	
kile	36.37	1.284	Bushel	
medimno	71.62	2.529	2 kile, 2003 reference	

(continued)

Table 6.2 (continued)

Region and unit	Equivalent liters (dm ³)	Equivalent cu ft US	Notes	Era
medimno or medinno	75.05	2.650	Used for grains, 1891 value	
gomari	163.7	5.779	128 oke, used for grain, consistent with 2003 reference	
Czechoslovakia (pre-1876, local variation, values from Moravia)				Medieval to pre-metric
merice	70.60	2.493	2003 reference	
korec or strych	93.59	3.305	1.325 merice, 2003 reference	
Denmark (pre-1907, many variations)				Medieval to pre-metric
Dry measure				
potte, pott, or pot	0.9662	0.03412	1891 value, consistent with 2003 reference	
halvotting or achtel	2.174	0.07677	1891 value, consistent with 2003 reference	
viertel	4.348	0.1535	2 achtel, 2003 reference	
ottingkar	4.348	0.1535	2 halvotting, 1891 value, see alternate value	
fjerdingskar	8.69	0.307	2 ottingkar, 1891 value	
ottingkar, skieppe, or skoëppe	17.39	0.6140	4 viertel, 2003 reference	
skoëppe	17.39	0.6140	2 fjerdingskar, 1891 value	
cubic fod	30.92	1.092	32 pott, 2003 reference	
fjerdingskar	34.78	1.228	2 ottingkar, 2003 reference	
tönde or korntönde (ordinary)	139.1	4.912	8 skoëppe, 4.5 cu fod, 144 pot, 1891 value, korntönde refers to corn, consistent with 2003 ref.	
tonde (coal, charcoal)	156	5.50	1891 value	
last	3,061	108.1	22 tönde, 2003 reference	
Liquid measure				
paegel or poegel	0.2415	0.008529	2003 reference	
pott	0.9662	0.03412	4 paegel, 2003 reference, reported in 1683 and 1891—consistent	
kande	1.932	0.06823	2 pott, 2003 reference	
stubchen	3.865	0.1365	2 kande, 2003 reference	
viertel	7.729	0.2729	2 stubchen, 2003 reference	
cubic fod	30.92	1.092	4 viertel, 2003 reference	
anker	38.65	1.365	5 viertel, 2003 reference	
anker	75.40	2.663	39 pot	

(continued)

Table 6.2 (continued)

Region and unit	Equivalent liters (dm ³)	Equivalent cu ft US	Notes	Era
tönde (tar)	116.0	4.096	120 pot	
tönde or smørtönde (beer, butter)	131.4	4.640	4.25 cu fod, 136 pot or potter, “barrel”, smørtönde refers to butter	
ohm	154.6	5.458	4 anker, 2003 reference	
oxhoft	231.9	8.188	6 anker, 2003 reference	
pipe	463.8	16.38	2 oxhoft, 2003 reference	
fuder	927.5	32.75	2 pipe, 2003 reference	
Egypt (pre-metric, local variations, see also weights)				Pre-metric
Liquid measure				
guirbeh	66.7	2.35	1867 value	
Dry measure (1867)				
kirat or k�rat	0.060	0.0021	1867 value	
kirat or k�rat	0.06445	0.002276	2003 reference	
kharroubah	0.12	0.0042	2 kirat, 1867 value	
khanoubah	0.1289	0.004552	2 kirat, 2003 reference	
toumnah or thoumn-kaddah	0.24	0.0084	2 kharroubah, 1867 value	
toumnah	0.2578	0.009103	2 khanoubah, 2003 reference	
robhah or roub-kaddah	0.48	0.017	2 toumnah, 1867 value	
robhah	0.5156	0.01821	2 toumnah, 2003 reference	
nisf-keddah	0.96	0.034	2 robhah, 1867 value	
nisf-keddah	1.031	0.03641	2 robhah, 2003 reference	
keddah or kaddah	1.91	0.0674	2 nisf-keddah, 1867 value	
keddah or kaddah	2.063	0.07283	2 nisf-keddah, 2003 reference	
malouah	3.82	0.135	2 keddah, 1867 value	
maloua	4.125	0.1457	2 keddah, 2003 reference	
ro, rob, or roubouh	7.64	0.270	2 malouah, 1867 value	
ro, rob, or roubouh	8.250	0.2913	2 maloua, 2003 reference	
keila or k�l�	15.28	0.5395	2 roubouh, 1867 value	
keila or k�l�	16.50	0.5826	2 rob, 2003 reference	
ouebeh	30.6	1.08	2 k�l�, 1867 value	
ardeb	183.4	6.475	6 ouebeh, 1867 value, value reported as 182–271 liters by different sources	
ardeb	198.0	6.992	12 keila, 2003 reference	
daribah	1,584	55.93	768 keddah, consistent with 2003 reference	

(continued)

Table 6.2 (continued)

Region and unit	Equivalent liters (dm ³)	Equivalent cu ft US	Notes	Era
Egypt (ancient, wide variations)				Ancient
ro	0.015	0.00053	1/320 heqat	
dja	0.300	0.0106	5/8 hinu or 20 ro	
hin or hinu	0.477	0.0168	Jar	
hekat or heqat	4.770	0.1684	10 hin, barrel	
double heqat or hekaty	9.54	0.337	2 heqat	
hekat-fedw or quadruple heqat	19.08	0.6737	4 heqat	
khar (New Kingdom)	76.80	2.712	Sack, 16 heqat	
khar (Middle Kingdom)	96.50	3.407	Sack, 20 heqat	
deny	143.1	5.053	Cubic Royal cubit, 30 hekat	
El Salvador (local variations, see also Central America, generally Spanish Castilian units used, significant conflicts among references)				Colonial to pre-metric
cuartillo or quartillo	0.51	0.018	2003 reference	
botella	0.65	0.023	32/25 quartillo, varied from 0.63 to 0.67 liters, used average, 2003 reference	
cajuella	16.3	0.574	25 botella, 2003 reference	
Eretria (early 20th century, local variations)				Medieval to pre-metric
messé	1.500	0.05297	2003 reference	
cabaho	6.000	0.2119	4 messé, 2003 reference	
tanica	18.00	0.6356	12 messé, 2003 reference	
ghebeta	24.00	0.8475	16 messé, 2003 reference	
entelam	192.0	6.780	128 messé, 2003 reference	
Estonia (early 20th century, local variations)				Medieval to pre-metric
hulmit	11.48	0.4054	2003 reference	
lof (Reval)	34.44	1.216	3 hulmit, 2003 reference	
lof (Livonian)	68.88	2.432	6 hulmit, 2003 reference	
tonne	137.8	4.864	12 hulmit, 2003 reference	
Ethiopia (pre-1963, local variations)				Medieval to pre-metric
Dry measure				
madega	0.44	0.016		
short ardeb	4.4	0.16		
long ardeb	10.56	0.3729		
Liquid measure				
kuba	1.016	0.03588		

(continued)

Table 6.2 (continued)

Region and unit	Equivalent liters (dm ³)	Equivalent cu ft US	Notes	Era
Finland (pre-1861, local variations)				Medieval to pre-metric
Undefined type				
kannor	2.595	0.09163	2003 reference	
sextingar	7.785	0.2749	3 kannor, 2003 reference	
ottingar	15.57	0.5498	2 sextingar, 2003 reference	
tunna	163.5	5.773	21 sextingar, 2003 reference	
Dry measure				
jumpru	0.0818	0.00289	“Virgin”	
kortteli	0.327	0.0116	used for both length and volume	
tuoppi	1.327	0.04687	Tankard	
pikkukappa	2.500	0.08828	Related to kannu	
kannu	2.617	0.09242	Jug	
kappa	5.496	0.1941	Used today in markets for potatoes as kappa or isokappa, defined as 5 liters	
nelikko	43.99	1.553		
panni	87.96	3.106		
tyynyri	175.0	6.179	Barrel dry measure	
motti (firewood, waste paper)	1,000	35.31		
lästi	2,110	74.51		
Liquid measure				
jumpru	0.0818	0.00289	“Virgin”	
kortteli	0.327	0.0116		
tuoppi	1.327	0.04687	Tankard	
pikkukappa	2.500	0.08828	Related to kannu	
kannu	2.617	0.09242	Jug	
kappa	5.496	0.1941		
ankkuri	39.26	1.386		
tyynyri	125.6	4.435	Barrel liquid measure	
lästi	1,507	53.21		
France (pre-metric, Appx 1790s, local variations)				Medieval to pre-metric
Dry measure				
pouce cube	0.0198	0.000701	French cubic inch	
litron	0.7901	0.02790	1/16 boisseau, 2003 reference	
quart	3.160	0.1116	4 litron, 2003 reference	

(continued)

Table 6.2 (continued)

Region and unit	Equivalent liters (dm ³)	Equivalent cu ft US	Notes	Era
boisseau	12.64	0.4463	4 quarts, 2003 reference	
pied cube	34.28	1.210	French cubic foot, dates to ancient times	
minot	37.93	1.339	3 boisseau, 2003 value	
mine	75.85	2.678	2 minot, 2003 reference	
setier	151.7	5.357	2 mine, 2003 reference	
muid	1,820	64.27	12 setier, 2003 reference	
voie (de Paris, wood)	1,920	67.80	Used for wood, 4 pieds × 4 pieds × 3 pieds 6 pouces, 2003 reference	
corde (Eaux et Forêts)	3,840	135.6	8 pieds × 4 pieds × 3 pieds 6 pouces, 2003 reference	
Liquid measure				
pouce cube	0.0198	0.000701	French cubic inch	
roquille	0.02975	0.001050	1/32 pinte, 2003 reference	
demi-posson	0.05950	0.002101	2 roquille, 2003 reference	
posson	0.1190	0.004202	2 demi-posson, 2003 reference	
demiard or demi-settier	0.2380	0.008404	Half a chopine, 2 posson, 2003 reference	
chopine or sétier	0.4761	0.01681	About a pint, 4 posson, 2003 reference	
pinte	0.9521	0.03362	1/36 French cubic foot, about 1 quart US, 2 chopine	
pot, quade, or cade	1.904	0.06723	2 pinte, 2003 reference	
velte	7.617	0.2690	4 pot, 2003 reference	
pied cube or amphora	34.28	1.210	French cubic foot, dates to ancient times	
quartaut	68.55	2.421	9 veltes, 2003 reference	
feuillette	137.1	4.841	2 quartauts, 2003 reference	
muid or tonneau	274.2	9.682	8 cubic French feet, 2 feuillettes, 2003 reference	
pipe	411.3	14.52	1.5 muid, 2003 reference	
tonneau de mer	1,440	50.85	2003 reference	
tonneau de jauge	2,830	99.93	2003 reference	
Germany (pre-1868, local variations)				Medieval to pre-metric
General measures				
kubikfuss (Bremen)	24.2	0.854	1891 value	
faden (Bremen)	1,742	61.49	72 kubikfuss, 1891 value	

(continued)

Table 6.2 (continued)

Region and unit	Equivalent liters (dm ³)	Equivalent cu ft US	Notes	Era
Dry measure				
schrott (Frankfort)	0.112	0.00396	1891 value	
becher (Baden)	0.150	0.00530	1891 value	
viertlein (Wurtemberg)	0.173	0.00611	1891 value	
massche (Frankfort)	0.448	0.0158	4 schrott, 1891 value	
ecklein (Wurtemberg)	0.692	0.0244	4 viertlein, 1891 value	
dreissiger (Bavaria)	1.158	0.04089	1891 value	
dreissiger (common)	1.158	0.04089	2003 reference	
mässlein (Wurtemberg)	1.385	0.04889	2 ecklein, 1891 value	
mässlein (Baden)	1.500	0.05297	10 becher, 1891 value	
mässeche (Saxony)	1.624	0.05733	1891 value	
gescheid (Frankfort)	1.793	0.06331	4 masschen, 1891 value	
becher or löcher (Brunswick, wheat)	1.909	0.06741	1891 value, wheat	
mässlein (Bavaria)	2.316	0.08178	2 dreissiger, 1891 value	
mässeche (Hesse-Cassel)	2.533	0.08944	1891 value	
achtel (Wurtemberg)	2.769	0.09778	2 mässlein, 1891 value	
spiten (Bremen)	4.629	0.1635	1891 value	
massel or achtel (Bavaria)	4.632	0.1636	2 mässlein, 1891 value	
mässel (common)	4.632	0.1636	4 dreissiger, 2003 reference	
mässeche (Hesse-Darmstadt)	5.001	0.1766	1891 value	
viertel (Wurtemberg)	5.538	0.1956	2 achtel, 1891 value	
metze (Saxony)	6.494	0.2293	4 mässechen, 1891 value	
spinte (Hamburg)	6.581	0.2324	1891 value, 1891 value	
sechter (Frankfort)	7.172	0.2532	4 gescheid, 1891 value	
vierfass (Brunswick, wheat)	7.636	0.2696	4 becher, wheat, 1891 value	
vierfass (Hanover)	7.790	0.2751	1891 value, 1891 value	
fass (Lubeck, wheat)	8.895	0.3141	1891 value	
metze (Hesse-Cassel)	10.13	0.3578	4 mässechen, 1891 value	
drittel (Hanover)	10.39	0.3668	1891 value	
metze (Frankfort)	14.34	0.5065	2 sechter, 1891 value	
sester (Baden)	15.00	0.5297	10 mässlein, 1891 value	
viertel (Bremen)	18.52	0.6538	4 spiten, 1891 value	
viertel (Bavaria)	18.53	0.6542	4 massel, 1891 value	
gescheid (Hesse-Darmstadt)	20.00	0.7063	4 mässechen, 1891 value	
simri (Wurtemberg)	22.15	0.7823	4 viertel, 1891 value	

(continued)

Table 6.2 (continued)

Region and unit	Equivalent liters (dm ³)	Equivalent cu ft US	Notes	Era
viertel (Saxony)	25.98	0.9172	4 metzen, 1891 value	
himt (Hamburg)	26.33	0.9296	4 spinten, 1891 value	
simmer (Frankfort)	28.69	1.013	2 metzen, 1891 value	
himt (Brunswick, wheat)	30.54	1.079	4 vierfass, wheat, 1891 value	
himt (Hanover)	31.16	1.100	4 vierfass or 3 drittel, 1891 value	
scheffel (Lubeck, wheat)	35.58	1.256	4 fass, 1891 value, for oats and fruit = 39.5 liters	
metze (Bavaria)	37.06	1.308	2 viertel, 1891 value	
metzen (common)	37.06	1.309	8 mässel, 2003 reference	
himt (Hesse-Cassel)	40.53	1.431	4 metzen, 1891 value	
fass (Hamburg)	52.65	1.859	2 himt, 1891 value	
scheffel (Bremen)	74.06	2.615	4 viertel, 1891 value	
kümpf (Hesse-Darmstadt)	80.01	2.825	4 gescheid, 1891 value	
scheffel (Hesse-Cassel)	81.05	2.862	2 himt, 1891 value	
scheffel (Saxony)	103.9	3.669	4 viertel, 1891 value	
scheffel (Hamburg)	105.3	3.718	2 fass, 1891 value	
malter or achtel (Frankfort)	114.8	4.052	4 simmer, 1891 value	
tonne (Lubeck, wheat)	142.3	5.026	4 scheffel, 1891 value	
malter (Baden)	150.0	5.297	10 sester, 1891 value	
kalkbütte (Hesse-Darmstadt, lime)	156.3	5.518	10 cu fuss, 1891 value	
scheffel (Wurtemberg)	177.2	6.258	8 simri, 1891 value	
malter (Hanover)	187.0	6.602	6 himt, 1891 value	
scheffel (Bavaria)	222.3	7.851	6 metzen, 1891 value	
sheffel (common)	222.4	7.852	6 metzen, 2003 reference	
scheffel (Brunswick, wheat)	305.4	10.79	Specific for wheat, 1891 value, 10 himt	
simmer (Hesse-Darmstadt)	320.0	11.30	4 kümpf, 1891 value	
scheffel (Brunswick, oats)	366.5	12.94	Commodity specific for oats, 1891 value	
drömt (Lubeck, wheat)	427.0	15.08	3 tonnen, 1891 value	
wispel (Hamburg)	1,053	37.18	10 scheffel, 1891 value	
wispel (Brunswick, wheat)	1,222	43.14	4 scheffel, wheat, 1891 value	
malter (Saxony)	1,247	44.03	12 scheffel, 1891 value	
malter (Hesse-Darmstadt)	1,280	45.20	4 simmer, 1891 value	

(continued)

Table 6.2 (continued)

Region and unit	Equivalent liters (dm ³)	Equivalent cu ft US	Notes	Era
wispel (Hanover)	1,496	52.82	8 malter, 1891 value	
züber (Baden)	1,500	52.97	10 malter, 1891 value	
wispel (Saxony)	2,494	88.06	2 malter, 1891 value	
klafter	2,905	102.6	For firewood	
last (Bremen)	2,963	104.6	40 scheffel, 1891 value	
last (Hanover)	2,992	105.6	2 wispel, 1891 value	
Klafter (Bavaria, wood)	3,133	110.6	126 cubic fuss, 3.1325 cu meters, 1891 value	
last (Hamburg)	3,159	111.5	3 wispel, 1891 value	
last (Lubeck, wheat)	3,416	120.6	8 drömt, 1891 value	
Liquid measure				
glas (Baden)	0.150	0.00530	1891 value	
quartier (Saxony)	0.151	0.00531	1891 value, Leipsic, Dresden 88.9% of this	
mingel (Bremen)	0.201	0.00711	1891 value	
ort (Lubeck)	0.234	0.00826	1891 value	
schoppen (Frankfort)	0.448	0.0158	1891 value, based on eichmass	
össel (Hamburg)	0.451	0.0159	1891 value	
schoppe (Wurtemberg)	0.459	0.0162		
nössel (Brunswick)	0.468	0.0165	1891 value	
planke (Lubeck)	0.468	0.0165	2 ort, 1891 value	
nössel (Hanover)	0.490	0.0173	1891 value	
schoppe (Hesse-Darmstadt)	0.528	0.0187	Similar for wine with different value, 1891 value	
schoppe (Hesse-Cassel, beer)	0.546	0.0193	Similar unit for wine with different value, 1891 value	
nösel (Leipzig)	0.600	0.0212	1/2 kanne	
nössel (Saxony)	0.602	0.0213	4 quartier, 1891 value, Leipsic, Desden 88.9%	
quartier (Bremen)	0.805	0.0284	4 mingel, 1891 value	
quartier (Hamburg)	0.902	0.0319	2 össel, 1891 value	
quartier (Brunswick)	0.935	0.0330	2 nössel, 1891 value	
quartier (Lubeck)	0.936	0.0331	2 planken, 1891 value	
kanne (Saxony)	0.950	0.0335	Jar, jug, bottle or can	
quartier (Hanover)	0.980	0.0346	2 nössel, 1891 value	
mass (Bavaria, wine)	1.002	0.03538	Example based on wine, 1891 value	
schenkmass (Nuremberg)	1.079	0.03810	1891 value	

(continued)

Table 6.2 (continued)

Region and unit	Equivalent liters (dm ³)	Equivalent cu ft US	Notes	Era
quart (common)	1.145	0.04043	2003 reference	
visirmass (Nuremberg)	1.147	0.04050	1891 value	
kanne (Leipzig)	1.200	0.04237	Jar, jug, bottle or can	
kanne (Saxony)	1.204	0.04251	2 nössel, 1891 value, Leipscic, Desden 88.9%	
mass (Baden)	1.500	0.05297	10 glas, 1891 value	
neumass (Frankfort)	1.593	0.05627	1891 value	
eichmass (Frankfort)	1.793	0.06330	4 schoppen, 1891 value	
kanne (Hamburg)	1.805	0.06373	2 quartier, 1891 value	
mass (Wurtemberg)	1.837	0.06486	4 schoppen	
kanne (Lubeck)	1.872	0.06611	2 quartier, 1891 value	
kanne (Hanover)	1.961	0.06923	2 quartier, 1891 value	
mass (Hesse-Cassel, wine)	1.984	0.07006	4 schoppen, 1891 value	
mass (Hesse-Darmstadt)	2.113	0.07463	4 schoppen, 1891 value	
mass (Hesse-Cassel, beer)	2.183	0.07707	4 schoppen, 1891 value	
stübchen (Bremen)	3.221	0.1138	4 quartier, 1891 value	
stübchen (Hamburg)	3.610	0.1275	2 kannen, 1891 value	
stübchen (Brunswick)	3.740	0.1321	4 quartier, 1891 value	
stübchen (Lubeck)	3.745	0.1322	2 kannen, 1891 value	
stübchen (Hanover)	3.921	0.1385	2 kannen, 1891 value	
viertel (Frankfort)	7.171	0.2532	4 eichmass, 4.5 neumass, 1891 value	
viertel (Hamburg)	7.219	0.2549	2 stübchen, 1891 value	
viertel (Bremen)	7.248	0.2559	9 quartier, 1891 value	
viertel (Lubeck)	7.489	0.2645	2 stübchen, 1891 value	
viertel (Hanover)	7.842	0.2769	2 stübchen, 1891 value	
viertel (Hesse-Darmstadt)	8.454	0.2985	4 mass, similar unit for wine with different value, 1891 value	
viertel (Hesse-Cassel, beer)	8.731	0.3083	4 mass, similar for wine with different value, 1891 value	
stützen (Baden)	15.00	0.5297	10 mass, 1891 value	
immi (Wurtemberg)	18.37	0.6486	10 mass	
eimer (Hamburg)	28.88	1.020	4 viertel, 1891 value	
eimer (Lubeck)	29.96	1.058	4 viertel, 1891 value	
anker (common)	34.35	1.213	30 quart, 2003 reference	
anker (Hamburg)	36.10	1.275	5 viertel, 1891 value	
anker (Bremen)	36.24	1.280	5 viertel, 1891 value	

(continued)

Table 6.2 (continued)

Region and unit	Equivalent liters (dm ³)	Equivalent cu ft US	Notes	Era
anker (Lubeck)	37.45	1.322	5 viertel, 1891 value	
anker (Hanover)	39.21	1.385	5 viertel, 1891 value	
müdde (Augsburg)	56.48	1.994	1891 value	
eimer (Hanover)	62.74	2.215	8 viertel, 1891 value	
eimer (Bavaria, wine)	64.13	2.265	64 mass, 1891 value	
anker (Saxony)	65.02	2.296	54 kannen, 1891 value, Leipsic, Desden 88.9%	
eimer (Bavaria, beer)	68.41	2.416	1891 value	
eimer (common)	68.70	2.426	2 anker, 2003 reference	
eimer (Saxony)	75.85	2.678	63 kannen, 1891 value, Leipsic, Desden 88.9%	
tonne (Hanover, beer)	102.0	3.600	26 stübchen, 1891 value	
ohm (common)	137.4	4.852	2 eimer, 2003 reference	
ohm (Frankfort)	143.4	5.064	20 viertel, 1891 value	
ahm (Hamburg)	144.4	5.098	4 anker, 1891 value	
ohm (Bremen)	145.0	5.119	4 anker, 1891 value	
ohm (Brunswick)	149.6	5.282	40 stübchen, 1891 value	
ahm (Lubeck)	149.8	5.289	4 anker, 1891 value	
ohm (Baden)	150.0	5.297	10 stützen, 1891 value	
ohm (Saxony)	151.7	5.357	2 eimer, 1891 value, Leipsic, Desden 88.9%	
ahm (Hanover)	156.8	5.538	4 anker, 1891 value	
ohm (Hesse-Darmstadt)	169.1	5.970	20 viertel, similar unit for wine with different value, 1891 value	
tonne (Hamburg)	173.3	6.118	24 viertel, 1891 value	
ohm (Hesse-Cassel, beer)	174.6	6.166	20 viertel, similar unit for wine with different value, 1891 value	
oxhoft (common)	206.1	7.278	3 eimer, 2003 reference	
oxhoft (Hamburg)	216.6	7.648	30 viertel, 1891 value	
oxhoft (Bremen)	217.4	7.678	6 anker, 1891 value	
oxhoft (Brunswick)	224.4	7.924	1891 value	
oxhoft (Lubeck)	224.7	7.934	30 viertel, 1891 value	
oxhoft (Saxony)	227.6	8.035	3 eimer, 1891 value, Leipsic, Desden 88.9%	
oxhoft (Hanover)	235.3	8.308	30 viertel, 1891 value	
eimer (Wurtemberg)	293.9	10.38	16 immi	
fass (Saxony)	379.3	13.39	5 eimer, 1891 value, Leipsic, Desden 88.9%	
fass (Brunswick, beer)	403.9	14.26	For beer, 1891 value, 108 stübchem	
fass (Hanover, beer)	407.8	14.40	4 tonnen, 1891 value	
fuder (common)	824.4	29.11	4 oxhoft, 2003 reference	

(continued)

Table 6.2 (continued)

Region and unit	Equivalent liters (dm ³)	Equivalent cu ft US	Notes	Era
fuder (Frankfort)	860.5	30.38	6 ohm, 1891 value	
fuder (Hamburg)	866.3	30.59	6 ahm, 1891 value	
fuder (Bremen)	869.8	30.71	6 ohm, 1891 value	
fuder (Brunswick)	897.6	31.69	6 ohm, 4 oxhoft, 1891 value	
fuder (Lubeck)	898.7	31.73	6 ahm, 1891 value	
fuder (Saxony)	910.2	32.14	6 ohm, 1891 value, Leipsic, Desden 88.9%	
fuder (Hanover)	941.1	33.23	6 ahm, 1891 value	
fuder (Hesse-Darmstadt)	1,014	35.82	6 ohm, similar unit for wine with different value, 1891 value	
fuder (Hesse-Cassel, beer)	1,048	36.99	6 ohm, similar unit for wine with different value, 1891 value	
fuder (Baden)	1,500	52.97	10 ohm, 1891 value	
fuder (Wurtemberg)	1,763	62.27	6 eimer	
Greece (ancient, local variations)				Ancient
Dry measure (Attic)				
kochliarion	0.00455	0.000161		
kyathos or cyanthos	0.0455	0.00161	10 kochliaria, reported as 0.045 liters in 2003	
oxybathon or oxybaphon	0.0683	0.00241	1.5 kyathoi, consistent with 2003 reference	
kotylē, cotyle, or hēmīna	0.273	0.0096	6 kyathoi, consistent with 2003 reference	
xestēs or sexte	0.546	0.0193	12 kyathoi, Roman sexarius, reported as 0.54 liters in 2003	
choinix or chenica	1.092	0.03856	24 kyathoi, reported as 1.08 liters in 2003	
hēmiekton	4.368	0.1542	4 choinikes	
hekteus or hektos	8.736	0.3085	8 choinikes, reported as 8.64 liters in 2003	
medimnos	52.42	1.851	48 choinikes, reported as 51.84 liters in 2003	
Liquid measure (Attic)				
kochliarion	0.00455	0.000161	Spoon	
xēmē	0.00910	0.000321	2 kochliaria	
mustron	0.0114	0.000402	2.5 kochliaria	
konchē	0.0228	0.000803	5 kochliaria	
kyathos	0.0455	0.00161	10 kochliaria	
oxybathon	0.0683	0.00241	1.5 kyathoi	
tetarton or hēmikotylē	0.1365	0.004820	3 kyathoi	
kotylē, trublion, cotyle, or hēmīna	0.273	0.0096	6 kyathoi, consistent with 2003 reference	

(continued)

Table 6.2 (continued)

Region and unit	Equivalent liters (dm ³)	Equivalent cu ft US	Notes	Era
xestēs	0.546	0.0193	12 kyathoi, Roman sexarius	
chous, khous, or congius	3.276	0.1157	72 kyathoi, reported as 3.24 liters in 2003	
maris	6.48	0.229	2 chous, 2003 reference	
amphora	19.44	0.6864	3 maris, 2003 reference	
keramion	26.21	0.9254	8 choes, Roman amphora	
metrētēs	39.31	1.388	12 choes, 2 amphora, reported as 38.88 in 2003	
Greece (pre-1836, local variations)				Medieval to pre-metric
oka (liquid)	1.337	0.04721	Varied, used average, consistent with 2003 reference	
bachel	29.93	1.057	Bushel, approx	
baril (liquid)	74.24	2.621	Consistent with 2003 reference	
staro	89.79	3.171	3 bachelors or 2.548 bushels, approx	
Guatemala (local variations, see also Central America, generally Spanish Castilian units used, significant conflicts among references)				Colonial to pre-metric
cuartillo or quartillo	0.51	0.018	2003 reference	
botella	0.65	0.023	32/25 quartillo, varied from 0.63 to 0.67 liters, used average, 2003 reference	
cajuella	16.3	0.574	25 botella, 2003 reference	
Haiti (pre-1921, local variations, AKA Hayti)				Colonial to pre-metric
baril	100	3.531	2003 reference	
corde	3,840	135.6	192/5 baril, 2003 reference	
toise or toise cube	8,000	282.5	80 baril, 2003 reference	
Honduras (local variations, see also Central America, generally Spanish Castilian units used, significant conflicts among references)				Colonial to pre-metric
cuartillo or quartillo	0.51	0.018	2003 reference	
botella	0.65	0.023	32/25 quartillo, varied from 0.63 to 0.67 liters, used average, 2003 reference	
cajuella	16.3	0.574	25 botella, 2003 reference	
Hungary (pre-1874, local variations)				Medieval to pre-metric
halbe or itcze	0.8484	0.02996	1/64 eimer, 1891 value, consistent with 2003 reference	

(continued)

Table 6.2 (continued)

Region and unit	Equivalent liters (dm ³)	Equivalent cu ft US	Notes	Era
eimer	54.30	1.917	Varied greatly by region 54–73 liters, typical 64 halbe, 1891 values, consistent with 2003 reference	
metzen or ako	62.53	2.208	Dry measure, 1891 value, also reported as 62.45 l in 2003 reference	
fass	198.9	7.023	Approximate, 1891 value	
Iceland (pre-1907, many other units)				Medieval to pre-metric
Dry measure				
pottar	0.9661	0.03411	As defined in 1921 conversion, 2003 reference	
kornskeppa	17.39	0.6140	18 pottar, 2003 reference	
cubic fet	30.92	1.092	32 pottar, 2003 reference	
anker	38.64	1.365	40 pottar, 2003 reference	
almenn turma	115.9	4.094	120 pottar, 2003 reference	
öltunna	131.4	4.639	136 pottar, 2003 reference	
korntunna	139.1	4.912	144 pottar, 2003 reference	
India (pre-Akbar, many units, local variation, primarily traded by weight and not volumes)				Pre-Akbar
Dry measure—rice and grains				
chattack (Bengal)	0.0129	0.000455	1891 value	
nilve	0.0625	0.00221	1/2 kolve	
khoonke (Bengal)	0.0644	0.00227	5 chattack, 1891 value	
kolve	0.125	0.00441	1/2 chipte	
olluck (Madras)	0.192	0.00678	1891 value	
chipte	0.250	0.00883	1/2 mapte	
mapte	0.500	0.0177	1/2 ser	
ser	1.000	0.03531	Approx 1 liters	
raik (Bengal)	1.030	0.03636	16 khoonke, 1891 value	
puddy (Madras)	1.537	0.05426	8 ollucks, 1891 value	
pallie (Bengal)	4.119	0.1455	4 raik, 1891 value	
adoulie (Bombay)	6.883	0.2430	1891 value	
mapp (Anjar)	7.774	0.2745	1891 value	
marcal (Madras)	12.29	0.4341	8 puddies, 1891 value, also reported as 14.2 liters	
shye (Anjar)	31.10	1.098	4 mapp, 1891 value	
mudi (Mangalore)	45.88	1.620	1891 value	

(continued)

Table 6.2 (continued)

Region and unit	Equivalent liters (dm ³)	Equivalent cu ft US	Notes	Era
parah or chunam (Madras)	61.47	2.170	5 marcals, 1891 value	
soallee (Bengal)	82.38	2.909	20 pallie, 1891 value	
parah (Bombay)	110.1	3.889	16 adoulies, 1891 value	
koorah (Maharatta, Bengal)	143.1	5.054	1891 value	
candaca (Mysore)	392.2	13.85	1891 value	
candy (Bombay)	881.0	31.11	8 parahs, 1891 value	
kahoon (Bengal, grain)	1,496	52.81	1891 value	
garce (Madras)	4,917	173.6	80 parahs, 1891 value	
Liquid measure				
chhatank	0.058	0.0021	1/4 pav, see notes on seer	
pav	0.23	0.0082	See notes on seer	
seer	0.93	0.033	4 pav, 0.933 kg Appx—so actual volume varies by commodity, values shown are for water	
maund	37.3	1.32	40 seer, see notes on seer	
India (nonspecific applications, non-metric, local variation, reported in 1966 and 2003 references)				Pre-metric
musti or pala	0.0516	0.00182	1966 value	
chattack	0.06881	0.002430	2003 reference	
khoonke	0.08602	0.003037	1.25 chattack, 2003 reference	
kunk	0.3441	0.01215	4 khoonke, 2003 reference	
cudava	0.413	0.0146	8 musti, 1966 value	
prastha	0.825	0.0291	2 cudava, 1966 value	
tipree	0.8602	0.03037	10 khoonke, 2003 reference	
raik	1.376	0.04860	4 kunk, 2003 reference	
seer	1.720	0.06075	2 tipree, 2003 reference	
adhaka	3.30	0.117	4 prastha, 1966 value	
pally	5.505	0.1944	4 raik, 2003 reference	
adoulie	6.881	0.2430	4 seer, 2003 reference	
drona	13.2	0.466	4 adhaka, 1966 value	
cumbha short	26.4	0.932	2 drona, 1966 value	
parah or soally	110.1	3.8877	16 adoulie, 2003 reference	
shari	211	7.46	8 cumbha short, 1966 value	
cumbha	264	9.32	10 cumba short, 1966 value	
candy	880.8	31.10	8 parah, 2003 reference	

(continued)

Table 6.2 (continued)

Region and unit	Equivalent liters (dm ³)	Equivalent cu ft US	Notes	Era
khahoon	1,762	62.20	2 candy, 2003 reference	
baha	2,640	93.22	10 cumbha, 1966 value	
garce	8,808	311.0	5 khahoon, 2003 reference	
Indonesia (pre-1923, local variations)				Colonial to pre-metric
kanne or kan	1.49	0.0527	Liquid measure, alternate reference	
kan or kanne	1.575	0.05562	2003 reference	
bambou	3.25	0.115	Dry measure, alternate reference	
koelak	3.741	0.1321	19/8 kan, 2003 reference	
kit	14.96	0.5284	4 koelak, 2003 reference	
takar	25.44	0.8982	17/10 kit, 2003 reference	
picul	66.14	2.335	13/5 takar, 2003 reference	
legger	606	21.4	Liquid measure, alternate reference	
kojang	1,984	70.06	30 picul, 2003 reference	
koyang	5,200	183.6	Dry measure, 1600 bambou, alternate reference	
Ionian Islands (generally British units with scattered use of Italian and Turkish units)				Pre-metric
Dry measure				
chilo	36.35	1.284	1 Imperial bushel, 1891 value	
Liquid measure				
dicotoli	0.568	0.0201	1 Imperial pint, 1891 value	
gallone	4.546	0.1605	1 Imperial gallon, 1891 value	
barille	72.74	2.568	16 Imperial gallons, 1891 value	
Ireland (pre-metric, local variations)				Medieval to pre-metric
eggshell	0.055	0.0019	Standard unit	
méisrin	0.660	0.0233		
Liquid measure				
noggin	0.02786	0.0009837	1/4 pint (Irish), pre-1824, 2003 reference	
pint	0.1114	0.003935	Pre-1824, 2003 reference	
quart	0.8915	0.03148	8 pints, pre-1824, 2003 reference	

(continued)

Table 6.2 (continued)

Region and unit	Equivalent liters (dm ³)	Equivalent cu ft US	Notes	Era
pottle	1.783	0.06296	2 quarts, pre-1824, 2003 reference	
gallon	3.566	0.1259	2 pottle, pre-1824, 2003 reference	
rundlet	64.18	2.266	18 gallons, pre-1824, 2003 reference	
barrel	112.3	3.966	31.5 gallons, pre-1824, 2003 reference	
tierce	149.8	5.288	42 gallons, pre-1824, 2003 reference	
hogshead or puncheon	299.5	10.58	2 tierce, pre-1824, 2003 reference	
tun	599.1	21.15	2 hogshead, pre-1824, 2003 reference	
pipe	1,198	42.31	2 tun, pre-1824, 2003 reference	
Italy (pre-1862, local variations, sampling of units)				Medieval to pre-metric
Dry measure (some examples of ranges)				
cucchiaro (Sardinia, Turin)	0.120	0.00423	1891 value, 1/20 copello	
bussola (Tuscany)	0.190	0.00672	1891 value	
quartuccio (Tuscany)	0.381	0.0134	2 bussoli	
mezzetta (Tuscany)	0.761	0.0269	2 quartucci	
gombette (Genoa)	1.258	0.04440	1891 value	
metadella (Tuscany)	1.523	0.05376	2 mezzete	
misure (Naples)	2.297	0.08112	1891 value	
copello (Sardinia, Turin)	2.396	0.08460	20 cucchiari, 1891 value	
quarticina (Bologna)	2.456	0.08671	1891 value	
quarterola (Parma)	2.938	0.1037	1891 value	
quartucci (Ancona)	3.193	0.1128	1891 value	
quartucci (Rome)	3.346	0.1181	1891 value	
quarto (Tuscany)	6.090	0.2150	4 metadelle	
quartière (Sardinia, Turin)	9.584	0.3384	4 copelli, 1891 value	
quarterone (Bologna)	9.823	0.3469	4 quarticini, 1891 value	
mina (Tuscany)	12.18	0.4301	2 quarti	
scorzo (Ancona)	12.77	0.4510	4 quartucci, 1891 value	
scorzo (Rome)	13.38	0.4726	4 quartucci, 1891 value	
quarto (Genoa)	15.09	0.5328	12 gombette, 1891 value	
starello (Ancona)	17.56	0.6202	1–3/8 scorzi, 1891 value	

(continued)

Table 6.2 (continued)

Region and unit	Equivalent liters (dm ³)	Equivalent cu ft US	Notes	Era
starello (Rome)	18.40	0.6498	1–3/8 scorzi, 1891 value	
mina (Sardinia, Turin)	19.17	0.6768	2 quartiere, 1891 value	
mina (Parma)	23.51	0.8300	8 quarteroli, 1891 value	
stajo (Tuscany)	24.36	0.8602	2 mine	
stajo (Sardinia, Turin)	38.34	1.354	2 mine, 1891 value	
stajo (Bologna)	39.29	1.387	4 quarterone, 1891 value	
stajo or staro (Parma)	47.01	1.660	2 mine, 1891 value	
tomolo (Naples)	55.14	1.947	24 misure, 1891 value	
quarta (Ancona)	70.25	2.481	4 starelli, 1891 value	
stajo (Modena)	70.40	2.486	1891 value	
sacco (Tuscany)	73.08	2.581	3 staja	
quarta (Rome)	73.61	2.599	4 starelli, 1891 value	
corba (Bologna)	78.58	2.775	2 staja, 1891 value	
sacco (Sardinia, Turin)	115.0	4.061	3 staje, 1891 value	
mina (Genoa)	120.7	4.263	8 quarti, 1891 value	
sacco (Modena)	140.8	4.972	2 staja, 1891 value	
salma generale (Sicily)	274.9	9.706	1891 value	
Dry measure (some examples of ranges, continued)				
rubbio (Ancona)	281.0	9.922	4 quarte, 1891 value	
rubbio (Rome)	294.4	10.40	4 quarte, 1891 value	
salma grosso (Sicily)	352.4	12.44	1891 value	
moggio (Tuscany)	584.6	20.64	1891 value, 8 sacci	
carro (Naples)	1,985	70.09	36 tomoli, 1891 value	
Liquid measure (some examples of ranges, varied by commodity)				
quartucco (Tuscany)	0.0753	0.00266	1891 value	
coppa (Venice, Milan)	0.100	0.00353	1891 value	
misurelle (Naples, oil)	0.103	0.00364	1891 value	
quartucci (Rome, oil)	0.112	0.00396	1891 value	
quartucci (Rome, wine)	0.114	0.00402	1891 value	
mezzetta (Tuscany)	0.151	0.00532	2 quartucci, 1891 value	
boccale (Tuscany)	0.301	0.0106	2 mezzette, 1891 value	
fogliette (Bologna)	0.327	0.0116	1891 value	
quartino (Piedmont, Turin)	0.391	0.0138	1891 value	
fogliette (Rome, oil)	0.449	0.0159	4 quarterucci, 1891 value	
foglietta (Roman St)	0.452	0.0160	1/4 boccale, using avg barile	
fogliette (Rome, wine)	0.456	0.0161	4 quarterucci, 1891 value	
pignate (Naples, oil)	0.495	0.0175	1891 value	

(continued)

Table 6.2 (continued)

Region and unit	Equivalent liters (dm ³)	Equivalent cu ft US	Notes	Era
quartuccio (Tuscany, wine)	0.570	0.0201	1/2 boccale	
fiasco (Tuscany)	0.602	0.0213	2 boccale, 1891 value	
quarto (Naples, oil)	0.619	0.0219	6 misurelle, 1891 value	
amole (Genoa)	0.718	0.0254	1891 value	
caraffa (Naples, wine and spirits)	0.730	0.0258	1891 value	
boccale (Piedmont, Turin)	0.782	0.0276	2 quartini, 1891 value	
pinta (Venice, Milan)	1.000	0.03531	10 coppi, 1891 value	
boccalo (Modena)	1.041	0.03677	1891 value	
boccale or mezzetta (Tuscany, wine)	1.140	0.04024	1/2 fiasco	
pinte (Genoa)	1.293	0.04567	1891 value	
boccale (Bologna)	1.310	0.04624	4 fogliette, 1891 value	
pinta (Piedmont, Turin)	1.565	0.05525	2 boccale, 1891 value	
boccale (Rome, oil)	1.796	0.06342	4 fogliette, 1891 value	
boccale (Rome, wine)	1.823	0.06437	4 fogliette, 1891 value	
fiasco (Modena)	2.083	0.07355	2 boccali, 1891 value	
fiasco (Tuscany, wine)	2.279	0.08049	1/20 barile	
rubbio (Piedmont, Turin)	9.388	0.3315	6 pinte, 1891 value	
barile (Tuscany, oil)	9.636	0.3402	16 fiasci, 1891 value	
stajo (Naples, oil)	9.903	0.3497	16 quarti, 20 pignate, 1891 value	
mina (Venice, Milan)	10.00	0.3531	10 pinte, 1891 value	
barile (Tuscany)	12.04	0.4253	20 fiasci, 1891 value	
socrzo (Rome, oil)	13.39	0.4727		
soma (Tuscany, oil)	19.27	0.6805	2 barile oil, 1891 value	
quarterone (Bologna)	19.64	0.6936	15 boccale, 1891 value	
barile da olio	33.40	1.179	Barrel of oil	
staia (Bologna)	39.29	1.387	1/2 corba	
barile (Modena)	41.66	1.471	20 fiasci, 1891 value	
barile (Naples, wine and spirits)	43.81	1.547	60 caraffi, 1891 value	
barile (Tuscany, wine)	45.59	1.610		
barile da vino	45.60	1.610	Barrel of wine	
brenta (Piedmont, Turin)	56.33	1.989	6 rubbi, 1891 value	
baril oil (Roman St)	57.48	2.029	1/16 botte	
barile (Rome, oil)	57.48	2.029	32 boccale, 1891 value	
barile (Rome, wine)	58.33	2.060	32 boccale, 1891 value	

(continued)

Table 6.2 (continued)

Region and unit	Equivalent liters (dm ³)	Equivalent cu ft US	Notes	Era
barile (Genoa)	64.66	2.283	50 pinte, 90 amole, 1891 value	
soma (Ancona)	69.98	2.471	1891 value	
corba (Bologna)	78.58	2.775	4 quarterone, 1891 value	
Salma (Sicily)	83.27	2.940	1891 value	
soma (Venice, Milan)	100.0	3.531	10 mine, 1891 value	
mina (Genoa, oil)	116.5	4.114	Oil	
mezzaruòla (Genoa)	129.3	4.567	2 barili, 1891 value	
salma (Naples, oil)	158.4	5.595	16 staja, 1891 value	
soma (Rome)	164.2	5.799	1891 value	
rubblo (Rome, oil)	294.5	10.40		
botta (Naples, wine and spirits)	525.7	18.56	12 barile, 1891 value	
carro (Piedmont, Turin)	563.3	19.89	10 bente, 1891 value	
botte (Rome, oil)	919.6	32.47	16 barile, 1891 value	
botte (Rome, wine)	933.4	32.96	16 barile, 1891 value	
carro (Naples, wine and spirits)	1,051	37.13	2 botti, 1891 value	
Japan (pre-1924, some units still used for sake)				Medieval to pre-metric
sai	0.00180	0.0000637		
shaku	0.01804	0.0006370	2003 reference	
gō or gō	0.1804	0.006370	10 shaku, common serving size for sake, 2003 reference	
itchigau	1.680	0.05932	1891 value	
shō or sho	1.804	0.06370	10 gō, common sake bottle size, 2003 reference	
gonghau	8.400	0.2966	5 itchigau, 1891 value	
ischiomassé	16.80	0.5932	2 gonghau, 1891 value	
to	18.04	0.6370	10 sho, 2003 reference	
ittomassé	168.0	5.932	10 ischiomassé, 1891 value	
koku	180.4	6.370	10 to, volume of rice a person would eat in a year, 2003 reference	
Java (primarily old Dutch units used, values varied by location)				Pre-metric
Dry measure				
bambou (Bantam)	3.25	0.115	1891 value	
koyang (Batavia, rice)	2,200	77.69	1891 value	
koyang (Bantam, rice)	5,200	183.6	1891 value	

(continued)

Table 6.2 (continued)

Region and unit	Equivalent liters (dm ³)	Equivalent cu ft US	Notes	Era
Liquid measure				
kanne	1.49	0.0527	1891 value	
legger (arrack or arak)	606	21.4	1891 value, arrack is distilled liquor	
Jewish				Medieval to modern
log	0.184	0.00649	11.21 cu in	
cabaho	0.735	0.0260	44.859 cu in	
omer or asseron	1.323	0.04672	80.727 cu in	
hin	2.205	0.07786	134.54 cu in	
metretes or Syrian firkin	3.393	0.1198	207 cu in	
seah or saton	4.410	0.1557	269.091 cu in	
hin (per Josephus)	6.787	0.2397	414.12 cu in	
bath or epha	13.23	0.4672	807.274 cu in	
seah or saton (per Josephus)	13.58	0.4794	828.28 cu in	
corus or chomer	132.3	4.672	8072.74 cu in	
Korea				Medieval or pre-metric
hop	0.1800	0.006356		
toe	1.800	0.06356		
mal	18.00	0.6356		
som	180.0	6.356		
Latvia (pre-1845, many others, variations)				Medieval or pre-metric
stoof	1.275	0.04503	2003 reference	
kanne	2.550	0.09006	2 stoof, 2003 reference	
kulmet	11.48	0.4053	9 stoof, 2003 reference	
anker	38.26	1.351	30 stoof, 2003 reference	
poure or loof	68.86	2.432	54 stoof, 2003 reference	
tonne	137.7	4.863	108 stoof, 2003 reference	
faden	4,077	144.0		
Libya (pre-1927, local variations)				Medieval or pre-metric
Dry measure (also definitions by weight)				
nufsbah or nufsorba	3.846	0.1358	1/2 orba, 2003 reference	
orba	7.692	0.2716	2 nufsbah, 2003 reference, defined at metrication, also defined as 7.5 l.	
marta	15.38	0.5432	2 orba, 2003 reference, usually measured by weight as 12 oka water	

(continued)

Table 6.2 (continued)

Region and unit	Equivalent liters (dm ³)	Equivalent cu ft US	Notes	Era
kele	23.08	0.8148	3 orba, 2003 reference, usually measured by weight as 24 oka water	
temem	30.77	1.086	4 orba, 2 marta, 2003 reference	
ueba	123.1	4.346	16 orba, 4 temen, 2003 reference	
Liquid measure (also definitions by weight)				
bozze	2.604	0.09195	1/24 barile, 2003 reference	
gorraf	12.50	0.4414	4.8 bozze, 1/5 barile, 2003 reference, usually defined by weight as 39/4 oka of water	
giarra	44.01	1.554	Roughly 50/71 barile, 2003 reference, usually measured by weight as about 34.3 oka water	
barile	62.50	2.207	5 gorraff, 2003 reference, also stated as 64.8 l at metrication	
Luxembourg (pre-1820)				Medieval or pre-metric
malter	191.0	6.744		
Madagascar (pre-1897, other units, local variations)				Medieval or pre-metric
bambou	2.002	0.07068	1891 value	
Madeira (vary slightly from Portuguese basis)				Pre-metric
pipa (wine)	416.4	14.70	1891 value	
Malta (pre-1921, also used British system)				Medieval or pre-metric
General capacities				
caffiso (common)	20.46	0.7224	2003 reference, corrected	
baril (common)	43.16	1.524	2003 reference, corrected	
salma (common)	290.9	10.27	2003 reference, corrected	
Liquid measure				
Beer, wine and spirits measure				
pints	0.142	0.00502		
terz	0.284	0.0100	Third	
nofs	0.568	0.0201	Half	
kartoçc	1.137	0.04015		
kwarta	5.398	0.1906	Quarter	
garra	10.80	0.3814		
barmil or barile	43.19	1.525	Barrel, 41.6 liters in 1891 for wine	

(continued)

Table 6.2 (continued)

Region and unit	Equivalent liters (dm ³)	Equivalent cu ft US	Notes	Era
Milk and oil measures				
kejla	0.128	0.00452	1921 Act only, measure	
kwartin	0.320	0.0113	1921 Act only, quarter	
terz	0.320	0.0113	Third	
nofs	0.639	0.0226	Half	
kartočč	1.279	0.04516		
kwarta	5.114	0.1806	Quarter	
qafiz or caffiso	20.46	0.7225	1921 Act only, 20.8 liters in 1891 for oil	
Dry measure				
lumin	0.0303	0.00107	1/600 tomna	
kejla or mondell	0.303	0.0107	1/60 tomna	
siegh	1.818	0.06419	Either 1/10 or 1/6 tomna, used 1/10 basis	
ghabara	3.031	0.1070	Some confusion on name, 1921 Act calls it a siegh, 1/6 tomna	
tomna or tumolo	18.18	0.6419		
modd or salma	290.9	10.27	Weigh, 16 tomna, 289.8 liters in 1891 for corn	
Cubic measure				
pulzier kubu	0.0104	0.000367	1/1728 xiber kubu	
fitel kubu	2.246	0.07931	1/8 xiber kubu	
xiber kubu	17.97	0.6345	Base unit	
qasba kubu	9,202	324.9	1 qasba cubed, 512 xiber kubu	
Mauritania (pre-1878, Old French and British, additional units listed)				Medieval to pre-metric
velte	7.570	0.2673	1/30 cash	
cash	227.1	8.019		
Mesopotamia (ancient units, approximate values, expect local variations, Anglicized names)				Ancient
shekel (Sumerian gin ₂ , Akkdian šiqḷu)	0.017	0.00059	1/60 bowl	
bowl (Sumerian sila ₃ , Akkdian qū)	1.0	0.035	Base unit	
vessel (Sumerian ban ₂ , Akkdian sutū)	10	0.35	10 bowls	
bushel (Sumerian ba-ri ₂ -ga, Akkdian parsiktu)	60	2.1	60 bowls	
gur-cube (Sumerian gur, Akkdian kurru)	300	10.6	300 bowls	

(continued)

Table 6.2 (continued)

Region and unit	Equivalent liters (dm ³)	Equivalent cu ft US	Notes	Era
Mexico (pre-1896, several units not listed, local variations)				Colonial to pre-metric
Dry measure				
cuartillo	1.892	0.06680	2003 reference	
almud or almude	7.567	0.2672	4 cuartillo, 2003 reference	
fanega	90.81	3.206	48 cuartillo, 12 almude, 2003 reference, reported as 54.6 liters in 1891	
carga	181.6	6.413	96 cuartillo, 2 fanega, 2003 reference	
Liquid measure				
cuartillo (wine)	0.4563	0.01611	Consistent with 2003 reference for general liquid volume	
cuartillo (oil)	0.506	0.0179		
frasco (wine basis)	2.366	0.08354	Approx, consistent with 1891 value reported	
jarra (wine basis)	8.213	0.2900	18 cuartillo, consistent with 2003 reference for general liquid volume	
baril (wine basis)	75.70	2.673	Approx, consistent with 1891 value reported	
Molucca Islands (primarily Netherlands plus local units and variations)				Pre-metric
koyang (Amboyna)	1,950	68.86	1891 value	
Morocco (pre-1923, local variations and units not listed)				Colonial to pre-metric
mudd, muhd, mud, or almude	14	0.49	2003 reference, also reported as 183 liters in 1891 (possible error)	
sahh or fanega	56	2.0	4 mudd, 2003 reference	
Muscat (local variations)				Pre-metric
sidio	0.882	0.0312	1891 value	
ferren	30.0	1.06	1891 value, 34 sidios	
Native America (Shoshone tribe, many other similar measures)				Pre-colonial
General: volume measured by sizes of containers. Very loosely defined. Individual knew how much a container held for various purposes, e.g. enough for “x” servings of food. Unable to identify larger measurement units (may not have really been needed)				
pinch	0.0006	0.00002	Cooking measure, very roughly estimated volume	
dash	0.003	0.0001	Cooking measure, very roughly estimated volume	

(continued)

Table 6.2 (continued)

Region and unit	Equivalent liters (dm ³)	Equivalent cu ft US	Notes	Era
handful	0.1	0.004	Cooking measure, very roughly estimated volume	
buffalo horn	0.4	0.01	Roughly consistent measure, very roughly estimated volume	
Netherlands (pre-1820 plus some 1891 terms, local variations, includes Holland and Dutch units)				Medieval to metric
Pre-metric units—dry				
kop	0.8519	0.03008	2003 reference	
vierd	6.815	0.2406	8 kop, 2003 reference	
schepel	27.26	0.9626	4 vierd, 2003 reference	
zak	81.78	2.888	3 shepel, 2003 reference	
mud or mudde	109.0	3.849	4 schepel, 2003 reference	
last	2,944	104.0	27 mud, 2003 reference	
Post-metric units—dry				
maatje	0.100	0.00353	Deciliter, 1891 term, “re-purposed” unit name	
kop	1.000	0.03531	Liter, 1891 term, “re-purposed” unit name	
schepel	10.00	0.3531	Decaliter, 1891 term, “re-purposed” unit name	
mudde	100.0	3.531	Hectoliter, 1891 term, “re-purposed” unit name	
scheepeston (wisse)	1,000	35.31	Kiloliter, 1891 term, “re-purposed” unit name	
last	3,000	105.9	30 hectoliters, 1891 term, “re-purposed” unit name	
Pre-metric units—liquid				
mutsjje	0.1500	0.005297	2003 reference	
pint	0.6000	0.02119	4 mutsjje, 2003 reference	
mingelen or mingle	1.200	0.04237	2 pint, 2003 reference, also reported as 1.211 liters	
stoop	2.400	0.08475	2 minglen, 2003 reference, also reported as 2.422 liters	
steekan	19.20	0.6780	8 stoop, 2003 reference	
anker	38.40	1.356	2 steekan, volume of small cask equal to 45 bottles, 2003 reference, also reported as 38.75 liters	

(continued)

Table 6.2 (continued)

Region and unit	Equivalent liters (dm ³)	Equivalent cu ft US	Notes	Era
aam	153.6	5.424	4 anker, 2003 reference, also reported as 155.0 liters	
oxhoofd, okshoofd, or oxhoofd	230.4	8.136	Oxhead, 6 anker, volume of large barrel, still used in wine and spirits trade, 2003 reference, also reported as 232.5 liters	
vat	921.6	32.54	4 oxhoofd, 2003 reference	
Post-metric units— liquids				
vingerhoed	0.010	0.00035	Centiliter, 1891 term	
maatje	0.100	0.00353	Deciliter, 1891 term	
kan	1.000	0.03531	Liter, 1891 term	
vat	100.0	3.531	Hectoliter, 1891 term, “re-purposed” unit name	
Nicaragua (local variations, see also Central America, generally Spanish Castilian units used, significant conflicts among references)				Colonial to pre-metric
cuartillo or quartillo	0.51	0.018	2003 reference	
botella	0.65	0.023	32/25 quartillo, varied from 0.63 to 0.67 liters, used average, 2003 reference	
cajuella	16.3	0.574	25 botella, 2003 reference	
Norway (pre-1887, local variations and additional units)				Medieval to pre-metric
Dry measure				
ort	0.327	0.0115	1891 value	
qwarter	1.308	0.04619	4 orts, 1891 value	
favn	2.232	0.07881	1 cubic alen, still used for firewood	
stop	5.232	0.1848	4 qwartern, 1891 value	
kanna	10.46	0.3695	2 stops, 1891 value	
kappe	18.31	0.6466	1891 value	
fjerding	73.25	2.587	7 kannas, 1891 value	
tønne or korntonde	139.0	4.907	Barrel, 4.5 cubic fot, 2003 reference	
span	293.0	10.35	4 fjerdingen, 1891 value	
tunna	586.0	20.69	2 spans, 32 kappes, 1891 value	
Liquid measure				
jungfru	0.0818	0.00289	1891 value	
qwarter	0.327	0.0116	4 jungfrus, 1891 value	
pot	0.9651	0.03408	2003 reference	
stop	1.309	0.04620	4 qwartern, 1891 value	

(continued)

Table 6.2 (continued)

Region and unit	Equivalent liters (dm ³)	Equivalent cu ft US	Notes	Era
kanna	2.617	0.09241	2 stops, 1891 value	
skjeppe	17.37	0.6133	1/4 tonne, 2003 reference	
tunna	125.6	4.436	48 kannas, 1891 value	
Oman (pre-metric, local variations, additional units not listed)				Medieval to pre-metric
sidios	0.88	0.031	1/34 ferren, approx	
ferren	30.0	1.06	Approx	
Ottoman Empire (pre-1933, local variations and additional units not listed)				Medieval to pre-metric
şinik	9.25	0.327	Peck	
kile (Istanbul)	37.0	1.31	Bushel, 4 şinik	
Paraguay (pre-1899, local variations and additional units not listed)				Colonial to pre-metric
Dry measure				
almude	24.0	0.847	8 frasco, 2003 reference	
fanega	288	10.2	12 almude, 2003 reference	
Liquid measure				
cuarta	0.757	0.0267	1/4 frasco, 2003 reference	
frasco	3.03	0.107	4 cuarta, 2003 reference	
baril	96.9	3.42	32 frasco, 2003 reference	
pipe	582	20.5	192 frasco, 6 baril, 2003 reference	
Persia or Iran (medieval period, local variations and additional units not listed, volumes based on weights of water, includes present day Iran)				Medieval to pre-metric
shekel	0.0083	0.00029	Approx 1 cubic aiwas	
sextario	0.326	0.0115	1891 value	
sextario	0.330	0.0117	2003 reference	
profane mina	0.500	0.0177	50 shekel, about 27 cubic aiwas, inconsistent, probably post-metric	
sacred mina	0.600	0.0212	60 shekel, about 1 cubic dva, inconsistent	
chenica	1.30	0.0461	4 sextarios, 1891 value	
chenica	1.32	0.0466	4 sextario, 2003 reference	
capicha	2.61	0.0921	2 chenicas, 1891 value	
capicha	2.64	0.0932	2 chenica, 2003 reference	
sabbitha	7.26	0.256	22 sextario, 2003 reference	
collothun or colluthun	8.15	0.288	1891 value	
collothun or colluthun	8.25	0.291	25 sextario, 2003 reference	
talent	25.00	0.8828	60 profane mina, approx 1 cubic trays	

(continued)

Table 6.2 (continued)

Region and unit	Equivalent liters (dm ³)	Equivalent cu ft US	Notes	Era
legana	39.6	1.40	15 capichas, 2003 reference	
artaba or arta	65.24	2.304	25 capichas, 8 collothun, 1891 value	
artaba or arta	66.0	2.33	8 colluthun, 2003 reference	
Persia or Iran (capacities also measured by weight, see weight conversion table for additional values reported in 2003 reference)				Ancient
Philippines (pre-1860, past Spanish, local variations and additional units not listed)				Medieval to pre-metric
apatan	9.990E-04	3.528E-05	2003 reference	
chupa	0.003996	0.0001411	4 apatan, 2003 reference	
ganta	3.996	0.1411	1000 chupa, 2003 reference	
kaban	99.90	3.528	25 ganta, 2003 reference	
Poland (pre-1872, many systems were used, local variations and additional units not shown, some units related to metric units)				Medieval to pre-metric
kwarterka	0.250	0.00883	2003 reference	
kwarta	1.00	0.0353	4 kwarterka, 2003 reference, possibly post-metric	
garniec (liquids)	3.753	0.1325	4 kwarta, 1891 value, reported as 4.000 liters in Warsaw and in 2003 reference	
cwierc	32.0	1.13	8 garniec, 2003 reference	
korzec (dry)	120.1	4.241	4 cwierc, 1891 value, reported as 128 liters in Warsaw and in 2003 reference	
łaszt (dry)	3,603	127.2	30 korzec, significant variation by location, history, and commodity	
Portugal (pre-1872, many systems were used, local variations and additional units not shown)				Medieval to pre-metric
Dry measure				
maquia (Lisbon)	0.845	0.0298	1891 value	
maquia (Oporto)	0.973	0.0344	1891 value	
outava (common)	1.69	0.0596	2003 reference	
outava (Lisbon)	1.690	0.05967	2 maquias, 1891 value	
outava (Oporto)	1.946	0.06871	2 maquias, 1891 value	
quarto (common)	3.38	0.119	2 outavas, 2003 reference	
quarto (Lisbon)	3.380	0.1193	2 outavas, 1891 value	
quarto (Oporto)	3.892	0.1374	2 outavas, 1891 value	
meio (common)	6.75	0.238	2 quartos, 2003 reference	

(continued)

Table 6.2 (continued)

Region and unit	Equivalent liters (dm ³)	Equivalent cu ft US	Notes	Era
alqueira (common)	13.5	0.477	2 meios, 2003 reference	
alquiére (Lisbon)	13.52	0.4774	4 quartos, 1891 value	
alquiére (Oporto)	15.57	0.5497	4 quartos, 1891 value	
fanga (common)	54.0	1.91	4 alqueiras, 2003 reference	
fanga (Lisbon)	54.08	1.909	4 alquiéres, 1891 value	
fanga (Oporto)	62.27	2.199	4 alquiéres, 1891 value	
fanga (Lisbon, coal)	745.9	26.34	Specific to coal, 1891 value	
moio (common)	810	28.6	15 fangas, 2003 reference	
moio (Lisbon)	811.2	28.64	15 fangas, 1891 value	
moio (Oporto)	934.0	32.98	15 fangas, 1891 value	
Liquid measure				
1/4 quartilho	0.0875	0.00309	Quarter-pint	
1/2 quartilho	0.175	0.00618	Half-pint	
quartilho (common)	0.344	0.0121	2003 reference	
quartilho	0.350	0.0124	Pint, 1/4 Canada	
quartilho (Lisbon)	0.360	0.0127	1891 value	
quartilho (Oporto)	0.522	0.0184	1891 value	
meio (common)	0.688	0.0243	2 quartilhos, 2003 reference	
Canada (common)	1.38	0.0486	2 meios, 2003 reference	
Canada	1.400	0.04944	4 quartilhos	
Canada (Lisbon)	1.438	0.05079	4 quartilhos, 1891 value	
Canada (Oporto)	2.090	0.07380	4 quartilhos, 1891 value	
alqueira (common)	2.75	0.0971	2 Canadas, 2003 reference	
pote or alquiére	8.400	0.2966	Pot, 6 Canadas	
pote or alquiére (Lisbon)	8.630	0.3047	6 Canadas, 1891 value	
pote or alquiére (Oporto)	12.54	0.4428	6 Canadas, 1891 value	
almude (common)	16.5	0.583	6 alqueiras, 2003 reference	
almude or cântaro	16.80	0.5932	2 potes	
almude or cântaro (Lisbon)	17.26	0.6095	2 potes, 1891 value	
almude or cântaro (Oporto)	25.08	0.8856	2 potes, 1891 value	
pipa	420.0	14.83	Barrel, 25 almudes	
bota or pipa (common)	429	15.1	26 almudes, 2003 reference	

(continued)

Table 6.2 (continued)

Region and unit	Equivalent liters (dm ³)	Equivalent cu ft US	Notes	Era
pipa or bota (Lisbon)	448.8	15.85	Barrel, 26 almudes, 1891 value	
pipa or bota (Oporto)	652.1	23.03	Barrel, 26 almudes, 1891 value	
tonel or tonelada	840.0	29.66	Cask, 600 Canadas	
tonnelada (common)	858	30.3	2 botas, 2003 reference	
tonel or tonelada (Lisbon)	897.5	31.69	Cask, 2 pipas, 1891 value	
tonel or tonelada (Oporto)	1,304	46.05	Cask, 2 pipas, 1891 value	
Prussia (local variations)				Medieval to pre-metric
Dry measure				
mässchen	0.859	0.0303	1891 value	
metze	3.435	0.1213	4 mässchen, 1891 value	
viertel	13.74	0.4851	4 metzen, 1891 value	
scheffel	54.96	1.941	4 viertel, 1891 value	
malter	659.5	23.29	12 scheffel, 1891 value	
wispel	989.2	34.93	18 scheffel, 1891 value	
last	3,957	139.7	6 malter, 1891 value	
Liquid measure				
össel	0.572	0.0202	1891 value	
quartier	1.145	0.04042	2 össel, 1891 value	
anker	34.35	1.213	30 quartier, 1891 value	
eimer	68.69	2.425	2 anker, 1891 value	
ohm	137.4	4.851	2 eimer, 1891 value	
fuder	824.3	29.11	6 ohm, 1891 value	
Romania (Roumania, including Moldavia and Wallachia, pre-metric, pre-1884)				Pre- and post-metric
Dry measure				
oke	1.54	0.0543	2003 reference	
dimeria	24.6	0.869	16 oke, 2003 reference	
mirze	197	6.95	8 dimeria, 2003 reference	
kilo	394	13.9	2 mirze, 2003 reference	
kilo	435.0	15.36	1891 value	
Liquid measure				
oka or oke	1.417	0.05003	1891 value, reported as 1.415 l in 2003 reference	
viadra or viacka	14.17	0.5003	10 oka, 1891 value, reported as 14.15 l in 2003 reference	

(continued)

Table 6.2 (continued)

Region and unit	Equivalent liters (dm ³)	Equivalent cu ft US	Notes	Era
Rome and Roman Empire (ancient, many systems were used, local variations and additional units not shown, see also Italy for units just before metrication)				Ancient
Base units				
sextarius	0.546	0.0193	1/6 congius, varied from 0.53 to 0.58 liters, Wikipedia value	
congius	3.276	0.1157	1/2 pes cubed or 1/8 amphora quadrantal, est'd	
amphora quadrantal	26.21	0.9254	Roman jar, 1 cubic pes or Roman foot, est'd	
Dry measure				
ligula	0.01144	0.0004040	1/288 congius, 2003 reference	
cyathus	0.04577	0.001616	1/72 congius, 2003 reference	
acetabulum	0.06865	0.002424	1/48 congius, 2003 reference	
quartarius	0.1373	0.004848	1/24 congius, 2003 reference	
hemina or cotyla	0.2746	0.009696	1/12 congius, 2003 reference	
sextarius	0.5493	0.01940	1/6 congius, 2003 reference	
semimodius or semodius	4.394	0.1552	1–1/3 congii, 2003 reference	
modius or muid	8.788	0.3103	2–2/3 congii, also listed as 8.62 liters, 2003 reference	
modius castrensis	13.2	0.465	Est'd, 4 congii, 2003 reference	
quadrantal	26.36	0.9308	3 modius, 2003 reference	
Liquid measure				
ligula or cochlearia	0.01144	0.0004041	1/288 congius, 1/48 sextarius, 2003 reference	
cyathus	0.04577	0.001616	1/72 congius, 2003 reference	
acetabulum	0.0687	0.00242	1/48 congius, 2003 reference	
quartarius	0.1373	0.004848	1/24 congius, 2003 reference	
hemina or cotyla	0.2746	0.009696	1/12 congius, 2003 reference	
sextarius	0.5493	0.01940	1/6 congius, 2003 reference	

(continued)

Table 6.2 (continued)

Region and unit	Equivalent liters (dm ³)	Equivalent cu ft US	Notes	Era
chenica	0.8239	0.02909	3/2 sextarius, 2003 reference	
congius	3.296	0.1164	Base unit, 2003 reference	
urna	13.18	0.4654	Urn, 4 congii, 2003 reference	
amphora quadrantal or metrete	26.37	0.9311	8 congii, 2003 reference	
culeus, culleus, or dolum	527.3	18.62	“Hogshead”, 160 congii, 2003 reference	
Russia (pre-1924, many systems were used, local variations and additional units not shown)				Medieval to pre-metric
Dry measure				
chast or tchast	0.1093	0.003861	Part, 1/30 garnets, consistent with 2003 reference	
kruzha or krushky	1.312	0.04633	Mug, 2/5 garnets, 12 chast, consistent with 2003 reference	
polougarnetz	1.640	0.05791	15 chast, 2003 reference	
garnets or garnetz	3.280	0.1158	Pot, 2 polougarnetz, consistent with 2003 reference	
tschetverka	6.560	0.2316	2 garnets, 1891 value	
vedro	13.12	0.4633	Bucket, 4 garnets, consistent with 2003 reference	
chetverik, tcheverik, or tschetverik	26.24	0.9265	Quarter, 8 garnets, consistent with 2003 reference	
pajak or payok	52.48	1.853	2 chetveriks, 2003 reference	
lof	64.72	2.285	592 chast, 2003 reference	
osmina or osmini	105.0	3.706	One-eighth, 32 garnets, 2 pajaks, consistent with 2003 reference	
chetvert, tschetviert, or chetviert	209.9	7.412	64 garnets, 2 osminas, consistent with 2003 reference	
Liquid measure				
shkalik, chkalik, or kosushka	0.06150	0.002172	Measure or shot, 1/200 vedro, consistent with 2003 reference	
charka or tcharka	0.1230	0.004343	“Wine glass”, 1/100 vedro, consistent with 1891 value and 2003 reference	
quar	0.384	0.0136	1891 value	
butylka (vodochnaya)	0.615	0.0217	Bottle of vodka, 1/20 vedro, 5 tcharka, consistent with 2003 reference	

(continued)

Table 6.2 (continued)

Region and unit	Equivalent liters (dm ³)	Equivalent cu ft US	Notes	Era
butylka (vynnaya) or polou-stoff	0.769	0.0271	Bottle of wine, 1/16 vedro, 6.25 tcharka, consistent with 2003 reference	
kruzhka, kronchka, krouchka, or shtof	1.230	0.04343	Mug or flagon, 1/10 vedro, 10 tcharka, consistent with 2003 reference	
chetvert, stoff, or shtof	1.537	0.05427	Quarter, 1/8 vedro, 2 bottles of wine, consistent with 2003 reference	
polou-vedro	6.15	0.217	4 stoffs, 1891 value	
vedro	12.30	0.4343	Bucket, 100 tcharkas, 2 polou-vedros, 10 kronchkas, consistent with 1891 value and 2003 reference	
stekar	18.45	0.6515	12 shtoff, 2003 reference	
anker	36.90	1.303	3 vedros, 2 stekar, 1891 value, consistent with 2003 reference	
pipe	442.8	15.64	12 anker, 2003 reference	
bochka, botchka, fass, or sarakowaja	492.0	17.37	Barrel, 40 vedro, 1891 value, consistent with 2003 reference	
Salvador (see El Salvador)				Colonial to pre-metric
Sandwich Islands (Hawaiian Islands, see also United Sates)				Pre-metric
barrel (whale oil)	119.2	4.210	1891 value, 31.5 gallons	
San Salvador (see El Salvador)				Colonial to pre-metric
Saudi Arabia (pre-metric (1962), see also Arabia)				Pre-metric
Dry measure				
mecdema	8.15	0.288	2003 reference	
kella	35.4	1.25	100/23 mecdema, 2003 reference	
teman	85.0	3.00	12/5 kella, 2003 reference	
Liquid measure				
vakia	0.059	0.0021	2003 reference	
nusfiah	0.95	0.034	16 vakia, 2003 reference	
cuddy	3.8	0.13	4 nusfiah, 2003 reference	
zudda	7.6	0.27	2 cuddy, 2003 reference	
ardabb or ardebb	1,581	55.82	208 zudda, 2003 reference	
Scotland (pre-1824, many systems were used, local variations and additional units not shown)				Medieval to pre-metric
Dry measure (quantities grew over time from original definition in 1500s)				
lippy, lippie, or forpet (wheat, peas, beans, rice, salt)	2.250	0.07947	2003 reference	
lippy, lippie, or forpet (oats, barley, malt)	3.283	0.1159	2003 reference	

(continued)

Table 6.2 (continued)

Region and unit	Equivalent liters (dm ³)	Equivalent cu ft US	Notes	Era
peck (wheat, peas, beans, rye, salt)	9.00	0.318	Things sold by level measure	
peck (wheat, peas, beans, rice, salt)	9.002	0.3179	4 lippy, 2003 reference	
peck (oats, barley, malt)	13.13	0.4637	4 lippy, for things sold by “heaped” measure, 2003 reference	
firlot (wheat, peas, beans, rice, salt)	36.01	1.271	4 peck, for things sold by “level” measure, 2003 reference	
firlot (oats, barley, malt)	52.53	1.855	4 pecks, for things sold by “heaped” measure, 2003 reference	
boll (wheat, peas, beans, rice, salt)	144.0	5.086	4 firlot, for things sold by “level” measure, 2003 reference	
boll (oats, barley, malt)	210.1	7.419	4 firlot, for things sold by “heaped” measure, 2003 reference	
chalder (wheat, peas, beans, rice, salt)	2,304	81.37	16 boll, for things sold by “level” measure, 2003 reference	
chalder (oats, barley, malt)	3,362	118.7	16 boll, for things sold by “heaped” measure, 2003 reference	
chalder (general, coal)	3,900	137.7	Legal limits for horse-drawn wagon on road, varied, e.g. coal, 1420–2690 kg, used 2500 kg typical	
Liquid measure (quantities grew over time from original definition in 1500 s)				
gill	0.1059	0.003741		
mutchkin	0.4238	0.01496	4 gill, 2003 reference	
chopin or choppin	0.8475	0.02993	2 mutchkins, also defined as 3 Imperial gills (inconsistent), 2003 reference	
Scots pint, jug, or joug	1.695	0.05985	4 mutchkins or 3 Imperial pints (1.704 l)	
quart	3.390	0.1197		
gallon	13.56	0.4788	16 chopins or 8 jousgs	
barrel	108.5	3.831	8 gallons	
Seychelles (pre-1880, used French, British, and other units, local variations and additional units not shown)				Colonial to pre-metric
velte	7.57	0.267	1/30 cash	
cash	227	8.02		
Siam (see Thailand)				Pre-metric
Slovakia (pre-1876, local variation, additional units not shown, see also Czechoslovakia)				Medieval to pre-metric
korec or strych	93.59	3.305		
Somalia (pre-1950, local variation, additional units not shown)				Medieval to pre-metric
caba	0.453	0.0160	2003 reference	
chela	1.359	0.04799	3 caba, 2003 reference	

(continued)

Table 6.2 (continued)

Region and unit	Equivalent liters (dm ³)	Equivalent cu ft US	Notes	Era
tabla	20.39	0.7198	15 chela, 2003 reference	
gisla	163.1	5.758	120 chela, 8 tabla, 2003 reference	
South Africa (pre-1922, primarily Dutch, local variation, additional units not shown)				Colonial to pre-metric
kanne	1.330	0.04696	1/388 legger	
gantang	9.200	0.3249		
balli	46.00	1.624	5 gantang	
muid	109.1	3.852		
ahm	129.0	4.555	1/4 legger	
legger	516.0	18.22		
Spain (pre-metric, local variation, additional units not shown, includes Spanish colonies during colonial period)				Medieval to pre-metric
Dry measure—huge local variation				
ochavillo	0.0734	0.00259	Also reported as 0.07227 l in 2003 reference	
racion	0.293	0.0104	4 ochavillos, reported as 0.2891 l in 2003 reference	
quartillo or cuartillo	1.174	0.04145	4 raciones, reported as 1.156 l in 2003 reference	
medio	2.348	0.08290	2 quartillos, reported as 2.313 l in 2003 reference	
almude or calemin	4.696	0.1658	2 medios, reported as 4.625 l in 2003 reference	
media fanega	26.00	0.9181	Range 13.1–55.5 liters, used avg (44 values)	
fanega	56.35	1.990	12 almudes, reported as 55.50 l in 2003 reference	
cahiz	676.2	23.88	12 fanegas, reported as 666.0 l in 2003 reference	
Liquid measure—huge local variation				
copas	0.1220	0.004308	2003 reference	
panilla (oil)	0.126	0.00444	1891 value	
copa	0.126	0.00445	1891 value	
panilla or quarterone	0.1564	0.005523	1/25 cuartilla, 2003 reference	
quartillo, cuartillo, or libra	0.504	0.01781	4 copas, 1891 value, reported as 0.4888 l in 2003 reference	
azumbre	2.017	0.07122	4 quartillos, 1891 value, reported as 1.955 l in 2003 reference	

(continued)

Table 6.2 (continued)

Region and unit	Equivalent liters (dm ³)	Equivalent cu ft US	Notes	Era
quartilla or cuartilla (oil)	3.140	0.1109	25 panillas, 1891 value	
quartilla or cuartilla (common)	3.910	0.1381	2003 reference	
arroba (oil)	8.440	0.2980	Range 0.37–15.6 liters, used avg	
cantara or arroba (wine)	9.940	0.3510	Range 0.47–30.4, used avg (44 values)	
arroba (oil)	12.56	0.4435	4 quartillos, 1891 value, consistent with value reported in 2003	
arroba or cantarra (common, water)	15.64	0.5523	2003 reference	
arroba or cantarra (wine)	16.13	0.5697	2003 reference	
arroba major or cantara	16.14	0.5698	8 azumbres, 1891 value	
moio (common, water)	250.2	8.835	16 arrobas, 2003 reference	
pipa (common, water)	422.3	14.91	27 arrobas, 2003 reference	
bota (common, water)	469.2	16.57	30 arrobas, 2003 reference	
Sri Lanka (pre-1970s, local variation, additional units not shown)				Medieval to pre-metric
Dry measure				
seer	0.706	0.0249	1/288 ammonam, defined in 1835 as cylinder 4.35" diameter and 4.35" high	
parrah	25.43	0.8978	1/8 ammonam, also reported as 1/16 in north, defined in 1835 as cube 11.571 inches on a side	
ammonam	203.4	7.182		
acre?	508.5	17.96	Ref: Maccauly, 2.5 ammonams in north	
Liquid measure				
seer	1.136	0.04011	Also listed as 1.06 liters or 1.86 Imp. Pints	
parrah	25.56	0.9025	6.75 gallons	
Sumatra				Pre-metric
pakha	0.550	0.0194	1891 value, liquid measure	
koolah	4.134	0.1460	1891 value, dry measure	

(continued)

Table 6.2 (continued)

Region and unit	Equivalent liters (dm ³)	Equivalent cu ft US	Notes	Era
Sweden [pre-1889, local variations and changes with time, additional units not shown, often used cubes of linear units (e.g. cubit fot)]				Medieval to pre-metric
General volumes				
storfavn	3,770	133.1		
kubikkfavn	5,850	206.6		
Dry measure				
junkfra or ort	0.08179	0.002888	2003 reference	
quarter	0.4362	0.01540	5–1/3 junkfra, 2003 reference	
stop	1.309	0.04621	3 quarter, 2003 reference	
kanna or canna	2.617	0.09241	2 stop, 2003 reference	
kappar	4.580	0.1617	3.5 stop, 2003 reference	
fjerdingsar	18.32	0.6469	4 kappar, 2003 reference	
spanna	73.28	2.588	4 fjerdingsar, 2003 reference	
tunna	146.6	5.175	2 spanna, 2003 reference	
koltunna	164.9	5.822	9 fjerdingsar, 2003 reference	
kolläst	1,979	69.86	12 koltunna, 2003 reference	
Liquid measure				
junfru or ort	0.08179	0.002888	2003 reference	
kvarter or quarter	0.3271	0.01155	4 junfru, 2003 reference	
pot	0.966	0.0341	1891 reference	
stop	1.309	0.04621	4 kvarter, 2003 reference	
kanna or canna	2.617	0.09241	2 stop, 2003 reference, consistent with 1891 reference, 1/10 cu fot	
fjärding	31.41	1.109	12 kanna, 2003 reference	
ankar or ankare	39.26	1.386	15 kanna, 2003 reference	
eimer	78.51	2.772	2 ankar, 2003 reference	
tunna	125.6	4.436	48 kanna, 2003 reference	
ohm	149.7	5.287	155 potter, alternate reference	
am, fat, or ohm	157.0	5.545	2 eimer, 2003 reference	
oxhoft	235.5	8.317	3 eimer, 2003 reference	
pipe	471.1	16.63	180 kanna, 2003 reference	
fuder	942.2	33.27	4 oxhoft, 2003 reference	

(continued)

Table 6.2 (continued)

Region and unit	Equivalent liters (dm ³)	Equivalent cu ft US	Notes	Era
Switzerland (pre-1868, local variations, additional units not shown)				Medieval to pre-metric
Dry measure				
1/16 quarteron	0.938	0.0331	1891 value	
emine	1.50	0.0530	1891 value	
1/4 quarteron	3.75	0.132	1891 value	
quarteron	15.0	0.530	5/9 cubic pied, 10 emines, 1891 value	
double quarteron	30.0	1.06	2 quarteron, 1891 value	
sac	150	5.30	10 quarteron, 1891 value	
Liquid measure				
1/8 pot	0.198	0.00700	1/8 pot, 1891 value	
1/4 pot	0.396	0.0140	1/4 pot, 1891 value	
1/2 pot	0.793	0.0280	1/2 pot, 1891 value	
pot	1.59	0.0560	1/18 cubic pied, 1891 value	
setier	39.6	1.40	25 pot, 1891 value	
muid	159	5.60	4 setiers, 1891 value	
Syria (pre-1935, local variations, additional units not shown)				Medieval to pre-metric
rotl	3.2	0.11	2003 reference	
makuk	800	28.2	250 rotl, 2003 reference	
garava	1,440	50.8	450 rotl, 2003 reference	
Tanzania (pre-1967, local variations, additional units not shown)				Medieval to pre-metric
djezla	257.4	9.089	Dry measure?	
Tatar (pre-1924, local variations, additional units not shown, see also Russia)				Medieval to pre-metric
Dry measure				
garnets	3.279	0.1158		
çirektän sigez	26.24	0.9265	8 garnets	
çirek	209.9	7.412		
çiläk	12,300	434.3		
Liquid measure				
podawqa	16.0	0.565	Pot, volume of 16 kg water	
poçiq	32.0	1.13	2 pot	
batman	64.0	2.26	4 pot	

(continued)

Table 6.2 (continued)

Region and unit	Equivalent liters (dm ³)	Equivalent cu ft US	Notes	Era
Thailand (pre-1923, local variations, additional units not shown, some are pre-metric names and post-metric values, mixture of dry and liquid measures, a bit confusing)				Medieval to metric
yip mue	0.00781	0.000276	Pinch	
niou	0.0100	0.000353	2003 reference	
chai meu or kam mue	0.0313	0.00110	Grain held in an enclosed hand, 3–1/8 niou, ~4 yip mue, 2003 reference	
kam meu or fai mue	0.125	0.00441	Grain held in palm, 4 chai meu, 2003 reference	
sat	0.295	0.0104	Dry measure, 1891 value	
changawn or laang	0.500	0.0177	4 kam meu, 2003 reference	
tanam, thanan, or kanahm	1.00	0.0353	Coconut shell measurement, 2 changawn, varies from 0.9 to 1.2 liters, assumed nominal value post metric, 2003 reference	
sesti	11.79	0.4163	40 sats, dry measure, 1891 value	
sat or thang	20.0	0.706	Bucket, 20 tanan, 2003 reference	
sat	25.0	0.883	Measuring bucket, ~25 thanan, alternate value	
tang	40.0	1.41	2 sat, 2003 reference	
cohi	50.7	1.79	Liquid measure, 1891 value	
tamlaum	400	14.1	10 tang, 2003 reference	
cohi	472	16.7	40 sesti, dry measure, 1891 value	
seste	800	28.2	2 tamlaum, 2003 reference	
ban	1,600	56.5	2 seste, 2003 reference	
kwian	2,000	70.6	Cartload, 100 thang	
koyan or kwien	3,200	113	2 ban, 2003 reference	
cohi	32,000	1130	10 koyan, 2003 reference	
Tripoli (see also Libya)				Pre-metric
Dry measure				
tiberi	2.03	0.0717	1891 value	
orbah	6.71	0.237	1891 value	
temen	26.8	0.947	4 orbahs, 1891 value	
cafiso	40.6	1.43	20 tiberi, 1891 value	
ueba or hueba	107	3.79	4 temen, 1891 value	

(continued)

Table 6.2 (continued)

Region and unit	Equivalent liters (dm ³)	Equivalent cu ft US	Notes	Era
Liquid measure				
mataro (oil)	23.3	0.824	1891 value	
Tunisia (pre-1895, local variations, additional units not shown)				Medieval to pre-metric
Dry measure				
saah	3.84	0.136	1/129 cafisso, 2003 reference	
whiba	31.0	1.09	1/16 cafisso, 8.06 saah, 2003 reference	
millerole (Marseilles)	64.0	2.26	2.06 whiba, 2003 reference	
cafisso or cafiz	496	17.5	16 whiba, 1891 value, consistent with 2003 reference	
Liquid measure				
metter or mitre	10.0	0.353	Approx., 1891 value	
Turkey (see also Ottoman Empire, values from both pre- and post-metric, a cubic zira was defined as 1,000 dm³ or liters in metric conversion, post-metric values of units then changed)				Pre- and post-metric
Dry and common measure				
chinik	8.82	0.311	Pre-metric, 1891 value	
chinik	25	0.88	Post-metric, 2003 reference	
kilo	35.3	1.25	4 chiniks, pre-metric, 1891 value	
kile	100	3.53	post metric, 4 chinik, 2003 reference	
fortin	141	4.98	4 kilos, pre-metric, 1891 value	
fortin	400	14.1	Post-metric, 4 kile, 2003 reference	
cubic zira	1,000	35.3	Post-metric, 10 kile, 2003 reference	
Liquid measure				
almud	5.227	0.1846	Pre-metric, 1891 value	
United Kingdom (includes England, Great Britain, and former possessions, customary units, major local variations and changes over time)				Medieval to pre-metric
Generic volume measures				
cubic foot	28.32	1.000	1891 value	
cubic yard	764.6	27.00	1891 value	

(continued)

Table 6.2 (continued)

Region and unit	Equivalent liters (dm ³)	Equivalent cu ft US	Notes	Era
Dry measure (based on Imperial Measure, post 1824)				
pint	0.5683	0.02007	1891 value	
quart	1.137	0.04013	2 pints, 1891 value	
pottle	2.273	0.08026	1/2 dry gallon, 2 quarts, 1891 value	
gallon	4.546	0.1605	4 dry quarts or 8 dry pints, 1891 value	
peck	9.087	0.3209	2 dry gallons, 1891 value	
kenning	18.17	0.6417	2 peck or 4 dry gallons, 1891 value	
bushel	36.35	1.283	2 kenning, 4 pecks, 8 dry gallons, 1891 value	
strike	72.69	2.567	2 bushels, 16 dry gallons, 1891 value	
coomb or dry barrel	145.4	5.134	2 strike, 4 bushels, 32 dry gallons, 1891 value	
quarter or dry hogshead	290.8	10.27	2 coomb, 64 dry gallons, 1/4 dry tun, 1891 value	
dry tun	1,164	41.09		
wey or load	1,454	51.34	5 quarters, 1891 value	
last	2,908	102.7	2 weys, 1891 value	
Liquid measure (based on Imperial gallon, post 1824)				
minim or drop	5.919E-05	2.090E-06		
dram	0.00355	0.000125	60 minim, 1/8 fluid ounce	
teaspoon	0.00474	0.000167	80 minim, 1/6 fluid ounce	
tablespoon or mouthful	0.0142	0.000502	4 dram, 3 teaspoons, 1/2 fluid ounce	
pony	0.0213	0.000752	6 dram, 3/4 fluid ounce	
fluid ounce	0.0284	0.00100	2 tablespoons	
jigger	0.0426	0.00150	3 tablespoons, 2 pony, 1.5 fluid ounces	
jack or jackpot	0.0710	0.00251	5 tablespoons, 2.5 fluid ounces, doubled for milk and beer in Northern England	
gill	0.142	0.00502	2 jack or 5 fluid ounces (doubled for milk or beer in N. England)	
cup	0.284	0.0100	2 gill, 10 fluid ounces	
pint	0.568	0.0201	1 cups, 20 fluid ounces	
quart	1.137	0.04013	2 pint, 40 fluid ounces, 1/4 gallon	
pottle	2.273	0.08026	2 quarts, 80 fluid ounces, 1/2 gallon	

(continued)

Table 6.2 (continued)

Region and unit	Equivalent liters (dm ³)	Equivalent cu ft US	Notes	Era
corn gallon	4.407	0.1556	268.8 cu inches	
Imperial gallon (1824)	4.546	0.1605	2 pottle, 4 quarts, 8 pints, 160 fluid ounces, based on volume of 10 lbs distilled water at 62°F, 277.274 cu inches	
beer gallon	4.623	0.1633	282 cu inches	
Apothecaries' fluid measure				
minim or drop	5.919E-05	2.090E-06	1891 value	
drachm	0.00355	0.000125	60 minim, 1891 value	
ounce	0.02841	0.001003	8 drachm, 1891 value	
pint	0.5683	0.02007	20 ounces, 1891 value	
Imperial gallon	4.546	0.1605	8 pints, 1891 value	
Special units (based on Imperial measures, post 1824)				
oil barrel	159.1	5.618	35 gallons Imperial, 42 wine gallons	
perch (stone)	700.8	24.75	24.75 cft dry stone	
cord (firewood)	3,625	128.0	128 cft firewood, 4 ft × 4 ft × 8 ft	
Beer, ale, wine, spirits (amounts were not always the same in practice, little standardization)				
gill (wine)	0.142	0.00501	1891 value	
gill (beer, ale)	0.144	0.00510	1891 value	
pint (wine)	0.568	0.0201	4 gills, 1891 value	
pint (beer, ale)	0.578	0.0204	4 gills, 1891 value	
reputed quart (bottle, wine)	0.7577	0.02675	Still used for champagne exclusively	
quart (wine)	1.136	0.04011	2 pints, 1891 value	
quart (beer, ale)	1.155	0.04079	2 pints, 1891 value	
magnum (bottle, wine)	1.515	0.05350	Still used for champagne exclusively	
jeroboam (bottle, wine)	3.031	0.1070	Still used for champagne exclusively	
gallon (wine)	4.543	0.1604	4 quarts, basically Imperial gallon, 1891 value	
rehoboam (bottle, wine)	4.546	0.1605	Still used for champagne exclusively	
gallon (beer, ale, ~ 1454–1824)	4.621	0.1632	4 quarts	
methuselah (bottle, wine)	6.819	0.2408	Still used for champagne exclusively	
salmarazd (bottle, wine)	9.092	0.3210	Still used for champagne exclusively	

(continued)

Table 6.2 (continued)

Region and unit	Equivalent liters (dm ³)	Equivalent cu ft US	Notes	Era
belshazzar (bottle, wine)	12.12	0.4280	Still used for champagne exclusively	
nabuchadnezzar (bottle, wine)	15.15	0.5350	Still used for champagne exclusively	
solomon (bottle, wine)	17.82	0.6292	Still used for champagne exclusively	
pin (beer)	20.79	0.7343	4.5 Imp gallons, 1/8 beer barrel	
firkin (ale, beer, goods)	41.59	1.469	2 pins, 9 Imp gallons, 1/4 beer barrel	
octave (whiskey)	73.00	2.578		
rundlet (wine)	81.78	2.888	18 wine gallons, 1/7 wine pipe	
kilderkin (ale, beer, goods)	81.83	2.889	2 firkins, 18 gallons, 1/2 beer barrel	
quarter (beer, wine, spirits, average)	107.0	3.778	Range 77–136 liters, average	
aum (hock, average)	141.0	4.979	Range 136–145 liters, average	
barrel (wine)	143.1	5.054	31.5 wine gallons, 1/2 wine hogshead	
barrel (beer)	166.4	5.874	2 kinderkins, 36 Imp gallons, 2/3 beer hogshead	
tierce (wine)	190.8	6.738	42 wine gallons, 1/2 puncheon, 1/3 wine pipe, also reported as 36 gallons in 1891	
hogshead (Madeira, average)	212.0	7.486	Range 205–218 liters, average	
hogshead (average)	237.0	8.369	Range 200–273 liters, average	
hogshead (beer)	249.5	8.811	3 kinderkins, 54 Imp gallons, 1.5 beer barrels	
hogshead (brandy, average)	266.0	9.393	Range 255–277 liters, average	
hogshead (wine)	286.2	10.11	2 wine barrels, 63 wine gallons, 1/4 wine tun, also reported as 54 gallons in 1891, actual amount varies with type of wine	
puncheon (beer)	332.7	11.75	Range 318–546 liters, average	
puncheon or tertian (wine)	381.7	13.48	2 tierce, 84 wine gallons, 1/3 wine tun, reported as same as pipe or butt in 1891 as 108 gallons	

(continued)

Table 6.2 (continued)

Region and unit	Equivalent liters (dm ³)	Equivalent cu ft US	Notes	Era
puncheon (beer, wine, spirits, average)	432.0	15.25	Range 318–546 liters, average	
pipe (beer, wine, spirits, average)	478.0	16.88	Range 409–546 liters, average	
pipe or butt (beer)	499.1	17.62	2 beer hogsheads, 3 beer barrels, 108 Imp gal.	
butt (beer, wine, spirits, average)	512.0	18.08	Range 491–532 liters, average	
pipe or butt (wine)	572.5	20.21	2 wine hogsheads, 3 tierce, 7 roundlet, or 126 wine gallons, reported as 108 gallons in 1891, varies from 90 to 120 gal. depending on type of wine	
tonneau or tun (beer, wine, spirits, average)	887.0	31.32	Range 864–909 liters, average	
tun (beer)	998.1	35.24	2 beer pipes, 216 gallons	
tun (wine)	1,145	40.43	2 wine pipe, 3 puncheon, 252 wine gallons	
aum (hock, average)	1,194	42.16	Range 1182–1205 liters, average	
United States (customary units, based on English units before 1824)				Colonial to modern
General volumes				
cubic inch	0.01639	0.0005786		
cubic foot	28.32	1.000	1,728 cu in	
cord foot (wood)	453.1	16.00	16 cft, 1891 value	
cubic yard	764.6	27.00	27 cu ft	
shipping ton	1,133	40.00	40 cft, 1891 value, typically about 1 long ton wheat	
acre foot	1,233,482	43,560	43,560 cft, 1 ft over 1 acre, normally water	
register ton	2,832	100.0	100 cft, 1891 value, used for ship capacity, typically ship can only carry about 75–80% of this weight	
cord (wood)	3,625	128.0	8 cord feet	
cubic mile	4.169E+12	1.472E+11		
Dry measure				
pint or chopine	0.5506	0.01944	33.6 cu in	
quart	1.101	0.03888	2 pints	
gallon	4.405	0.1555	4 quarts, seldom used	
peck	8.810	0.3111	2 gallons	
bushel or Winchester bushel	35.24	1.244	4 pecks	
firkin	39.64	1.400	9 gallons	

(continued)

Table 6.2 (continued)

Region and unit	Equivalent liters (dm ³)	Equivalent cu ft US	Notes	Era
barrel	115.6	4.083	3.281 bushels	
chaldron (coke, coal)	1,269	44.80	36 bushels, 1891 value, also reported as 36 <u>gallons</u>	
Liquid measure				
minim	6.161E-05	2.176E-06	~ 1 drop, 0.95 grains water	
fluid dram	0.003697	0.0001305	60 minim	
teaspoon	0.004929	0.0001740	80 minim	
teaspoon (metric)	0.00500	0.0001766	5 cc	
tablespoon	0.01479	0.0005221	3 teaspoons, 4 fluid drams	
tablespoon (metric)	0.01500	0.0005297	15 cc	
fluid ounce	0.02957	0.001044	2 tablespoons, 1.0408 wt oz water, 1/128 gallon	
shot or jigger	0.04436	0.001566	3 tablespoons	
gill or half-cup	0.1183	0.004177	4 fluid ounces	
cup	0.2366	0.008354	2 gill or 8 fluid ounces	
pint	0.4732	0.01671	2 cups, 16.65 wt ounces water, roughly 1 lb avoirdupois	
quart	0.9464	0.03342	2 pints	
gallon	3.785	0.1337	4 gallons, 231 cu inches, Winchester gallon	
anker	37.85	1.337	10 gallons, 1891 value	
runlet	68.14	2.406	18 gallons, 1891 value	
barrel (beer)	117.3	4.144	31 gal	
barrel	119.2	4.210	31.5 gallons, 1/2 hogshead	
barrel (whiskey, kerosene)	151.4	5.347	40 gallons	
barrel (petroleum oil)	159.0	5.614	42 gallons, 2/3 hogshead	
tierce	159.0	5.614	42 gallons, 1891 value	
hogshead	238.5	8.421	63 gallons, 524.7 pounds water	
puncheon	318.0	11.23	84 gallons, 1891 value	
pipe	477.0	16.84	126 gallons, 1891 value	
tun	953.9	33.68	252 gallons, 1891 value, ~ 1 long ton water	
demijohn			Varied from 3 to 10 gallons, wicker-enclosed, narrow neck bottle, no-specific conversion possible	

(continued)

Table 6.2 (continued)

Region and unit	Equivalent liters (dm ³)	Equivalent cu ft US	Notes	Era
Wine measure (see also United Kingdom)				
gallon (wine)	3.785	0.1337		
anker (wine)	37.85	1.337	10 gallons	
tierce (wine)	159.0	5.613	42 gallons	
hogshead (wine)	238.5	8.420	63 gallons	
puncheon (wine)	317.9	11.23	2 tierces	
pipe (wine)	476.9	16.84	2 hogsheads	
tun (wine)	953.8	33.68	2 pipes	
Cooking measure				
drop, drp, gtt	4.929E-04	1.740E-05		
pinch	6.161E-04	2.176E-05	1/48 fluid ounce	
salt spoon, ssp	0.001232	0.00004351	2.5 drops	
coffee spoon, csp	0.002464	0.00008702	5 drops	
dash	0.002957	0.0001044	6 drops	
teaspoon, tsp	0.004929	0.0001740	10 drops	
dessertspoon, dst	0.009858	0.0003481	20 drops	
tablespoon, tbsp, tls, Tsp	0.01479	0.0005221	3 teaspoons	
coffee measure	0.02957	0.001044	1 fluid ounce, 2 tablespoons	
fluid ounce	0.02957	0.001044	2 tablespoons	
wine glassful	0.1479	0.005221	5 fluid ounces	
teacupful, tcf	0.1479	0.005221	5 fluid ounces	
cup	0.2366	0.008354	8 fluid ounces	
breakfast cup, tumblerful	0.2957	0.01044	10 fluid ounces	
water glassful	0.4732	0.01671	16 fluid ounces	
Stacked firewood				
board foot measure, bfm, fbm (wood)	2.254	0.07959	1/12 cft	
whole deal (wood)	16.23	0.5731	12 ft × 11 in × 5/8 in	
faggot, fgt (wood)	27.04	0.9548	1/9.42 cft	
cubic foot or timber foot, cft, cu ft, ft ³ (wood)	28.32	1.000	Same as standard cft	
deal (wood, US)	38.94	1.375	12 ft × 11 in × 1.5 in	
deal (wood, UK)	247.8	8.750	7 ft × 6 ft × 2.5 in	
cord-foot, cd-ft (wood)	453.1	16.00	16 cft	
load, unhewn (wood)	755.2	26.67	320 bfm	
load, squared (wood)	1,189	41.98	42 cft	
house cord (wood)	1,208	42.66	1/3 cord	

(continued)

Table 6.2 (continued)

Region and unit	Equivalent liters (dm ³)	Equivalent cu ft US	Notes	Era
rick (wood)	1,208	42.66	4 ft × 8 ft × 16 in	
face cord (wood)	1,813	64.02	1/2 cord	
stack, stk (wood)	3,058	108.0	108 cft	
cord, cd (wood)	3,625	128.0	128 cft	
split deal (wood)	3,625	128.0	12 ft × 8 ft × 16 in	
standard (St. Petersburg, Pittsburgh, wood)	4,673	165.0	165 cft	
Uruguay (pre-1866, local variations, additional units not shown)				Colonial to pre-metric
fanega	274	9.68		
Venezuela (pre-1857, local variations, additional units not shown)				Colonial to pre-metric
arroba	16.14	0.5698		
Vietnam (pre-metric, early 20th Century, local variations, no unified system, additional units not shown)				Medieval to pre-metric
toát or nhón	0.0002	0.00001	Grain	
sao or nhăm	0.002	0.00007	Grain, 10 toát	
lẻ (unhusked rice)	0.100	0.00353	Different from other measures	
cáp	0.200	0.00706	100 sao	
bát	0.500	0.0177		
đầu	1.000	0.03531	2 bat or 5 cáp	
thưng or thăng	2.000	0.07062	1000 sao	
hao or shita	28.26	0.9979	2003 reference	
toa	56.52	1.996	2 shita, 2003 reference	
hộc (unhusked rice)	60.00	2.119	Different from other measures	
lẻ or than	1,600.00	56.50	1 ngũ × 1 ngũ × 1 thước	
miếng	14,400.00	508.5	3 ngũ × 3 ngũ × 1 thước	
hộc	16,000.00	565.0	10 lẻ, 10 ngũ × 1 ngũ × 1 thước	
Wales (pre-metric, local variations, additional units not shown, see also English units)				Medieval to pre-metric
hestawr	70.5	2.49	2 Winchester bushels, approx (1836 basis)	
West Indies				Colonial to pre-metric

(continued)

Table 6.2 (continued)

Region and unit	Equivalent liters (dm ³)	Equivalent cu ft US	Notes	Era
Spanish units used in: Cuba, Puerto Rico, Isle of Pines, Curacao, and Culebra				
French units used in: Martinique, Deseada, Guadeloupe, Marie Galante, Le Saintes, and part of St. Martin				
Swedish units used in St. Bartholomew				
Dutch (Netherlands) units used in: Part of St. Martin, Buen Ayre, Oruba (Aruba), and Tortuga				
Danish units used in: Santa Cruz, St. Thomas, and St. Jan or St. John, but also use English standards for length				
English units used in: Jamaica, Barbados, Grenada, Santa Lucia, St. Vincent, Trinidad, Tobago, Antigua, Bermuda, Dominica, Nevis, Montserrat, St. Kitt's, Tortola, Bahamas, and minor islands. Units are essentially US Customary				
Independent units used in: Haiti and Santo Domingo				
Dry measures				
fanega (Spanish)	110	3.89	1891 value	
Liquid measures				
arroba (Spanish)	15.5	0.548	1891 value	
barique (French)	189	6.68	1891 value	
puncheon (English)	386	13.6	1891 value	
Zanzibar				Pre-metric
djezla	257	9.09	1891 value	

Table 6.3 Alphabetical table of historical volume/capacity measurement conversion factors Multiple sources, see references section

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
1/16 quarteron	0.938	0.0331	Switzerland	Medieval to pre-metric	Dry	1891 value
1/2 pot	0.793	0.0280	Switzerland	Medieval to pre-metric	Liquid	1/2 pot, 1891 value
1/2 quartilho	0.175	0.00618	Portugal	Medieval to pre-metric	Liquid	Half-pint
1/4 pot	0.396	0.0140	Switzerland	Medieval to pre-metric	Liquid	1/4 pot, 1891 value
1/4 quarteron	3.75	0.132	Switzerland	Medieval to pre-metric	Dry	1891 value
1/4 quartilho	0.0875	0.00309	Portugal	Medieval to pre-metric	Liquid	Quarter-pint
1/8 pot	0.198	0.00700	Switzerland	Medieval to pre-metric	Liquid	1/8 pot, 1891 value
aam	153.6	5.424	Netherlands, Holland	Medieval to metric	Liquid	4 anker, 2003 reference, also reported as 155.0 liters
acetabulum	0.06865	0.002424	Roman Empire	Ancient	Dry	1/48 congius, 2003 reference
acetabulum	0.0687	0.00242	Roman Empire	Ancient	Liquid	1/48 congius, 2003 reference
achtel	2.174	0.07677	Denmark	Medieval to pre-metric	Dry	1891 value, consistent with 2003 reference
achtel	7.686	0.2714	Austrian Empire	Pre-metric	Dry	1891 value, 2 müller massel, consistent with 2003 reference
achtel (Bavaria)	4.632	0.1636	Germany	Medieval to pre-metric	Dry	2 mässlein, 1891 value
achtel (Frankfort)	114.8	4.052	Germany	Medieval to pre-metric	Dry	4 simmer, 1891 value
achtel (Württemberg)	2.769	0.09778	Germany	Medieval to pre-metric	Dry	2 mässlein, 1891 value
acre foot	1,233,482	43,560	United States	Colonial to modern	General	43,560 cft, 1 ft over 1 acre, normally water
acre?	508.5	17.96	Sri Lanka, Ceylon	Medieval to pre-metric	Dry	Ref: Maccauly, 2.5 ammonams in north
adhaka	3.30	0.117	India	Pre-metric	Liquid	4 prastha, 1966 value
adoulie	6.881	0.2430	India	Pre-metric	Liquid	4 seer, 2003 reference
adoulie (Bombay)	6.883	0.2430	India	Pre-Akbar	Dry, rice, grains	1891 value

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
ahm	129.0	4.555	South Africa	Colonial to pre-metric	Liquid	1/4 legger
ahm (Hamburg)	144.4	5.098	Germany	Medieval to pre-metric	Liquid	4 anker, 1891 value
ahm (Hanover)	156.8	5.538	Germany	Medieval to pre-metric	Liquid	4 anker, 1891 value
ahm (Lubeck)	149.8	5.289	Germany	Medieval to Pre-Metric	Liquid	4 anker, 1891 value
ako	62.53	2.208	Hungary	Medieval to pre-metric	Dry	Dry measure, 1891 value, also reported as 62.45 l in 2003 reference
almenn turma	115.9	4.094	Iceland	Medieval to pre-metric	Dry	120 pottar, 2003 reference
al mud	5.227	0.1846	Turkey, Ottoman Empire	Pre- and post-metric	Liquid	Pre-metric, 1891 value
al mud	7.567	0.2672	Mexico	Colonial to pre-metric	Dry	4 cuartillo, 2003 reference
al mud	1.044	0.0369	Balearic Islands	Pre-metric	Dry	2003 reference
al mud	1.999	0.07059	Balearic Islands	Pre-metric	Liquid	2003 reference
al mud	4.696	0.1658	Spain	Medieval to pre-metric	Dry	2 medios, reported as 4.625 l in 2003 reference
al mud	7.567	0.2672	Mexico	Colonial to pre-metric	Dry	4 cuartillo, 2003 reference
al mud	8.083	0.2854	Chile	Colonial to pre-metric	Dry	8 cuartillo, 2003 reference
al mud	14	0.49	Morocco	Colonial to pre-metric	General	2003 reference, also reported as 183 liters in 1891 (possible error)
al mud	16.5	0.583	Portugal	Medieval to pre-metric	Liquid	6 alqueiras, 2003 reference
al mud	16.80	0.5932	Portugal	Medieval to pre-metric	Liquid	2 potes
al mud	24.0	0.847	Paraguay	Colonial to pre-metric	Dry	8 frasco, 2003 reference
al mud	31.94	1.128	Brazil	Colonial to pre-metric	General	6 alquiera, 2003 reference
al mud (Lisbon)	17.26	0.6095	Portugal	Medieval to pre-metric	Liquid	2 potes, 1891 value
al mud (Oporto)	25.08	0.8856	Portugal	Medieval to pre-metric	Liquid	2 potes, 1891 value

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
alqueira	2.75	0.0971	Portugal	Medieval to pre-metric	Liquid	2 Canadas, 2003 reference
alqueira	13.5	0.477	Portugal	Medieval to pre-metric	Dry	2 meios, 2003 reference
alqueire	5.324	0.1880	Brazil	Colonial to pre-metric	General	2 Canada, but reported as 40–320 liters in some references, range actually appears to have been 3.5–5.3 liters in other references, used 2003 reference value
alquiera	3.626	0.1280	Brazil	Colonial to pre-metric	General	2003 reference
alquiera	4.076	0.1439	Brazil	Colonial to pre-metric	Dry, Salt	2003 reference
alquiera	5.324	0.1880	Brazil	Colonial to pre-metric	General	2 Canada, but reported as 40–320 liters in some references, range actually appears to have been 3.5–5.3 liters in other references, used 2003 reference value
alquiera (Bahia)	3.524	0.1244	Brazil	Colonial to pre-metric	General	2003 reference
alquiere	11.98	0.4229	Azores	Pre-metric	Dry	2 meios, 1891 value
alquiere	8.400	0.2966	Portugal	Medieval to pre-metric	Liquid	Pot, 6 Canadas
alquiere (Lisbon)	8.630	0.3047	Portugal	Medieval to pre-metric	Liquid	6 Canadas, 1891 value
alquiere (Lisbon)	13.52	0.4774	Portugal	Medieval to pre-metric	Dry	4 quartos, 1891 value
alquiere (Oporto)	12.54	0.4428	Portugal	Medieval to pre-metric	Liquid	6 Canadas, 1891 value
alquiere (Oporto)	15.57	0.5497	Portugal	Medieval to pre-metric	Dry	4 quartos, 1891 value
am	157.0	5.545	Sweden	Medieval to pre-metric	Liquid	2 eimer, 2003 reference
ammonam	203.4	7.182	Sri Lanka, Ceylon	Medieval to pre-metric	Dry	
amole (Genoa)	0.718	0.0254	Italy	Medieval to pre-metric	Liquid	1891 value
amomam	204	7.19	Ceylon, Sri Lanka	Colonial to pre-metric	Dry	1891 value

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
amphora	19.44	0.6864	Greece (Attic)	Ancient	Liquid	3 maris, 2003 reference
amphora	34.28	1.210	France	Medieval to pre-metric	Liquid	French cubic foot, dates to ancient times
amphora	26.21	0.9254	Roman Empire	Ancient	General	Roman jar, 1 cubic pes or Roman foot, est'd
amphora quadrantal	26.37	0.9311	Roman Empire	Ancient	Liquid	8 congi, 2003 reference
ankar	39.26	1.386	Sweden	Medieval to pre-metric	Liquid	15 kanna, 2003 reference
ankare	39.26	1.386	Sweden	Medieval to pre-metric	Liquid	15 kanna, 2003 reference
anker	34.35	1.213	Prussia	Medieval to pre-metric	Liquid	30 quartier, 1891 value
anker	34.35	1.213	Germany	Medieval to pre-metric	Liquid	30 quart, 2003 reference
anker	36.90	1.303	Russia	Medieval to pre-metric	Liquid	3 vedros, 2 stekar, 1891 value, consistent with 2003 reference
anker	37.85	1.337	United States	Colonial to modern	Liquid, wine	10 gallons
anker	37.85	1.337	United States	Colonial to modern	Liquid	10 gallons, 1891 value
anker	38.26	1.351	Latvia	Medieval to pre-metric	General	30 stoof, 2003 reference
anker	38.40	1.356	Netherlands, Holland	Medieval to metric	Liquid	2 steekan, volume of small cask equal to 45 bottles, 2003 reference, also reported as 38.75 liters
anker	38.64	1.365	Iceland	Medieval to pre-metric	Dry	40 pottar, 2003 reference
anker	38.65	1.365	Denmark	Medieval to pre-metric	Liquid	5 viertel, 2003 reference
anker	75.40	2.663	Denmark	Medieval to pre-metric	Liquid	39 pot
anker (Bremen)	36.24	1.280	Germany	Medieval to pre-metric	Liquid	5 viertel, 1891 value
anker (Hamburg)	36.10	1.275	Germany	Medieval to pre-metric	Liquid	5 viertel, 1891 value
anker (Hanover)	39.21	1.385	Germany	Medieval to pre-metric	Liquid	5 viertel, 1891 value
anker (Lubeck)	37.45	1.322	Germany	Medieval to pre-metric	Liquid	5 viertel, 1891 value

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
anker (Saxony)	65.02	2.296	Germany	Medieval to pre-metric	Liquid	54 kannen, 1891 value, Leipsic, Desden 88.9%
ankkuri	39.26	1.386	Finland	Medieval to pre-metric	Liquid	
apatan	9.990E-04	3.528E-05	Philippines	Medieval to pre-metric	General	2003 reference
apple gallon	3.028	0.1069	Cornwall	Medieval to pre-metric	Dry, apples	Based on weight of 7 lbs
ardaba (Talmudic)			Biblical, Talmudic	Ancient	General	Unable to locate good definition of size
ardabb	1,581	55.82	Saudi Arabia	Pre-metric	Liquid	208 zudda, 2003 reference
ardeb	183.4	6.475	Egypt	Pre-metric	Dry	6 ouebelh, 1867 value, value reported as 182–271 liters by different sources
ardeb	198.0	6.992	Egypt	Pre-metric	Dry	12 keila, 2003 reference
ardeb (Gondar)	4.039	0.1426	Abyssinia	Pre-metric	Grain	For grain, at Gondar, 1891 value
ardeb (long)	10.6	0.374	Abyssinia	Pre-metric	General	24 madeqa, 2003 reference
ardeb (Massowah)	11.75	0.4147	Abyssinia	Pre-metric	Grain	For grain, at Massowah, 1891 value
ardeb (short)	4.40	0.155	Abyssinia	Pre-metric	General	10 madeqa, 2003 reference
ardebb	1,581	55.82	Saudi Arabia	Pre-metric	Liquid	208 zudda, 2003 reference
arroba	8,440	0.2980	Spain	Medieval to pre-metric	Liquid, oil	Range 0.37–15.6 liters, used avg
arroba	9,940	0.3510	Spain	Medieval to pre-metric	Liquid, wine	Range 0.47–30.4, used avg (44 values)
arroba	12.56	0.4435	Spain	Medieval to pre-metric	Liquid, oil	4 quartillos, 1891 value, consistent with value reported in 2003
arroba	15.64	0.5523	Spain	Medieval to pre-metric	Liquid, water	2003 reference
arroba	16.13	0.5697	Spain	Medieval to pre-metric	Liquid, wine	2003 reference
arroba	16.14	0.5698	Cuba	Colonial to pre-metric	Liquid	4.263 gallons

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
arroba	16.14	0.5698	Venezuela	Colonial to pre-metric	General	
arroba	35.55	1.255	Chile	Colonial to pre-metric	Liquid	32 cuartillo, also reported as 32.33 liters in 2003 reference
arroba (Spanish)	15.5	0.548	West Indies	Colonial to pre-metric	Liquid	1891 value
arroba mayor	16.14	0.5698	Spain	Medieval to pre-metric	Liquid	8 azumbres, 1891 value
arta	65.24	2.304	Persia, Iran	Medieval to pre-metric	General	25 capichas, 8 collothun, 1891 value
arta	66.0	2.33	Persia, Iran	Medieval to pre-metric	General	8 collothun, 2003 reference
artaba	65.24	2.304	Persia, Iran	Medieval to pre-metric	General	25 capichas, 8 collothun, 1891 value
artaba	66.0	2.33	Persia, Iran	Medieval to pre-metric	General	8 collothun, 2003 reference
asseron	1.323	0.04672	Jewish, Israel	Medieval to modern	General	80.727 cu in
aum	141.0	4.979	United Kingdom, England	Medieval to pre-metric	Liquid, hock	Range 136–145 liters, average
aum	1,194	42.16	United Kingdom, England	Medieval to pre-metric	Liquid, hock	Range 1182–1205 liters, average
azumbre	2.017	0.07122	Spain	Medieval to pre-metric	Liquid	4 quartillos, 1891 value, reported as 1.955 l in 2003 reference
bachel	29.93	1.057	Greece	Medieval to pre-metric	Dry	Bushel, approx
baha	2,640	93.22	India	Pre-metric	Liquid	10 cumbha, 1966 value
balli	46.00	1.624	South Africa	Colonial to pre-metric	Liquid	5 gantang
bambou	2.002	0.07068	Madagascar	Pre-metric	General	1891 value
bambou	3.25	0.115	Indonesia	Colonial to pre-metric	Dry	Dry measure, alternate reference
bambou (Bantam)	3.25	0.115	Java	Pre-metric	Dry	1891 value
ban	1,600	56.5	Thailand, Siam	Medieval to metric	General	2 seste, 2003 reference

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
ban ₂	10	0.35	Sumer	Ancient	Dry	10 bowls
barcella	12.00	0.4237	Balearic Islands	Pre-metric	Liquid	6 almudes, 2003 reference
ba-ri ₂ -ga	60	2.1	Sumer	Ancient	Dry	60 bowls
baril	43.16	1.524	Malta	Medieval to pre-metric	General	2003 reference, corrected
baril	74.24	2.621	Greece	Medieval to pre-metric	Liquid	Consistent with 2003 reference
baril	75.70	2.673	Mexico	Colonial to pre-metric	Liquid, wine	Approx, consistent with 1891 value reported
baril	76.00	2.684	Argentina	Colonial to pre-metric	Liquid	32 frascos, 2003 reference
baril	96.9	3.42	Paraguay	Colonial to pre-metric	Liquid	32 frasco, 2003 reference
baril	100	3.531	Haiti, Hayti	Colonial to pre-metric	General	2003 reference
baril oil (Roman St)	57.48	2.029	Italy	Medieval to pre-metric	Liquid, oil	1/16 botte
barile	43.19	1.525	Malta	Medieval to pre-metric	Liquid, beer, wine, spirits	Barrel, 41.6 liters in 1891 for wine
barile	62.50	2.207	Libya	Medieval to pre-metric	Liquid	5 gorraff, 2003 reference, also stated as 64.8 l at metrication
barile (Genoa)	64.66	2.283	Italy	Medieval to pre-metric	Liquid	50 pinte, 90 amole, 1891 value
barile (Modena)	41.66	1.471	Italy	Medieval to pre-metric	Liquid	20 fiasci, 1891 value
barile (Naples)	43.81	1.547	Italy	Medieval to pre-metric	Liquid, wine, spirits	60 caraffi, 1891 value
barile (Rome)	57.48	2.029	Italy	Medieval to pre-metric	Liquid, oil	32 boccale, 1891 value
barile (Rome)	58.33	2.060	Italy	Medieval to pre-metric	Liquid, wine	32 boccale, 1891 value
barile (Tuscany)	9.636	0.3402	Italy	Medieval to pre-metric	Liquid, oil	16 fiasci, 1891 value
barile (Tuscany)	12.04	0.4253	Italy	Medieval to pre-metric	Liquid	20 fiasci, 1891 value

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
barile (Tuscany)	45.59	1.610	Italy	Medieval to pre-metric	Liquid, wine	
barile da olio	33.40	1.179	Italy	Medieval to pre-metric	Liquid, oil	Barrel of oil
barile da vino	45.60	1.610	Italy	Medieval to pre-metric	Liquid, wine	Barrel of wine
barille	72.74	2.568	Ionian Islands	Pre-metric	Liquid	16 Imperial gallons, 1891 value
barique	189	6.68	West Indies	Colonial to pre-metric	Liquid	1891 value
barmil	43.19	1.525	Malta	Medieval to pre-metric	Liquid, beer, wine, spirits	Barrel, 41.6 liters in 1891 for wine
barrel	108.5	3.831	Scotland	Medieval to pre-metric	Liquid	8 gallons
barrel	112.3	3.966	Ireland	Medieval to pre-metric	Liquid	31.5 gallons, pre-1824, 2003 reference
barrel	115.6	4.083	United States	Colonial to modern	Dry	3.281 bushels
barrel	117.3	4.144	United States	Colonial to modern	Liquid, beer	31 gal
barrel	119.2	4.210	Sandwich Islands, Hawaii	Pre-metric	Liquid, oil	1891 value, 31.5 gallons, whale oil
barrel	119.2	4.210	United States	Colonial to modern	Liquid	31.5 gallons, 1/2 hogshead
barrel	143.1	5.054	United Kingdom, England	Medieval to pre-metric	Liquid, wine	31.5 wine gallons, 1/2 wine hogshead
barrel	151.4	5.347	United States	Colonial to modern	Liquid, whiskey, oil	40 gallons
barrel	159.0	5.614	United States	Colonial to modern	Liquid, petroleum oil	42 gallons, 2/3 hogshead
barrel	159.1	5.618	United Kingdom, England	Medieval to pre-metric	Liquid, oil	35 gallons Imperial, 42 wine gallons

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
barrel	166.4	5.874	United Kingdom, England	Medieval to pre-metric	Liquid, beer	2 kinderkins, 36 Imp gallons, 2/3 beer hogshead
barrile	22.71	0.8020	Cuba	Colonial to pre-metric	General	2003 reference
bát	0.500	0.0177	Vietnam, Annam	Medieval to pre-metric	General	
bath	13.23	0.4672	Jewish, Israel	Medieval to modern	General	807.274 cu in
bath (Israeli)	22.97	0.8112	Biblical, Talmudic	Ancient	Liquid	Measure, archeologists indicate a bath may have been 22 liters
batman	64.0	2.26	Tatar	Medieval to pre-metric	Liquid	4 pot
batos (Israeli)	22.97	0.8112	Biblical, Talmudic	Ancient	Liquid	Measure, archeologists indicate a bath may have been 22 liters
becher	0.4804	0.01696	Austrian Empire	Pre-metric	Dry	1891 value, consistent with 2003 reference
becher (Baden)	0.150	0.00530	Germany	Medieval to pre-metric	Dry	1891 value
becher (Brunswick)	1.909	0.06741	Germany	Medieval to pre-metric	Dry, wheat	1891 value, wheat
beer gallon	4.623	0.1633	United Kingdom, England	Medieval to pre-metric	Liquid, beer	282 cu inches
belshazzar	12.12	0.4280	United Kingdom, England	Medieval to pre-metric	Liquid, wine	Still used for champagne exclusively
bezah (Israeli)	0.0533	0.00188	Biblical, Talmudic	Ancient	Dry	Egg, 1/6 log
bfm	2.254	0.07959	United States	Colonial to modern	Wood	1/12 cft
board foot measure	2.254	0.07959	United States	Colonial to modern	Wood	1/12 cft

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
boccale (Bologna)	1.310	0.04624	Italy	Medieval to pre-metric	Liquid	4 fogliette, 1891 value
boccale (Piedmont, Turin)	0.782	0.0276	Italy	Medieval to pre-metric	Liquid	2 quartini, 1891 value
boccale (Rome)	1.796	0.06342	Italy	Medieval to pre-metric	Liquid, oil	4 fogliette, 1891 value
boccale (Rome)	1.823	0.06437	Italy	Medieval to pre-metric	Liquid, wine	4 fogliette, 1891 value
boccale (Tuscany)	0.301	0.0106	Italy	Medieval to pre-metric	Liquid	2 mezzette, 1891 value
boccale (Tuscany)	1.140	0.04024	Italy	Medieval to pre-metric	Liquid, wine	1/2 fiasco
boccalo (Modena)	1.041	0.03677	Italy	Medieval to pre-metric	Liquid	1891 value
bochka	492.0	17.37	Russia	Medieval to pre-metric	Liquid	Barrel, 40 vedro, 1891 value, consistent with 2003 reference
bocoy	136.3	4.812	Cuba	Colonial to pre-metric	General	6 barrile, 2003 reference
boisseau	12.64	0.4463	France	Medieval to pre-metric	Dry	4 quarts, 2003 reference
boll	144.0	5.086	Scotland	Medieval to pre-metric	Dry, wheat, peas, beans, rice, salt	4 firlof, for things sold by "level" measure, 2003 reference
boll	210.1	7.419	Scotland	Medieval to pre-metric	Dry, oats, barley, malt	4 firlof, for things sold by "heaped" measure, 2003 reference
bota	429	15.1	Portugal	Medieval to pre-metric	Liquid	26 almudes, 2003 reference
bota	469.2	16.57	Spain	Medieval to pre-metric	Liquid, water	30 arrobas, 2003 reference
bota (Lisbon)	448.8	15.85	Portugal	Medieval to pre-metric	Liquid	Barrel, 26 almudes, 1891 value
bota (Oporto)	652.1	23.03	Portugal	Medieval to pre-metric	Liquid	Barrel, 26 almudes, 1891 value
botchka	492.0	17.37	Russia	Medieval to pre-metric	Liquid	Barrel, 40 vedro, 1891 value, consistent with 2003 reference

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
botella	0.65	0.023	Central America	Colonial to pre-metric	General	32/25 cuartillo, varied from 0.63 to 0.67 liters, used average, 2003 reference
botella	0.65	0.023	Costa Rica	Colonial to pre-metric	General	32/25 cuartillo, varied from 0.63 to 0.67 liters, used average, 2003 reference
botella	0.65	0.023	El Salvador	Colonial to pre-metric	General	32/25 cuartillo, varied from 0.63 to 0.67 liters, used average, 2003 reference
botella	0.65	0.023	Guatemala	Colonial to pre-metric	General	32/25 cuartillo, varied from 0.63 to 0.67 liters, used average, 2003 reference
botella	0.65	0.023	Honduras	Colonial to pre-metric	General	32/25 cuartillo, varied from 0.63 to 0.67 liters, used average, 2003 reference
botella	0.65	0.023	Nicaragua	Colonial to pre-metric	Liquids	32/25 cuartillo, varied from 0.63 to 0.67 liters, used average, 2003 reference
botta (Naples)	525.7	18.56	Italy	Medieval to pre-metric	Liquid, wine, spirits	12 barile, 1891 value
botte (Rome)	919.6	32.47	Italy	Medieval to pre-metric	Liquid, oil	16 barile, 1891 value
botte (Rome)	933.4	32.96	Italy	Medieval to pre-metric	Liquid, wine	16 barile, 1891 value
bowl	1.0	0.035	Mesopotamia	Ancient	Dry	Base unit
bozze	2.604	0.09195	Libya	Medieval to pre-metric	Liquid	1/24 barile, 2003 reference
breakfast cup	0.2957	0.01044	United States	Colonial to modern	Cooking	10 fluid ounces
brenta (Piedmont, Turin)	56.33	1.989	Italy	Medieval to pre-metric	Liquid	6 rubbi, 1891 value
buffalo horn	0.4	0.01	Shoshone	Pre-colonial	Cooking	Roughly consistent measure, very roughly estimated volume
bushel	35.24	1.244	United States	Colonial to modern	Dry	4 pecks

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
bushel	36.35	1.283	United Kingdom, England	Medieval to pre-metric	Dry	2 kenning, 4 pecks, 8 dry gallons, 1891 value
bushel	60	2.1	Mesopotamia	Ancient	Dry	60 bowls
bushel	105.5	3.726	Cornwall	Medieval to pre-metric	Dry, grain, potatoes	3 Winchester bushels barley, wheat, or potatoes; value shown is from 1696
bussola (Tuscany)	0.190	0.00672	Italy	Medieval to pre-metric	Dry	1891 value
butt	499.1	17.62	United Kingdom, England	Medieval to pre-metric	Liquid, beer	2 beer hogsheads, 3 beer barrels, 108 Imp gal.
butt	512.0	18.08	United Kingdom, England	Medieval to pre-metric	Liquid, beer, wine, spirits	Range 491–532 liters, average
butt	572.5	20.21	United Kingdom, England	Medieval to pre-metric	Liquid, wine	2 wine hogsheads, 3 tierce, 7 roundlet, or 126 wine gallons, reported as 108 gallons in 1891, varies from 90 to 120 gal. depending on type of wine
butylka (vodochnaya)	0.615	0.0217	Russia	Medieval to pre-metric	Liquid, vodka	Bottle of vodka, 1/20 vedro, 5 tcharka, consistent with 2003 reference
butylka (vynnaya)	0.769	0.0271	Russia	Medieval to pre-metric	Liquid, wine	Bottle of wine, 1/16 vedro, 6.25 tcharka, consistent with 2003 reference
byee	0.505	0.0178	Burma, Birmah, Myanmar	Pre-metric	General	4 zalay, 2003 reference
caba	0.453	0.0160	Somalia	Medieval to pre-metric	Liquid	2003 reference
cabaho	0.735	0.0260	Jewish, Israel	Medieval to modern	General	44.859 cu in

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
cabaho	6.000	0.2119	Eretria	Medieval to pre-metric	General	4 messé, 2003 reference
cade	1.904	0.06723	France	Medieval to pre-metric	Liquid	2 pinte, 2003 reference
caffiso	20.46	0.7224	Malta	Medieval to pre-metric	General	2003 reference, corrected
caffiso	20.46	0.7225	Malta	Medieval to pre-metric	Liquid, milk, oil	1921 Act only, 20.8 liters in 1891 for oil
caffiso	317.5	11.21	Algeria	Medieval to pre-metric	General	Consistent with 1891 value and 2003 reference, ~ 15.85 tarri
cafiso	40.6	1.43	Tripoli, Libya	Pre-metric	Dry	20 tiberi, 1891 value
cafisso	496	17.5	Tunisia	Medieval to pre-metric	Dry	16 whiba, 1891 value, consistent with 2003 reference
cafiz	496	17.5	Tunisia	Medieval to pre-metric	Dry	16 whiba, 1891 value, consistent with 2003 reference
cahiz	676.2	23.88	Spain	Medieval to pre-metric	Dry	12 fanegas, reported as 666.0 l in 2003 reference
cajuella	16.3	0.574	Central America	Colonial to pre-metric	General	25 botella, 2003 reference
cajuella	16.3	0.574	Costa Rica	Colonial to pre-metric	General	25 botella, 2003 reference
cajuella	16.3	0.574	El Salvador	Colonial to pre-metric	General	25 botella, 2003 reference
cajuella	16.3	0.574	Guatemala	Colonial to pre-metric	General	25 botella, 2003 reference
cajuella	16.3	0.574	Honduras	Colonial to pre-metric	General	25 botella, 2003 reference
cajuella	16.3	0.574	Nicaragua	Colonial to pre-metric	Liquids	25 botella, 2003 reference
calemin	4.696	0.1658	Spain	Medieval to pre-metric	Dry	2 medios, reported as 4.625 l in 2003 reference
calisse	317.5	11.21	Algeria	Medieval to pre-metric	General	Consistent with 1891 value and 2003 reference, ~ 15.85 tarri

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
Canada	1.38	0.0486	Portugal	Medieval to pre-metric	Liquid	2 meios, 2003 reference
Canada	1.400	0.04944	Portugal	Medieval to pre-metric	Liquid	4 quartilhos
Canada	2.662	0.09399	Brazil	Colonial to pre-metric	General	1/12 almude
Canada (Lisbon)	1.438	0.05079	Portugal	Medieval to pre-metric	Liquid	4 quartilhos, 1891 value
Canada (Oporto)	2.090	0.07380	Portugal	Medieval to pre-metric	Liquid	4 quartilhos, 1891 value
candaca (Mysore)	392.2	13.85	India	Pre-Akbar	Dry, rice, grains	1891 value
candy	880.8	31.10	India	Pre-metric	Liquid	8 parah, 2003 reference
candy (Bombay)	881.0	31.11	India	Pre-Akbar	Dry, rice, grains	8 parahs, 1891 value
canna	2.617	0.09241	Sweden	Medieval to pre-metric	Dry	2 stop, 2003 reference
canna	2.617	0.09241	Sweden	Medieval to pre-metric	Liquid	2 stop, 2003 reference, consistent with 1891 reference, 1/10 cu fot
cantara	9.940	0.3510	Spain	Medieval to pre-metric	Liquid, Wine	Range 0.47–30.4, used avg (44 values)
cantara	16.14	0.5698	Spain	Medieval to pre-metric	Liquid	8 azumbres, 1891 value
cantara	16.14	0.5698	Central America	Colonial to pre-metric	Liquid	4 cuartillas, 1891 reference
cântaro	16.80	0.5932	Portugal	Medieval to pre-metric	Liquid	2 potes
cântaro (Lisbon)	17.26	0.6095	Portugal	Medieval to pre-metric	Liquid	2 potes, 1891 value
cântaro (Oporto)	25.08	0.8856	Portugal	Medieval to pre-metric	Liquid	2 potes, 1891 value
cantara	15.64	0.5523	Spain	Medieval to pre-metric	Liquid, water	2003 reference
cantara	16.13	0.5697	Spain	Medieval to pre-metric	Liquid, wine	2003 reference
cáp	0.200	0.00706	Vietnam, Annam	Medieval to pre-metric	General	100 sao

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
capicha	2.61	0.0921	Persia, Iran	Medieval to pre-metric	General	2 chenicás, 1891 value
capicha	2.64	0.0932	Persia, Iran	Medieval to pre-metric	General	2 chenica, 2003 reference
caraffa (Naples)	0.730	0.0258	Italy	Medieval to pre-metric	Liquid, wine, spirits	1891 value
carga	152	5.38	Crete, Candia	Colonial to pre-metric	Dry	1891 value
carga	181.6	6.413	Mexico	Colonial to pre-metric	Dry	96 cuartillo, 2 fanega, 2003 reference
cargueiro	80.00	2.825	Brazil	Colonial to pre-metric	General	Mule-load, 2 barrels of 40 liters each
carro (Naples)	1,051	37.13	Italy	Medieval to pre-metric	Liquid, wine, spirits	2 botti, 1891 value
carro (Naples)	1,985	70.09	Italy	Medieval to pre-metric	Dry	36 tomoli, 1891 value
carro (Piedmont, Turin)	563.3	19.89	Italy	Medieval to pre-metric	Liquid	10 bente, 1891 value
cash	227.1	8.019	Mauritania	Medieval to pre-metric	General	
cash	227	8.02	Seychelles	Colonial to pre-metric	Liquid	
cass	4.732	0.1671	Cyprus	Colonial to pre-metric	Liquid	Used for liquids, 1891 value, consistent with 2003 reference
cd	3,625	128.0	United States	Colonial to modern	Wood	128 cft
cd-ft	453.1	16.00	United States	Colonial to modern	Wood	16 cft
cft	28.32	1.000	United States	Colonial to modern	Wood	Same as standard cft
chai meu	0.0313	0.00110	Thailand, Siam	Medieval to metric	Dry	Grain held in an enclosed hand, 3-1/8 niou, ~4 yip mue, 2003 reference
chaldar	2,304	81.37	Scotland	Medieval to pre-metric	Dry, wheat, peas, beans, rice, salt	16 boll, for things sold by “level” measure, 2003 reference

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
chalder	3,362	118.7	Scotland	Medieval to pre-metric	Dry, oats, barley, malt	16 boll, for things sold by "heaped" measure, 2003 reference
chalder	3,900	137.7	Scotland	Medieval to pre-metric	Dry, general, coal	Legal limits for horse-drawn wagon on road, varied, e.g. coal, 1420–2690 kg, used 2500 kg typical
chaldron	1,269	44.80	United States	Colonial to modern	Dry, coal, coke	36 bushels, 1891 value, also reported as 36 gallons
changawn	0.500	0.0177	Thailand, Siam	Medieval to metric	General	4 kam meu, 2003 reference
chao	0.01035	0.0003655	China	Medieval to pre-metric	General	1/100 shēng, 10 qō, 1966 value
charka	0.1230	0.004343	Russia	Medieval to pre-metric	Liquid	"Wine glass", 1/100 vedro, consistent with 1891 value and 2003 reference
chast	0.1093	0.003861	Russia	Medieval to pre-metric	Dry	Part, 1/30 garnets, consistent with 2003 reference
chattack	0.06881	0.002430	India	Pre-metric	Liquid	2003 reference
chattack (Bengal)	0.0129	0.000455	India	Pre-Akbar	Dry, rice, grains	1891 value
chei	103.5	3.656	China	Medieval to pre-metric	General	100 shēng, "picul", 2 hou, 1966 value
chela	1.359	0.04799	Somalia	Medieval to pre-metric	Liquid	3 caba, 2003 reference
cheng	1.035	0.03656	China	Medieval to pre-metric	General	5 yo, 1966 value
chenica	0.8239	0.02909	Roman Empire	Ancient	Liquid	3/2 sextarius, 2003 reference
chenica	1.092	0.03856	Greece (Attic)	Ancient	Dry	24 kyathoi, reported as 1.08 liters in 2003
chenica	1.30	0.0461	Persia, Iran	Medieval to pre-metric	General	4 sextarios, 1891 value
chenica	1.32	0.0466	Persia, Iran	Medieval to pre-metric	General	4 sextario, 2003 reference
chetverik	26.24	0.9265	Russia	Medieval to pre-metric	Dry	Quarter, 8 garnets, consistent with 2003 reference

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
chetvert	1.537	0.05427	Russia	Medieval to pre-metric	Liquid	Quarter, 1/8 vedro, 2 bottles of wine, consistent with 2003 reference
chetvert	209.9	7.412	Russia	Medieval to pre-metric	Dry	64 garnets, 2 osminas, consistent with 2003 reference
chetvert	209.9	7.412	Russia	Medieval to pre-metric	Dry	64 garnets, 2 osminas, consistent with 2003 reference
chhatank	0.058	0.0021	India	Pre-Akbar	Liquid	1/4 pav, See notes on seer
chilo	36.35	1.284	Ionian Islands	Pre-metric	Dry	1 Imperial bushel, 1891 value
chinik	8.82	0.311	Turkey, Ottoman Empire	Pre- and post-metric	General, dry	Pre-metric, 1891 value
chinik	25	0.88	Turkey, Ottoman Empire	Pre- and post-metric	General, dry	Post-metric, 2003 reference
chipte	0.250	0.00883	India	Pre-Akbar	Dry, rice, grains	1/2 mapte
chkalik	0.06150	0.002172	Russia	Medieval to pre-metric	Liquid	Measure or shot, 1/200 vedro, consistent with 2003 reference
choinix	1.092	0.03856	Greece (Attic)	Ancient	Dry	24 kyathoi, reported as 1.08 liters in 2003
choinix (Israeli)	1.079	0.03810	Biblical, Talmudic	Ancient	Dry	Dry quart, New Testament
chomer	132.3	4.672	Jewish, Israel	Medieval to modern	General	8072.74 cu in
chopin	0.8475	0.02993	Scotland	Medieval to pre-metric	Liquid	2 mutchkins, also defined as 3 Imperial gills (inconsistent), 2003 reference
chopine	0.4761	0.01681	France	Medieval to pre-metric	Liquid	About a pint, 4 posson, 2003 reference
chopine	0.5506	0.01944	United States	Colonial to modern	Dry	33.6 cu in

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
choppin	0.8475	0.02993	Scotland	Medieval to pre-metric	Liquid	2 mutchkins, also defined as 3 Imperial gills (inconsistent), 2003 reference
chous	3.276	0.1157	Greece (Attic)	Ancient	Liquid	72 kyathoi, reported as 3.24 liters in 2003
chunam (Madras)	61.47	2.170	India	Pre-Akbar	Dry, rice, grains	5 marcals, 1891 value
chundoo	0.240	0.00847	Ceylon, Sri Lanka	Colonial to pre-metric	Dry	~1.2 pint US, 1891 value
chupa	0.003996	0.0001411	Philippines	Medieval to pre-metric	General	4 apatan, 2003 reference
çiläk	12.300	434.3	Tatar	Medieval to pre-metric	Dry	
çirek	209.9	7.412	Tatar	Medieval to pre-metric	Dry	
çirektän sigez	26.24	0.9265	Tatar	Medieval to pre-metric	Dry	8 gamets
ço	0.001035	0.00003655	China	Medieval to pre-metric	General	10 quei, 1966 value
cochlearia	0.01144	0.0004041	Roman Empire	Ancient	Liquid	1/288 congius, 1/48 sextarius, 2003 reference
coffee measure	0.02957	0.001044	United States	Colonial to modern	Cooking	1 fluid ounce, 2 tablespoons
coffee spoon	0.002464	0.00008702	United States	Colonial to modern	Cooking	5 drops
cohi	50.7	1.79	Thailand, Siam	Medieval to metric	General	Liquid measure, 1891 value
cohi	472	16.7	Thailand, Siam	Medieval to metric	Dry	40 sesti, dry measure, 1891 value
cohi	32,000	1130	Thailand, Siam	Medieval to metric	General	10 koyan, 2003 reference
collothun	8.15	0.288	Persia, Iran	Medieval to pre-metric	General	1891 value
collothun	8.25	0.291	Persia, Iran	Medieval to pre-metric	General	25 sextario, 2003 reference
colluthun	8.15	0.288	Persia, Iran	Medieval to pre-metric	General	1891 value
colluthun	8.25	0.291	Persia, Iran	Medieval to pre-metric	General	25 sextario, 2003 reference
congius	3.276	0.1157	Greece (Attic)	Ancient	Liquid	72 kyathoi, reported as 3.24 liters in 2003

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
congius	3.276	0.1157	Roman Empire	Ancient	General	1/2 pes cubed or 1/8 amphora quadrantal, est'd
congius	3.296	0.1164	Roman Empire	Ancient	Liquid	Base unit, 2003 reference
coomb	145.4	5.134	United Kingdom, England	Medieval to pre-metric	Dry	2 strike, 4 bushels, 32 dry gallons, 1891 value
copa	0.126	0.00445	Spain	Medieval to pre-metric	Liquid	1891 value
copas	0.1220	0.004308	Spain	Medieval to pre-metric	Liquid	2003 reference
copello (Sardinia, Turin)	2.396	0.08460	Italy	Medieval to pre-metric	Dry	20 cucchiari, 1891 value
coppa (Venice, Milan)	0.100	0.00353	Italy	Medieval to pre-metric	Liquid	1891 value
cor (Israeli)	229.7	8.111	Biblical, Talmudic	Ancient	Dry	2 letek
corba (Bologna)	78.58	2.775	Italy	Medieval to pre-metric	Liquid	4 quarterone, 1891 value
corba (Bologna)	78.58	2.775	Italy	Medieval to pre-metric	Dry	2 staja, 1891 value
cord	3,625	128.0	United States	Colonial to modern	General	8 cord feet
cord	3,625	128.0	United Kingdom, England	Medieval to pre-metric	Dry, firewood	128 cft firewood, 4 ft × 4 ft × 8 ft
cord	3,625	128.0	United States	Colonial to modern	Wood	128 cft
cord	6,827	241.1	Austrian Empire	Pre-metric	Dry, wood	1/2 cubic klafter, 1891 value
cord foot	453.1	16.00	United States	Colonial to modern	General	16 cft, 1891 value
corde	3,840	135.6	Haiti, Hayti	Colonial to pre-metric	General	192/5 baril, 2003 reference
corde (Eaux et Forêts)	3,840	135.6	France	Medieval to pre-metric	Dry, wood	8 pieds × 4 pieds × 3 pieds 6 pouces, 2003 reference

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
cord-foot	453.1	16.00	United States	Colonial to modern	Wood	16 cft
corn gallon	4.407	0.1556	United Kingdom, England	Medieval to pre-metric	Liquid	268.8 cu inches
corus	132.3	4.672	Jewish, Israel	Medieval to modern	General	8072.74 cu in
cotyla	0.2746	0.009696	Roman Empire	Ancient	Dry	1/12 congius, 2003 reference
cotyla	0.2746	0.009696	Roman Empire	Ancient	Liquid	1/12 congius, 2003 reference
cotyla	0.276	0.0097	Byzantine Empire, Turkey	Ancient	Liquid	1/8 litra
cotyle	0.273	0.0096	Greece (Attic)	Ancient	Dry	6 kyathoi, consistent with 2003 reference
cotyle	0.273	0.0096	Greece (Attic)	Ancient	Liquid	6 kyathoi, consistent with 2003 reference
csp	0.002464	0.00008702	United States	Colonial to modern	Cooking	5 drops
cu ft	28.32	1.000	United States	Colonial to modern	Wood	Same as standard cft
cuarta	0.5938	0.02097	Argentina	Colonial to pre-metric	Liquid	1/4 frasco, 2 octava, 2003 reference
cuarta	0.757	0.0267	Paraguay	Colonial to pre-metric	Liquid	1/4 frasco, 2003 reference
cuartilla	3.140	0.1109	Spain	Medieval to pre-metric	Liquid, oil	25 panillas, 1891 value
cuartilla	3.910	0.1381	Spain	Medieval to pre-metric	Liquid	2003 reference
cuartilla	13.87	0.4898	Central America	Colonial to pre-metric	Dry	1891 reference
cuartilla	34.30	1.211	Argentina	Colonial to pre-metric	Dry	1/4 fanega, 2003 reference
cuartilla	4.03	0.142	Central America	Colonial to pre-metric	Liquid	1891 reference
cuartillo	0.4563	0.01611	Mexico	Colonial to pre-metric	Liquid, wine	Consistent with 2003 reference for general liquid volume
cuartillo	0.504	0.01781	Spain	Medieval to pre-metric	Liquid	4 copas, 1891 value, reported as 0.4888 l in 2003 reference

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
cuartillo	0.506	0.0179	Mexico	Colonial to pre-metric	Liquid, oil	
cuartillo	0.51	0.018	Central America	Colonial to pre-metric	General	2003 reference
cuartillo	0.51	0.018	Costa Rica	Colonial to pre-metric	General	2003 reference
cuartillo	0.51	0.018	El Salvador	Colonial to pre-metric	General	2003 reference
cuartillo	0.51	0.018	Guatemala	Colonial to pre-metric	General	2003 reference
cuartillo	0.51	0.018	Honduras	Colonial to pre-metric	General	2003 reference
cuartillo	0.51	0.018	Nicaragua	Colonial to pre-metric	Liquids	2003 reference
cuartillo	1.111	0.03923	Chile	Colonial to pre-metric	Liquid	Also reported as 1.1 liters in 1891 and 1,010 liters in 2003 reference
cuartillo	1.174	0.04145	Spain	Medieval to pre-metric	Dry	4 raciones, reported as 1.156 l in 2003 reference
cuartillo	1.892	0.06680	Mexico	Colonial to pre-metric	Dry	2003 reference
cuba	1.012	0.03573	Abyssinia	Pre-metric	General	23/10 madega, 2003 reference
cuba	1.017	0.03590	Abyssinia	Pre-metric	General	1891 value
cubic fet	30.92	1.092	Iceland	Medieval to pre-metric	Dry	32 pottar, 2003 reference
cubic fod	30.92	1.092	Denmark	Medieval to pre-metric	Liquid	4 viertel, 2003 reference
cubic fod	30.92	1.092	Denmark	Medieval to pre-metric	Dry	32 pott, 2003 reference
cubic foot	28.32	1.000	United States	Colonial to modern	General	1,728 cu in
cubic foot	28.32	1.000	United Kingdom, England	Medieval to pre-metric	General	1891 value
cubic foot	28.32	1.000	United States	Colonial to modern	Wood	Same as standard cft
cubic inch	0.01639	0.0005786	United States	Colonial to modern	General	
cubic mile	4.169E+12	1.472E+11	United States	Colonial to modern	General	

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
cubic yard	764.6	27.00	United States	Colonial to modern	General	27 cu ft
cubic yard	764.6	27.00	United Kingdom, England	Medieval to pre-metric	General	1891 value
cubic zira	1,000	35.3	Turkey, Ottoman Empire	Pre- and post-metric	General, dry	Post-metric, 10 kile, 2003 reference
cucchiaro (Sardinia, Turin)	0.120	0.00423	Italy	Medieval to pre-metric	Dry	1891 value, 1/20 copello
cudava	0.413	0.0146	India	Pre-metric	Liquid	8 musti, 1966 value
cuddy	3.8	0.13	Saudi Arabia	Pre-metric	Liquid	4 nusfiah, 2003 reference
cuddy	7.567	0.2672	Arabia	Ancient to pre-metric	Liquid	1891 value, 8 noosfias
cuerta	114.0	4.025	Argentina	Colonial to pre-metric	Liquid	48 frasco, 2003 reference
culeus	527.3	18.62	Roman Empire	Ancient	Liquid	"Hogshead", 160 congii, 2003 reference
culleus	527.3	18.62	Roman Empire	Ancient	Liquid	"Hogshead", 160 congii, 2003 reference
cumbha	264	9.32	India	Pre-metric	Liquid	10 cumba short, 1966 value
cumbha short	26.4	0.932	India	Pre-metric	Liquid	2 drona, 1966 value
cup	0.2366	0.008354	United States	Colonial to modern	Liquid	2 gill or 8 fluid ounces
cup	0.2366	0.008354	United States	Colonial to modern	Cooking	8 fluid ounces
cup	0.284	0.0100	United Kingdom, England	Medieval to pre-metric	Liquid	2 gill, 10 fluid ounces
cwierc	32.0	1.13	Poland	Medieval to pre-metric	Liquid	8 garniec, 2003 reference
cyanthos	0.0455	0.00161	Greece (Attic)	Ancient	Dry	10 kochliaria, reported as 0.045 L in 2003
cyathus	0.04577	0.001616	Roman Empire	Ancient	Dry	1/72 congius, 2003 reference

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
cyathus	0.04577	0.001616	Roman Empire	Ancient	Liquid	1/72 congius, 2003 reference
dàn	103.5	3.656	China	Medieval to pre-metric	General	100 shēng, “picul”, 2 hou, 1966 value
daribah	1,584	55.93	Egypt	Pre-metric	Dry	768 keddah, consistent with 2003 reference
dash	0.002957	0.0001044	United States	Colonial to modern	Cooking	6 drops
dash	0.003	0.0001	Shoshone	Pre-colonial	Cooking	Cooking measure, very roughly estimated volume
đầu	1.000	0.03531	Vietnam, Annam	Medieval to pre-metric	General	2 bat or 5 cáp
deal	38.94	1.375	United States	Colonial to modern	Wood	12 ft × 11 in × 1.5 in
deal	247.8	8.750	United Kingdom, England	Colonial to modern	Wood	7 ft × 6 ft × 2.5 in
demiard	0.2380	0.008404	France	Medieval to pre-metric	Liquid	Half a chopine, 2 posson, 2003 reference
demijohn			United States	Colonial to modern	Liquid	Varied from 3 to 10 gallons, wicker-enclosed, narrow neck bottle, no-specific conversion possible
demi-posson	0.05950	0.002101	France	Medieval to pre-metric	Liquid	2 roquille, 2003 reference
demi-settier	0.2380	0.008404	France	Medieval to pre-metric	Liquid	Half a chopine, 2 posson, 2003 reference
deny	143.1	5.053	Egypt	Ancient	General	Cubic Royal cubit, 30 hekat
dessertspoon	0.009858	0.0003481	United States	Colonial to modern	Cooking	20 drops
dicotoli	0.568	0.0201	Ionian Islands	Pre-metric	Liquid	1 Imperial pint, 1891 value
dimeria	24.6	0.869	Romania, Roumania	Pre- and Post-metric	Dry	16 oke, 2003 reference
dja	0.300	0.0106	Egypt	Ancient	General	5/8 hinu or 20 ro
djezla	257.4	9.089	Tanzania	Medieval to pre-metric	Dry?	Dry measure?

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
djezla	257	9.09	Zanzibar	Pre-Metric	General	1891 value
dolium	527.3	18.62	Roman Empire	Ancient	Liquid	"Hogshead", 160 congii, 2003 reference
dōu	10.35	0.3655	China	Medieval to pre-metric	General	10 shēng, 1966 value
double heqat	9.54	0.337	Egypt	Ancient	General	2 heqat
double quarteron	30.0	1.06	Switzerland	Medieval to pre-metric	Dry	2 quarteron, 1891 value
drachm	0.00355	0.000125	United Kingdom, England	Medieval to pre-metric	Liquid, apothecaries'	60 minim, 1891 value
dram	0.00355	0.000125	United Kingdom, England	Medieval to pre-metric	Liquid	60 minim, 1/8 fluid ounce
dreiling	1,358	47.96	Austrian Empire	Pre-metric	Liquid	1891 value, 24 eimer
dreiling	1,698	59.95	Austrian Empire	Pre-metric	Liquid	10 eimer, 2003 reference
dreissiger	1.158	0.04089	Germany	Medieval to pre-metric	Dry	2003 reference
dreissiger (Bavaria)	1.158	0.04089	Germany	Medieval to pre-metric	Dry	1891 value
drittel (Hanover)	10.39	0.3668	Germany	Medieval to pre-metric	Dry	1891 value
drömt (Lubeck)	427.0	15.08	Germany	Medieval to pre-metric	Dry, wheat	3 tonnen, 1891 value
drona	13.2	0.466	India	Pre-metric	Liquid	4 adhaka, 1966 value
drop	5.919E-05	2.090E-06	United Kingdom, England	Medieval to pre-metric	Liquid	
drop	5.919E-05	2.090E-06	United Kingdom, England	Medieval to pre-metric	Liquid, apothecaries'	1891 value

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
drop	4.929E-04	1.740E-05	United States	Colonial to modern	Cooking	
drp	4.929E-04	1.740E-05	United States	Colonial to modern	Cooking	
dry barrel	145.4	5.134	United Kingdom, England	Medieval to pre-metric	Dry	2 strike, 4 bushels, 32 dry gallons, 1891 value
dry hogshead	290.8	10.27	United Kingdom, England	Medieval to pre-metric	Dry	2 coomb, 64 dry gallons, 1/4 dry tun, 1891 value
dry tun	1,164	41.09	United Kingdom, England	Medieval to pre-metric	Dry	
dst	0.009858	0.0003481	United States	Colonial to modern	Cooking	20 drops
ecklein (Wurtemberg)	0.692	0.0244	Germany	Medieval to pre-metric	Dry	4 viertlein, 1891 value
eggshell	0.055	0.0019	Ireland	Medieval to pre-metric	General	Standard unit
eichmass (Frankfort)	1.793	0.06330	Germany	Medieval to pre-metric	Liquid	4 schoppen, 1891 value
eimer	54.30	1.917	Hungary	Medieval to pre-metric	General	Varied greatly by region 54–73 liters, typical 64 halbe, 1891 values, consistent with 2003 reference
eimer	56.60	1.998	Austrian Empire	Pre-metric	Liquid	1891 value, 4 viertel, consistent with 2003 reference
eimer	68.69	2.425	Prussia	Medieval to pre-metric	Liquid	2 anker, 1891 value
eimer	68.70	2.426	Germany	Medieval to pre-metric	Liquid	2 anker, 2003 reference
eimer	78.51	2.772	Sweden	Medieval to pre-metric	Liquid	2 ankar, 2003 reference

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
eimer (Bavaria)	64.13	2.265	Germany	Medieval to pre-metric	Liquid, wine	64 mass, 1891 value
eimer (Bavaria)	68.41	2.416	Germany	Medieval to pre-metric	Liquid, beer	1891 value
eimer (Bohemia)	61.09	2.157	Austrian Empire	Pre-metric	Liquid	32 pinten, 1891 value
eimer (Hamburg)	28.88	1.020	Germany	Medieval to pre-metric	Liquid	4 viertel, 1891 value
eimer (Hanover)	62.74	2.215	Germany	Medieval to pre-metric	Liquid	8 viertel, 1891 value
eimer (Lubeck)	29.96	1.058	Germany	Medieval to pre-metric	Liquid	4 viertel, 1891 value
eimer (Saxony)	75.85	2.678	Germany	Medieval to pre-metric	Liquid	63 kannen, 1891 value, Leipsic, Desden 88.9%
eimer (Wurtemberg)	293.9	10.38	Germany	Medieval to pre-metric	Liquid	16 immi
emine	1.50	0.0530	Switzerland	Medieval to pre-metric	Dry	1891 value
entelam	192.0	6.780	Eretria	Medieval to pre-metric	General	128 messé, 2003 reference
epah (Israeli)	22.9	0.809	Biblical, Talmudic	Ancient	Dry	3 tse'ah, AKA bath, one "assload"
epha	13.23	0.4672	Jewish, Israel	Medieval to modern	General	807.274 cu in
ephah (Israeli)	22.9	0.809	Biblical, Talmudic	Ancient	Dry	3 tse'ah, AKA bath, one "assload"
face cord	1.813	64.02	United States	Colonial to modern	Wood	1/2 cord
faden	4.077	144.0	Latvia	Medieval to pre-metric	General	
faden (Bremen)	1.742	61.49	Germany	Medieval to pre-metric	General	72 kubikfuss, 1891 value
faggot	27.04	0.9548	United States	Colonial to modern	Wood	1/9.42 cft
fai mue	0.125	0.00441	Thailand, Siam	Medieval to metric	Dry	Grain held in palm, 4 chai meu, 2003 reference
fanega	55.48	1.959	Central America	Colonial to pre-metric	Dry	4 cuartillas, 1891 reference

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
fanega	56	2.0	Morocco		General	4 mudd, 2003 reference
fanega	56.35	1.990	Cuba	Colonial to pre-metric	Dry	1.599 bushels
fanega	56.35	1.990	Spain	Medieval to pre-metric	Dry	12 almudes, reported as 55.50 l in 2003 reference
fanega	60.56	2.138	Cuba	Colonial to pre-metric	Liquid	16 gallons
fanega	90.81	3.206	Mexico	Colonial to pre-metric	Dry	48 cuartillo, 12 almude, 2003 reference, reported as 54.6 liters in 1891
fanega	97.00	3.425	Chile	Colonial to pre-metric	Dry	12 almude, 2003 reference, also reported as 90.7 liters in 1891
fanega	137.2	4.845	Argentina	Colonial to pre-metric	Dry	4 cuartilla, consistent with 1891 and 2003 references
fanega	274	9.68	Uruguay	Colonial to pre-metric	General	
fanega	288	10.2	Paraguay	Colonial to pre-metric	Dry	12 almude, 2003 reference
fanega (Spanish)	110	3.89	West Indies	Colonial to pre-metric	Dry	1891 value
fanga	47.91	1.692	Azores	Pre-metric	Dry	4 alquires, 1891 value
fanga	54.0	1.91	Portugal	Medieval to pre-metric	Dry	4 alqueiras, 2003 reference
fanga (Lisbon)	54.08	1.909	Portugal	Medieval to pre-metric	Dry	4 alquiéres, 1891 value
fanga (Lisbon)	745.9	26.34	Portugal	Medieval to pre-metric	Dry, coal	Specific to coal, 1891 value
fanga (Oporto)	62.27	2.199	Portugal	Medieval to pre-metric	Dry	4 alquiéres, 1891 value
fass	198.9	7.023	Hungary	Medieval to pre-metric	Dry	Approximate, 1891 value
fass	492.0	17.37	Russia	Medieval to pre-metric	Liquid	Barrel, 40 vedro, 1891 value, consistent with 2003 reference
fass	566.0	19.98	Austrian Empire	Pre-metric	Liquid	10 eimer, 2003 reference
fass (Bohemia)	244.4	8.628	Austrian Empire	Pre-metric	Liquid	4 eimer, 1891 value

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
fass (Brunswick)	403.9	14.26	Germany	Medieval to pre-metric	Liquid, beer	For beer, 1891 value, 108 stüßhem
fass (Hamburg)	52.65	1.859	Germany	Medieval to pre-metric	Dry	2 hint, 1891 value
fass (Hanover)	407.8	14.40	Germany	Medieval to pre-metric	Liquid, beer	4 tonnen, 1891 value
fass (Lubeck)	8.895	0.3141	Germany	Medieval to pre-metric	Dry, wheat	1891 value
fass (Saxony)	379.3	13.39	Germany	Medieval to pre-metric	Liquid	5 eimer, 1891 value, Leipsic, Desden 88.9%
fat	157.0	5.545	Sweden	Medieval to pre-metric	Liquid	2 eimer, 2003 reference
favn	2.232	0.07881	Norway	Medieval to pre-metric	Dry	1 cubic alen, still used for firewood
fbm	2.254	0.07959	United States	Colonial to modern	Wood	1/12 cft
ferren	30.0	1.06	Muscat	Pre-metric	General	1891 value, 34 sidios
ferren	30.0	1.06	Oman	Medieval to pre-metric	General	Approx
feuillette	137.1	4.841	France	Medieval to pre-metric	Liquid	2 quartauts, 2003 reference
fgt	27.04	0.9548	United States	Colonial to modern	Wood	1/9.42 cft
fiasco (Modena)	2.083	0.07355	Italy	Medieval to pre-metric	Liquid	2 boccali, 1891 value
fiasco (Tuscany)	0.602	0.0213	Italy	Medieval to pre-metric	Liquid	2 boccale, 1891 value
fiasco (Tuscany)	2.279	0.08049	Italy	Medieval to pre-metric	Liquid, wine	1/20 barile
firkin	39.64	1.400	United States	Colonial to Modern	Dry	9 gallons
firkin	41.59	1.469	United Kingdom, England	Medieval to pre-metric	Liquid, beer, ale	2 pins, 9 Imp gallons, 1/4 beer barrel
firlot	36.01	1.271	Scotland	Medieval to pre-metric	Dry, wheat, peas, beans, rice, salt	4 peck, for things sold by "level" measure, 2003 reference

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
firlot	52.53	1.855	Scotland	Medieval to pre-metric	Dry, oats, barley, malt	4 pecks, for things sold by “heaped” measure, 2003 reference
fitel kubu	2.246	0.07931	Malta	Medieval to pre-metric	General	1/8 xiber kubu
fjårding	31.41	1.109	Sweden	Medieval to pre-metric	Liquid	12 kanna, 2003 reference
fjerdings	73.25	2.587	Norway	Medieval to pre-metric	Dry	7 kannas, 1891 value
fjerdingsar	18.32	0.6469	Sweden	Medieval to pre-metric	Dry	4 kappar, 2003 reference
fjerdingskar	8.69	0.307	Denmark	Medieval to pre-metric	Dry	2 ottingkar, 1891 value
fjerdingskar	34.78	1.228	Denmark	Medieval to pre-metric	Dry	2 ottingkar, 2003 reference
fluid dram	0.003697	0.0001305	United States	Colonial to modern	Liquid	60 minim
fluid ounce	0.02957	0.001044	United States	Colonial to modern	Liquid	2 tablespoons, 1.0408 wt oz water, 1/128 gallon
fluid ounce	0.02957	0.001044	United States	Colonial to modern	Cooking	2 tablespoons
fluid ounce	0.0591	0.00209	United Kingdom, England	Medieval to pre-metric	Liquid	2 tablespoons
foglietta (Roman St)	0.452	0.0160	Italy	Medieval to pre-metric	Liquid	1/4 boccale, using avg barile
fogliette (Bologna)	0.327	0.0116	Italy	Medieval to pre-metric	Liquid	1891 value
fogliette (Rome)	0.449	0.0159	Italy	Medieval to pre-metric	Liquid, oil	4 quarterucci, 1891 value
fogliette (Rome)	0.456	0.0161	Italy	Medieval to pre-metric	Liquid, wine	4 quarterucci, 1891 value
forpet	2.250	0.07947	Scotland	Medieval to pre-metric	Dry, wheat, peas, beans, rice, salt	2003 reference

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
forpet	3.283	0.1159	Scotland	Medieval to pre-metric	Dry, oats, barley, malt	2003 reference
fortin	141	4.98	Turkey, Ottoman Empire	Pre- and post-metric	General, dry	4 kilos, pre-metric, 1891 value
fortin	400	14.1	Turkey, Ottoman Empire	Pre- and post-metric	General, dry	Post-metric, 4 kile, 2003 reference
frasco	2.366	0.08354	Mexico	Colonial to pre-metric	Liquid, wine	Approx, consistent with 1891 value reported
frasco	2.375	0.08386	Argentina	Colonial to pre-metric	Liquid	4 cuarta, reported as 0.237 liters in 1891— may be incorrect, value from 2003 reference
frasco	3.03	0.107	Paraguay	Colonial to pre-metric	Liquid	4 cuarta, 2003 reference
ft ³	28.32	1.000	United States	Colonial to modern	Wood	Same as standard cft
fuder	824.3	29.11	Prussia	Medieval to pre-metric	Liquid	6 ohm, 1891 value
fuder	824.4	29.11	Germany	Medieval to pre-metric	Liquid	4 oxhoft, 2003 reference
fuder	927.5	32.75	Denmark	Medieval to pre-metric	Liquid	2 pipe, 2003 reference
fuder	942.2	33.27	Sweden	Medieval to pre-metric	Liquid	4 oxhoft, 2003 reference
fuder	1,811	63.95	Austrian Empire	Pre-metric	Liquid	1891 value, 32 eimer, consistent with 2003 reference
fuder (Baden)	1,500	52.97	Germany	Medieval to pre-metric	Liquid	10 ohm, 1891 value
fuder (Bremen)	869.8	30.71	Germany	Medieval to pre-metric	Liquid	6 ohm, 1891 value
fuder (Brunswick)	897.6	31.69	Germany	Medieval to pre-metric	Liquid	6 ohm, 4 oxhoft, 1891 value
fuder (Frankfort)	860.5	30.38	Germany	Medieval to pre-metric	Liquid	6 ohm, 1891 value
fuder (Hamburg)	866.3	30.59	Germany	Medieval to pre-metric	Liquid	6 ahm, 1891 value

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
fuder (Hanover)	941.1	33.23	Germany	Medieval to pre-metric	Liquid	6 ahm, 1891 value
fuder (Hesse-Cassel)	1,048	36.99	Germany	Medieval to pre-metric	Liquid, beer	6 ohm, similar unit for wine with different value, 1891 value
fuder (Hesse-Darmstadt)	1,014	35.82	Germany	Medieval to pre-metric	Liquid	6 ohm, similar unit for wine with different value, 1891 value
fuder (Lubeck)	898.7	31.73	Germany	Medieval to pre-metric	Liquid	6 ahm, 1891 value
fuder (Saxony)	910.2	32.14	Germany	Medieval to pre-metric	Liquid	6 ohm, 1891 value, Leipsic, Desden 88.9%
fuder (Wurtemberg)	1,763	62.27	Germany	Medieval to pre-metric	Liquid	6 eimer
futtermassel	1.922	0.06785	Austrian Empire	Pre-metric	Dry	1891 value, 2 kleine massel, consistent with 2003 reference
gallon	3.566	0.1259	Ireland	Medieval to pre-metric	Liquid	2 pottle, pre-1824, 2003 reference
gallon	3.785	0.1337	United States	Colonial to modern	Liquid, Wine	
gallon	3.785	0.1337	United States	Colonial to modern	Liquid	4 gallons, 231 cu inches, Winchester gallon
gallon	4.405	0.1555	United States	Colonial to modern	Dry	4 quarts, seldom used
gallon	4.534	0.1601	Cornwall	Medieval to pre-metric	Liquid	Based on weight of material, 10 lbs water
gallon	4.543	0.1604	United Kingdom, England	Medieval to pre-metric	Liquid, wine	4 quarts, basically Imperial gallon, 1891 value
gallon	4.546	0.1605	United Kingdom, England	Medieval to pre-metric	Dry	4 dry quarts or 8 dry pints, 1891 value
gallon	13.56	0.4788	Scotland	Medieval to pre-metric	Liquid	16 chopins or 8 jouns

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
gallon (~1454-1824)	4.621	0.1632	United Kingdom, England	Medieval to pre-metric	Liquid, beer, ale	4 quarts
gallone	4.546	0.1605	Ionian Islands	Pre-metric	Liquid	1 Imperial gallon, 1891 value
ganta	3.996	0.1411	Philippines	Medieval to pre-metric	General	1000 chupa, 2003 reference
gantang	9.200	0.3249	South Africa	Colonial to pre-metric	Liquid	
gantang	26.0	0.918	Borneo	Pre-metric	General	1891 value
garab (Talmudic)			Biblical, Talmudic	Ancient	General	Unable to locate good definition of size
garava	1,440	50.8	Syria	Medieval to pre-metric	General	450 rotl, 2003 reference
garce	8,808	311.0	India	Pre-metric	Liquid	5 khahoon, 2003 reference
garce (Madras)	4,917	173.6	India	Pre-Akbar	Dry, rice, grains	80 parahs, 1891 value
garnets	3,279	0.1158	Tatar	Medieval to pre-metric	Dry	
garnets	3,280	0.1158	Russia	Medieval to pre-metric	Dry	Pot, 2 polougarnetz, consistent with 2003 reference
garnetz	3,280	0.1158	Russia	Medieval to pre-metric	Dry	Pot, 2 polougarnetz, consistent with 2003 reference
garniec	3,753	0.1325	Poland	Medieval to pre-metric	Liquid	4 kwarta, 1891 value, reported as 4,000 liters in Warsaw and in 2003 reference
garra	10.80	0.3814	Malta	Medieval to pre-metric	Liquid, beer, wine, spirits	
gê	0.1035	0.003655	China	Medieval to pre-metric	General	1/10 shēng, 10 chao, 1966 value
geriwa (Talmudic)			Biblical, Talmudic	Ancient	General	Unable to locate good definition of size

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
gerrah (Minorca)	12.06	0.4258	Balearic Islands	Pre-metric	Dry	1891 value
gescheid (Frankfort)	1.793	0.06331	Germany	Medieval to pre-metric	Dry	4 masschen, 1891 value
gescheid (Hesse-Darmstadt)	20.00	0.7063	Germany	Medieval to pre-metric	Dry	4 mässechen, 1891 value
ghabara	3.031	0.1070	Malta	Medieval to pre-metric	Dry	Some confusion on name, 1921 Act calls it a siegh, 1/6 totna
ghebeta	24.00	0.8475	Eretria	Medieval to pre-metric	General	16 messé, 2003 reference
giarra	44.01	1.554	Libya	Medieval to pre-metric	Liquid	Roughly 50/71 barile, 2003 reference, usually measured by weight as about 34.3 oka water
gill	0.1059	0.003741	Scotland	Medieval to pre-metric	Liquid	4 fluid ounces
gill	0.1183	0.004177	United States	Colonial to modern	Liquid	
gill	0.142	0.00502	United Kingdom, England	Medieval to pre-metric	Liquid	2 jack or 5 fluid ounces (doubled for milk or beer in N. England)
gill	0.142	0.00501	United Kingdom, England	Medieval to pre-metric	Liquid, wine	1891 value
gill	0.144	0.00510	United Kingdom, England	Medieval to pre-metric	Liquid, beer, ale	1891 value
gin ₂	0.017	0.00059	Sumer	Ancient	Dry	1/60 bowl
gisla	163.1	5.758	Somalia	Medieval to pre-metric	Liquid	120 chela, 8 tabla, 2003 reference
glas (Baden)	0.150	0.00530	Germany	Medieval to pre-metric	Liquid	1891 value

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
gô	0.1804	0.006370	Japan	Medieval to pre-metric	General	10 shaku, common serving size for sake, 2003 reference
gō	0.1804	0.006370	Japan	Medieval to pre-metric	General	10 shaku, common serving size for sake, 2003 reference
gomari	163.7	5.779	Cyprus	Colonial to pre-metric	Dry, Grains	128 oke, used for grain, consistent with 2003 reference
gombette (Genoa)	1.258	0.04440	Italy	Medieval to pre-metric	Dry	1891 value
gonghau	8.400	0.2966	Japan	Medieval to pre-metric	General	5 ichigau, 1891 value
gorraf	12.50	0.4414	Libya	Medieval to pre-metric	Liquid	4.8 bozze, 1/5 barile, 2003 reference, usually defined by weight as 39/4 oka of water
grosses massel	1.922	0.06785	Austrian Empire	Pre-metric	Dry	1891 value, 2 kleine massel, consistent with 2003 reference
gtt	4.929E-04	1.740E-05	United States	Colonial to modern	Cooking	
gudda	7.567	0.2672	Arabia	Ancient to pre-metric	Liquid	1891 value, 8 noosfias
guirbeh	66.7	2.35	Egypt	Pre-metric	Liquid	1867 value
gur	300	10.6	Sumer	Ancient	Dry	300 bowls
gur-cube	300	10.6	Mesopotamia	Ancient	Dry	300 bowls
halbe	0.7075	0.02498	Austrian Empire	Pre-metric	Liquid	1891 value, 2 seidel, consistent with 2003 reference
halbe	0.8484	0.02996	Hungary	Medieval to pre-metric	General	1/64 eimer, 1891 value, consistent with 2003 reference
halbe mass	0.7075	0.02498	Austrian Empire	Pre-metric	Liquid	1891 value, 2 seidel, consistent with 2003 reference
half-cup	0.1183	0.004177	United States	Colonial to modern	Liquid	4 fluid ounces

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
half-xesta	0.276	0.0097	Byzantine Empire, Turkey	Ancient	Liquid	1/8 litra
halvotting	2.174	0.07677	Denmark	Medieval to pre-metric	Dry	1891 value, consistent with 2003 reference
handful	0.1	0.004	Shoshone	Pre-colonial	Cooking	Cooking measure, very roughly estimated volume
handful	3.367	0.1189	Byzantine Empire, Turkey	Ancient	Liquid	1–13/24 litra
hao	28.26	0.9979	Vietnam, Annam	Medieval to pre-metric	General	2003 reference
hekat	4.770	0.1684	Egypt	Ancient	General	10 hin, barrel
hekat-fedw	19.08	0.6737	Egypt	Ancient	General	4 heqat
hekaty	9.54	0.337	Egypt	Ancient	General	2 heqat
hekteus	8.736	0.3085	Greece (Attic)	Ancient	Dry	8 choinikes, reported as 8.64 liters in 2003
hektos	8.736	0.3085	Greece (Attic)	Ancient	Dry	8 choinikes, reported as 8.64 liters in 2003
hēmiektion	4.368	0.1542	Greece (Attic)	Ancient	Dry	4 choinikes
hēmikotylē	0.1365	0.004820	Greece (Attic)	Ancient	Liquid	3 kyathoi
hemina	0.2746	0.009696	Roman Empire	Ancient	Dry	1/12 congius, 2003 reference
hemina	0.2746	0.009696	Roman Empire	Ancient	Liquid	1/12 congius, 2003 reference
hēmīna	0.273	0.0096	Greece (Attic)	Ancient	Dry	6 kyathoi, consistent with 2003 reference
hēmīna	0.273	0.0096	Greece (Attic)	Ancient	Liquid	6 kyathoi, consistent with 2003 reference
heqat	4.770	0.1684	Egypt	Ancient	General	10 hin, barrel
hestawr	70.5	2.49	Wales	Medieval to pre-metric	Dry	2 Winchester bushels, approx (1836 basis)
himt (Brunswick)	30.54	1.079	Germany	Medieval to pre-metric	Dry, wheat	4 vierflass, wheat, 1891 value
himt (Hamburg)	26.33	0.9296	Germany	Medieval to pre-metric	Dry	4 spinten, 1891 value

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
hint (Hanover)	31.16	1.100	Germany	Medieval to pre-metric	Dry	4 vierfass or 3 drittel, 1891 value
hint (Hesse-Cassel)	40.53	1.431	Germany	Medieval to pre-metric	Dry	4 metzen, 1891 value
hin	0.477	0.0168	Egypt	Ancient	General	Jar
hin	2.205	0.07786	Jewish, Israel	Medieval to modern	General	134.54 cu in
hin (Israeli)	3.829	0.1352	Biblical, Talmudic	Ancient	Liquid	
hin (per Josephus)	6.787	0.2397	Jewish, Israel	Medieval to modern	General	414.12 cu in
hinu	0.477	0.0168	Egypt	Ancient	General	Jar
hộc	60.00	2.119	Vietnam, Annam	Medieval to pre-metric	General	Different from other measures
hộc	16,000.00	565.0	Vietnam, Annam	Medieval to pre-metric	General	10 lè, 10 ngũ × 1 ngũ × 1 thước
hogshead	212.0	7.486	United Kingdom, England	Medieval to pre-metric	Liquid, Madeira	Range 205–218 liters, average
hogshead	237.0	8.369	United Kingdom, England	Medieval to pre-metric	Liquid	Range 200–273 liters, average
hogshead	238.5	8.420	United States	Colonial to modern	Liquid, wine	63 gallons
hogshead	238.5	8.421	United States	Colonial to modern	Liquid	63 gallons, 524.7 pounds water
hogshead	249.5	8.811	United Kingdom, England	Medieval to pre-metric	Liquid, beer	3 kinderkins, 54 Imp gallons, 1.5 beer barrels
hogshead	266.0	9.393	United Kingdom, England	Medieval to pre-metric	Liquid, brandy	Range 255–277 liters, average

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Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
hogshead	286.2	10.11	United Kingdom, England	Medieval to pre-metric	Liquid, wine	2 wine barrels, 63 wine gallons, 1/4 wine tun, also reported as 54 gallons in 1891, actual amount varies with type of wine
hogshead	299.5	10.58	Ireland	Medieval to pre-metric	Liquid	2 tierce, pre-1824, 2003 reference
homer (Israeli)	229.7	8.111	Biblical, Talmudic	Ancient	Dry	2 letek
hop	0.1800	0.006356	Korea	Medieval to pre-metric	General	
hou	51.77	1.828	China	Medieval to pre-metric	General	50 shēng, 5 to, 1966 value
house cord	1.208	42.66	United States	Colonial to modern	Wood	1/3 cord
hú	51.77	1.828	China	Medieval to pre-metric	General	50 shēng, 5 to, 1966 value
hueba	107	3.79	Tripoli, Libya	Pre-metric	Dry	4 temen, 1891 value
hulmit	11.48	0.4054	Estonia	Medieval to pre-metric	General	2003 reference
immi (Wurtemberg)	18.37	0.6486	Germany	Medieval to pre-metric	Liquid	10 mass
Imperial gallon	4.546	0.1605	United Kingdom, England	Medieval to pre-metric	Liquid, apothecaries'	8 pints, 1891 value
Imperial gallon (1824)	4.546	0.1605	United Kingdom, England	Medieval to pre-metric	Liquid	2 pottle, 4 quarts, 8 pints, 160 fluid ounces, based on volume of 10 lbs distilled water at 62°F, 277.274 cu inches
ischiomassé	16.80	0.5932	Japan	Medieval to pre-metric	General	2 gonghau, 1891 value
issaron (Israeli)		0.000	Biblical, Talmudic	Ancient	Dry	1/10 ephah, not part of original system, Egyptian or Assyrian influence, undefined
itchigau	1.680	0.05932	Japan	Medieval to pre-metric	General	1891 value

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
itcze	0.8484	0.02996	Hungary	Medieval to pre-metric	General	1/64 eimer, 1891 value, consistent with 2003 reference
ittomassé	168.0	5.932	Japan	Medieval to pre-metric	General	10 ischiomassé, 1891 value
jack	0.0710	0.00251	United Kingdom, England	Medieval to pre-metric	Liquid	5 tablespoons, 2.5 fluid ounces, doubled for milk and beer in Northern England
jackpot	0.0710	0.00251	United Kingdom, England	Medieval to pre-metric	Liquid	5 tablespoons, 2.5 fluid ounces, doubled for milk and beer in Northern England
jarra	8.213	0.2900	Mexico	Colonial to pre-metric	Liquid, wine	18 cuartillo, consistent with 2003 reference for general liquid volume
jeroboam	3.031	0.1070	United Kingdom, England	Medieval to pre-metric	Liquid, wine	Still used for champagne exclusively
jigger	0.0426	0.00150	United Kingdom, England	Medieval to pre-metric	Liquid	3 tablespoons, 2 pony, 1.5 fluid ounces
jigger	0.04436	0.001566	United States	Colonial to modern	Liquid	3 tablespoons
joug	1.695	0.05985	Scotland	Medieval to pre-metric	Liquid	4 mutchkins or 3 Imperial pints (1.704 l)
ju	0.1	0.004	China	Medieval to pre-metric	General	Handful, traditional, very rough estimate
jug	1.695	0.05985	Scotland	Medieval to pre-metric	Liquid	4 mutchkins or 3 Imperial pints (1.704 l)
jumpru	0.0818	0.00289	Finland	Medieval to pre-metric	Dry	“Virgin”
jumpru	0.0818	0.00289	Finland	Medieval to pre-metric	Liquid	“Virgin”
jungfru	0.0818	0.00289	Norway	Medieval to pre-metric	Liquid	1891 value
jungfru	0.08179	0.002888	Sweden	Medieval to pre-metric	Liquid	2003 reference

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
junkfra	0.08179	0.002888	Sweden	Medieval to pre-metric	Dry	2003 reference
kab (Israeli)	1.276	0.04506	Biblical, Talmudic	Ancient	Liquid	
kab (Israeli)	1.28	0.0452	Biblical, Talmudic	Ancient	Dry	4 log
kab (Talmudic)	1.3	0.046	Biblical, Talmudic	Ancient	General	Estimated size
kaban	99.90	3.528	Philippines	Medieval to pre-metric	General	25 ganta, 2003 reference
kaddah	1.91	0.0674	Egypt	Pre-metric	Dry	2 nisf-keddah, 1867 value
kaddah	2.063	0.07283	Egypt	Pre-metric	Dry	2 nisf-keddah, 2003 reference
kahoon (Bengal, grain)	1,496	52.81	India	Pre-Akbar	Dry, rice, grains	1891 value
kalkbütte (Hesse-Darmstadt)	156.3	5.518	Germany	Medieval to pre-metric	Dry, lime	10 cu fuss, 1891 value
kalkmützel	153.7	5.428	Austrian Empire	Pre-metric	Dry, lime	2.5 metzen, 1891 value
kam meu	0.125	0.00441	Thailand, Siam	Medieval to metric	Dry	Grain held in palm, 4 chai meu, 2003 reference
kam mue	0.0313	0.00110	Thailand, Siam	Medieval to metric	Dry	Grain held in an enclosed hand, 3-1/8 niou, ~4 yip mue, 2003 reference
kan	1.000	0.03531	Netherlands, Holland	Medieval to metric	Liquids	Liter, 1891 term
kan	1.49	0.0527	Indonesia	Colonial to pre-metric	Liquid	Liquid measure, alternate reference
kan	1.575	0.05562	Indonesia	Colonial to pre-metric	Liquid	2003 reference
kanahm	1.00	0.0353	Thailand, Siam	Medieval to metric	General	Coconut shell measurement, 2 changawn, varies from 0.9 to 1.2 liters, assumed nominal value post metric, 2003 reference

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
kande	1.932	0.06823	Denmark	Medieval to pre-metric	Liquid	2 pott, 2003 reference
kanna	2.617	0.09241	Norway	Medieval to pre-metric	Liquid	2 stops, 1891 value
kanna	2.617	0.09241	Sweden	Medieval to pre-metric	Dry	2 stop, 2003 reference
kanna	2.617	0.09241	Sweden	Medieval to pre-metric	Liquid	2 stop, 2003 reference, consistent with 1891 reference, 1/10 cu fot
kanna	10.46	0.3695	Norway	Medieval to pre-metric	Dry	2 stops, 1891 value
kanne	0.7075	0.02498	Austrian Empire	Pre-metric	Liquid	1891 value, 2 seidel, consistent with 2003 reference
kanne	1.330	0.04696	South Africa	Colonial to pre-metric	Liquid	1/388 legger
kanne	1.49	0.0527	Indonesia	Colonial to pre-metric	Liquid	Liquid measure, alternate reference
kanne	1.49	0.0527	Java	Pre-metric	Liquid	1891 value
kanne	1.575	0.05562	Indonesia	Colonial to pre-metric	Liquid	2003 reference
kanne	2.550	0.09006	Latvia	Medieval to pre-metric	General	2 stoof, 2003 reference
kanne (Hamburg)	1.805	0.06373	Germany	Medieval to pre-metric	Liquid	2 quartier, 1891 value
kanne (Hanover)	1.961	0.06923	Germany	Medieval to pre-metric	Liquid	2 quartier, 1891 value
kanne (Leipzig)	1.200	0.04237	Germany	Medieval to pre-metric	Liquid	Jar, jug, bottle or can
kanne (Lubeck)	1.872	0.06611	Germany	Medieval to pre-metric	Liquid	2 quartier, 1891 value
kanne (Saxony)	0.950	0.0335	Germany	Medieval to pre-metric	Liquid	Jar, jug, bottle or can
kanne (Saxony)	1.204	0.04251	Germany	Medieval to pre-metric	Liquid	2 nössel, 1891 value, Leipsic, Desden 88.9%
kannor	2.595	0.09163	Finland	Medieval to pre-metric	General	2003 reference
kannu	2.617	0.09242	Finland	Medieval to pre-metric	Dry	Jug
kannu	2.617	0.09242	Finland	Medieval to pre-metric	Liquid	Jug
kantang	7.5	0.26	Cambodia	Post-metric	General	3/16 sesep, 7.5 muoi, 2003 reference

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
kapiza (Talmudic)			Biblical, Talmudic			
kappa	5.496	0.1941	Finland	Ancient	General	Unable to locate good definition of size
kappa	5.496	0.1941	Finland	Medieval to pre-metric	Dry	Used today in markets for potatoes as kappa or isokappa, defined as 5 liters
kappa	5.496	0.1941	Finland	Medieval to pre-metric	Liquid	
kappar	4.580	0.1617	Sweden	Medieval to pre-metric	Dry	3.5 stop, 2003 reference
kappe	18.31	0.6466	Norway	Medieval to pre-metric	Dry	1891 value
kartoëc	1.137	0.04015	Malta	Medieval to pre-metric	Liquid, beer, wine, spirits	
kartoëc	1.279	0.04516	Malta	Medieval to pre-metric	Liquid, milk, oil	
kartos	5.116	0.1806	Cyprus	Colonial to pre-metric	General	4 oke, 2003 reference
kav (Israeli)	1.28	0.0452	Biblical, Talmudic	Ancient	Dry	4 log
keddah	1.91	0.0674	Egypt	Pre-metric	Dry	2 nisf-keddah, 1867 value
keddah	2.063	0.07283	Egypt	Pre-metric	Dry	2 nisf-keddah, 2003 reference
keila	15.28	0.5395	Egypt	Pre-metric	Dry	2 roubouh, 1867 value
keila	16.50	0.5826	Egypt	Pre-metric	Dry	2 rob, 2003 reference
kejla	0.128	0.00452	Malta	Medieval to pre-metric	Liquid, milk, oil	1921 Act only, measure
kejla	0.303	0.0107	Malta	Medieval to pre-metric	Dry	1/60 tomna
kele	23.08	0.8148	Libya	Medieval to pre-metric	Dry	3 orba, 2003 reference, usually measured by weight as 24 oka water
kélé	15.28	0.5395	Egypt	Pre-metric	Dry	2 roubouh, 1867 value
kélé	16.50	0.5826	Egypt	Pre-metric	Dry	2 rob, 2003 reference
kella	3.4	0.12	Arabia	Ancient to pre-metric	Dry	Estimated, 1891 value

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
kella	35.4	1.25	Saudi Arabia	Pre-metric	Dry	100/23 mecdema, 2003 reference
kenning	18.17	0.6417	United Kingdom, England	Medieval to pre-metric	Dry	2 peck or 4 dry gallons, 1891 value
keramion	26.21	0.9254	Greece (Attic)	Ancient	Liquid	8 choes, Roman amphora
kérat	0.060	0.0021	Egypt	Pre-metric	Dry	1867 value
kérat	0.06445	0.002276	Egypt	Pre-metric	Dry	2003 reference
ke'zayit (Israeli)	0.0267	0.000942	Biblical, Talmudic	Ancient	Dry	1/2 or 1/3 bezah or unrelated? Exact value is unclear.
khahoon	1.762	62.20	India	Pre-metric	Liquid	2 candy, 2003 reference
khanoubah	0.1289	0.004552	Egypt	Pre-metric	Dry	2 kirat, 2003 reference
khar (Middle Kingdom)	96.50	3.407	Egypt	Ancient	General	Sack, 20 heqat
khar (New Kingdom)	76.80	2.712	Egypt	Ancient	General	Sack, 16 heqat
kharroubah	0.12	0.0042	Egypt	Pre-metric	Dry	2 kirat, 1867 value
khô	0.1035	0.003655	China	Medieval to pre-metric	General	1/10 shēng, 10 chao, 1966 value
khoonke	0.08602	0.003037	India	Pre-metric	Liquid	1.25 chattack, 2003 reference
khoonke (Bengal)	0.0644	0.00227	India	Pre-Akbar	Dry, rice, grains	5 chattack, 1891 value
khoul	16.69	0.5892	Algeria	Medieval to pre-metric	General	Consistent with 1891 value and 2003 reference
khoull	16.69	0.5892	Algeria	Medieval to pre-metric	General	Consistent with 1891 value and 2003 reference

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
khoulé	16.69	0.5892	Algeria	Medieval to pre-metric	General	Consistent with 1891 value and 2003 reference
khous	3.276	0.1157	Greece (Attic)	Ancient	Liquid	72 kyathoi, reported as 3.24 liters in 2003
kilderkin	81.83	2.889	United Kingdom, England	Medieval to pre-metric	Liquid, Beer, Ale	2 firkins, 18 gallons, 1/2 beer barrel
kile	35.81	1.264	Cyprus	Colonial to pre-metric	General	7 kartos, 2003 reference
kile	36.37	1.284	Cyprus	Colonial to pre-metric	Dry	Bushel
kile	100	3.53	Turkey, Ottoman Empire	Pre- and post-metric	General, dry	post metric, 4 chinik, 2003 reference
kile (Istanbul)	37.0	1.31	Ottoman Empire, Turkey	Pre-metric	Dry	Bushel, 4 şinik
kilo	35.3	1.25	Turkey, Ottoman Empire	Pre- and post-metric	General, dry	4 chiniks, pre-metric, 1891 value
kilo	394	13.9	Romania, Roumania	Pre- and post-metric	Dry	2 mirze, 2003 reference
kilo	435.0	15.36	Romania, Roumania	Pre- and post-metric	Dry	1891 value
kirat	0.060	0.0021	Egypt	Pre-metric	Dry	1867 value
kirat	0.06445	0.002276	Egypt	Pre-metric	Dry	2003 reference
kit	14.96	0.5284	Indonesia	Colonial to pre-metric	Liquid	4 koelak, 2003 reference
klaffer	2.905	102.6	Germany	Medieval to pre-metric	Dry	For firewood
Klafter (Bavaria)	3,133	110.6	Germany	Medieval to pre-metric	Dry, wood	126 cubic fuss, 3,1325 cu meters, 1891 value
kleines massel	0.961	0.0339	Austrian Empire	Pre-metric	Dry	1891 value, 2 becher

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
kochlianion	0.00455	0.000161	Greece (Attic)	Ancient	Dry	
kochlianion	0.00455	0.000161	Greece (Attic)	Ancient	Liquid	Spoon
koelak	3.741	0.1321	Indonesia	Colonial to pre-metric	Liquid	19/8 kan, 2003 reference
kojang	1.984	70.06	Indonesia	Colonial to pre-metric	Liquid	30 picul, 2003 reference
koku	180.4	6.370	Japan	Medieval to pre-metric	General	10 to, volume of rice a person would eat in a year, 2003 reference
kolläst	1.979	69.86	Sweden	Medieval to pre-metric	Dry	12 koltunna, 2003 reference
kolleh	16.69	0.5892	Algeria	Medieval to pre-metric	General	Consistent with 1891 value and 2003 reference
koltunna	164.9	5.822	Sweden	Medieval to pre-metric	Dry	9 fjerdingar, 2003 reference
kolve	0.125	0.00441	India	Pre-Akbar	Dry, rice, grains	1/2 chipte
konchē	0.0228	0.000803	Greece (Attic)	Ancient	Liquid	5 kochliaria
koolah	4.134	0.1460	Sumatra	Pre-metric	Dry	1891 value, dry measure
koorah (Mahratta, Bengal)	143.1	5.054	India	Pre-Akbar	Dry, rice, grains	1891 value
kop	0.8519	0.03008	Netherlands, Holland	Medieval to metric	Dry	2003 reference
kop	1.000	0.03531	Netherlands, Holland	Medieval to metric	Dry	Liter, 1891 term, "re-purposed" unit name
kop-tsong	0.052	0.0018	China	Medieval to pre-metric	Liquid	Alternate system, 1891 value
kor (Israeli)	229.7	8.111	Biblical, Talmudic	Ancient	Dry	2 letek
kor (Israeli)	229.7	8.112	Biblical, Talmudic	Ancient	Liquid	

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
korec	93.59	3.305	Czechoslovakia, Moravia	Medieval to pre-metric	General	1.325 merice, 2003 reference
korec	93.59	3.305	Slovakia	Medieval to pre-metric	Liquid	
kornskeppa	17.39	0.6140	Iceland	Medieval to pre-metric	Dry, com	18 pottar, 2003 reference
korntonde	139.0	4.907	Norway	Medieval to pre-metric	Dry, com	Barrel, 4.5 cubic fot, 2003 reference
korntonde	139.1	4.912	Denmark	Medieval to pre-metric	Dry, com	8 skoëppe, 4.5 cu fod, 144 pot, 1891 value, consistent with 2003 reference
korntunna	139.1	4.912	Iceland	Medieval to pre-metric	Dry, com	144 pottar, 2003 reference
koros (Israeli)	229.7	8.112	Biblical, Talmudic	Ancient	Liquid	
kortteli	0.327	0.0116	Finland	Medieval to pre-metric	Dry	used for both length and volume
kortteli	0.327	0.0116	Finland	Medieval to pre-metric	Liquid	
korzec	120.1	4.241	Poland	Medieval to pre-metric	Dry	4 cwierc, 1891 value, reported as 128 liters in Warsaw and in 2003 reference
kosushka	0.06150	0.002172	Russia	Medieval to pre-metric	Liquid	Measure or shot, 1/200 vedro, consistent with 2003 reference
kotylē	0.273	0.0096	Greece (Attic)	Ancient	Dry	6 kyathoi, consistent with 2003 reference
kotylē	0.273	0.0096	Greece (Attic)	Ancient	Liquid	6 kyathoi, consistent with 2003 reference
kouza	10.23	0.3612	Cyprus	Colonial to pre-metric	General	8 oke, 2003 reference
koyan	3,200	113	Thailand, Siam	Medieval to metric	General	2 ban, 2003 reference
koyang	5,200	183.6	Indonesia	Colonial to pre-metric	Dry	Dry measure, 1600 bambou, alternate reference
koyang (Amboyna)	1,950	68.86	Molucca Islands	Pre-metric	General	1891 value

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
koyang (Bantam)	5,200	183.6	Java	Pre-metric	Dry, rice	1891 value
koyang (Batavia)	2,200	77.69	Java	Pre-metric	Dry, rice	1891 value
kronchka	1,230	0.04343	Russia	Medieval to pre-metric	Liquid	Mug or flagon, 1/10 vedro, 10 tcharka, consistent with 2003 reference
krouchka	1,230	0.04343	Russia	Medieval to pre-metric	Liquid	Mug or flagon, 1/10 vedro, 10 tcharka, consistent with 2003 reference
krushky	1,312	0.04633	Russia	Medieval to pre-metric	Dry	Mug, 2/5 gamets, 12 chast, consistent with 2003 reference
kruzhka	1,230	0.04343	Russia	Medieval to pre-metric	Liquid	Mug or flagon, 1/10 vedro, 10 tcharka, consistent with 2003 reference
kruzhka	1,312	0.04633	Russia	Medieval to pre-metric	Dry	Mug, 2/5 gamets, 12 chast, consistent with 2003 reference
kuba	1,012	0.03573	Abyssinia	Pre-metric	General	23/10 madega, 2003 reference
kuba	1,016	0.03588	Ethiopia	Medieval to pre-metric	Liquid	
kuba	1,017	0.03590	Abyssinia	Pre-metric	General	1891 value
kubikfuss (Bremen)	24.2	0.854	Germany	Medieval to pre-metric	General	1891 value
kubikkfavn	5,850	206.6	Sweden	Medieval to pre-metric	General	
kulmet	11.48	0.4053	Latvia	Medieval to pre-metric	General	9 stoof, 2003 reference
kümpf (Hesse-Darmstadt)	80.01	2.825	Germany	Medieval to pre-metric	Dry	4 gescheid, 1891 value
kuna (Talmudic)			Biblical, Talmudic	Ancient	General	Unable to locate good definition of size
kunk	0.3441	0.01215	India	Pre-metric	Liquid	4 khoonke, 2003 reference

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
kuru	300	10.6	Akkadia	Ancient	Dry	300 bowls
kvarter	0.3271	0.01155	Sweden	Medieval to pre-metric	Liquid	4 junfru, 2003 reference
kwai	4.04	0.143	Burma, Birmah, Myanmar	Pre-metric	General	2 seit, 2003 reference
kwarta	1.00	0.0353	Poland	Medieval to pre-metric	General	4 kwarterka, 2003 reference, possibly post-metric
kwarta	5.114	0.1806	Malta	Medieval to pre-metric	Liquid, milk, oil	Quarter
kwarta	5.398	0.1906	Malta	Medieval to pre-metric	Liquid, beer, wine, spirits	Quarter
kwarterka	0.250	0.00883	Poland	Medieval to pre-metric	General	2003 reference
kwartin	0.320	0.0113	Malta	Medieval to pre-metric	Liquid, milk, oil	1921 Act only, quarter
kwian	2,000	70.6	Thailand, Siam	Medieval to metric	General	Cartload, 100 thang
kwien	3,200	113	Thailand, Siam	Medieval to metric	General	2 ban, 2003 reference
kyathos	0.0455	0.00161	Greece (Attic)	Ancient	Dry	10 kochliaria, reported as 0.045 liters in 2003
kyathos	0.0455	0.00161	Greece (Attic)	Ancient	Liquid	10 kochliaria
laang	0.500	0.0177	Thailand, Siam	Medieval to metric	General	4 kam meu, 2003 reference
lamany	0.126	0.00446	Burma, Birmah, Myanmar	Pre-metric	General	2003 reference
last	2,908	102.7	United Kingdom, England	Medieval to pre-metric	Dry	2 weys, 1891 value

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
last	2,944	104.0	Netherlands, Holland	Medieval to metric	Dry	27 mud, 2003 reference
last	3,000	105.9	Netherlands, Holland	Medieval to metric	Dry	30 hectoliters, 1891 term, "re-purposed" unit name
last	3,061	108.1	Denmark	Medieval to pre-metric	Dry	22 tönde, 2003 reference
last	3,957	139.7	Prussia	Medieval to pre-metric	Dry	6 malter, 1891 value
last (Bremen)	2,963	104.6	Germany	Medieval to pre-metric	Dry	40 scheffel, 1891 value
last (Hamburg)	3,159	111.5	Germany	Medieval to pre-metric	Dry	3 wispel, 1891 value
last (Hanover)	2,992	105.6	Germany	Medieval to pre-metric	Dry	2 wispel, 1891 value
last (Lubeck)	3,416	120.6	Germany	Medieval to pre-metric	Dry, wheat	8 drömt, 1891 value
lästi	1,507	53.21	Finland	Medieval to pre-metric	Liquid	
lästi	2,110	74.51	Finland	Medieval to pre-metric	Dry	
lastre	2,058	72.67	Argentina	Colonial to pre-metric	Dry	15 fanega, also reported as 12 fanegas in some references
łaszt	3,603	127.2	Poland	Medieval to pre-metric	Dry	30 korzec, significant variation by location, history, and commodity
lè	1,600.00	56.50	Vietnam, Annam	Medieval to pre-metric	General	1 ngũ × 1 ngũ × 1 thước
lè	0.100	0.00353	Vietnam, Annam	Medieval to pre-metric	Dry, unhusked rice	Different from other measures
legana	39.6	1.40	Persia, Iran	Medieval to pre-metric	General	15 capichas, 2003 reference
legger	516.0	18.22	South Africa	Colonial to pre-metric	Liquid	
legger	606	21.4	Indonesia	Colonial to pre-metric	Liquid	Liquid measure, alternate reference
legger	606	21.4	Java	Pre-metric	Liquid, spirits	1891 value, arrack or arak is distilled liquor

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
letek (Israeli)	114.8	4.054	Biblical, Talmudic	Ancient	Dry	5 ephah
leftek (Israeli)	114.8	4.054	Biblical, Talmudic	Ancient	Dry	5 ephah
libra	0.504	0.01781	Spain	Medieval to pre-metric	Liquid	4 copas, 1891 value, reported as 0.4888 l in 2003 reference
ligula	0.01144	0.0004040	Roman Empire	Ancient	Dry	1/288 congius, 2003 reference
ligula	0.01144	0.0004041	Roman Empire	Ancient	Liquid	1/288 congius, 1/48 sextarius, 2003 reference
lippie	2.250	0.07947	Scotland	Medieval to pre-metric	Dry, wheat, peas, beans, rice, salt	2003 reference
lippie	3.283	0.1159	Scotland	Medieval to pre-metric	Dry, oats, barley, malt	2003 reference
lippy	2.250	0.07947	Scotland	Medieval to pre-metric	Dry, wheat, peas, beans, rice, salt	2003 reference
lippy	3.283	0.1159	Scotland	Medieval to pre-metric	Dry, oats, barley, malt	2003 reference
liter	2.189	0.07729	Byzantine Empire, Turkey	Ancient	Liquid	Base unit, liquid measure
litra	2.189	0.07729	Byzantine Empire, Turkey	Ancient	Liquid	Base unit, liquid measure
litron	0.7901	0.02790	France	Medieval to pre-metric	Dry	1/16 boisseau, 2003 reference
load	1.454	51.34	United Kingdom, England	Medieval to pre-metric	Dry	5 quarters, 1891 value

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
load (squared)	1,189	41.98	United States	Colonial to modern	Wood	42 cft
load (unhewn)	755.2	26.67	United States	Colonial to modern	Wood	320 bfm
löcher (Brunswick)	1,909	0.06741	Germany	Medieval to pre-metric	Dry, wheat	1891 value, wheat
lof	64.72	2.285	Russia	Medieval to pre-metric	Dry	592 chast, 2003 reference
lof (Livonian)	68.88	2.432	Estonia	Medieval to pre-metric	General	6 hulmit, 2003 reference
lof (Reval)	34.44	1.216	Estonia	Medieval to pre-metric	General	3 hulmit, 2003 reference
log	0.184	0.00649	Jewish, Israel	Medieval to modern	General	11.21 cu in
log	0.505	0.0178	Biblical, Talmudic	Ancient	General	Base unit, 1/60 maris
log (Israeli)	0.32	0.011	Biblical, Talmudic	Ancient	Dry	Base unit
log (Israeli)	0.320	0.0113	Biblical, Talmudic	Ancient	Liquid	
long ardeb	10.56	0.3729	Ethiopia	Medieval to pre-metric	Dry	
loof	68.86	2.432	Latvia	Medieval to pre-metric	General	54 stoof, 2003 reference
lumin	0.0303	0.00107	Malta	Medieval to pre-metric	Dry	1/600 tomma
maatje	0.100	0.00353	Netherlands, Holland	Medieval to Metric	Dry	Deciliter, 1891 term, "re-purposed" unit name
maatje	0.100	0.00353	Netherlands, Holland	Medieval to metric	Liquids	Deciliter, 1891 term
madega	0.44	0.016	Abyssinia	Pre-metric	General	2003 reference
madega	0.44	0.016	Ethiopia	Medieval to pre-metric	Dry	
madega (Gondar)	0.404	0.0143	Abyssinia	Pre-metric	Grain	1/10 ardeb, for grain, at Gondar, 1891 value (continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
madega (Massowah)	0.489	0.0173	Abyssinia	Pre-metric	Grain	1/24 ardeb, for grain, at Massowah, 1891 value
magnum	1.515	0.05350	United Kingdom, England	Medieval to pre-metric	Liquid, wine	Still used for champagne exclusively
makuk	800	28.2	Syria	Medieval to pre-metric	General	250 rotl, 2003 reference
mal	18.00	0.6356	Korea	Medieval to pre-metric	General	
maloua	4.125	0.1457	Egypt	Pre-metric	Dry	2 keddah, 2003 reference
malouah	3.82	0.135	Egypt	Pre-metric	Dry	2 keddah, 1867 value
malter	191.0	6.744	Luxembourg	Medieval to pre-metric	General	
malter	659.5	23.29	Prussia	Medieval to pre-metric	Dry	12 scheffel, 1891 value
malter (Baden)	150.0	5.297	Germany	Medieval to pre-metric	Dry	10 sester, 1891 value
malter (Frankfort)	114.8	4.052	Germany	Medieval to pre-metric	Dry	4 simmer, 1891 value
malter (Hanover)	187.0	6.602	Germany	Medieval to pre-metric	Dry	6 hint, 1891 value
malter (Hesse-Darmstadt)	1,280	45.20	Germany	Medieval to pre-metric	Dry	4 simmer, 1891 value
malter (Saxony)	1,247	44.03	Germany	Medieval to pre-metric	Dry	12 scheffel, 1891 value
mapp (Anjar)	7.774	0.2745	India	Pre-Akbar	Dry, rice, grains	1891 value
mapte	0.500	0.0177	India	Pre-Akbar	Dry, rice, grains	1/2 ser
maquia (Lisbon)	0.845	0.0298	Portugal	Medieval to pre-metric	Dry	1891 value
maquia (Oporto)	0.973	0.0344	Portugal	Medieval to pre-metric	Dry	1891 value
marcal (Madras)	12.29	0.4341	India	Pre-Akbar	Dry, rice, grains	8 puddies, 1891 value, also reported as 14.2 liters

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
maris	6.48	0.229	Greece (Attic)	Ancient	Liquid	2 chous, 2003 reference
maris	30.30	1.070	Biblical, Talmudic	Ancient	General	Vol of water equal to 1 royal talent
martā	15.38	0.5432	Libya	Medieval to pre-metric	Dry	2 orba, 2003 reference, usually measured by weight as 12 oka water
mass	1.415	0.04996	Austrian Empire	Pre-metric	Liquid	1891 value, 2 kannen, consistent with 2003 reference
mass (Baden)	1.500	0.05297	Germany	Medieval to pre-metric	Liquid	10 glas, 1891 value
mass (Bavaria)	1.002	0.03538	Germany	Medieval to pre-metric	Liquid, wine	Example based on wine, 1891 value
mass (Hesse-Cassel)	1.984	0.07006	Germany	Medieval to pre-metric	Liquid, wine	4 schoppen, 1891 value
mass (Hesse-Cassel)	2.183	0.07707	Germany	Medieval to pre-metric	Liquid, beer	4 schoppen, 1891 value
mass (Hesse-Darmstadt)	2.113	0.07463	Germany	Medieval to pre-metric	Liquid	4 schoppen, 1891 value
mass (Württemberg)	1.837	0.06486	Germany	Medieval to pre-metric	Liquid	4 schoppen
massche (Frankfort)	0.448	0.0158	Germany	Medieval to pre-metric	Dry	4 schrott, 1891 value
mäschen	0.859	0.0303	Prussia	Medieval to pre-metric	Dry	1891 value
mässeche (Hesse-Cassel)	2.533	0.08944	Germany	Medieval to pre-metric	Dry	1891 value
mässeche (Hesse-Darmstadt)	5.001	0.1766	Germany	Medieval to pre-metric	Dry	1891 value

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
mässeche (Saxony)	1.624	0.05733	Germany	Medieval to pre-metric	Dry	1891 value
massel (Bavaria)	4.632	0.1636	Germany	Medieval to pre-metric	Dry	2 mässlein, 1891 value
massel (Bohemia)	5.850	0.2066	Austrian Empire	Pre-metric	Dry	12 seidel, 1891 value
mässel (common)	4.632	0.1636	Germany	Medieval to pre-metric	Dry	4 dreissiger, 2003 reference
mässlein (Baden)	1.500	0.05297	Germany	Medieval to pre-metric	Dry	10 becher, 1891 value
mässlein (Bavaria)	2.316	0.08178	Germany	Medieval to pre-metric	Dry	2 dreissiger, 1891 value
mässlein (Württemberg)	1.385	0.04889	Germany	Medieval to pre-metric	Dry	2 ecklein, 1891 value
mataro	23.3	0.824	Tripoli, Libya	Pre-metric	Liquid, oil	1891 value
maund	37.3	1.32	India	Pre-Akbar	Liquid	40 seer, see notes on seer
mecdemna	8.15	0.288	Saudi Arabia	Pre-metric	Dry	2003 reference
mecmeda	3.4	0.12	Arabia	Ancient to pre-metric	Dry	Estimated, 1891 value
media fanega	26.00	0.9181	Spain	Medieval to pre-metric	Dry	Range 13.1–55.5 liters, used avg (44 values)
medimno	71.62	2.529	Cyprus	Colonial to pre-metric	Dry	2 kile, 2003 reference
medimno	75.05	2.650	Cyprus	Colonial to pre-metric	Dry, grains	Used for grains, 1891 value
medimnos	52.42	1.851	Greece (Attic)	Ancient	Dry	48 choinikes, reported as 51.84 liters in 2003
medinno	75.05	2.650	Cyprus	Colonial to pre-metric	Dry, grains	Used for grains, 1891 value
medio	2.348	0.08290	Spain	Medieval to pre-metric	Dry	2 quartillos, reported as 2.313 l in 2003 reference
meio	0.688	0.0243	Portugal	Medieval to pre-metric	Liquid	2 quartillos, 2003 reference
meio	5.988	0.2115	Azores	Pre-metric	Dry	2 quartos, 1891 value

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
meio	6.75	0.238	Portugal	Medieval to pre-metric	Dry	2 quartos, 2003 reference
meisrin	0.660	0.0233	Ireland	Medieval to pre-metric	General	
merice	70.60	2.493	Czechoslovakia, Moravia	Medieval to pre-metric	General	2003 reference
messé	1.500	0.05297	Eretria	Medieval to pre-metric	General	2003 reference
metadella (Tuscany)	1.523	0.05376	Italy	Medieval to pre-metric	Dry	2 mezzete
metalli	17.90	0.6321	Algeria	Medieval to pre-metric	Liquid, oil	For oil, 2003 reference
methuselāh	6.819	0.2408	United Kingdom, England	Medieval to pre-metric	Liquid, wine	Still used for champagne exclusively
metrete	26.37	0.9311	Roman Empire	Ancient	Liquid	8 congii, 2003 reference
metretes	3.393	0.1198	Jewish, Israel	Medieval to modern	General	207 cu in
metrētēs	39.31	1.388	Greece (Attic)	Ancient	Liquid	12 choes, 2 amphora, reported as 38.88 in 2003
metretes (Israeli)	39.00	1.377	Biblical, Talmudic	Ancient	Liquid	New Testament
metter	10.0	0.353	Tunisia	Medieval to pre-metric	Liquid	Approx., 1891 value
metze	3.435	0.1213	Prussia	Medieval to pre-metric	Dry	4 mässehen, 1891 value
metze	61.49	2.171	Austrian Empire	Pre-metric	Dry	1891 value, 4 viertel, consistent with 2003 reference
metze (Bavaria)	37.06	1.308	Germany	Medieval to pre-metric	Dry	2 viertel, 1891 value
metze (Frankfort)	14.34	0.5065	Germany	Medieval to pre-metric	Dry	2 sechter, 1891 value
metze (Hesse-Cassel)	10.13	0.3578	Germany	Medieval to pre-metric	Dry	4 mässehen, 1891 value

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
metze (Saxony)	6.494	0.2293	Germany	Medieval to pre-metric	Dry	4 mäschen, 1891 value
metzel	61.49	2.171	Austrian Empire	Pre-metric	Dry	1891 value, 4 viertel, consistent with 2003 reference
metzen	37.06	1.309	Germany	Medieval to pre-metric	Dry	8 mäsael, 2003 reference
metzen	62.53	2.208	Hungary	Medieval to pre-metric	Dry	Dry measure, 1891 value, also reported as 62.45 l in 2003 reference
mezzaruola (Genoa)	129.3	4.567	Italy	Medieval to pre-metric	Liquid	2 barili, 1891 value
mezzetta (Tuscany)	0.151	0.00532	Italy	Medieval to pre-metric	Liquid	2 quartucci, 1891 value
mezzetta (Tuscany)	0.761	0.0269	Italy	Medieval to pre-metric	Dry	2 quartucci
mezzetta (Tuscany)	1.140	0.04024	Italy	Medieval to pre-metric	Liquid, Wine	1/2 fiasco
miéng	14,400.00	508.5	Vietnam, Annam	Medieval to pre-metric	General	3 ngũ × 3 ngũ × 1 thườc
millerole (Marseilles)	64.0	2.26	Tunisia	Medieval to pre-metric	Dry	2.06 whiba, 2003 reference
mina	0.505	0.0178	Biblical, Talmudic	Ancient	General	Base unit, 1/60 maris
mina (Genoa)	116.5	4.114	Italy	Medieval to pre-metric	Liquid, oil	Oil
mina (Genoa)	120.7	4.263	Italy	Medieval to pre-metric	Dry	8 quarti, 1891 value
mina (Parma)	23.51	0.8300	Italy	Medieval to pre-metric	Dry	8 quarteroli, 1891 value
mina (Sardinia, Turin)	19.17	0.6768	Italy	Medieval to pre-metric	Dry	2 quartièrè, 1891 value
mina (Tuscany)	12.18	0.4301	Italy	Medieval to pre-metric	Dry	2 quarti

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
mina (Venice, Milan)	10.00	0.3531	Italy	Medieval to pre-metric	Liquid	10 pinte, 1891 value
mine	75.85	2.678	France	Medieval to pre-metric	Dry	2 minot, 2003 reference
mingel (Bremen)	0.201	0.00711	Germany	Medieval to pre-metric	Liquid	1891 value
mingelen	1.200	0.04237	Netherlands, Holland	Medieval to metric	Liquid	2 pint, 2003 reference, also reported as 1.211 liters
mingle	1.200	0.04237	Netherlands, Holland	Medieval to metric	Liquid	2 pint, 2003 reference, also reported as 1.211 liters
minim	5.919E-05	2.090E-06	United Kingdom, England	Medieval to pre-metric	Liquid	
minim	5.919E-05	2.090E-06	United Kingdom, England	Medieval to pre-metric	Liquid, apothecaries'	1891 value
minim	6.161E-05	2.176E-06	United States	Colonial to modern	Liquid	~1 drop, 0.95 grains water
minot	37.93	1.339	France	Medieval to pre-metric	Dry	3 boisseau, 2003 value
minot	39.2	1.38	Canada	Pre-metric	Dry, wheat	Used for wheat in southern regions, 1891 value
mirze	197	6.95	Romania, Roumania	Pre- and post-metric	Dry	8 dimeria, 2003 reference
mistate	11.2	0.394	Crete, Candia	Colonial to pre-metric	Liquid, oil	1891 value
misure (Naples)	2.297	0.08112	Italy	Medieval to pre-metric	Dry	1891 value
misurelle (Naples)	0.103	0.00364	Italy	Medieval to pre-metric	Liquid, oil	1891 value
mitre	10.0	0.353	Tunisia	Medieval to pre-metric	Liquid	Approx., 1891 value
modd	290.9	10.27	Malta	Medieval to pre-metric	Dry	Weigh, 16 tomna, 289.8 liters in 1891 for corn

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
modios	87.55	3.092	Byzantine Empire, Turkey	Ancient	Liquid	Liquid measure
modios (Israeli)	8.46	0.299	Biblical, Talmudic	Ancient	Dry	Bushel, New Testament
modius	8.788	0.3103	Roman Empire	Ancient	Dry	2-2/3 congii, also listed as 8.62 liters, 2003 reference
modius (Talmudic)			Biblical, Talmudic	Ancient	General	Unable to locate good definition of size
modius castrensis	13.2	0.465	Roman Empire	Ancient	Dry	Est'd, 4 congii, 2003 reference
moggio (Tuscany)	584.6	20.64	Italy	Medieval to pre-metric	Dry	1891 value, 8 sacci
moio	250.2	8.835	Spain	Medieval to pre-metric	Liquid, water	16 arrobas, 2003 reference
moio	319.4	11.28	Brazil	Colonial to pre-metric	General	10 almude, 2003 reference
moio	810	28.6	Portugal	Medieval to pre-metric	Dry	15 fangas, 2003 reference
moio (Lisbon)	811.2	28.64	Portugal	Medieval to pre-metric	Dry	15 fangas, 1891 value
moio (Oporto)	934.0	32.98	Portugal	Medieval to pre-metric	Dry	15 fangas, 1891 value
mondell	0.303	0.0107	Malta	Medieval to pre-metric	Dry	1/60 tomna
motti	1,000	35.31	Finland	Medieval to pre-metric	Dry, firewood, waste paper	
mouthful	0.0142	0.000502	United Kingdom, England	Medieval to pre-metric	Liquid	4 dram, 3 teaspoons, 1/2 fluid ounce
mud	14	0.49	Morocco	Colonial to pre-metric	General	2003 reference, also reported as 183 liters in 1891 (possible error)
mud	109.0	3.849	Netherlands, Holland	Medieval to metric	Dry	4 schepel, 2003 reference

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
mudd	14	0.49	Morocco	Colonial to pre-metric	General	2003 reference, also reported as 183 liters in 1891 (possible error)
muḍde	100.0	3.531	Netherlands, Holland	Medieval to metric	Dry	Hectoliter, 1891 term, "re-purposed" unit name
muḍde	109.0	3.849	Netherlands, Holland	Medieval to metric	Dry	4 schepel, 2003 reference
miḍde (Augsburg)	56.48	1.994	Germany	Medieval to pre-metric	Liquid	1891 value
mudi (Mangalore)	45.88	1.620	India	Pre-Akbar	Dry, rice, grains	1891 value
muhd	14	0.49	Morocco	Colonial to pre-metric	General	2003 reference, also reported as 183 liters in 1891 (possible error)
muid	8.788	0.3103	Roman Empire	Ancient	Dry	2-2/3 congii, also listed as 8.62 liters, 2003 reference
muid	109.1	3.852	South Africa	Colonial to pre-metric	Liquid	
muid	159	5.60	Switzerland	Medieval to pre-metric	Liquid	4 setiers, 1891 value
muid	274.2	9.682	France	Medieval to pre-metric	Liquid	8 cubic French feet, 2 feuilletes, 2003 reference
muid	1,820	64.27	France	Medieval to pre-metric	Dry	12 setier, 2003 reference
müller-massel	3.843	0.1357	Austrian Empire	Pre-metric	Dry	1891 value, 2 grosse massel, consistent with 2003 reference
muoi	1.0	0.035	Cambodia	Post-metric	General	1/40 sesep, 2003 reference
musti	0.0516	0.00182	India	Pre-metric	Liquid	1966 value
mustron	0.0114	0.000402	Greece (Attic)	Ancient	Liquid	2.5 kochliaria
mutchkin	0.4238	0.01496	Scotland	Medieval to pre-metric	Liquid	4 gill, 2003 reference

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
muth	1.844	65.11	Austrian Empire	Pre-metric	Dry	1891 value, 30 metzen, consistent with 2003 reference
muthmassel	3.843	0.1357	Austrian Empire	Pre-metric	Dry	1891 value, 2 grosse massel, consistent with 2003 reference
mutseje	0.1500	0.005297	Netherlands, Holland	Medieval to metric	Liquid	2003 reference
nabuchadnezzar	15.15	0.5350	United Kingdom, England	Medieval to pre-metric	Liquid, wine	Still used for champagne exclusively
nelikko	43.99	1.553	Finland	Medieval to pre-metric	Dry	
neumass (Frankfort)	1.593	0.05627	Germany	Medieval to pre-metric	Liquid	1891 value
nhâm	0.002	0.00007	Vietnam, Annam	Medieval to pre-metric	General	Grain, 10 toát
nhón	0.0002	0.00001	Vietnam, Annam	Medieval to pre-metric	General	Grain
nilve	0.0625	0.00221	India	Pre-Akbar	Dry, rice, grains	1/2 kolve
niou	0.0100	0.000353	Thailand, Siam	Medieval to metric	General	2003 reference
nisf-keddah	0.96	0.034	Egypt	Pre-metric	Dry	2 robhah, 1867 value
nisf-keddah	1.031	0.03641	Egypt	Pre-metric	Dry	2 robhah, 2003 reference
nofs	0.568	0.0201	Malta	Medieval to pre-metric	Liquid, beer, wine, spirits	Half
nofs	0.639	0.0226	Malta	Medieval to pre-metric	Liquid, milk, oil	Half
noggin	0.02786	0.0009837	Ireland	Medieval to pre-metric	Liquid	1/4 pint (Irish), pre-1824, 2003 reference
noosfia	0.946	0.0334	Arabia	Ancient to pre-metric	Liquid	16 vakias, 1891 value

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
nösel (Leipzig)	0.600	0.0212	Germany	Medieval to pre-metric	Liquid	1/2 kanne
nössel (Brunswick)	0.468	0.0165	Germany	Medieval to pre-metric	Liquid	1891 value
nössel (Hanover)	0.490	0.0173	Germany	Medieval to pre-metric	Liquid	1891 value
nössel (Saxony)	0.602	0.0213	Germany	Medieval to pre-metric	Liquid	4 quartier, 1891 value, Leipsic, Desden 88.9%
nufsorba	3.846	0.1358	Libya	Medieval to pre-metric	Dry	1/2 orba, 2003 reference
nufsorbah	3.846	0.1358	Libya	Medieval to pre-metric	Dry	1/2 orba, 2003 reference
nusfiāh	0.946	0.0334	Arabia	Ancient to pre-metric	Liquid	16 vakias, 1891 value
nusfiāh	0.95	0.034	Saudi Arabia	Pre-metric	Liquid	16 vakia, 2003 reference
ochavillo	0.0734	0.00259	Spain	Medieval to pre-metric	Dry	Also reported as 0.07227 l in 2003 reference
octava	0.2969	0.01048	Argentina	Colonial to pre-metric	Liquid	1/8 frasco, 2003 reference
octave	73.00	2.578	United Kingdom, England	Medieval to pre-metric	Liquid, whiskey	
ohm	137.4	4.851	Prussia	Medieval to pre-metric	Liquid	2 eimer, 1891 value
ohm	137.4	4.852	Germany	Medieval to pre-metric	Liquid	2 eimer, 2003 reference
ohm	149.7	5.287	Sweden	Medieval to pre-metric	Liquid	155 potter, alternate reference
ohm	154.6	5.458	Denmark	Medieval to pre-metric	Liquid	4 anker, 2003 reference
ohm	157.0	5.545	Sweden	Medieval to pre-metric	Liquid	2 eimer, 2003 reference
ohm (Baden)	150.0	5.297	Germany	Medieval to pre-metric	Liquid	10 stützen, 1891 value
ohm (Bremen)	145.0	5.119	Germany	Medieval to pre-metric	Liquid	4 anker, 1891 value
ohm (Brunswick)	149.6	5.282	Germany	Medieval to pre-metric	Liquid	40 stübchen, 1891 value

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
ohm (Frankfort)	143.4	5.064	Germany	Medieval to pre-metric	Liquid	20 viertel, 1891 value
ohm (Hesse-Cassel)	174.6	6.166	Germany	Medieval to pre-metric	Liquid, beer	20 viertel, similar unit for wine with different value, 1891 value
ohm (Hesse-Darmstadt)	169.1	5.970	Germany	Medieval to pre-metric	Liquid	20 viertel, similar unit for wine with different value, 1891 value
ohm (Saxony)	151.7	5.357	Germany	Medieval to pre-metric	Liquid	2 eimer, 1891 value, Leipsic, Desden 88.9%
oka	1.337	0.04721	Greece	Medieval to pre-metric	Liquid	Varied, used average, consistent with 2003 reference
oka	1.417	0.05003	Romania, Roumania	Pre- and post-metric	Liquid	1891 value, reported as 1.415 l in 2003 reference
oke	1.279	0.04515	Cyprus	Colonial to pre-metric	General	2003 reference
oke	1.31	0.0462	Crete, Candia	Colonial to pre-metric	Liquid	1891 value
oke	1.417	0.05003	Romania, Roumania	Pre- and post-metric	Liquid	1891 value, reported as 1.415 l in 2003 reference
oke	1.54	0.0543	Romania, Roumania	Pre- and post-metric	Dry	2003 reference
okshoofd	230.4	8.136	Netherlands, Holland	Medieval to metric	Liquid, wine, spirits	Oxhead, 6 anker, volume of large barrel, still used in wine and spirits trade, 2003 reference, also reported as 232.5 liters
olluck (Madräs)	0.192	0.00678	India	Pre-Akbar	Dry, rice, grains	1891 value
öltunna	131.4	4.639	Iceland	Medieval to pre-metric	Dry	136 pottar, 2003 reference
omer	1.323	0.04672	Jewish, Israel	Medieval to modern	General	80.727 cu in
omer (Israeli)	2.29	0.0809	Biblical, Talmudic	Ancient	Dry	

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
orba	7.692	0.2716	Libya	Medieval to pre-metric	Dry	2 nufisorbah, 2003 reference, defined at metrication, also defined as 7.5 l.
orbah	6.71	0.237	Tripoli, Libya	Pre-metric	Dry	1891 value
ort	0.08179	0.002888	Sweden	Medieval to pre-metric	Dry	2003 reference
ort	0.08179	0.002888	Sweden	Medieval to pre-metric	Liquid	2003 reference
ort	0.327	0.0115	Norway	Medieval to pre-metric	Dry	1891 value
ort (Lubeck)	0.234	0.00826	Germany	Medieval to pre-metric	Liquid	1891 value
osmina	105.0	3.706	Russia	Medieval to pre-metric	Dry	One-eighth, 32 garnets, 2 pajaks, consistent with 2003 reference
osmini	105.0	3.706	Russia	Medieval to pre-metric	Dry	One-eighth, 32 garnets, 2 pajaks, consistent with 2003 reference
össe	0.572	0.0202	Prussia	Medieval to pre-metric	Liquid	1891 value
össe (Hamburg)	0.451	0.0159	Germany	Medieval to pre-metric	Liquid	1891 value
ottingar	15.57	0.5498	Finland	Medieval to pre-metric	General	2 sextingar, 2003 reference
ottingkar	4.348	0.1535	Denmark	Medieval to pre-metric	Dry	2 halvotting, 1891 value, see alternate value
ottingkar	17.39	0.6140	Denmark	Medieval to pre-metric	Dry	4 viertel, 2003 reference
ouebeh	30.6	1.08	Egypt	Pre-metric	Dry	2 kélé, 1867 value
ounce	0.02841	0.001003	United Kingdom, England	Medieval to pre-metric	Liquid, apothecaries'	8 drachm, 1891 value
ounce	0.182	0.00644	Byzantine Empire, Turkey	Ancient	Liquid	1/12 litra, Liquid measure
outava (common)	1.69	0.0596	Portugal	Medieval to pre-metric	Dry	2003 reference
outava (Lisbon)	1.690	0.05967	Portugal	Medieval to pre-metric	Dry	2 maquias, 1891 value

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
outava (Oporto)	1.946	0.06871	Portugal	Medieval to pre-metric	Dry	2 maquias, 1891 value
oxhoft	231.9	8.188	Denmark	Medieval to pre-metric	Liquid	6 anker, 2003 reference
oxhoft	235.5	8.317	Sweden	Medieval to pre-metric	Liquid	3 eimer, 2003 reference
oxhoft (Bremen)	217.4	7.678	Germany	Medieval to pre-metric	Liquid	6 anker, 1891 value
oxhoft (Brunswick)	224.4	7.924	Germany	Medieval to pre-metric	Liquid	1891 value
oxhoft (common)	206.1	7.278	Germany	Medieval to pre-metric	Liquid	3 eimer, 2003 reference
oxhoft (Hamburg)	216.6	7.648	Germany	Medieval to pre-metric	Liquid	30 viertel, 1891 value
oxhoft (Hanover)	235.3	8.308	Germany	Medieval to pre-metric	Liquid	30 viertel, 1891 value
oxhoft (Lubeck)	224.7	7.934	Germany	Medieval to pre-metric	Liquid	30 viertel, 1891 value
oxhoft (Saxony)	227.6	8.035	Germany	Medieval to pre-metric	Liquid	3 eimer, 1891 value, Leipsic, Desden 88.9%
oxhoofd	230.4	8.136	Netherlands, Holland	Medieval to metric	Liquid, wine, spirits	Oxhead, 6 anker, volume of large barrel, still used in wine and spirits trade, 2003 reference, also reported as 232.5 liters
oxhooft	230.4	8.136	Netherlands, Holland	Medieval to metric	Liquid, wine, spirits	Oxhead, 6 anker, volume of large barrel, still used in wine and spirits trade, 2003 reference, also reported as 232.5 liters
oxybaphon	0.0683	0.00241	Greece (Attic)	Ancient	Dry	1.5 kyathoi, consistent with 2003 reference
oxybathon	0.0683	0.00241	Greece (Attic)	Ancient	Dry	1.5 kyathoi, consistent with 2003 reference
oxybathon	0.0683	0.00241	Greece (Attic)	Ancient	Liquid	1.5 kyathoi
paegel	0.2415	0.008529	Denmark	Medieval to pre-metric	Liquid	2003 reference
pajak	52.48	1.853	Russia	Medieval to pre-metric	Dry	2 chetveriks, 2003 reference
pakha	0.550	0.0194	Sumatra	Pre-metric	Liquid	1891 value, liquid measure

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
pala	0.0516	0.00182	India	Pre-metric	Liquid	1966 value
pallie (Bengal)	4.119	0.1455	India	Pre-Akbar	Dry, rice, grains	4 raik, 1891 value
pally	5.505	0.1944	India	Pre-metric	Liquid	4 raik, 2003 reference
panilla	0.126	0.00444	Spain	Medieval to pre-metric	Liquid, oil	1891 value
panilla	0.1564	0.005523	Spain	Medieval to pre-metric	Liquid	1/25 cuartilla, 2003 reference
panni	87.96	3.106	Finland	Medieval to pre-metric	Dry	
parah	110.1	3.8877	India	Pre-metric	Liquid	16 adoulie, 2003 reference
parah (Bombay)	110.1	3.889	India	Pre-Akbar	Dry, rice, grains	16 adoulies, 1891 value
parah (Madras)	61.47	2.170	India	Pre-Akbar	Dry, rice, grains	5 marcals, 1891 value
parrah	25.43	0.8978	Sri Lanka, Ceylon	Medieval to pre-metric	Dry	1/8 ammonam, also reported as 1/16 in north, defined in 1835 as cube 11.571 inches on a side
parrah	25.5	0.902	Ceylon, Sri Lanka	Colonial to pre-metric	Liquid	1891 value
parrah	25.56	0.9025	Sri Lanka, Ceylon	Medieval to pre-metric	Liquid	6.75 gallons
parsiktu	60	2.1	Akkadia	Ancient	Dry	60 bowls
pav	0.23	0.0082	India	Pre-Akbar	Liquid	See notes on seer
payok	52.48	1.853	Russia	Medieval to pre-metric	Dry	2 chetveriks, 2003 reference
peck	8.810	0.3111	United States	Colonial to modern	Dry	2 gallons

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
peck	9.00	0.318	Scotland	Medieval to pre-metric	Dry, wheat, peas, beans, rice, salt	Things sold by level measure
peck	9.002	0.3179	Scotland	Medieval to pre-metric	Dry, wheat, peas, beans, rice, salt	4 lippy, 2003 reference
peck	9.087	0.3209	United Kingdom, England	Medieval to pre-metric	Dry	2 dry gallons, 1891 value
peck	13.13	0.4637	Scotland	Medieval to pre-metric	Dry, oats, barley, malt	4 lippy, for things sold by "heaped" measure, 2003 reference
perch	700.8	24.75	United Kingdom, England	Medieval to pre-metric	Dry, stone	24.75 cft dry stone
pfiff	0.1769	0.006245	Austrian Empire	Pre-metric	Liquid	1891 value, consistent with 2003 reference
picul	66.14	2.335	Indonesia	Colonial to pre-metric	Liquid	13/5 takar, 2003 reference
pied cube	34.28	1.210	France	Medieval to pre-metric	Dry	French cubic foot, dates to ancient times
pied cube	34.28	1.210	France	Medieval to pre-metric	Liquid	French cubic foot, dates to ancient times
pignate (Naples)	0.495	0.0175	Italy	Medieval to pre-metric	Liquid, oil	1891 value
pikkukappa	2.500	0.08828	Finland	Medieval to pre-metric	Dry	Related to kannu
pikkukappa	2.500	0.08828	Finland	Medieval to pre-metric	Liquid	Related to kannu
pin	20.79	0.7343	United Kingdom, England	Medieval to pre-metric	Liquid, beer	4.5 Imp gallons, 1/8 beer barrel
pinch	0.0006	0.00002	Shoshone	Pre-colonial	Cooking	Cooking measure, very roughly estimated volume

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
pinch	6.161E-04	2.176E-05	United States	Colonial to modern	Cooking	1/48 fluid ounce
ping	517.7	18.28	China	Medieval to pre-metric	General	5 chei, 1966 value
pint	0.1114	0.003935	Ireland	Medieval to pre-metric	Liquid	Pre-1824, 2003 reference
pint	0.4732	0.01671	United States	Colonial to modern	Liquid	2 cups, 16.65 wt ounces water, roughly 1 lb avordupois
pint	0.5506	0.01944	United States	Colonial to modern	Dry	33.6 cu in
pint	0.568	0.0201	United Kingdom, England	Medieval to pre-metric	Liquid, wine	4 gills, 1891 value
pint	0.5683	0.02007	United Kingdom, England	Medieval to pre-metric	Dry	1891 value
pint	0.568	0.0201	United Kingdom, England	Medieval to pre-metric	Liquid	1 cups, 20 fluid ounces
pint	0.5683	0.02007	United Kingdom, England	Medieval to pre-metric	Liquid, apothecaries'	20 ounces, 1891 value
pint	0.578	0.0204	United Kingdom, England	Medieval to pre-metric	Liquid, beer, ale	4 gills, 1891 value
pint	0.6000	0.02119	Netherlands, Holland	Medieval to metric	Liquid	4 mutsjie, 2003 reference
pinta (Piedmont, Turin)	1.565	0.05525	Italy	Medieval to pre-metric	Liquid	2 boccale, 1891 value

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
pinta (Venice, Milan)	1.000	0.03531	Italy	Medieval to pre-metric	Liquid	10 coppi, 1891 value
pinte	0.9521	0.03362	France	Medieval to pre-metric	Liquid	1/36 French cubic foot, about 1 quart US, 2 chopine
pinte (Bohemia)	1.909	0.06741	Austrian Empire	Pre-metric	Liquid	4 seidel, 1891 value
pinte (Genoa)	1.293	0.04567	Italy	Medieval to pre-metric	Liquid	1891 value
pints	0.142	0.00502	Malta	Medieval to pre-metric	Liquid, beer, wine, spirits	
pipa	383.3	13.53	Brazil	Colonial to pre-metric	General	12 almude, also reported as 15 almude or 479.2 liters in 2003 reference
pipa	416.4	14.70	Madeira	Pre-metric	Liquid, Wine	1891 value
pipa	420.0	14.83	Portugal	Medieval to pre-metric	Liquid	Barrel, 25 almudes
pipa	422.3	14.91	Spain	Medieval to pre-metric	Liquid, water	27 arrobas, 2003 reference
pipa	429	15.1	Portugal	Medieval to pre-metric	Liquid	26 almudes, 2003 reference
pipa	456.0	16.10	Argentina	Colonial to pre-metric	Liquid	192 frasco, 4 cuarta, 2003 reference
pipa (Lisbon)	448.8	15.85	Portugal	Medieval to pre-metric	Liquid	Barrel, 26 almudes, 1891 value
pipa (Oporto)	652.1	23.03	Portugal	Medieval to pre-metric	Liquid	Barrel, 26 almudes, 1891 value
pipe	411.3	14.52	France	Medieval to pre-metric	Liquid	1.5 muid, 2003 reference
pipe	442.8	15.64	Russia	Medieval to pre-metric	Liquid	12 anker, 2003 reference
pipe	463.8	16.38	Denmark	Medieval to pre-metric	Liquid	2 oxhoft, 2003 reference
pipe	471.1	16.63	Sweden	Medieval to pre-metric	Liquid	180 kanna, 2003 reference
pipe	476.9	16.84	United States	Colonial to modern	Liquid, wine	2 hogsheads
pipe	477.0	16.84	United States	Colonial to modern	Liquid	126 gallons, 1891 value

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
pipe	478.0	16.88	United Kingdom, England	Medieval to pre-metric	Liquid, beer, wine, spirits	Range 409–546 liters, average
pipe	499.1	17.62	United Kingdom, England	Medieval to pre-metric	Liquid, beer	2 beer hogsheads, 3 beer barrels, 108 Imp gal.
pipe	582	20.5	Paraguay	Colonial to pre-metric	Liquid	192 frasco, 6 baril, 2003 reference
pipe	1,198	42.31	Ireland	Medieval to pre-metric	Liquid	2 tun, pre-1824, 2003 reference
pipe	572.5	20.21	United Kingdom, England	Medieval to pre-metric	Liquid, wine	2 wine hogsheads, 3 tierce, 7 roundlet, or 126 wine gallons, reported as 108 gallons in 1891, varies from 90 to 120 gal. depending on type of wine
planke (Lubeck)	0.468	0.0165	Germany	Medieval to pre-metric	Liquid	2 ort, 1891 value
podawqa	16.0	0.565	Tatar	Medieval to pre-metric	Liquid	Pot, volume of 16 kg water
poegel	0.2415	0.008529	Denmark	Medieval to pre-metric	Liquid	2003 reference
polougarnetz	1.640	0.05791	Russia	Medieval to pre-metric	Dry	15 chast, 2003 reference
polou-stoff	0.769	0.0271	Russia	Medieval to pre-metric	Liquid, wine	Bottle of wine, 1/16 vedro, 6.25 tcharka, consistent with 2003 reference
polou-vedro	6.15	0.217	Russia	Medieval to pre-metric	Liquid	4 stoffs, 1891 value
pony	0.0213	0.000752	United Kingdom, England	Medieval to pre-metric	Liquid	6 dram, 3/4 fluid ounce
posson	0.1190	0.004202	France	Medieval to pre-metric	Liquid	2 demi-posson, 2003 reference
pot	0.9651	0.03408	Norway	Medieval to pre-metric	Liquid	2003 reference
pot	0.966	0.0341	Sweden	Medieval to pre-metric	Liquid	1891 reference

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
pot	0.9662	0.03412	Denmark	Medieval to pre-metric	Dry	1891 value, consistent with 2003 reference
pot	1.59	0.0560	Switzerland	Medieval to pre-metric	Liquid	1/18 cubic pied, 1891 value
pot	1.904	0.06723	France	Medieval to pre-metric	Liquid	2 pinte, 2003 reference
pote	8.400	0.2966	Portugal	Medieval to pre-metric	Liquid	Pot, 6 Canadas
pote (Lisbon)	8.630	0.3047	Portugal	Medieval to pre-metric	Liquid	6 Canadas, 1891 value
pote (Oporto)	12.54	0.4428	Portugal	Medieval to pre-metric	Liquid	6 Canadas, 1891 value
pott	0.9662	0.03412	Denmark	Medieval to pre-metric	Liquid	4 paegel, 2003 reference, reported in 1683 and 1891—consistent
pott	0.9662	0.03412	Denmark	Medieval to pre-metric	Dry	1891 value, consistent with 2003 reference
pottar	0.9661	0.03411	Iceland	Medieval to pre-metric	Dry	As defined in 1921 conversion, 2003 reference
potte	0.9662	0.03412	Denmark	Medieval to pre-metric	Dry	1891 value, consistent with 2003 reference
pottle	1.783	0.06296	Ireland	Medieval to pre-metric	Liquid	2 quarts, pre-1824, 2003 reference
pottle	2.273	0.08026	United Kingdom, England	Medieval to pre-metric	Dry	1/2 dry gallon, 2 quarts, 1891 value
pottle	2.273	0.08026	United Kingdom, England	Medieval to pre-metric	Liquid	2 quarts, 80 fluid ounces, 1/2 gallon
pouce cube	0.0198	0.000701	France	Medieval to pre-metric	Dry	French cubic inch
pouce cube	0.0198	0.000701	France	Medieval to pre-metric	Liquid	French cubic inch
poure	68.86	2.432	Latvia	Medieval to pre-metric	General	54 stoof, 2003 reference
poçiç	32.0	1.13	Tatar	Medieval to pre-metric	Liquid	2 pot
prastha	0.825	0.0291	India	Pre-metric	Liquid	2 cudava, 1966 value

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
probmetze	0.06005	0.002120	Austrian Empire	Pre-metric	Dry	2003 reference
profane mina	0.500	0.0177	Persia, Iran	Medieval to pre-metric	General	50 shekel, about 27 cubic aiwas, inconsistent, probably post-metric
puddy (Madras)	1.537	0.05426	India	Pre-Akbar	Dry, rice, grains	8 ollucks, 1891 value
pulzier kubu	0.0104	0.000367	Malta	Medieval to pre-metric	General	1/1728 xiber kubu
puncheon	299.5	10.58	Ireland	Medieval to pre-metric	Liquid	2 tierce, pre-1824, 2003 reference
puncheon	317.9	11.23	United States	Colonial to modern	Liquid, wine	2 tierces
puncheon	318.0	11.23	United States	Colonial to modern	Liquid	84 gallons, 1891 value
puncheon	332.7	11.75	United Kingdom, England	Medieval to pre-metric	Liquid, Beer	Range 318–546 liters, average
puncheon	381.7	13.48	United Kingdom, England	Medieval to pre-metric	Liquid, wine	2 tierce, 84 wine gallons, 1/3 wine tun, reported as same as pipe or butt in 1891 as 108 gallons
puncheon	432.0	15.25	United Kingdom, England	Medieval to pre-metric	Liquid, beer, wine, spirits	Range 318–546 liters, average
puncheon (English)	386	13.6	West Indies	Colonial to pre-metric	Liquid	1891 value
qab (Israeli)	1.276	0.04506	Biblical, Talmudic	Ancient	Liquid	
qab (Israeli)	1.28	0.0452	Biblical, Talmudic	Ancient	Dry	4 log
qafiz	20.46	0.7225	Malta	Medieval to pre-metric	Liquid, Milk, Oil	1921 Act only, 20.8 liters in 1891 for oil

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
qak (Israeli)	1.28	0.0452	Biblical, Talmudic	Ancient	Dry	4 log
qasba kubu	9.202	324.9	Malta	Medieval to pre-metric	General	1 qasba cubed, 512 xiber kubu
qometz (Talmudic)			Biblical, Talmudic	Ancient	General	Unable to locate good definition of size
qū	1.0	0.035	Akkadia	Ancient	Dry	Base unit
quade	1.904	0.06723	France	Medieval to pre-metric	Liquid	2 pinte, 2003 reference
quadrantal	26.36	0.9308	Roman Empire	Ancient	Dry	3 modius, 2003 reference
quadruple heqat	19.08	0.6737	Egypt	Ancient	General	4 heqat
quar	0.384	0.0136	Russia	Medieval to pre-metric	Liquid	1891 value
quart	0.8915	0.03148	Ireland	Medieval to pre-metric	Liquid	8 pints, pre-1824, 2003 reference
quart	1.101	0.03888	United States	Colonial to modern	Dry	2 pints
quart	1.136	0.04011	United Kingdom, England	Medieval to pre-metric	Liquid, wine	2 pints, 1891 value
quart	1.137	0.04013	United Kingdom, England	Medieval to pre-metric	Dry	2 pints, 1891 value
quart	1.137	0.04013	United Kingdom, England	Medieval to pre-metric	Liquid	2 pint, 40 fluid ounces, 1/4 gallon
quart	1.145	0.04043	Germany	Medieval to pre-metric	Liquid	2003 reference
quart	1.155	0.04079	United Kingdom, England	Medieval to pre-metric	Liquid, beer, ale	2 pints, 1891 value

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
quart	3.160	0.1116	France	Medieval to pre-metric	Dry	4 litron, 2003 reference
quart	3.390	0.1197	Scotland	Medieval to pre-metric	Liquid	
quart	0.9464	0.03342	United States	Colonial to modern	Liquid	2 pints
quart (reputed)	0.7577	0.02675	United Kingdom, England	Medieval to pre-metric	Liquid, wine	Still used for champagne exclusively
quarta (Ancona)	70.25	2.481	Italy	Medieval to pre-metric	Dry	4 starelli, 1891 value
quarta (common)	71.97	2.541	Balearic Islands	Pre-metric	Liquid	6 barcellas, 2003 reference
quarta (Rome)	73.61	2.599	Italy	Medieval to pre-metric	Dry	4 starelli, 1891 value
quartarius	0.1373	0.004848	Roman Empire	Ancient	Dry	1/24 congius, 2003 reference
quartarius	0.1373	0.004848	Roman Empire	Ancient	Liquid	1/24 congius, 2003 reference
quarta	68.55	2.421	France	Medieval to pre-metric	Liquid	9 veltes, 2003 reference
quarte (common)	4.175	0.1474	Balearic Islands	Pre-metric	Dry	4 almudes, 2003 reference
quart	0.3271	0.01155	Sweden	Medieval to pre-metric	Liquid	4 junfru, 2003 reference
quart	0.4362	0.01540	Sweden	Medieval to pre-metric	Dry	5-1/3 junkfra, 2003 reference
quart	107.0	3.778	United Kingdom, England	Medieval to pre-metric	Liquid, beer, wine, spirits	Range 77-136 liters, average
quart	290.8	10.27	United Kingdom, England	Medieval to pre-metric	Dry	2 coomb, 64 dry gallons, 1/4 dry tun, 1891 value
quarterola (Parma)	2.938	0.1037	Italy	Medieval to pre-metric	Dry	1891 value
quarteron	15.0	0.530	Switzerland	Medieval to pre-metric	Dry	5/9 cubic pied, 10 emines, 1891 value
quarterone	0.1564	0.005523	Spain	Medieval to pre-metric	Liquid	1/25 cuartilla, 2003 reference

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
quarterone (Bologna)	9.823	0.3469	Italy	Medieval to pre-metric	Dry	4 quarticini, 1891 value
quarterone (Bologna)	19.64	0.6936	Italy	Medieval to pre-metric	Liquid	15 boccale, 1891 value
quartés (Majorca)	4.174	0.1474	Balearic Islands	Pre-metric	Dry	1891 value
quarticina (Bologna)	2.456	0.08671	Italy	Medieval to pre-metric	Dry	1891 value
quartier	1.145	0.04042	Prussia	Medieval to pre-metric	Liquid	2 össel, 1891 value
quartier (Bremen)	0.805	0.0284	Germany	Medieval to pre-metric	Liquid	4 mingel, 1891 value
quartier (Brunswick)	0.935	0.0330	Germany	Medieval to pre-metric	Liquid	2 nössel, 1891 value
quartier (Hamburg)	0.902	0.0319	Germany	Medieval to pre-metric	Liquid	2 össel, 1891 value
quartier (Hanover)	0.980	0.0346	Germany	Medieval to pre-metric	Liquid	2 nössel, 1891 value
quartier (Lubeck)	0.936	0.0331	Germany	Medieval to pre-metric	Liquid	2 planken, 1891 value
quartier (Saxony)	0.151	0.00531	Germany	Medieval to pre-metric	Liquid	1891 value, Leipsic, Desden 88.9% of this
quartière (Sardinia, Turin)	9.584	0.3384	Italy	Medieval to pre-metric	Dry	4 copelli, 1891 value
quartilho	0.350	0.0124	Portugal	Medieval to pre-metric	Liquid	Pint, 1/4 Canada
quartilho (Lisbon)	0.360	0.0127	Portugal	Medieval to pre-metric	Liquid	1891 value
quartilho (Oporto)	0.522	0.0184	Portugal	Medieval to pre-metric	Liquid	1891 value
quarrilla	3.140	0.1109	Spain	Medieval to pre-metric	Liquid, Oil	25 panillas, 1891 value
quarrilla	3.910	0.1381	Spain	Medieval to pre-metric	Liquid	2003 reference
quartillo	0.344	0.0121	Portugal	Medieval to pre-metric	Liquid	2003 reference

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
quartillo	0.504	0.01781	Spain	Medieval to pre-metric	Liquid	4 copas, 1891 value, reported as 0.4888 l in 2003 reference
quartillo	0.51	0.018	Central America	Colonial to pre-metric	General	2003 reference
quartillo	0.51	0.018	Costa Rica	Colonial to pre-metric	General	2003 reference
quartillo	0.51	0.018	El Salvador	Colonial to pre-metric	General	2003 reference
quartillo	0.51	0.018	Guatemala	Colonial to pre-metric	General	2003 reference
quartillo	0.51	0.018	Honduras	Colonial to pre-metric	General	2003 reference
quartillo	0.51	0.018	Nicaragua	Colonial to pre-metric	Liquids	2003 reference
quartillo	1.111	0.03923	Chile	Colonial to pre-metric	Liquid	Also reported as 1.1 liters in 1891 and 1.010 liters in 2003 reference
quartillo	1.174	0.04145	Spain	Medieval to pre-metric	Dry	4 raciones, reported as 1.156 l in 2003 reference
quartin	27.14	0.9583	Balearic Islands	Pre-metric	Dry	26 almudes, 2003 reference
quartin (Majorca)	27.13	0.9580	Balearic Islands	Pre-metric	Dry	1891 value
quartino (Piedmont, Turin)	0.391	0.0138	Italy	Medieval to pre-metric	Liquid	1891 value
quarto	2.994	0.1057	Azores	Pre-metric	Dry	1891 value
quarto	3.38	0.119	Portugal	Medieval to pre-metric	Dry	2 outavas, 2003 reference
quarto (Genoa)	15.09	0.5328	Italy	Medieval to pre-metric	Dry	12 gombette, 1891 value
quarto (Lisbon)	3.380	0.1193	Portugal	Medieval to pre-metric	Dry	2 outavas, 1891 value
quarto (Naples)	0.619	0.0219	Italy	Medieval to pre-metric	Liquid, Oil	6 misurelle, 1891 value
quarto (Oporto)	3.892	0.1374	Portugal	Medieval to pre-metric	Dry	2 outavas, 1891 value
quarto (Tuscany)	6.090	0.2150	Italy	Medieval to pre-metric	Dry	4 metadelle

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
quartucci (Ancona)	3.193	0.1128	Italy	Medieval to pre-metric	Dry	1891 value
quartucci (Rome)	0.112	0.00396	Italy	Medieval to pre-metric	Liquid, oil	1891 value
quartucci (Rome)	0.114	0.00402	Italy	Medieval to pre-metric	Liquid, wine	1891 value
quartucci (Rome)	3.346	0.1181	Italy	Medieval to pre-metric	Dry	1891 value
quartuccio (Tuscany)	0.381	0.0134	Italy	Medieval to pre-metric	Dry	2 bussoli
quartucco (Tuscany)	0.0753	0.00266	Italy	Medieval to pre-metric	Liquid	1891 value
quartucco (Tuscany)	0.570	0.0201	Italy	Medieval to pre-metric	Liquid, wine	1/2 boccale
quei	1.0350E -04	3.6547E -06	China	Medieval to pre-metric	General	1966 value
quarter	0.327	0.0116	Norway	Medieval to pre-metric	Liquid	4 jungfrus, 1891 value
quarter	1.308	0.04619	Norway	Medieval to pre-metric	Dry	4 orts, 1891 value
racion	0.293	0.0104	Spain	Medieval to pre-metric	Dry	4 ochavillos, reported as 0.2891 l in 2003 reference
raik	1.376	0.04860	India	Pre-metric	Liquid	4 kunk, 2003 reference
raik (Bengal)	1.030	0.03636	India	Pre-Akbar	Dry, rice, grains	16 khoonke, 1891 value
register ton	2,832	100.0	United States	Colonial to modern	General	100 cft, 1891 value, used for ship capacity, typically ship can only carry about 75–80% of this weight
rehoboam	4.546	0.1605	United Kingdom, England	Medieval to pre-metric	Liquid, Wine	Still used for champagne exclusively

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
rick	1,208	42.66	United States	Colonial to modern	Wood	4 ft × 8 ft × 16 in
ro	0.015	0.00053	Egypt	Ancient	General	1/320 heqat
ro	7.64	0.270	Egypt	Pre-metric	Dry	2 malouah, 1867 value
ro	8,250	0.2913	Egypt	Pre-metric	Dry	2 maloua, 2003 reference
rob	7.64	0.270	Egypt	Pre-metric	Dry	2 malouah, 1867 value
rob	8,250	0.2913	Egypt	Pre-metric	Dry	2 maloua, 2003 reference
robhah	0.48	0.017	Egypt	Pre-metric	Dry	2 tounmah, 1867 value
robhah	0.5156	0.01821	Egypt	Pre-metric	Dry	2 tounmah, 2003 reference
roquille	0.02975	0.001050	France	Medieval to pre-metric	Liquid	1/32 pinte, 2003 reference
rotl	3.2	0.11	Syria	Medieval to pre-metric	General	2003 reference
roub-kaddah	0.48	0.017	Egypt	Pre-metric	Dry	2 tounmah, 1867 value
roubough	7.64	0.270	Egypt	Pre-metric	Dry	2 malouah, 1867 value
roubough	8,250	0.2913	Egypt	Pre-metric	Dry	2 maloua, 2003 reference
rubbio (Ancona)	281.0	9.922	Italy	Medieval to pre-metric	Dry	4 quarte, 1891 value
rubbio (Piedmont, Turin)	9,388	0.3315	Italy	Medieval to pre-metric	Liquid	6 pinte, 1891 value
rubbio (Rome)	294.4	10.40	Italy	Medieval to pre-metric	Dry	4 quarte, 1891 value
rubblo (Rome)	294.5	10.40	Italy	Medieval to pre-metric	Liquid, oil	
rundlet	64.18	2.266	Ireland	Medieval to pre-metric	Liquid	18 gallons, pre-1824, 2003 reference
rundlet	81.78	2.888	United Kingdom, England	Medieval to pre-metric	Liquid, wine	18 wine gallons, 1/7 wine pipe
runlet	68.14	2.406	United States	Colonial to modern	Liquid	18 gallons, 1891 value

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
saâ	48.06	1.697	Algeria	Medieval to pre-metric	General	2.4 tarri, 2003 reference, also reported as 48 l in 1891
saah	3.84	0.136	Tunisia	Medieval to pre-metric	Dry	1/129 cafisso, 2003 reference
saah	48.06	1.697	Algeria	Medieval to pre-metric	General	2.4 tarri, 2003 reference, also reported as 48 l in 1891
sabbitha	7.26	0.256	Persia, Iran	Medieval to pre-metric	General	22 sextario, 2003 reference
sac	150	5.30	Switzerland	Medieval to pre-metric	Dry	10 quarteron, 1891 value
sacco (Modena)	140.8	4.972	Italy	Medieval to pre-metric	Dry	2 staja, 1891 value
sacco (Sardinia, Turin)	115.0	4.061	Italy	Medieval to pre-metric	Dry	3 staje, 1891 value
sacco (Tuscany)	73.08	2.581	Italy	Medieval to pre-metric	Dry	3 staja
sacred mina	0.600	0.0212	Persia, Iran	Medieval to pre-metric	General	60 shekel, about 1 cubic dva, inconsistent
sahh	56	2.0	Morocco	Colonial to pre-metric	General	4 mudd, 2003 reference
sai	0.00180	0.0000637	Japan	Medieval to pre-metric	General	
salma	290.9	10.27	Malta	Medieval to pre-metric	Dry	Weigh, 16 tomna, 289.8 liters in 1891 for corn
salma	290.9	10.27	Malta	Medieval to pre-metric	General	2003 reference, corrected
salma (Naples)	158.4	5.595	Italy	Medieval to pre-metric	Liquid, oil	16 staja, 1891 value
Salma (Sicily)	83.27	2.940	Italy	Medieval to pre-metric	Liquid	1891 value
salma generale (Sicily)	274.9	9.706	Italy	Medieval to pre-metric	Dry	1891 value
salma grosso (Sicily)	352.4	12.44	Italy	Medieval to pre-metric	Dry	1891 value

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
salmarazd	9.092	0.3210	United Kingdom, England	Medieval to pre-metric	Liquid, wine	Still used for champagne exclusively
salt spoon	0.001232	0.00004351	United States	Colonial to modern	Cooking	2.5 drops
sao	0.002	0.00007	Vietnam, Annam	Medieval to pre-metric	General	Grain, 10 toát
sarakowaja	492.0	17.37	Russia	Medieval to pre-metric	Liquid	Barrel, 40 vedro, 1891 value, consistent with 2003 reference
sat	0.295	0.0104	Thailand, Siam	Medieval to metric	Dry	Dry measure, 1891 value
sat	20.0	0.706	Thailand, Siam	Medieval to metric	General	Bucket, 20 tanan, 2003 reference
sat	25.0	0.883	Thailand, Siam	Medieval to metric	General	Measuring bucket, ~25 thanan, alternate value
saton	4.410	0.1557	Jewish, Israel	Medieval to modern	General	269.091 cu in
saton (Israeli)	7.68	0.271	Biblical, Talmudic	Ancient	Dry	6 kav
saton (per Josephus)	13.58	0.4794	Jewish, Israel	Medieval to modern	General	828.28 cu in
scheepston (wisse)	1,000	35.31	Netherlands, Holland	Medieval to metric	Dry	Kiloliter, 1891 term, "re-purposed" unit name
scheffel	54.96	1.941	Prussia	Medieval to pre-metric	Dry	4 viertel, 1891 value
scheffel (Bavaria)	222.3	7.851	Germany	Medieval to pre-metric	Dry	6 metzen, 1891 value
scheffel (Bremen)	74.06	2.615	Germany	Medieval to pre-metric	Dry	4 viertel, 1891 value
scheffel (Brunswick)	305.4	10.79	Germany	Medieval to pre-metric	Dry, wheat	Specific for wheat, 1891 value, 10 himt
scheffel (Brunswick)	366.5	12.94	Germany	Medieval to pre-metric	Dry, oats	Commodity specific for oats, 1891 value

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
scheffel (Hamburg)	105.3	3.718	Germany	Medieval to pre-metric	Dry	2 fass, 1891 value
scheffel (Hesse-Cassel)	81.05	2.862	Germany	Medieval to pre-metric	Dry	2 hint, 1891 value
scheffel (Lubeck)	35.58	1.256	Germany	Medieval to pre-metric	Dry, wheat	4 fass, 1891 value, for oats and fruit = 39.5 liters
scheffel (Saxony)	103.9	3.669	Germany	Medieval to pre-metric	Dry	4 viertel, 1891 value
scheffel (Wurtemberg)	177.2	6.258	Germany	Medieval to pre-metric	Dry	8 simri, 1891 value
schenknass (Nuremberg)	1.079	0.03810	Germany	Medieval to pre-metric	Liquid	1891 value
schepel	10.00	0.3531	Netherlands, Holland	Medieval to metric	Dry	Decaliter, 1891 term, “re-purposed” unit name
schepel	27.26	0.9626	Netherlands, Holland	Medieval to metric	Dry	4 vierd, 2003 reference
schoppe (Hesse-Cassel)	0.546	0.0193	Germany	Medieval to pre-metric	Liquid, beer	Similar unit for wine with different value, 1891 value
schoppe (Hesse-Darmstadt)	0.528	0.0187	Germany	Medieval to pre-metric	Liquid	Similar for wine with different value, 1891 value
schoppe (Wurtemberg)	0.459	0.0162	Germany	Medieval to pre-metric	Liquid	
schoppen (Frankfort)	0.448	0.0158	Germany	Medieval to pre-metric	Liquid	1891 value, based on eichmass
schrott (Frankfort)	0.112	0.00396	Germany	Medieval to pre-metric	Dry	1891 value
scorzo (Ancona)	12.77	0.4510	Italy	Medieval to pre-metric	Dry	4 quartucci, 1891 value

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
scorzo (Rome)	13.38	0.4726	Italy	Medieval to pre-metric	Dry	4 quartucci, 1891 value
Scots pint	1.695	0.05985	Scotland	Medieval to pre-metric	Liquid	4 mutchkins or 3 Imperial pints (1.704 l)
seah	4.410	0.1557	Jewish, Israel	Medieval to modern	General	269.091 cu in
seah (per Josephus)	13.58	0.4794	Jewish, Israel	Medieval to modern	General	828.28 cu in
sechter (Frankfort)	7.172	0.2532	Germany	Medieval to pre-metric	Dry	4 gescheid, 1891 value
seer	0.706	0.0249	Sri Lanka, Ceylon	Medieval to pre-metric	Dry	1/288 ammonam, defined in 1835 as cylinder 4.35" diameter and 4.35" high
seer	0.93	0.033	India	Pre-Akbar	Liquid	4 pav, 0.933 kg Appx—so actual volume varies by commodity, values shown are for water
seer	1.14	0.0401	Ceylon, Sri Lanka	Colonial to pre-metric	Liquid	1891 value
seer	1.136	0.04011	Sri Lanka, Ceylon	Medieval to pre-metric	Liquid	Also listed as 1.06 liters or 1.86 Imp. Pints
seer	1.720	0.06075	India	Pre-metric	Liquid	2 tipree, 2003 reference
seidel	0.3537	0.01249	Austrian Empire	Pre-metric	Liquid	1891 value, 2 pfiff, consistent with 2003 reference
seidel (Bohemia)	0.477	0.0169	Austrian Empire	Pre-metric	Liquid	1891 value
seidel (Bohemia)	0.488	0.0172	Austrian Empire	Pre-metric	Dry	1891 value
sei-shi	122	4.32	China	Medieval to pre-metric	Dry, grain	Alternate system, 1891 value
seit	2.02	0.0713	Burma, Birmah, Myanmar	Pre-metric	General	2 zayoot, 2003 reference
semimodius	4.394	0.1552	Roman Empire	Ancient	Dry	1—1/3 congii, 2003 reference

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
semodius	4.394	0.1552	Roman Empire	Ancient	Dry	1–1/3 congii, 2003 reference
ser	1.000	0.03531	India	Pre-Akbar	Dry, rice, grains	Approx 1 liter
sesep	40	1.4	Cambodia	Post-metric	General	40 muoi, 2003 reference
seste	800	28.2	Thailand, Siam	Medieval to metric	General	2 tamlaum, 2003 reference
sester (Baden)	15.00	0.5297	Germany	Medieval to pre-metric	Dry	10 mässlein, 1891 value
sesti	11.79	0.4163	Thailand, Siam	Medieval to metric	Dry	40 sats, dry measure, 1891 value
setier	39.6	1.40	Switzerland	Medieval to pre-metric	Liquid	25 pot, 1891 value
setier	151.7	5.357	France	Medieval to pre-metric	Dry	2 mine, 2003 reference
sétier	0.4761	0.01681	France	Medieval to pre-metric	Liquid	About a pint, 4 posson, 2003 reference
sextario	0.326	0.0115	Persia, Iran	Medieval to pre-metric	General	1891 value
sextario	0.330	0.0117	Persia, Iran	Medieval to pre-metric	General	2003 reference
sextarius	0.546	0.0193	Roman Empire	Ancient	General	1/6 congius, varied from 0.53 to 0.58 liters, Wikipedia value
sextarius	0.5493	0.01940	Roman Empire	Ancient	Dry	1/6 congius, 2003 reference
sextarius	0.5493	0.01940	Roman Empire	Ancient	Liquid	1/6 congius, 2003 reference
sexe	0.546	0.0193	Greece (Attic)	Ancient	Dry	12 kyathoi, Roman sexarius, reported as 0.54 liters in 2003
sextingar	7.785	0.2749	Finland	Medieval to pre-metric	General	3 kannor, 2003 reference
shaku	0.01804	0.0006370	Japan	Medieval to pre-metric	General	2003 reference
sháo	0.01035	0.0003655	China	Medieval to pre-metric	General	1/100 shēng, 10 cǒ, 1966 value
shari	211	7.46	India	Pre-metric	Liquid	8 cumbha short, 1966 value
sheffel	222.4	7.852	Germany	Medieval to pre-metric	Dry	6 metzen, 2003 reference

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
shekel	0.0083	0.00029	Persia, Iran	Medieval to pre-metric	General	Approx 1 cubic aiwas
shekel	0.017	0.00059	Mesopotamia	Ancient	Dry	1/60 bowl
shēng	1.035	0.03656	China	Medieval to pre-metric	General	5 yo, 1966 value
shing-shi	0.77	0.027	China	Medieval to pre-metric	Dry, grain	Alternate system, 1891 value
shing-tsong	0.52	0.018	China	Medieval to pre-metric	Liquid	10 kop, alternate system, 1891 value
shipping ton	1,133	40.00	United States	Colonial to modern	General	40 cft, 1891 value, typically about 1 long ton wheat
shita	28.26	0.9979	Vietnam, Annam	Medieval to pre-metric	General	2003 reference
shkalik	0.06150	0.002172	Russia	Medieval to pre-metric	Liquid	Measure or shot, 1/200 vedro, consistent with 2003 reference
sho	1.804	0.06370	Japan	Medieval to pre-metric	General	10 gō, common sake bottle size, 2003 reference
shō	1.804	0.06370	Japan	Medieval to pre-metric	General	10 gō, common sake bottle size, 2003 reference
short ardeb	4.4	0.16	Ethiopia	Medieval to pre-metric	Dry	
shot	0.04436	0.001566	United States	Colonial to modern	Liquid	3 tablespoons
shtof	1.230	0.04343	Russia	Medieval to pre-metric	Liquid	Mug or flagon, 1/10 vedro, 10 tcharka, consistent with 2003 reference
shtoff	1.537	0.05427	Russia	Medieval to pre-metric	Liquid	Quarter, 1/8 vedro, 2 bottles of wine, consistent with 2003 reference
shye (Anjar)	31.10	1.098	India	Pre-Akbar	Dry, rice, grains	4 mapp, 1891 value
sidio	0.882	0.0312	Muscat	Pre-metric	General	1891 value
sidios	0.88	0.031	Oman	Medieval to pre-metric	General	1/34 ferren, approx

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
siegh	1.818	0.06419	Malta	Medieval to pre-metric	Dry	Either 1/10 or 1/6 tomna, used 1/10 basis
silā ₃	1.0	0.035	Sumer	Ancient	Dry	Base unit
simmer (Frankfort)	28.69	1.013	Germany	Medieval to pre-metric	Dry	2 metzen, 1891 value
simmer (Hesse-Darmstadt)	320.0	11.30	Germany	Medieval to pre-metric	Dry	4 kümpf, 1891 value
simri (Wurtemberg)	22.15	0.7823	Germany	Medieval to pre-metric	Dry	4 viertel, 1891 value
šinik	9.25	0.327	Ottoman Empire, Turkey	Pre-metric	Dry	Peck
šiqu	0.017	0.00059	Akkadia	Ancient	Dry	1/60 bowl
skieppe	17.39	0.6140	Denmark	Medieval to pre-metric	Dry	4 viertel, 2003 reference
skjeppe	17.37	0.6133	Norway	Medieval to pre-metric	Liquid	1/4 tønne, 2003 reference
skeøppe	17.39	0.6140	Denmark	Medieval to pre-metric	Dry	4 viertel, 2003 reference
skeøppe	17.39	0.6140	Denmark	Medieval to pre-metric	Dry	2 fjerdingkar, 1891 value
smørtønde	131.4	4.640	Denmark	Medieval to pre-metric	Liquid, butter	4.25 cu fod, 136 pot or potter, "barrel", smørtønde refers to butter
soallee (Bengal)	82.38	2.909	India	Pre-Akbar	Dry, rice, grains	20 pallie, 1891 value
soally	110.1	3.8877	India	Pre-metric	Liquid	16 adoulie, 2003 reference
soerzo (Rome)	13.39	0.4727	Italy	Medieval to pre-metric	Liquid, oil	
solomon	17.82	0.6292	United Kingdom, England	Medieval to pre-metric	Liquid, wine	Still used for champagne exclusively

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
som	180.0	6.356	Korea	Medieval to pre-metric	General	
soma (Ancona)	69.98	2.471	Italy	Medieval to pre-metric	Liquid	1891 value
soma (Rome)	164.2	5.799	Italy	Medieval to pre-metric	Liquid	1891 value
soma (Tuscany)	19.27	0.6805	Italy	Medieval to pre-metric	Liquid, oil	2 barile oil, 1891 value
soma (Venice, Milan)	100.0	3.531	Italy	Medieval to pre-metric	Liquid	10 mine, 1891 value
span	293.0	10.35	Norway	Medieval to pre-metric	Dry	4 fjerdings, 1891 value
spanna	73.28	2.588	Sweden	Medieval to pre-metric	Dry	4 fjerdingar, 2003 reference
spinte (Hamburg)	6.581	0.2324	Germany	Medieval to pre-metric	Dry	1891 value, 1891 value
spiten (Bremen)	4.629	0.1635	Germany	Medieval to pre-metric	Dry	1891 value
split deal	3.625	128.0	United States	Colonial to modern	Wood	12 ft × 8 ft × 16 in
ssah	48.06	1.697	Algeria	Medieval to pre-metric	General	2.4 tarri, 2003 reference, also reported as 48 l in 1891
ssp	0.001232	0.00004351	United States	Colonial to modern	Cooking	2.5 drops
stack	3.058	108.0	United States	Colonial to modern	Wood	108 cft
staia (Bologna)	39.29	1.387	Italy	Medieval to pre-metric	Liquid	1/2 corba
stajo (Bologna)	39.29	1.387	Italy	Medieval to pre-metric	Dry	4 quarterone, 1891 value
stajo (Modena)	70.40	2.486	Italy	Medieval to pre-metric	Dry	1891 value
stajo (Naples)	9.903	0.3497	Italy	Medieval to pre-metric	Liquid, oil	16 quarti, 20 pignate, 1891 value
stajo (Parma)	47.01	1.660	Italy	Medieval to pre-metric	Dry	2 mine, 1891 value
stajo (Sardinia, Turin)	38.34	1.354	Italy	Medieval to pre-metric	Dry	2 mine, 1891 value

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
stajo (Tuscany)	24.36	0.8602	Italy	Medieval to pre-metric	Dry	2 mine
standard (St. Petersburg, Pittsburgh)	4.673	165.0	United States	Colonial to modern	Wood	165 cft
starello (Ancona)	17.56	0.6202	Italy	Medieval to pre-metric	Dry	1–3/8 scorzi, 1891 value
starello (Rome)	18.40	0.6498	Italy	Medieval to pre-metric	Dry	1–3/8 scorzi, 1891 value
staro	89.79	3.171	Greece	Medieval to pre-metric	Dry	3 bachel or 2.548 bushels, approx
staro (Parma)	47.01	1.660	Italy	Medieval to pre-metric	Dry	2 mine, 1891 value
steekan	19.20	0.6780	Netherlands, Holland	Medieval to metric	Liquid	8 stoop, 2003 reference
stekar	18.45	0.6515	Russia	Medieval to pre-metric	Liquid	12 shloff, 2003 reference
stk	3,058	108.0	United States	Colonial to modern	Wood	108 cft
stoff	1.537	0.05427	Russia	Medieval to pre-metric	Liquid	Quarter, 1/8 vedro, 2 bottles of wine, consistent with 2003 reference
stoof	1.275	0.04503	Latvia	Medieval to pre-metric	General	2003 reference
stoop	2.400	0.08475	Netherlands, Holland	Medieval to metric	Liquid	2 minglen, 2003 reference, also reported as 2.422 liters
stop	1.309	0.04620	Norway	Medieval to pre-metric	Liquid	4 quarters, 1891 value
stop	1.309	0.04621	Sweden	Medieval to pre-metric	Dry	3 quarter, 2003 reference
stop	1.309	0.04621	Sweden	Medieval to pre-metric	Liquid	4 kvarter, 2003 reference
stop	5.232	0.1848	Norway	Medieval to pre-metric	Dry	4 quarters, 1891 value
storfiavn	3,770	133.1	Sweden	Medieval to pre-metric	General	
strich (Bohemia)	93.60	3.305	Austrian Empire	Pre-metric	Dry	4 viertel, 1891 value

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
strike	72.69	2.567	United Kingdom, England	Medieval to pre-metric	Dry	2 bushels, 16 dry gallons, 1891 value
strych	93.59	3.305	Czechoslovakia, Moravia	Medieval to pre-metric	General	1.325 merice, 2003 reference
strych	93.59	3.305	Slovakia	Medieval to pre-metric	Liquid	
stübchen	3.865	0.1365	Denmark	Medieval to pre-metric	Liquid	2 kande, 2003 reference
stübchen (Bremen)	3.221	0.1138	Germany	Medieval to pre-metric	Liquid	4 quartier, 1891 value
stübchen (Brunswick)	3.740	0.1321	Germany	Medieval to pre-metric	Liquid	4 quartier, 1891 value
stübchen (Hamburg)	3.610	0.1275	Germany	Medieval to pre-metric	Liquid	2 kannen, 1891 value
stübchen (Hanover)	3.921	0.1385	Germany	Medieval to pre-metric	Liquid	2 kannen, 1891 value
stübchen (Lubeck)	3.745	0.1322	Germany	Medieval to pre-metric	Liquid	2 kannen, 1891 value
stübich	123.0	4.343	Austrian Empire	Pre-metric	Dry, coal, coke	2 metzen, 1891 value
stützen (Baden)	15.00	0.5297	Germany	Medieval to pre-metric	Liquid	10 mass, 1891 value
sutū	10	0.35	Akkadia	Ancient	Dry	10 bowls
Syrian firkin	3.393	0.1198	Jewish, Israel	Medieval to modern	General	207 cu in
tabla	20.39	0.7198	Somalia	Medieval to pre-metric	Liquid	15 chela, 2003 reference
tablespoon	0.0142	0.000502	United Kingdom, England	Medieval to pre-metric	Liquid	4 dram, 3 teaspoons, 1/2 fluid ounce

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
tablespoon	0.01479	0.0005221	United States	Colonial to modern	Liquid	3 teaspoons, 4 fluid drams
tablespoon	0.01479	0.0005221	United States	Colonial to modern	Cooking	3 teaspoons
tablespoon (metric)	0.01500	0.0005297	United States	Colonial to modern	Liquid	15 cc
takar	25.44	0.8982	Indonesia	Colonial to pre-metric	Liquid	17/10 kit, 2003 reference
talent	25.00	0.8828	Persia, Iran	Medieval to pre-metric	General	60 profane mina, approx 1 cubic trayas
tamlaum	400	14.1	Thailand, Siam	Medieval to metric	General	10 tang, 2003 reference
tanam	1.00	0.0353	Thailand, Siam	Medieval to metric	General	Coconut shell measurement, 2 changawn, varies from 0.9 to 1.2 liters, assumed nominal value post metric, 2003 reference
tang	40.0	1.41	Thailand, Siam	Medieval to metric	General	2 sat, 2003 reference
tanica	18.00	0.6356	Eretria	Medieval to pre-metric	General	12 messé, 2003 reference
tao	15	0.53	Cambodia	Post-metric	General	3/8 sesep, 2 kantang, 2003 reference
tarie	20.02	0.7071	Algeria	Medieval to pre-metric	General	1/12 caffiso, 1.2 khoul, 2003 reference, also reported as 19.84 l in 1891
tarri	20.02	0.7071	Algeria	Medieval to pre-metric	General	1/12 caffiso, 1.2 khoul, 2003 reference, also reported as 19.84 l in 1891
tau-tsong	5.2	0.18	China	Medieval to pre-metric	Liquid	10 shing, alternate system, 1891 value
tbsp	0.01479	0.0005221	United States	Colonial to modern	Cooking	3 teaspoons
tcf	0.1479	0.005221	United States	Colonial to modern	Cooking	5 fluid ounces
teharka	0.1230	0.004343	Russia	Medieval to pre-metric	Liquid	“Wine glass”, 1/100 vedro, consistent with 1891 value and 2003 reference
techst	0.1093	0.003861	Russia	Medieval to pre-metric	Dry	Part, 1/30 garnets, consistent with 2003 reference

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
theverik	26.24	0.9265	Russia	Medieval to pre-metric	Dry	Quarter, 8 gamets, consistent with 2003 reference
teacupful	0.1479	0.005221	United States	Colonial to modern	Cooking	5 fluid ounces
teaspoon	0.00474	0.000167	United Kingdom, England	Medieval to pre-metric	Liquid	80 minim, 1/6 fluid ounce
teaspoon	0.004929	0.0001740	United States	Colonial to modern	Liquid	80 minim
teaspoon	0.004929	0.0001740	United States	Colonial to modern	Cooking	10 drops
teaspoon (metric)	0.00500	0.0001766	United States	Colonial to modern	Liquid	5 cc
teman	85.0	3.00	Saudi Arabia	Pre-metric	Dry	12/5 kella, 2003 reference
teman	136	4.80	Arabia	Ancient to pre-metric	Dry, rice	For rice = 168 lbs, converted to volume, 40 kellas, 1891 value, rice ~ 35 lb/cft
temem	30.77	1.086	Libya	Medieval to pre-metric	Dry	4 orba, 2 marta, 2003 reference
temen	26.8	0.947	Tripoli, Libya	Pre-metric	Dry	4 orbahs, 1891 value
tertian	381.7	13.48	United Kingdom, England	Medieval to pre-metric	Liquid, wine	2 tierce, 84 wine gallons, 1/3 wine tun, reported as same as pipe or butt in 1891 as 108 gallons
terz	0.284	0.0100	Malta	Medieval to pre-metric	Liquid, beer, wine, spirits	Third
terz	0.320	0.0113	Malta	Medieval to pre-metric	Liquid, milk, oil	Third
tetarton	0.1365	0.004820	Greece (Attic)	Ancient	Liquid	3 kyathoi
than	1,600.00	56.50	Vietnam, Annam	Medieval to pre-metric	General	1 ngũ × 1 ngũ × 1 thườc
thanan	1.00	0.0353	Thailand, Siam	Medieval to metric	General	Coconut shell measurement, 2 changawn, varies from 0.9 to 1.2 liters, assumed nominal value post metric, 2003 reference

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
thang	20.0	0.706	Thailand, Siam	Medieval to metric	General	Bucket, 20 tanan, 2003 reference
thang	30	1.1	Cambodia	Post-metric	General	3/4 sesep, 2 tao, 2003 reference
thăng	2.000	0.07062	Vietnam, Annam	Medieval to pre-metric	General	1000 sao
thoumm-kaddah	0.24	0.0084	Egypt	Pre-metric	Dry	2 kharroubah, 1867 value
thung	2.000	0.07062	Vietnam, Annam	Medieval to pre-metric	General	1000 sao
tiberi	2.03	0.0717	Tripoli, Libya	Pre-Metric	Dry	1891 value
tierce	149.8	5.288	Ireland	Medieval to pre-metric	Liquid	42 gallons, pre-1824, 2003 reference
tierce	159.0	5.613	United States	Colonial to modern	Liquid, wine	42 gallons
tierce	159.0	5.614	United States	Colonial to modern	Liquid	42 gallons, 1891 value
tierce	190.8	6.738	United Kingdom, England	Medieval to pre-metric	Liquid, wine	42 wine gallons, 1/2 puncheon, 1/3 wine pipe, also reported as 36 gallons in 1891
timber foot	28.32	1.000	United States	Colonial to modern	Wood	Same as standard cft
tipree	0.8602	0.03037	India	Pre-metric	Liquid	10 khoonke, 2003 reference
tls	0.01479	0.0005221	United States	Colonial to modern	Cooking	3 teaspoons
to	10.35	0.3655	China	Medieval to pre-metric	General	10 shēng, 1966 value
to	18.04	0.6370	Japan	Medieval to pre-metric	General	10 sho, 2003 reference
toa	56.52	1.996	Vietnam, Annam	Medieval to pre-metric	General	2 shita, 2003 reference
toát	0.0002	0.00001	Vietnam, Annam	Medieval to pre-metric	General	Grain
toe	1.800	0.06356	Korea	Medieval to pre-metric	General	
toise	8,000	282.5	Haiti, Hayti	Medieval to pre-metric	General	80 barił, 2003 reference
toise cube	8,000	282.5	Haiti, Hayti	Colonial to pre-metric	General	80 barił, 2003 reference
tomand	136	4.80	Arabia	Colonial to pre-metric	Dry, rice	For rice = 168 lbs, converted to volume, 40 kellas, 1891 value, rice ~35 lb/cft

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
tonna	18.18	0.6419	Malta	Medieval to pre-metric	Dry	
tomolo (Naples)	55.14	1.947	Italy	Medieval to pre-metric	Dry	24 misure, 1891 value
tonde	156	5.50	Denmark	Medieval to pre-metric	Dry, coal, charcoal	1891 value
tönde	116.0	4.096	Denmark	Medieval to pre-metric	Liquid, tar	120 pot
tönde	131.4	4.640	Denmark	Medieval to pre-metric	Liquid, beer	4.25 cu fod, 136 pot or potter, "barrel", smørtønde refers to butter
tönde	139.1	4.912	Denmark	Medieval to pre-metric	Dry, ordinary	8 skøppe, 4.5 cu fod, 144 pot, 1891 value, consistent with 2003 reference
tonel	840.0	29.66	Portugal	Medieval to pre-metric	Liquid	Cask, 600 Canadas
tonel	958.2	33.83	Brazil	Colonial to pre-metric	General	30 almude, 2003 reference
tonel (Lisbon)	897.5	31.69	Portugal	Medieval to pre-metric	Liquid	Cask, 2 pipas, 1891 value
tonel (Oporto)	1,304	46.05	Portugal	Medieval to pre-metric	Liquid	Cask, 2 pipas, 1891 value
tonelada	840.0	29.66	Portugal	Medieval to pre-metric	Liquid	Cask, 600 Canadas
tonelada	960.4	33.91	Argentina	Colonial to pre-metric	Dry	7 fanega, 2003 reference
tonelada (Lisbon)	897.5	31.69	Portugal	Medieval to pre-metric	Liquid	Cask, 2 pipas, 1891 value
tonelada (Oporto)	1,304	46.05	Portugal	Medieval to pre-metric	Liquid	Cask, 2 pipas, 1891 value
tonne	137.7	4.863	Latvia	Medieval to pre-metric	General	108 stoof, 2003 reference
tonne	137.8	4.864	Estonia	Medieval to pre-metric	General	12 hulmit, 2003 reference
tønne	139.0	4.907	Norway	Medieval to pre-metric	Dry	Barrel, 4.5 cubic fot, 2003 reference
tonne (Hamburg)	173.3	6.118	Germany	Medieval to pre-metric	Liquid	24 viertel, 1891 value
tonne (Hanover)	102.0	3.600	Germany	Medieval to pre-metric	Liquid, beer	26 stübchen, 1891 value
tonne (Lubeck)	142.3	5.026	Germany	Medieval to pre-metric	Dry, wheat	4 scheffel, 1891 value

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
tonneau	274.2	9.682	France	Medieval to pre-metric	Liquid	8 cubic French feet, 2 feuilletes, 2003 reference
tonneau	887.0	31.32	United Kingdom, England	Medieval to pre-metric	Liquid, beer, wine, spirits	Range 864–909 liters, average
tonneau de jauge	2,830	99.93	France	Medieval to pre-metric	Liquid	2003 reference
tonneau de mer	1,440	50.85	France	Medieval to pre-metric	Liquid	2003 reference
tonnelada	858	30.3	Portugal	Medieval to pre-metric	Liquid	2 botas, 2003 reference
tounnah	0.24	0.0084	Egypt	Pre-metric	Dry	2 kharroubah, 1867 value
tounnah	0.2578	0.009103	Egypt	Pre-metric	Dry	2 kharroubah, 2003 reference
trublion	0.273	0.0096	Greece (Attic)	Ancient	Liquid	6 kyathoi, consistent with 2003 reference
tschetverik	26.24	0.9265	Russia	Medieval to pre-metric	Dry	Quarter, 8 gamets, consistent with 2003 reference
tschetverka	6.560	0.2316	Russia	Medieval to pre-metric	Dry	2 gamets, 1891 value
tschetviert	209.9	7.412	Russia	Medieval to pre-metric	Dry	64 gamets, 2 osminas, consistent with 2003 reference
tse'ah (Israeli)	7.68	0.271	Biblical, Talmudic	Ancient	Dry	6 kav
tsp	0.004929	0.0001740	United States	Colonial to modern	Cooking	10 drops
Tsp	0.01479	0.0005221	United States	Colonial to modern	Cooking	3 teaspoons
tuman (Talmudic)			Biblical, Talmudic	Ancient	General	Unable to locate good definition of size
tumblerful	0.2957	0.01044	United States	Colonial to modern	Cooking	10 fluid ounces
tumolo	18.18	0.6419	Malta	Medieval to pre-metric	Dry	

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
tun	599.1	21.15	Ireland	Medieval to pre-metric	Liquid	2 hogshead, pre-1824, 2003 reference
tun	887.0	31.32	United Kingdom, England	Medieval to pre-metric	Liquid, beer, wine, spirits	Range 864–909 liters, average
tun	953.8	33.68	United States	Colonial to modern	Liquid, wine	2 pipes
tun	953.9	33.68	United States	Colonial to modern	Liquid	252 gallons, 1891 value, ~1 long ton water
tun	998.1	35.24	United Kingdom, England	Medieval to pre-metric	Liquid, beer	2 beer pipes, 216 gallons
tun	1,145	40.43	United Kingdom, England	Medieval to pre-metric	Liquid, wine	2 wine pipe, 3 puncheon, 252 wine gallons
tunna	125.6	4.436	Norway	Medieval to pre-metric	Liquid	48 kannas, 1891 value
tunna	125.6	4.436	Sweden	Medieval to pre-metric	Liquid	48 kanna, 2003 reference
tunna	146.6	5.175	Sweden	Medieval to pre-metric	Dry	2 spanna, 2003 reference
tunna	163.5	5.773	Finland	Medieval to pre-metric	General	21 sextingar, 2003 reference
tunna	586.0	20.69	Norway	Medieval to pre-metric	Dry	2 spans, 32 kappes, 1891 value
tuoppi	1.327	0.04687	Finland	Medieval to pre-metric	Dry	Tankard
tuoppi	1.327	0.04687	Finland	Medieval to pre-metric	Liquid	Tankard
tynnyri	125.6	4.435	Finland	Medieval to pre-metric	Liquid	Barrel liquid measure
tynnyri	175.0	6.179	Finland	Medieval to pre-metric	Dry	Barrel dry measure
ueba	107	3.79	Tripoli, Libya	Pre-metric	Dry	4 temen, 1891 value
ueba	123.1	4.346	Libya	Medieval to pre-metric	Dry	16 orba, 4 temen, 2003 reference

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
ukla (Talmudic)			Biblical, Talmudic	Ancient	General	Unable to locate good definition of size
uma	13.18	0.4654	Roman Empire	Ancient	Liquid	Um, 4 congii, 2003 reference
vakia	0.059	0.0021	Arabia	Ancient to pre-metric	Liquid	1891 value
vakia	0.059	0.0021	Saudi Arabia	Pre-metric	Liquid	2003 reference
vat	100.0	3.531	Netherlands, Holland	Medieval to metric	Liquids	Hectoliter, 1891 term, "re-purposed" unit name
vat	921.6	32.54	Netherlands, Holland	Medieval to metric	Liquid	4 oxhooft, 2003 reference
vedro	12.30	0.4343	Russia	Medieval to pre-metric	Liquid	Bucket, 100 tcharkas, 2 polou-vedros, 10 kronchkas, consistent with 1891 value and 2003 reference
vedro	13.12	0.4633	Russia	Medieval to pre-metric	Dry	Bucket, 4 garnets, consistent with 2003 reference
velte	7.570	0.2673	Mauritania	Medieval to pre-metric	General	1/30 cash
velte	7.57	0.267	Seychelles	Colonial to pre-metric	Liquid	1/30 cash
velte	7.617	0.2690	France	Medieval to pre-metric	Liquid	4 pot, 2003 reference
vessel	10	0.35	Mesopotamia	Ancient	Dry	10 bowls
viacka	14.17	0.5003	Romania, Roumania	Pre- and post-metric	Liquid	10 oka, 1891 value, reported as 14.15 l in 2003 reference
viadra	14.17	0.5003	Romania, Roumania	Pre- and post-metric	Liquid	10 oka, 1891 value, reported as 14.15 l in 2003 reference
vierd	6.815	0.2406	Netherlands, Holland	Medieval to metric	Dry	8 kop, 2003 reference

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
vierfass (Brunswick)	7.636	0.2696	Germany	Medieval to pre-metric	Dry, wheat	4 becher, wheat, 1891 value
vierfass (Hanover)	7.790	0.2751	Germany	Medieval to pre-metric	Dry	1891 value, 1891 value
viertel	4.348	0.1535	Denmark	Medieval to pre-metric	Dry	2 achtel, 2003 reference
viertel	7.729	0.2729	Denmark	Medieval to pre-metric	Liquid	2 stubchen, 2003 reference
viertel	13.74	0.4851	Prussia	Medieval to pre-metric	Dry	4 metzen, 1891 value
viertel	14.15	0.4996	Austrian Empire	Pre-metric	Liquid	1891 value, 10 mass, consistent with 2003 reference
viertel	15.37	0.5428	Austrian Empire	Pre-metric	Dry	1891 value, 2 achtel, consistent with 2003 reference
viertel (Bavaria)	18.53	0.6542	Germany	Medieval to pre-metric	Dry	4 massel, 1891 value
viertel (Bohemia)	23.40	0.8263	Austrian Empire	Pre-metric	Dry	4 massel, 1891 value
viertel (Bremen)	7.248	0.2559	Germany	Medieval to pre-metric	Liquid	9 quartier, 1891 value
viertel (Bremen)	18.52	0.6538	Germany	Medieval to pre-metric	Dry	4 spiten, 1891 value
viertel (Frankfort)	7.171	0.2532	Germany	Medieval to pre-metric	Liquid	4 eichmass, 4.5 neumass, 1891 value
viertel (Hamburg)	7.219	0.2549	Germany	Medieval to pre-metric	Liquid	2 stubchen, 1891 value
viertel (Hanover)	7.842	0.2769	Germany	Medieval to pre-metric	Liquid	2 stubchen, 1891 value
viertel (Hesse-Cassel)	8.731	0.3083	Germany	Medieval to pre-metric	Liquid, beer	4 mass, similar for wine with different value, 1891 value
viertel (Hesse-Darmstadt)	8.454	0.2985	Germany	Medieval to pre-metric	Liquid	4 mass, similar unit for wine with different value, 1891 value
viertel (Lubeck)	7.489	0.2645	Germany	Medieval to pre-metric	Liquid	2 stubchen, 1891 value
viertel (Saxony)	25.98	0.9172	Germany	Medieval to pre-metric	Dry	4 metzen, 1891 value

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
viertel (Württemberg)	5.538	0.1956	Germany	Medieval to pre-metric	Dry	2 achtel, 1891 value
viertlein (Württemberg)	0.173	0.00611	Germany	Medieval to pre-metric	Dry	1891 value
vingerhoed	0.010	0.00035	Netherlands, Holland	Medieval to metric	Liquids	Centiliter, 1891 term
visirmass (Nuremberg)	1.147	0.04050	Germany	Medieval to pre-metric	Liquid	1891 value
voie (de Paris, wood)	1,920	67.80	France	Medieval to pre-metric	Dry, wood	Used for wood, 4 pieds × 4 pieds × 3 pieds 6 pouses, 2003 reference
vuong mot bat tay	1.0	0.035	Cambodia	Post-metric	General	1/40 sesep, 2003 reference
vuong mot gia	40	1.4	Cambodia	Post-metric	General	40 muoi, 2003 reference
water glassful	0.4732	0.01671	United States	Colonial to modern	Cooking	16 fluid ounces
wey	1,454	51.34	United Kingdom, England	Medieval to pre-metric	Dry	5 quarters, 1891 value
whiba	31.0	1.09	Tunisia	Medieval to pre-metric	Dry	1/16 cafisso, 8.06 saah, 2003 reference
whole deal	16.23	0.5731	United States	Colonial to modern	Wood	12 ft × 11 in × 5/8 in
Winchester bushel	35.24	1.244	United States	Colonial to modern	Dry	4 pecks
wine glassful	0.1479	0.005221	United States	Colonial to modern	Cooking	5 fluid ounces
wispel	989.2	34.93	Prussia	Medieval to pre-metric	Dry	18 scheffel, 1891 value
wispel (Brunswick)	1,222	43.14	Germany	Medieval to pre-metric	Dry, wheat	4 scheffel, wheat, 1891 value
wispel (Hamburg)	1,053	37.18	Germany	Medieval to pre-metric	Dry	10 scheffel, 1891 value

(continued)

Table 6.3 (continued)

Unit (qualifier)	Equivalent liters (dm ³)	Equivalent cu ft US	Region	Era	Common Applic.	Notes
wispel (Hanover)	1,496	52.82	Germany	Medieval to pre-metric	Dry	8 malter, 1891 value
wispel (Saxony)	2,494	88.06	Germany	Medieval to pre-metric	Dry	2 malter, 1891 value
xēmē	0.00910	0.000321	Greece (Attic)	Ancient	Liquid	2 kochliaria
xesta	0.548	0.0194	Byzantine Empire, Turkey	Ancient	Liquid	1/4 litra
xestēs	0.546	0.0193	Greece (Attic)	Ancient	Dry	12 kyathoi, Roman sexarius, reported as 0.54 liters in 2003
xestēs	0.546	0.0193	Greece (Attic)	Ancient	Liquid	12 kyathoi, Roman sexarius
xestes (Israeli)	0.53	0.019	Biblical, Talmudic	Ancient	Dry	Pot, dry pint, New Testament
xiber kubu	17.97	0.6345	Malta	Medieval to pre-metric	General	Base unit
yi	0.2	0.007	China	Medieval to pre-metric	General	Double handful, traditional, very rough estimate
yip mue	0.00781	0.000276	Thailand, Siam	Medieval to metric	Dry	Pinch
yo	0.2071	0.007313	China	Medieval to pre-metric	General	2 khō, 1966 value
zak	81.78	2.888	Netherlands, Holland	Medieval to metric	Dry	3 shepel, 2003 reference
zalay	0.253	0.00892	Burma, Birmah, Myanmar	Pre-metric	General	2 lamany, 2003 reference
zayoot	1.01	0.0357	Burma, Birmah, Myanmar	Pre-metric	General	2 byee, 2003 reference
züber (Baden)	1,500	52.97	Germany	Medieval to pre-metric	Dry	10 malter, 1891 value
zudda	7.6	0.27	Saudi Arabia	Pre-metric	Liquid	2 cuddy, 2003 reference

Conclusion

Volume was an historical, base measurement unit for all types of fluids, granular solids, and objects. Capacity is the maximum capability of a tank, vessel, or other container to hold a given volume of material. Capacities are generally measured in the same units as volume. Units appropriate for everyday use are most commonly cubes of small linear measurement units and/or have their own set of unit definitions and names, such as those for cooking. Both conventions are common. Larger units are driven by industry, commerce, or science and are normally expressed as cubes of linear or spherical dimensions. Extremely small units are based on cubes of linear or spherical measures as driven by scientific needs. As with area, the development of methods for calculating volumes has progressed through history from simple concepts involving spheres, cubes, and other shapes to integral calculus applied to complex shapes. Methods for measurement of volume include direct linear measurement of an object with subsequent calculation, use of standardized measuring devices (cups, spoons, tanks, etc.), and integration of volumetric flow rates over time entering a container. Extensive listings of conversion factors from historical units to modern volume units are provided for various locales and eras in world history.

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Chapter 7

Historical Weight and Mass



Abstract Weight was an historical, base measurement unit representing the apparent “heaviness” of a physical object under the influence of gravity. The concept of mass developed somewhat later. For practical, daily applications in a terrestrial frame of reference, weight can be converted to mass with small error. Weight is normally what is measured by available devices, such as balances and weighing scales. The “operational weight” measured this way is close to the actual weight, for normal purposes. Weight standards have evolved from rough standards based on rocks, through standards based on the weights of various grains, to a standard based on the International Prototype Kilogram of mass. This is the only base unit of measurement that still uses a physical artifact as the international standard. The methods of measurement for weight and mass are discussed in this chapter, along with their sources and typical magnitudes of errors. There is an extensive listing of conversion factors for historical units to modern volume units provided for various locales and eras in world history.

Introduction

The quantification or measurement of weight and its standardization are important for commerce, manufacturing, cooking, and other everyday activities. It is made necessary by our poor ability to estimate weight by inspection, although attempts at inspection are still often used to gauge weight. The density of an object can well disguise weight and throw off our guesses. An old riddle asks: “Which weighs more, a pound of lead or a pound of feathers?” Many times, someone will answer a pound of lead, but they actually weigh the same because they each are one “pound”. (This illustration breaks down a little in some historical systems where the same unit name applies to different actual weights or masses of specific commodities, but we will ignore that for now.)

Weight and Mass [17, 18, 20]

For most of recorded history, weight was a base measurement of a quantity of material or an object. The concept of mass has been a relatively recent development. Often weight and mass are considered to be the same, but the definitions of these two types of measurements are different, even though the unit names may be the same in some systems.

Specifically, weight is the force exerted on any physical object by gravity or gravitational acceleration. Mass is an inherent property of a physical object that resists a change in motion from an applied force. Mass is more generic than weight and works with acceleration applied in any direction. We will explore the historical development of these concepts in a minute. For now, we will provide some working understanding.

The weight of an object would be different on different planets or locations, for instance. A 100 pound (force) object (in vacuum) here on earth would only “weigh” about 39 pound (force) on Mars or it would “weigh” about 114 pound (force) on Saturn. Weight even around the earth varies slightly with location (especially latitude) and with altitude. A 100 pound object on earth would weigh around 99.7 pounds (in vacuum) at 30,000 feet altitude and 45 degrees latitude, for instance. Latitude also has a significant effect on the weight of an object. Our average “100 pound object” at the equator would actually weigh 99.7 pounds because of the effects of the earth’s rotation (centrifugal effect) and at the North Pole the object would weigh 100.3 pound because there is little centrifugal effect. In all these cases, the mass of the same object is constant at 100 pounds (mass). We will discuss the difference between pounds mass and pounds force in greater detail later.

For practical, everyday purposes, variations in weight with latitude, altitude, and buoyancy are not significant enough to require special adjustments. For scientific purposes, it may be necessary to make such adjustments to obtain accurate results. It is also necessary to consider these factors in any endeavors in space or in accelerations other than gravitational.

As noted above, mass is generally related to weight through gravitational acceleration:

$$\text{Weight} = \text{Mass} \times \text{Gravitational Acceleration} \quad (7.1)$$

Since weight is essentially a unit of force (i.e. the force exerted on an object by gravity), we can generically view the relationship between weight and mass as a special case of Newton’s Second Law of motion (simplified):

$$\overrightarrow{\text{Force}} = \text{Mass} \times \overrightarrow{\text{Acceleration}} \quad (7.2)$$

Both force and acceleration are vector quantities (meaning they act in specific directions). In the case of gravity, the net acceleration vector acts essentially vertically downward toward the center of the larger mass (say earth), or alternately one

mass is attracted to another mass with corresponding vectors pointing toward the centers of the two masses.

In this chapter, because of the common, interchangeable usage of the terms mass and weight, we will treat the two types of measurements together and somewhat loosely in our conversion factors. Understand that weight is mainly just mass under the influence of gravity.

We will start by exploring the development of the concepts of weight and, somewhat later, mass in more detail. The relative magnitudes of many of the weight units applied through history will be compared to identify patterns and to help understand the development of the measurement systems. Finally, the chapter concludes with tables of historical conversion factors dating back to the earliest available information.

Historical Concepts of Weight and Mass

[7, 8, 17, 18, 20, 22, 23, 34]

Early in human development, the fact that one object was “heavier” than another object was observed. People were not quite able to reconcile the reasons for this or understand differences in density, but they had a practical, working understanding of “heavier” versus “lighter”. They knew that a larger object or more pieces of a bulk material of the same type was “heavier”. They understood that the differences in “heaviness” corresponded with the amount of material—i.e. if you had a total of two objects of similar size and material, they were twice as heavy as one of the objects. They might not have an exact concept of the quantities, but they knew directionally that more objects weighed more.

Plato, the Greek philosopher (~427 to ~347 BC, depending on the reference), viewed the concept of weight as the tendency of like objects to be attracted to or try to seek other similar objects. Paraphrasing this, a heavy object tried harder to get closer to the earth, the ultimate heavy object, than a lighter object did. This was conceptual and philosophical as opposed to a quantitative relationship.

Plato’s student, Aristotle (384–322 BC), viewed weight through the concept of the basic terrestrial elements of his time: air, earth, fire, and water. Surrounding the terrestrial sphere was the celestial aether. His universe was earth-centric and nothing beyond the moon existed but the aether. This was still a philosophical approach, as opposed to experimental.

To Aristotle, earth was considered the ultimate embodiment of “weight” while fire was considered to be the opposite, or “levity”, within the terrestrial sphere. Air and water were somewhere between. Weight was the tendency of the terrestrial elements to return to their natural order, with earth toward the middle (the earth-centric view), then water, air, and finally fire rising to the top layer. Objects might contain a mixture of the elements, which would determine where they would end up in this natural order. He recognized that the rates at which objects fell depended on the medium in which they were falling. He defined the speed of a

falling object as being directly proportional to the weight of the object and inversely proportional to the density of the medium. He also postulated that there must be continual action on an object for it to continue in motion. Hereafter, the concepts of weight and motion were related in physics.

Aristotle had a hard time dealing with the concept of time, hence he related speed to distance in his thinking. We now know Aristotle's concepts were not correct, but he had arrived at these ideas by philosophical observation and reasoning, without quantitative experimentation. This was a framework for physics that persisted into the 17th century AD, even though it was discredited in the Middle Ages.

Archimedes of Syracuse (287–212 BC), following in Aristotle's steps, compared weight and buoyancy, with a higher weight resulting in an object sinking. He recognized that the relative weight or buoyancy determined whether an object rose or fell in any medium, consistent with Aristotle's observations. This was still a qualitative, philosophical approach.

Euclid (mid-4th century to mid-3rd century BC) provided a useful concept for weight by defining weight as the relative "heaviness" of one object compared to another as established by using a balance scale. Since balances had been used in commerce for a couple thousand years, this was hardly an earth shattering revelation; but it did provide a clear, operational or experimental definition of weight that could be quantified.

Aristotle's ideas about weight and motion began to be challenged by a number of people in the Middle Ages. As opposed to the philosophical approach of the Greeks, those in the Middle East took a more practical, experimental, quantitative approach to understanding weight and the factors affecting it.

In the 6th century, John Philoponus of Alexandria (~490 to ~570 AD) proposed an early concept of inertia—that an object in motion would stay in motion until resistances (or other forces) slowed it down (paraphrasing). He partially opposed Aristotle's idea that continued force must be applied to keep an object in motion, but he still tried to reconcile observed and empirical motion data with Aristotle's approach. To do this, Philoponus postulated that the inclination of an object toward motion that was imparted to the object was only temporary and decayed (somehow) until the object stopped.

Philoponus also used experimental observations to note that two greatly unequal weights dropped from the same height would hit the ground at very close to the same time. Under Aristotle's view, the weights should hit the ground at different times proportional to their weight. Philoponus also espoused the view that, essentially, the laws of physics applied throughout the universe, including the celestial sphere. His approach to this was not popular with his contemporaries, even though he would eventually be proven to be more or less correct. The religious views of the time held earth apart from the rest of the universe. After his death, he was deemed a heretic, which limited the spread of his ideas for several centuries.

The Persian, Abū 'Alī al-Ḥusayn ibn 'Abd Allāh ibn Al-Hasan ibn Ali ibn Sīnā (Avicenna, ~980–1037 AD), developed Philoponus' and others' ideas into a new theory of motion. He proposed that an object in motion had the property of "mayl"

or self-motion, akin to momentum. This property could be expended or lost as the result of actions by external forces, like air resistance.

Abū 'Alī al-Ḥasan ibn al-Ḥasan ibn al-Haytham (Alhazen, ~965 to ~1040 AD) made numerous contributions to science and engineering, including understanding weight and gravity. He proposed that there was an attraction between two objects that would lead to them moving toward each other. This was an early equivalent concept to gravity. One of Alhazen's greatest contributions to science was his early practice of what became known as the Scientific Method. He made careful experiments, used mathematics to quantify and analyze his work, and thought critically of his own ideas, as well as those of others. He broke with Aristotle's idea of an earth-centric universe by noting that celestial bodies also followed the same principles as terrestrial objects.

Abu'l-Barakāt Hibat Allah ibn Malkā al-Baghdādī (Abu'l-Barakāt, ~1080–1164/5 AD) recognized that applied force to an object produced acceleration, not constant speed, thus totally voiding Aristotle's ideas on motion. He defined acceleration as the rate of change of speed, essentially the same definition we use today. He further articulated the Scientific Method as the best approach for understanding the physical world.

A Frenchman, Jean Buridan (~1295–1363 AD), developed the concept of impetus, building on the earlier works above. Impetus was the precursor of the concepts of inertia and momentum. Buridan saw impetus as a property of an object that was imparted to that object by some external force acting on the object. His approach was able to describe the expected motion of a projectile qualitatively, if not quantitatively. He noted that acceleration was produced when impetus was increased. Buridan maintained that impetus did not decrease spontaneously, as Aristotle defined; but, consistent with some of his predecessors, he maintained that action by an external factor was required to reduce it.

The landscape for scientific understanding of the universe was shaken in the 16th century AD by Nicolaus Copernicus (1473–1543 AD) when he proposed that the earth was not the fixed center of the universe, but the sun was the center. This new vision resulted in new efforts to understand the actions of gravity and relationships with weight and movement. His ideas were only slowly accepted. Many theologists strongly opposed this “helio-centric” universe, since it went against the Holy Scriptures, as interpreted at the time.

Galileo Galilei (1564–1642 AD) built on the works of Copernicus, in spite of the threat of punishment. He eventually was placed under house arrest in 1633 after being convicted of heresy for using Copernicus' ideas. His arrest lasted the rest of his life. Galileo used an experimental approach to exploring the concepts of gravity, weight, and motion. He is famous for demonstrating that the rate of an object falling is not affected by its weight significantly, a concept previously articulated by Philoponus. The popular story of Galileo's experiment has him dropping two weights from the Leaning Tower of Pisa; but the reality is that he rolled two weights down an inclined plane and was then able to gauge the time each reached a given point more easily. He was able to conclude that, without friction or resistance to motion, objects fell at the same rate or, more precisely, they accelerated at the same

rate under the influence of gravity. He was also able to determine that the speed at which an object fell was proportional to time, not weight or distance. This disproved Aristotle's contention that speed was proportional to distance traveled, which had been espoused incorrectly for centuries. Galileo concluded that the weight of an object was the same, regardless of its motion—i.e. weight depended on the amount of matter. This was movement toward the definition of mass.

Isaac Newton (1642–1726/27 AD) influenced the understanding of weight and mass in his work. He developed his Law of Universal Gravitation, which contended that any two objects are attracted to each other by a gravitational force that is inversely proportional to the square of the distance between their centers of mass. This law worked for all forms of attraction and explained both linear and non-linear motion of objects, such as orbits of the planets.

Newton separated weight into two fundamental properties of an object:

- Mass—which was part of an object's inertia
- Acceleration due to gravity

By definition, then, weight eventually took on the units of force as a result of Newton's laws. This approach was recognized formally about 300 years later in the 3rd General Conference on Weights and Measures in 1901.

Newton recognized that weight was affected by buoyancy of the medium in which an object was weighed, consistent with his predecessors, along with other factors. He noted that there is an apparent weight of a weighed object that depended on the weighing conditions and a true weight, which was independent of the weighing conditions. Newton considered time and space to be absolute and constant in this thinking. This view is fairly consistent with our every-day experience. This view persisted until the 20th century AD, and still mostly works for us today.

The early 20th century AD saw major changes in the fundamental concepts of physics. Time and space, as well as weight or mass, were recognized to be dependent on the frame of reference. Albert Einstein (1879–1955 AD) was one of the chief drivers of this new understanding of physics through his General Theory of Relativity. Weight really has been replaced by mass in this thinking, and mass is not necessarily a constant for a given object. For most situations, however, mass and weight can be considered constant within our ability to measure them under normal conditions.

The net result of all this historical development is that weight is the mass of an object or material times its acceleration due to gravity when the object is supported or moving perpendicular to the gravity vector. There is more discussion about fine-tuning this definition below, but essentially:

$$\text{Weight} = \text{mass} \times \text{gravitational acceleration} \quad (7.3)$$

In the next discussion, we will explore the development and definitions of mass and weight standards from standards based on “feel” to the very precise measurement instruments available today. We will talk more about fine-tuning or correcting weight measurements for various effects.

Different Definitions of Weight [17]

Pulling together the historical discussion, the standards, and other practices, there are several definitions of “weight”. Some are directly related to “mass” and some are standalone concepts. The most common definitions of weight and mass include:

- *Gravitational weight*—This is close to the “true weight” of an object and ties mass to weight directly. In this view,

$$W = mg \quad (7.4)$$

where:

W Gravitational weight

m Mass

g Standard acceleration of gravity (9.80665 m/s^2 or 32.17 ft/s^2)

This definition of gravity factors out the influences of buoyancy and other sources of weighing errors. It also results in the gravitational weight varying depending on the force of gravity in a specific locale. The acceleration of gravity is a downward pointing vector, so weight is also a downward pointing vector. The units for weight would be Newtons in the SI system or poundals in the U.S. Customary (English) system of measurement.

There are some alternate units applied which use the acceleration of gravity as g/g_c where g is the local acceleration of gravity and g_c is the standard acceleration of gravity along with some conversion factors ($g_c = 9.80665 \text{ m} \cdot \text{kg-wt/kg/s}^2$ metric or $32.17 \text{ ft} \cdot \text{lb}_f/\text{lb}_m/\text{s}^2$ US). Essentially, g/g_c is equal to one standard “gravity” on earth. Using this form of gravity, we have weight units of kilogram-weight (kg-wt) in the metric system and pounds-force (lb_f) or more commonly “pounds” in the U.S. Customary (English) system.

- *Operational weight*—In this definition, the operational weight is the force on an object created by the earth and measured by weighing. Any errors inherent in the weighing process or movements relative to true weight or mass are ignored. By the operational weight definition, the weight of an object can vary with an object’s motion, as well as location and other factors. For instance, if you weigh an object sitting still on the surface of the earth, you would get one weight. If you weigh the same object as it is accelerated upward in an elevator against the gravitational force of the earth, you get a different weight. If you weigh the object dropping down in an elevator, the weight will be different still. Same object—different weights.

$$W_{\text{Going Up}} > W_{\text{Stationary}} > W_{\text{Dropping Down}} \quad (7.5)$$

Since an object is never truly stationary in the universe, this definition can be vague in the general case.

- *ISO weight*—The International Standards Organization (ISO) defines weight in a terrestrial reference similar to gravitational weight. In their definition:

$$F_g = mg \quad (7.6)$$

where:

F_g Weight
 m Mass
 g Local acceleration of gravity

This definition may result in a weight that differs slightly from gravitational weight in that it uses the local acceleration of gravity and does not include the effects of motion or buoyancy.

- *Apparent weight*—This is the indicated weight of an object, regardless of the conditions of measurement. It incorporates all the various effects of buoyancy, motion, magnetic, air currents, and other impacts. It is the real-world weight of the object. You set the object on the scale and the scale gives you the apparent weight, assuming it is calibrated correctly.

Magnitudes of Weighing Errors [19]

For practical purposes, we generally have to weigh objects in air with the object and equipment more or less at rest (relative to our reference frame) with mechanical equipment that is designed to avoid most outside influences. The apparent weight in these conditions is close to the gravitational or ISO weights. The primary influences that are not eliminated are buoyancy and local gravitational variations. But, net-net, weight is proportional to mass and we can usually infer the mass of an object on earth in the same way we determine the weight. So, let's quantify the weighing errors.

The buoyancy effect during weighing for most objects is extremely small when weighing in air. Let's say we have a 1 kilogram mass (2.205 lb_m) of water and a 1 kg mass of iron, both in containers of negligible mass and volume. The volume occupied by 1 kg water is 1 liter (0.035 cft); but the volume occupied by 1 kg iron is about 0.127 liters (0.0045 cft). The weight measured will be off by the mass of the air that is displaced by the two volumes, hence:

Water: 1 liter $\times$ 29 grams air/22.4 liters (STP) = 1.3 grams (0.0029 lb) air

Iron: 0.127 liter $\times$ 29 grams air/22.4 liters (STP) = 0.16 grams (0.00035 lbs) air

The resulting errors in the indicated weights of the two materials, neglecting the correction for the counterweights, would be:

$$\begin{aligned}\text{Water: } & 1.3 \text{ g air}/1000 \text{ g water} \times 100\% = 0.13\% \text{ low} \\ \text{Iron: } & 0.16 \text{ g air}/1000 \text{ g water} \times 100\% = 0.016\% \text{ low}\end{aligned}$$

For practical purposes, these errors are negligible. For engineering purposes, since you will be working in air normally anyway, the error is effectively zero.

Now suppose we were weighing the same two items in water. The resulting errors in this case, neglecting other effects in the weighing apparatus would be:

$$\begin{aligned}\text{Water: } & 1 \text{ L displaced} \times 1000 \text{ g water/L}/1000 \text{ g water weighed} \times 100\% = 100\% \text{ error} \\ \text{Iron: } & 0.127 \text{ L displaced} \times 1000 \text{ g water/L}/1000 \text{ g iron weighed} \times 100\% = 12.7\% \text{ error}\end{aligned}$$

So the weighing error due to buoyancy can be large, depending on the medium in which you are weighing. Note that, in a vacuum, the buoyancy error would be zero. Fortunately, you can accurately calculate the buoyancy error and adjust for it, if necessary.

Similarly, the acceleration due to gravity varies as much as $\pm 0.25\%$ over the surface of the earth. Figure 7.1 shows the extent of this variation as determined by the Gravity Recovery and Climate Experiment (GRACE). This was a joint mission of NASA and the German Aerospace Center beginning in 2002. The unit “milligals” or $1/1000$ galileo (gal) indicated in Fig. 7.1 is equal to 0.00001 m/s^2 variations ($3.3 \times 10^{-5} \text{ ft/sec}^2$). Hence a variation in gravity of +50 milligals at a specific location would mean the acceleration of gravity at that location is 9.80715 m/s^2 (32.18 ft/sec^2) compared to a standard acceleration of 9.80665 m/s^2 (32.17 ft/sec^2), or 0.005% higher gravity. In practice, latitude (centrifugal forces) and altitude also play a role in the variation, leading to the larger potential variation number. Note that

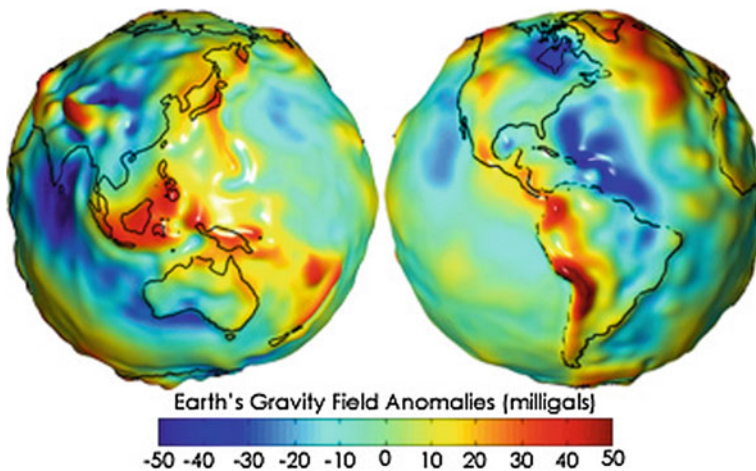


Fig. 7.1 Variation in earth's gravitational field. *Source* Gravity Recovery and Climate Experiment, U.S. NASA and German Aerospace Center

if you are weighing an object using a balance with standard reference or counter weights, the gravitational and positional forces act equally on both the object and the reference weights, so the error introduced by these forces becomes irrelevant. However, if you are using a spring scale or similar device for weighing (which has no counterweight arrangement), the gravitational and positional errors will exist in the indicated weight.

For the most part, in common practice, the errors produced by various influences on weighing are very small. If necessary, corrections can be made to compensate for the errors when doing detailed work that requires more exact weights or calculations of actual mass. In most terrestrial applications, the corrections can be ignored.

Development of Standards for Weight and Mass

[7, 8, 10, 12, 14, 16–18, 20, 22, 23, 30, 31, 34]

“Natural” Weight Measures

The application of “natural” weight measurements persists in the way people compare two objects or quantities of materials in their hands to judge how much one hand is holding compared to the other. In a study of the Shoshoni Tribe of North America in the early 20th Century, the practice of comparing quantities in each hand to establish weights was described [16]. Quoting a tribal Elder describing the approach to weight measurement by comparison:

“My mom used to take a rock on her left side, and she measured it against what she was holding on her other side. I’ve seen them do it. You picked a rock and then you needed to find something else of the same weight”

Of course this approach would be limited to things you could hold in your hands or in some standard container that a person could lift. The rock selected for the comparison constitutes a simple, primitive measurement standard unit. In the case of the Shoshoni, the standards would have been specific to the individual.

For trade and other purposes, some weight measurement standards would be necessary. The requirements for such standards would include:

- Capable of being used by everyone
- Portable or reproducible in any location
- Consistently applied

The natural environment offers several potential weight standards. Typical weight standards used have especially included various grains or seeds. Barley, corn, carob, rice, and wheat seeds have all been used for the base unit of weight. Larger (or smaller) weights were then established using agreed, standard proportions to create a full range of weights. An example of this approach is provided by the old British system of weight measures outlined in Table 7.1.

Table 7.1 Traditional British system for weight units [31]

Unit name	Metric, kg @ 1 gravity	U.S. Cust. Weight, pounds	Basis for unit
grain (gr)	0.00006480	0.0001429	Weight of grain seed from middle of ear of barley
dram or drachm (dr)	0.001772	0.003906	1/16 ounce
ounce (oz)	0.02835	0.06250	1/16 pound, 16 drams
pound (lb)	0.4536	1.000	7000 grains
nail or clove	3.175	7.000	7 pounds (for some commodities = 8 lbs)
stone (st)	6.350	14.00	14 pounds
quarter or tod	12.70	28.00	2 stones
hundredweight (cwt)	50.80	112.0	4 quarters
ton (T)	1,016	2,240	20 hundredweight

Note in the British system of weights that the base unit is a seed from the middle of an ear of barley that is well-formed. This is roughly consistent and portable as a measurement standard, while not always exact. This definition was adequate for the era in which it was applied. Note also that the grain of barley was used to define a pound as 7000 grains of barley. Barley grains were also used in the bases for other standards, like length, at the time. For subsequent units, then, fractions or multiples of the pound were used. This is primarily because a pound is a more convenient size for larger units. Units smaller than a pound were separated by a factor of 1/16, i.e. an ounce was 1/16 pound and a dram was 1/16 ounce. Units larger than a pound involved various whole number multiples; but, interestingly, did not use a factor of 16 again. The absolute values of some weight units in this system also depended on the commodity being measured. For example, a clove of wool would be 7 pounds whereas a clove of cheese was 8 pounds.

The British system's roots can be traced back to the middle ages. The need for standards of measurement was addressed in the Magna Carta around 1215. The concerns were specific to wine, ale, and barley at that time.

The British system is similar to other systems that date from before 3,000 BC. We find these systems in use in Mesopotamia, Sudan, Egypt, and China, for a few examples. Yet the actual values of weight or mass represented by a comparable unit varied significantly.

In most cases, the “natural” standards for weight were translated into standard reference weight artifacts for actual use. These “weights” were usually made from stone or metal and calibrated to the grain standard or against a standard kept by the governing authority. In England, the standards were maintained at Winchester.

We will discuss other types of weight unit systems a little later.

***Artificial Weight and Mass Standards* [10–12, 14, 34]**

Today, the weight and mass standards we use are based on artificial scales developed using specific physical artifacts. The artifacts are defined to weigh or have masses with specific values. This approach to standardization dates back many millennia, even while natural scales were being used.

For the artificial standards, a standard object is created and the weight or mass of that object is defined to be a specific value. Then, other units in the system are defined to be fractions or multiples of the standard object, just as the weight of a seed was used to define the traditional English system of weights above.

Physical copies of the standard weight or mass and the derived units are then made and distributed more widely as representative of the standard. These copies are certified as accurate to some level of precision. The copies can be used in commerce or they may, in turn, be copied to create additional standards. Of course, errors are introduced by multiple generations of copies and, as evidenced by English laws, deceptive practices and false or tainted standards have run rampant over the centuries.

There were often multiple “standards” for the same unit in different locales. Only in the past couple hundred years have people tried to standardize internationally.

In the case of weights and masses, the standards are compared to quantities being weighed using a balance scale. These scales are discussed in more detail below, but we know that copies of standard weights have existed for as long as balance scales because such weights have been found in ancient excavations dating back to before 3000 BC.

Because of the need for greater accuracy and an increasing range of measurement, the use of the various natural standards has long been replaced by weight standards based on defined artifacts for the past thousand years or so.

The current weight/mass standard is the International Prototype Kilogram (IPK) maintained by the International Bureau of Weights and Measures in France. This standard is discussed more fully in the chapter on Metric and U.S. measurement systems. Other weight standards, including those in the U.S./English weight system are defined in terms of the IPK.

Measuring Weight [19]

The Balance Scale

A balance scale is the earliest recorded device used to determine that the weight of one object or material is equal to another, reference object’s weight. In its simplest form, the scale consists to two pans or trays suspended from (or supported by) a beam that is, in turn, supported so that it can tip back and forth. The pans are equal distances on either side of the beam support point or fulcrum and the beam is also centered over the fulcrum. See Fig. 7.2a.

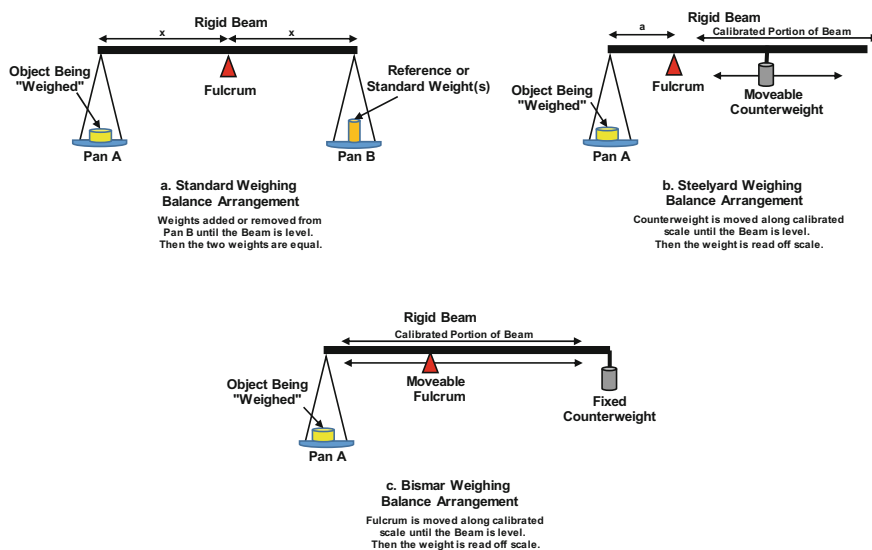


Fig. 7.2 Types of weighing balances

You place a known weight on one pan of the balance and a quantity of a material you want to weigh on the opposite pan. To make the weights equal, you would add more material to that pan until the beam of the balance is horizontal.

Alternately, you could place a material you wanted to weigh on one pan and then add or remove standard weights from the opposite pan until the beam was horizontal and the weights were “balanced”.

The earliest evidence of balance scales dates from around 2400 BC in present-day Pakistan. Use of balances was well-established in Egypt by 1878 BC.

A rough, quantitative understanding of leverage, led to the development of variations to the equal arm balance that used unequal arm lengths before about 400 BC.

The Roman “steelyard” consisted of a beam with a fixed fulcrum point and fixed weighing tray or hook for the load. See Fig. 7.2b. A counterweight was moved along the beam opposite the load until the beam was balanced (level). The beam on the counterweight side had a calibrated scale indicating the weight of the load. This approach allowed for a small device which could weigh very heavy loads by making use of leverage. The approach is still applied today in the beam scales used in medical offices and fitness centers.

Another unequal beam approach was the bismar, which was not very accurate. See Fig. 7.2c. The bismar consisted of a beam with a fixed weight on one end. At the opposite end you hung the load to be weighed. The fulcrum point was moved along a calibrated scale on the beam until balance was achieved and the weight was indicated by the scale.

The balance scale is still used today for many applications. Accuracy of these scales can be very good when they are properly designed and maintained. A typical

beam analytical balance is capable of measuring to around $\pm 0.1 \text{ mg}$ ($\pm 2.2 \times 10^{-7} \text{ lb}$) accuracy. The Watt balance, being developed to establish a new standard for the kilogram, has a relative accuracy of 3.6×10^{-8} which would be about ± 36 micrograms ($\pm 7.9 \times 10^{-8} \text{ lb}$) for a 1 kg mass, with a target of ± 10 micrograms ($2.2 \times 10^{-8} \text{ lb}$).

Other Types of Scales

There are other types of balances today which may also operate differently from beam-type balances. Among these are:

- *Spring scales*—This type of balance makes use of the linear relationship of force to stretching or compression of a spring. The load required to compress (or stretch) a spring is proportional to the distance the spring is compressed (or stretched): $F = K \cdot D$, where K is the spring constant and D is the compression (or stretch) distance. The spring(s) supports a weighing platform. The distance the load compresses (or stretches) the spring is measured mechanically and converted to weight that is displayed on a scale at one gravity. This type of scale is inexpensive and accurate enough for most purposes. The principle is used in kitchen, bathroom, grocery, and other simple scales requiring only nominal accuracy. The scale is subject to errors from gravitational variations (as much as $\pm 0.25\%$), spring accuracy and fatigue, temperature effects, and friction, among other factors.
- *Hydraulic or pneumatic scales*—These scales use the pressure generated by a load supported by a pneumatic or hydraulic cylinder to sense the weight of the load. They can be used for very heavy loads, such as those supported by a large hydraulic crane. The measured weight is shown on a pressure display calibrated to indicate the weight of the load. Accuracies of these types of scales are limited, but are sufficient for their intended purposes. Errors are introduced by the same factors affecting other measurement methods.
- *Electronic scales*—These scales can also use springs or can use the deflection of a beam under load or can use direct downward force on “load cells” to measure weight. The movement of the spring, beam, or load cell is detected by strain gauges. A strain gauge is a device which changes its electrical resistance based on the very tiny physical deformation of the strain gauge under load. The electrical signal is translated into the weight of the load. Very heavy loads and moving loads can be weighed using one or more strain gauges. This type of measurement is subject to the same errors as the other methods of measurement.

Sources of Error in Weighing Instruments

Because almost all scales weigh items in air, use gravity, and have some mechanical aspect, there are numerous sources of error in the measured value from a scale.

Some of these were detailed in previous discussion and are provided here for completeness, while others are introduced by the weighing device. Among the sources of error are:

- *Buoyancy*—Objects are normally weighed in atmospheric air. The air displaced has a definite weight, so the actual measured weight of a load must be corrected for the displaced air weight for best accuracy. This is normally only important for low density items, however. It would be a big problem if you were going to measure the weight of an inflated hot air balloon or of some aerogel. Fortunately, normal accuracy is sufficient without the correction for most cases. Refer to the earlier discussion for the relative magnitude of this type of error.
- *Reference standard weight*—Your measured value is only as good as the standard weight (or the calibration) used for your scale. An inaccurate weight or corrosion of the standard weight can lead to error. Very small weight standards for analytical balances can be rendered inaccurate by factors as simple as residual oil from a person's skin that sticks to the weight, hence these small weights are usually handled with tweezers and are never touched.
- *Air movement around the load or balance*—For small weights, the tiny air drafts and movements we normally experience without thinking about them can significantly affect the accuracy of the measurement. For analytical balances, the item being weighed is normally enclosed in a shielded area and time is allowed after closing up the shield to prevent error from air currents. For large weights, this is not normally a significant error source.
- *Friction in the mechanical balance*—Friction creates hysteresis in the mechanical movement of the scale components that results in error. The scale indicator will stop moving at a different point than if the scale mechanism were frictionless. Fine balances use a sharp knife-edge fulcrum to control this error source, but these fulcrums will wear with use and accuracy will be reduced.
- *Airborne contaminants collection*—If you are measuring a very tiny weight, the dust in the air can be your enemy. Dust particles don't weigh much, but they do weigh something and can contribute to the apparent weight of the item. For larger weights, of course, this is not significant.
- *Electronic component drift*—If you are using an electronic scale, such as one that employs load cells, the circuitry may drift due to degradation of the electronic components or temperature effects on the components. This can be a significant impact. Periodic calibration checks using standard weights are necessary. It may also be necessary to compensate readings for temperature or provide a controlled-temperature environment for the weighing equipment.
- *Mechanical component compromise or thermal effects*—Similar to electronic drift, the mechanical components used for the balance can wear, get misaligned, or expand and contract due to temperature. Springs can fatigue in spring balances. You can permanently damage a component by overload. All of these factors can create measurement error. Regular maintenance can eliminate errors from misalignment and wear. Temperature compensation may be required.

- *Magnetic fields near balance*—Since many components of balances are ferrous steel or other materials with significant magnetic susceptibilities, the presence of nearby magnetic fields can cause errors. The best practice here is to eliminate the magnetic fields to eliminate this as a source of error. Nearby strong, high voltage equipment may have similar effects.
- *Electrostatic fields*—In dry air, electrostatic fields are easily generated. For very small weights, residual electrical charges can impact the indicated weight. This is not an issue with larger weights.
- *Corrosion or other chemical activity*—Many balance components are made from metals that can corrode over time. This can lead to errors from mechanical components that are not up to specification. Similarly, some substances will react with air as you are weighing them, thus their weight is changing all the time. For most applications, these factors are not issues, however.
- *Condensation on cold items*—Suppose you wanted to weigh a very cold item on a balance in the air. As you were weighing the item, it would be condensing water from the air and the weight would be changing. In most cases, this would not be a factor, but it could be for some items.
- *Evaporation from the item or absorption from the air during weighing*—For very accurate work, the moisture content (or other volatile content) of the item being weighed needs to remain constant. If you place a wet filter cake on a balance to weigh it, the weight will be changing as additional moisture evaporates. Similarly, let's suppose you carefully dried a hygroscopic material in a desiccator and then put it on the balance. The weighing would have to be done quickly because the material will begin picking up moisture from the air immediately. In most weighing operations, however, neither of these issues is a significant cause of error.
- *Natural convection around hot or cold items*—Placing a hot or cold item on the balance will generate air currents around the item that will create error. This primarily would apply to small weights, but even larger weights can be affected.
- *Gravitational differences*—As noted in earlier discussion, the earth's net gravitational force varies significantly from place to place—at least significantly enough relative to accurate measurement. The gravity at the poles is higher than at the equator, for instance. The difference is as much as $\pm 0.25\%$. If you are using a balance, this is not important since the same gravitational force is acting on both the item being weighed and the standard reference weight. For scales that measure force, like spring scales or load cells, the difference in local gravity makes a difference. A weighing scale needs to be calibrated using a standard weight for the best accuracy at its specific location. Refer to the previous discussion of the magnitude of errors for a more complete treatment of gravitational effects.
- *Vibration and seismic impacts*—Our world provides multiple sources of vibration, from earth movements to vehicle traffic to ventilation systems to loud music. All these can impact the accuracy of weights measured on balances and scales. Avoiding some of these errors is simple—for instance, don't weigh things during an earthquake. Avoiding small vibration errors may mean providing a more massive foundation for the weighing equipment or relocating where you can eliminate the vibration.

As you can see there are several possible sources of error when measuring weight or mass with a scale that we seldom consider. The most significant sources are mechanical, vibration, and electronic problems with the weighing apparatus. These affect the full range of magnitudes. The other sources of error affect primarily measurement of small weights, although they may occasionally affect larger weights. Be aware of the possible error sources and seek to avoid or eliminate them.

Metric and U.S./English Weight and Mass Units [10–12]

For normal use, weighing really relates to determining the mass of something on earth. The tables in this chapter apply to this definition.

Formally, in the SI System, a one kilogram “mass” under the acceleration of gravity ($9.80665 \text{ m/s}^2/32.17 \text{ ft/sec}^2$) would have a weight of 9.807 Newtons (2.205 lb). Newton is the unit of weight (or force) in the SI System. Now we seldom measure weights in Newtons, however. The unit does get used for force.

There is also an alternate unit that uses metric factors, but is not an SI unit. The kilogram-weight or kilogram-force described in the discussion on types of weight is one of these alternate units. It is comparable to the pound-force in that a kilogram-weight (kg-wt) represents the weight of a one kilogram mass under the influence of one standard earth gravity—essentially a gravitational weight.

In the U.S. Customary/English system of units, there are a couple of choices. By far, the most commonly used unit is the pound-force (lb_f) or, more commonly simply the pound. This is equal to one pound-mass (lb_m) under the influence of one earth gravity, again a gravitational weight. Normally, $1 \text{ pound-force} = 1 \text{ pound-mass}$ on the earth’s surface. More technically, we need to introduce a conversion factor, g_c to make the units come out right. Hence:

$$1 \text{ lb}_f = 1 \text{ lb}_m \times g/g_c \quad (7)$$

where:

lb_f pounds-force or weight

lb_m pounds-mass

g acceleration of gravity, normally $\sim 32.17 \text{ ft/sec}^2$

g_c $32.17 \text{ ft} \cdot \text{lb}_f/\text{lb}_m/\text{sec}^2$ conversion factor

If we follow the metric model for defining force or weight, the U.S. (English) system uses the “poundal” as the comparable force unit, which is defined by:

$$1 \text{ poundal} = 1 \text{ lb}_m \times 32.17 \text{ ft/sec}^2 \quad (8)$$

So a poundal is equal to 32.17 pounds-force. Poundals times $1/32.17$ or 0.03108 equals pounds-force or weight.

The alternate unit for mass in the U.S. (English) system is the “slug”. One slug is the mass that requires a one pound force to produce an acceleration of 1 ft/s^2 . Hence:

$$1 \text{ lb}_f = 1 \text{ slug} \times 1 \text{ ft/s}^2 \quad (9)$$

It then follows that 1 slug is equivalent to 32.17 pounds-mass.

In the final analysis, however, you will normally encounter only a few units in the presently used systems. In the SI metric system mass is in kilograms and force is expressed in Newtons. In the U.S. Customary/English system, mass is expressed in pounds-mass and force or weight is in pounds-force, with the g/g_c factor used where needed. You do have to be careful about when and where you apply g_c and remember that it is just a conversion factor—check your units for consistency.

Other Systems for Weight [10, 18, 20, 30, 31]

The normal systems we use for weighing are the SI metric system and the U.S. Customary (or English) system. The U.S. system is called the avoirdupois system, formally, and derived from the English weight system in the 1700 s.

There are four other historical systems for weight or mass that persist today in specific applications. These are:

- Apothecaries’ system.
- Troy system.
- Tower system.
- Gem and Pearl units.

Apothecaries’ System

Apothecary measures were used for medicines and fine goods. They are still applied in some cases. This system is a separate and ancient system of measurement that parallels, and sometimes coincides, with common measurements. We touched on the volumetric measures in this system in the chapter on volume. In the apothecaries’ system, the largest unit of weight is the pound (lb ap) and the smallest unit is the grain (gr ap), so the weights measured can be very small. Units in this system, within English measurement since 1824 AD, include:

- grain, gr ap (0.0000648 kg/0.00014 lb av)
- scruple, s ap (20 gr ap, 0.0013 kg/0.0029 lb av)
- dram, dr ap (3 s ap, 0.00389 kg/0.00858 lb av)
- ounce, oz ap (8 dr ap, 0.0311 kg/0.0686 lb av)
- pound, lb ap (12 oz ap = 1 troy pound, 0.373 kg/0.823 lb av)

Troy System

The troy system was used for coins and precious metals in the English systems after 1526 AD, although its genesis dates back much further. It ties to and parallels the apothecaries' system, with a few different names for units:

- grain, gr t (0.0000648 kg/0.00014 lb av, same as apothecaries' measure)
- pennyweight, dwt t (24 grains, 0.00156 kg/0.00344 lb av)
- ounce, oz t (20 dwt t, 0.0311 kg/0.0686 lb av, same as apothecaries' ounce)
- mark, mk t (8 oz t, 0.249 kg/0.549 lb av)
- pound, lb t (12 oz t, 0.373 kg/0.823 lb av, same as apothecaries' pound)

Tower System

Before 1526, the English used the Tower system for coins and precious metals. The unit names in this system are the same as in the troy system, but the magnitudes represented by the units differ. In this system:

- grain, gr T (0.0000455 kg/0.000100 lb av)
- pennyweight, dwt T (32 gr T, 0.00146 kg/0.00322 lb av)
- ounce, oz T (24 dwt T = 640 gr T, 0.029 kg/0.064 lb av)
- mark, mk T (8 oz T, 0.232 kg/0.512 lb av)
- pound, lb T (12 oz T, 7680 gr T, 0.350 kg/ 0.770 lb av)

Gem and Pearl Units

There are different measurement units applied to gems and pearls. These are often related to definitions for weights of these items defined by international agreement in 1907. Some of the units used date back many millennia. In many cases, the stated weights of old gemstones will differ from the weight that would be currently assigned due to local and historical variations in the standards.

In this system, we find units like:

- point (0.000002 kg/0.000004 lb av)—Points are used for small diamonds and high value gems.
- grain (0.00005 kg/0.00011 lb av)—This is the unit used for pearls.
- carat (0.0002 kg/0.00044 lb av)—This unit was defined internationally in 1907, but unit is much older. Derived from the seed of the African Coral Tree or the kernal in a carob seed. This value has varied significantly over time and location.
- gram (0.001 kg/0.0022 lb av)—5 carats. This unit is used for lower value gemstones.
- momme (0.00375 kg/0.00827 lb av)—Old Japanese unit for pearls, superseded by the grain.

The unit “carat” in this system is not to be confused with the term “karat” used for indicating the purity of gold or other precious metals. Carat is a weight, while karat is a concentration. In gold, $\text{karats}/24 \times 100\%$ is the percentage gold content of an object. For instance, 18 karat gold is $18/24 \times 100\% = 75\%$ gold.

Comparisons of Historical Unit Magnitudes

Across civilizations and eras, the orders of magnitude for various historical weight and mass units are compared in Fig. 7.3. The smallest units tend to be used for precious metals, drug, and fine goods. The larger units are normally related to shipping.

There are very small and very large mass units used that are several orders of magnitude outside the Fig. 7.3 range. These units are usually associated with scientific measurements. Some examples are:

- Atomic mass unit (amu) or Dalton (Da or u , $1.66\ldots \times 10^{-27}$ kg/ 3.66×10^{-27} lb)—This unit is used in measuring weights of atoms and subatomic particles. It is the weight of one neutron or proton. Formally, it is defined as 1/12 of the mass of a C^{12} atom.
- Earth mass ($M_{\oplus}$ or M_T or M_E or E , 5.97×10^{24} kg/ 1.32×10^{25} lb)—This unit is used to compare the masses of solid planets and other heavenly bodies of nominal size in astronomical terms.
- Jupiter mass (M_J or M_{JUP} , 1.90×10^{27} kg/ 4.2×10^{27} lb)—This unit is used to compare the masses of large planets, like gas giants in astronomy.
- Solar mass ($M_{\odot}$, 1.99×10^{30} kg/ 4.39×10^{30} lb)—This unit is used to compare the masses of larger heavenly bodies in astronomy, such as stars or galaxies. It is 332,946 times the earth mass.

Note that multiple sources listed in the “References” section were used to develop this comparison; hence, the individual sources are not repeated here.

Historical Weight and Mass Conversion Factors [1-6, 9-17, 21, 24-33]

Two tables are offered here for weight/mass conversion factors:

- Table 7.2 provides weight/mass conversions for different locations, regions, eras, and historical civilizations listed alphabetically by location in both metric and U.S. Customary units.
- Table 7.3 provides the same weight/mass conversion options as Table 7.2, except that the conversions are all listed alphabetically, without regard to location or era.

Virtually all the sources listed in the “References” section were used in this compilation; hence, the individual sources are not repeated here.

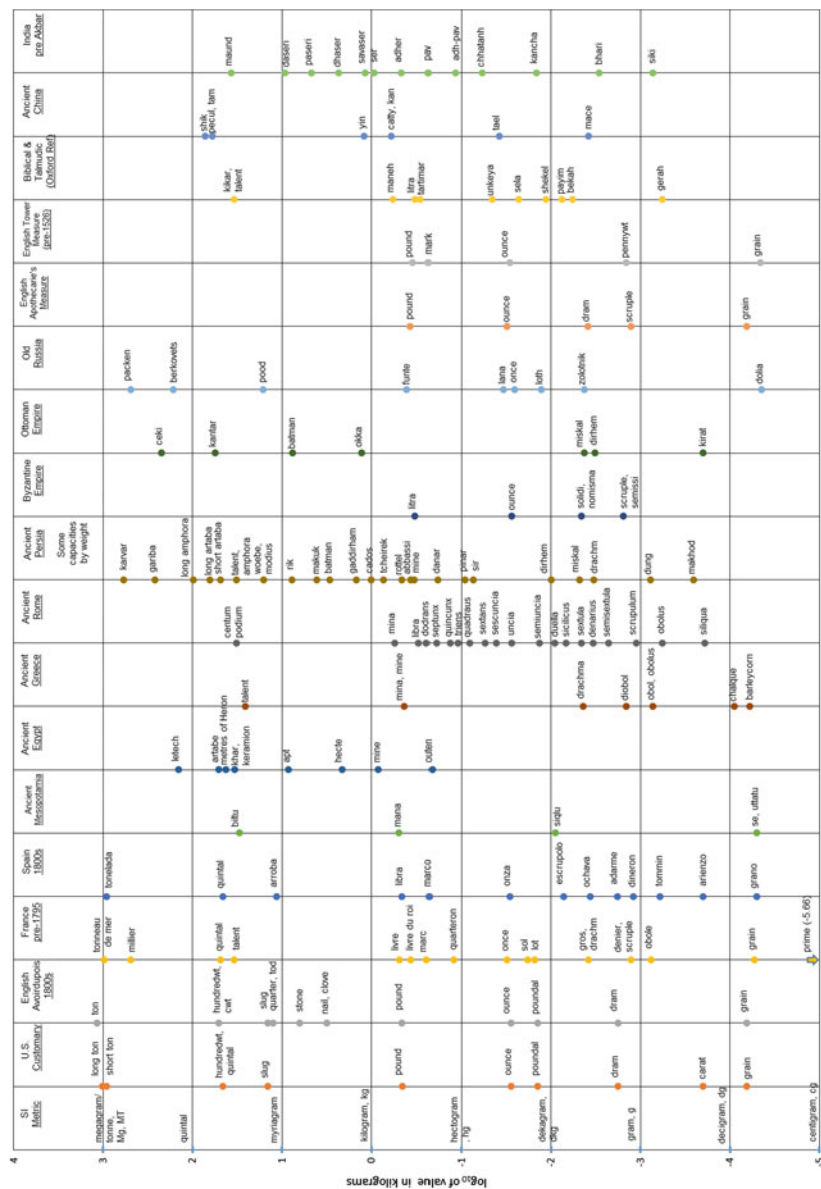


Fig. 7.3 Relative magnitudes of historical weight/mass units. Multiple sources, see References

Table 7.2 Historical weight/mass measurement conversion factors by location and era. Multiple sources, see References

Region and unit	Equivalent kgs at 1 grav.	Equivalent lbs at 1 grav.	Notes	Era
Abyssinia				Pre-metric
dirhem, derime	0.00259	0.00571	Drachm, 1891 value, consistent with 2003 reference	
wakea	0.0259	0.0571	Ounce, 10 dirhems, 1891 value, consistent with 2003 reference	
mocha	0.0311	0.0686	12 dirhems, 1 troy ounce, consistent with 2003 reference	
rotl, rottolo, or liter	0.311	0.686	Pound, 12 wakeas, 4800 grains, 1891 value, consistent with 2003 reference	
mond or maund	9.95	21.9	32 rotl, 1891 value	
Afghanistan (Below were mostly used for narcotics, current, other measurements are from Persia)				Colonial to modern
tulee	0.01	0.02	Varies	
puri	1	2.2	Slightly less, approx	
maan	4.50	9.92	Cannabis, opium, heroin	
khaltar	7.00	15.4	Approx	
mon	50.0	110	Used in Quetta	
kharwar	454.5	1,002	~ 1,000 lbs US	
Algeria (local variations, pre-1843, values depend on commodity)				Medieval to pre-metric
Common measure				
grain	0.0000648	0.000143	Calculated from 1891 reference	
karob	0.000194	0.000429	3 grains, 1891 value	
gyral	0.000207	0.000456	2003 reference	
metical or metsquat	0.004708	0.01038	2003 reference	
ukkia	0.03413	0.07524	Ounce, 7.25 metical, 2003 reference	
wakea	0.341	0.752	12.04 oz, 1891 value	
rottolo à thary	0.5461	1.204	16 ukkia, 2003 reference	
rottolo à khaldary or rotl gheddari	0.6143	1.354	2, 2003 reference, consistent with 1891 value, applied to fruits	
rottolo à kebyr or rotl khebir	0.8191	1.806	24 ukkia, also reported as 0.922 kg in 1891	
cantar à thary	54.61	120.4	100 rottolo à thary	

(continued)

Table 7.2 (continued)

Region and unit	Equivalent kgs at 1 grav.	Equivalent lbs at 1 grav.	Notes	Era
cantar à khaldary, cantaro gheddari, or quontar gheddari	61.43	135.4	100 rottolo à khadhary	
cantar à kebyr, cantaro khebir, or quontar khebir	81.91	180.6	100 rottolo à kebyr	
Precious metals and fine goods				
mitkal or metrical (gold)	0.00467	0.0103	72.06 gr, 1891 value	
rotl feuddi (gold, silver)	0.497	1.10	1891 value	
rotl attari (spices)	0.546	1.20	1891 value	
cantaro or quontar feuddi (gold, silver)	49.7	110	100 rotl, 1891 value	
cantaro or quontar attari (spices)	54.6	120	100 rotl, 1891 value	
Annam (See also Vietnam, local variations)				Pre-metric
ly	0.0000391	0.0000861	Subdivided by factors of 10 to 1/1,000,000 (largely imaginary), 1891 value	
phan	0.000391	0.000861	10 ly, 1891 value	
dong	0.00391	0.00861	10 phan, 1891 value	
tael (Cochin China)	0.0383	0.0844	1891 value	
luong	0.0391	0.0861	10 dong, 1891 value	
nen	0.3905	0.8609	10 luong, 1891 value	
cân	0.6248	1.378	1.6 nen, 1891 value	
yen	6.25	13.8	10 cân, 1891 value	
binh	31.24	68.88	5 yen, 1891 value	
ta	62.48	137.8	2 binh, 1891 value	
quần	312.4	688.8	5 ta, 1891 value	
Arabia, Weights (Changed over time, “System of the Prophet”, local variations, different values depending on reference, 1891 reference numbers were in use at that time)				Ancient to pre-metric
danik (Mocha)	0.000509	0.00112	7.86 grains, 1891 value	
dihrem	0.00283	0.00624	2003 reference	
coffala (Mocha for gold, silver)	0.00311	0.00686	48 grains, 1891 value	
miscal (Mocha)	0.00467	0.0103	72 grains, 1891 value	
nevat	0.0142	0.0313	5 dihrem, 2003 reference	
vakia (typical)	0.0340	0.0750	1891 value	
nasch	0.0567	0.125	4 nevat, 2003 reference	

(continued)

Table 7.2 (continued)

Region and unit	Equivalent kgs at 1 grav.	Equivalent lbs at 1 grav.	Notes	Era
oukia	0.113	0.249	2 nasch, 2003 reference	
rotl (Jidda)	0.166	0.366	1891 value	
wakega (Mocha for gold, silver)	0.311	0.686	1891 value	
rotl or rotolo	0.340	0.750	3 oukia, 2003 reference	
wakega (Mocha, typical)	0.4536	1.00	1891 value	
rotl (Bet-el-faki)	0.462	1.02	1891 value	
man or mine	0.680	1.50	2 rotl, 2003 reference	
maund or maon (Jidda)	0.830	1.83	1891 value	
maund or maon (Bet-el-faki)	0.925	2.04	1891 value	
ocque or oka	1.36	3.00	2 man, 2003 reference	
maund or maon (typical)	1.36	3.00	40 vakias, 1891 value	
frazil (typical)	13.6	30.0	10 maunds, 1891 value	
quantar or talent	34.0	75.0	25 oka, 2003 reference	
kikkar	42.5	93.7	125 rotl, 2003 reference	
bahar (Jidda)	83.0	183	100 maunds, 1891 value	
bahar (typical)	204	450	15 frazils, 1891 value	
bahar (Bet-el-faki)	370	816	400 maunds, 1891 value	
Arabia capacities (Capacity measured by weight, see also volumetric capacities, varied by region and over time)				Ancient
mudd	0.6800	1.499	2003 reference	
caphite, kist, or kiladja	1.360	2.998	2 mudd, 2003 reference	
sâa	2.720	5.996	2 caphite, 2003 reference	
makuk	4.080	8.995	3 caphite, 2003 reference	
ferk	8.160	17.99	2 makuk, 2003 reference	
khoull or woëbe	16.32	35.98	2 ferk, 2003 reference	
cafiz or talent	32.64	71.96	2 khoull, 2003 reference	

(continued)

Table 7.2 (continued)

Region and unit	Equivalent kgs at 1 grav.	Equivalent lbs at 1 grav.	Notes	Era
modius	40.80	89.95	5 ferk, 2003 reference	
artabe or amphora	65.28	143.9	2 cafiz, 2003 reference	
gariba or den	261.1	575.6	4 artabe, 2003 reference	
Argentina (pre-1863, varied by region, units from Buenos Aires shown)				Colonial to pre-metric
grano or granos	0.00004985	0.0001099	1/9216 libra, 2003 reference	
adarme	0.001795	0.003956	1/256 libra, 36 granos, 2003 reference	
onza	0.02871	0.06330	1/16 libra, 16 adarme, 2003 reference	
marco (gold, silver)	0.2297	0.5063	3544.4 grains, 1891 value	
libra de farmacia	0.3445	0.7595	3/4 libra, 1891 value	
libra (common)	0.4594	1.013	16 onza, 1891 value, consistent with 2003 reference	
arroba	11.48	25.32	25 libras, 1891 value, consistent with 2003 reference	
arroba (Buenos Aires)	11.50	25.36	25.3583 lbs, 1891 value	
quintal	45.94	101.3	4 arrobas, 100 libra, 1891 value, consistent with 2003 reference	
tonelada	918.7	2,025	20 quintals, 2000 libras, 1891 value, consistent with 2003 reference	
Austrian Empire (Local variations)				Pre-metric
Ordinary commercial measure				
pfennige, dernat, or pfenig	0.001094	0.002411	1891 value, consistent with 2003 reference	
quentchen	0.004375	0.009645	4 pfennige, 1891 value, consistent with 2003 reference	
loth	0.01750	0.03858	4 quentchen, 1891 value, consistent with 2003 reference	
unze	0.03500	0.07716	2 loth, 1891 value, consistent with 2003 reference	
vierding or vierling	0.1400	0.3086	4 unzen, 1891 value, consistent with 2003 reference	
mark	0.2800	0.6173	2 vierding, 1891 value, consistent with 2003 reference	

(continued)

Table 7.2 (continued)

Region and unit	Equivalent kgs at 1 grav.	Equivalent lbs at 1 grav.	Notes	Era
zollpfund (Zollverein)	0.5000	1.102	For customs, 1891 value, post-metric	
münzpfund	0.5000	1.102	1891 value, post-metric	
pfund	0.5600	1.235	2 mark, 1891 value, slightly less in Bohemia, consistent with 2003 reference	
stein	11.20	24.69	20 pfund, 1891 value, consistent with 2003 reference	
centner or zentner	56.00	123.5	5 stein, 1891 value, consistent with 2003 reference	
centner (Bohemia, Prague)	67.2	148	6 stein, 1891 value, approximate, local variation, pfund is slightly lighter	
lägel (steel)	70.00	154.3	1891 value	
saum (steel)	140.0	308.6	250 pfund, 2 lägel, 1891 value	
saum	154.0	339.5	275 pfund, 1891 value, consistent with 2003 reference	
karch	224.0	493.8	4 centner, 1891 value, consistent with 2003 reference	
schiffslast (shipping ton)	1,120	2,469	20 centner, 1891 value	
last (ordinary ton)	2,240	4,938	40 centner, 1891 value	
Precious metals measure				
karat (jewels)	0.0002061	0.0004543	3.1799 grains, 1891 value	
pfennig (prec. mtl.)	0.001094	0.002411	1891 value	
quentchen (prec. mtl.)	0.004375	0.009645	4 pfennig, 1891 value	
loth (prec. mtl.)	0.01750	0.03858	4 quentchen, 1891 value	
mark (prec. mtl.)	0.2800	0.6173	4333 grains, 16 loth, 1891 value	
Apothecaries' weight				
gran	0.00007313	0.0001612	1891 value, also reported as 0.00007292 kg in 2003 reference	
scrupel	0.001463	0.003224	20 gran, 1891 value, also reported as 0.001458 kg in 2003 reference	
drachme	0.004388	0.009673	3 scrupel, 1891 value, also reported as 0.004375 kg in 2003 reference	

(continued)

Table 7.2 (continued)

Region and unit	Equivalent kgs at 1 grav.	Equivalent lbs at 1 grav.	Notes	Era
unze	0.03510	0.07738	8 drachmen, 1891 value, also reported as 0.03500 kg in 2003 reference	
pfund	0.4212	0.9286	6499 troy grains, 12 unzen, 1891 value, also reported as 0.4200 kg in 2003 reference	
Balearic Islands (Used Spanish system, local variations, old units)				Pre-metric
libra	0.400	0.882	1891 value	
roto	0.408	0.899	2003 reference	
libra mayor	1.22	2.70	3 rottolos, 2003 reference	
quartano or corta	3.67	8.10	3 libra mayors, 2003 reference	
arroba	10.6	23.4	26 rottolos, 2003 reference	
misura	14.7	32.4	4 quartanos, 2003 reference	
cantaro barbaresco	40.8	89.9	100 rottolos, 2003 reference	
cantaro	42.4	93.5	4 arrobas, 2003 reference	
cargo	1,146	2,526	27 cantaros, 2003 reference	
Belgium (Used units of France, early metric system adoption, pre-metric)				Pre-metric
loth	0.01530	0.03372	2003 reference	
once	0.03059	0.06745	2 loth, 2003 reference	
marc	0.2448	0.5396	8 once, 2003 reference	
livre	0.4895	1.079	2 marc, 2003 reference	
stein	3.916	8.633	8 livre, 2003 reference	
quintal	48.95	107.9	100 livre, 2003 reference	
chariot	80.77	178.1	165 livre, 2003 reference	
balle	97.90	215.8	2 quintal, 2003 reference	
shiffpfund	146.9	323.7	3 quintal, 2003 reference	
charge	195.8	431.7	2 balle, 2003 reference	
Belgium (French measures used in 1891 (metric), but may have different names, example below)				1891
livre	1.000	2.205	1891 value	

(continued)

Table 7.2 (continued)

Region and unit	Equivalent kgs at 1 grav.	Equivalent lbs at 1 grav.	Notes	Era
Biblical and Talmudic (Approx, used Babylonian system, no agreement on exact values, weights also translated to coins, varied as much as 100% by location and over time)				Ancient
Based on Heavy Royal Talent (with 50 shekels/mina, at one time was 60)				
gerah or giru	0.00101	0.00223		
dinar	0.0101	0.0223	10 gerah	
pim	0.0135	0.0297	1-1/3 dinar	
shekel	0.0202	0.0445	1.5 pim	
sela	0.0404	0.0891	2 shekel	
unkeya	0.0808	0.178	2 sela	
tartimar	0.505	1.11	6-1/4 unkeya	
maneh, mina, or litra	1.01	2.23	2 tartimar	
kikar, kikkar, or talent	60.6	134	60 maneh	
Based on Heavy Common Talent (with 50 shekels/mina, at one time was 60)				
gerah or giru	0.000982	0.00217		
dinar	0.00982	0.0217	10 gerah	
pim	0.0131	0.0289	1-1/3 dinar	
shekel	0.0196	0.0433	1.5 pim	
sela	0.03930	0.0866	2 shekel	
unkeya	0.0786	0.173	2 sela	
tartimar	0.491	1.08	6-1/4 unkeya	
maneh, mina, or litra	0.9824	2.166	2 tartimar	
kikar, kikkar, or talent	58.9	130	60 maneh	
Based on Oxford Biblical Studies Online (with 50 shekels/mina, at one time was 60)				
gerah or giru	0.000571	0.00126		
dinar, beka, bekah, or beqa	0.00571	0.0126	10 gerah (half a shekel)	
pim or payim	0.00762	0.0168	1-1/3 dinar	
shekel	0.0114	0.0252	1.5 pim	
sela	0.02285	0.05037	2 shekel	
unkeya	0.0457	0.101	2 sela	
tartimar	0.286	0.630	6-1/4 unkeya	
litra or libra	0.326	0.720		
maneh, mina, or mna	0.571	1.26	2 tartimar	
kikar, kikkar, or talent	34.3	75.6	60 maneh	
Bolivia (Spanish origins, pre-metric)				Pre-metric
arroba	11.50	25.35	1891 value	
quintal	46.00	101.4	4 arrobas, 1891 value	

(continued)

Table 7.2 (continued)

Region and unit	Equivalent kgs at 1 grav.	Equivalent lbs at 1 grav.	Notes	Era
Borneo (Dutch and English units used, local variations, approximate local values listed)				Pre-metric
malaborong	0.000138	0.000305	1891 value	
tica	0.000415	0.000914	3 malaborong	
copang	0.000622	0.00137	1.5 tica	
mace	0.00249	0.00548	4 copang	
pahaw	0.00995	0.0219	4 mace	
tael	0.0398	0.0877	4 pahaws, 614 troy grains	
pecul	61.52	135.6		
Brazil (pre-1862, many local variations, values from 1891 and 2003 references)				Colonial to pre-metric
quilate (gems)	0.0001993	0.0004393	3.075 grains	
outava (topaz)	0.003705	0.008167	57.17 grains	
onça or onza	0.02869	0.06325	Ounce, 2003 reference	
marco	0.2295	0.5060	Half-pound, 8 onza, 2003 reference	
libra	0.4591	1.012	Pound, 2 marco, 2003 reference	
arroba	14.69	32.38	32 libras, 2003 reference	
quintal	58.76	129.5	128 libras, 4 arroba, 2003 reference	
tonelada	793.2	1,749	1,728 libras, 54 arroba, 2003 reference	
Burma or Birmah (AKA Rangoon, now Republic of the Union of Myanmar)				Pre-metric
ruay	0.000255	0.000562	2003 reference	
pai	0.00102	0.00225	4 ruay, 2003 reference	
moo	0.00204	0.00450	2 pai, 2003 reference	
mat	0.00408	0.00899	2 moo, 2003 reference	
tical	0.01512	0.03333	1891 value	
tical	0.0163	0.0360	4 mat, 2003 reference	
catty	0.5040	1.111	1891 value	
catty	0.544	1.20	33-1/3 tical, 2003 reference	
vis or vis	1.512	3.333	3 catties, 100 ticals, 1891 value	
vis or vis	1.63	3.60	3 catty, 2003 reference	
candy	226.8	500.0	150 vis, 1891 value	
candy	245	540	150 viss, 2003 reference	

(continued)

Table 7.2 (continued)

Region and unit	Equivalent kgs at 1 grav.	Equivalent lbs at 1 grav.	Notes	Era
Byzantine Empire (Ancient units, local variations)				Ancient
scruple	0.00155	0.00342	1/24 Greek ounce	
semissis	0.00227	0.00500	1/12 Greek ounce	
solidi	0.00455	0.0100	Circa 309 AD, reduced over time to 0.00443 kg by 9th century	
nomisma	0.00455	0.0100	1/6 Greek ounce	
ounce	0.0273	0.0602	=Roman uncia	
litra or Roman pound	0.3276	0.7222	72 gold solidi, circa 309 AD, reduced over time to 0.319 kg by 9th century	
Cambodia (See also Annam and Vietnam, appear to be pre-metric names and post metric values)				Post-metric
lin	0.0000375	0.0000827	3/80 muoi, 2003 reference	
hun	0.000375	0.000827	3/8 muoi, 10 lin, 2003 reference	
muoi or mot dong can tay	0.00100	0.00220	2-2/3 hun, 2003 reference	
chin	0.00375	0.00827	25 lin, 2003 reference	
tael	0.0375	0.0827	75/2 muoi, 10 chin, 2003 reference	
neal	0.600	1.32	600 muoi, 16 tael, 2003 reference	
pram roi or mot can tay	1.00	2.20	1000 muoi, 2003 reference	
chong	30.00	66.14	30,000 muoi, 30 pram roi, 2003 reference	
hap or picul	60.00	132.3	600,000 muoi, 2 chong, 2003 reference	
Canada				Pre-metric
General: Pre-metric conversion (1970s), Canada used English Imperial system				
Canary Islands (Spanish system, local variations)				Pre-metric
libra	0.4603	1.015		
Celebes (Generally Dutch units, local variations)				Pre-metric
pecul	61.53	135.6		
Central America (See individual countries for additional information, local variations, primarily Spanish system, potential conflicts among references)				Colonial to pre-metric
libra	0.4731	1.043	1891 value	
arroba	11.83	26.07	25 libras, 1891 value	
caja	16.0	35.3	2003 reference	

(continued)

Table 7.2 (continued)

Region and unit	Equivalent kgs at 1 grav.	Equivalent lbs at 1 grav.	Notes	Era
quintal	47.31	104.3	4 arrobas, 1891 value	
fanega	92.0	203	23/4 caja, 2003 reference	
carga	161	355	7/4 fanega, 2003 reference	
Ceylon (Primarily English measures in 1891, local units and variations, typical values below for local system similar to Burma, see Sri Lanka, includes Madras)				Pre-metric
fanam	0.0001969	0.0004340	2003 reference	
pagoda	0.007087	0.01562	36 fanam, 2003 reference	
pollam or varahan	0.03544	0.07812	5 pagoda, 2003 reference	
powa	0.07087	0.1562	2 pollam, 2003 reference	
seer	0.2835	0.6250	4 powa, 2003 reference	
vis or viss	1.417	3.125	5 seer, 2003 reference	
maund	11.34	25.00	8 vis, 2003 reference	
candy or bahar	226.8	500.0	20 maund, 18891 value, consistent with 2003 reference	
candy (older value)	236.2	520.7	Older value (pre 1891)	
Chile (pre-1848, local variations)				Colonial to pre-metric
granos	0.00004992	0.0001101	Grain, 1/9216 libra, 2003 reference	
adarme	0.001797	0.003962	1/256 libra, 36 granos, 2003 reference	
castellano	0.004601	0.01014	1/100 libra, 2003 reference	
onza	0.02876	0.06339	Ounce, 16 adarme, 2003 reference	
libra or libbra	0.4601	1.014	Pound, 16 onza, 2003 reference, also reported as 0.473 kg in 1891	
arroba	11.50	25.36	25 libra, 2003 reference	
quintale	46.01	101.4	100 libra, 4 arroba, 2003 reference	
China (1891, local variations, sampling of units)				Medieval to pre-metric
mace	0.003780	0.008333	1891 value	
tael	0.03780	0.08333	10 mace, 1891 value	
catty or kan	0.6048	1.333	16 tael, 1891 value	

(continued)

Table 7.2 (continued)

Region and unit	Equivalent kgs at 1 grav.	Equivalent lbs at 1 grav.	Notes	Era
yin	1.210	2.667	2 catties, 1891 value	
pecul or tam	60.48	133.3	50 yin, 1891 value	
shik	72.6	160	1891 value	
China (1915–1929, local variations)				Pre-metric
háo	0.000003730	0.000008223	1/10,000 liǎng	
shu	0.00001554	0.00003426		
li, lǐ, or cash	0.0000373	0.00008223	1/1000 liǎng	
fēn or candareen	0.000373	0.0008223	1/100 liǎng	
zhu	0.001554	0.003426	100 shu	
qián, tsouen, or mace	0.003730	0.008223	1/10 liǎng	
liǎng or tael	0.03730	0.08223	Chinese ounce, 24 zhu	
jīn, tchin, or catty	0.5968	1.316	Chinese pound, 16 liǎng	
jun or kwan	17.90	39.46	30 jīn	
tan	59.68	131.6	100 jīn	
dan or shih	71.62	157.9	4 jun	
China (1930–1958, old names with metric definitions)				Post-metric
sī	0.000000313	0.000000689	1/1600000 jīn	
háo	0.00000313	0.00000689	1/160000 jīn	
li or cash	0.0000313	0.0000689	1/16000 jīn	
fēn or candareen	0.000313	0.000689	1/1600 jīn	
qián or mace	0.00313	0.00689	1/160 jīn	
liǎng or tael	0.0313	0.0689	Chinese ounce, 1/16 jīn	
jīn or catty	0.500	1.102	Chinese pound	
dan or picul	50.00	110.2	“Chinese hundredweight”, 100 jīn	
China (Since 1959, old names with metric definitions)				Post-metric
li or cash	0.0000500	0.000110	1/10,000 jīn	
fēn or candareen	0.000500	0.00110	1/1600 jīn	
qián or mace	0.00500	0.0110	1/160 jīn	
liǎng or tael	0.050	0.110	“Chinese ounce”	
jīn or catty	0.500	1.10	“Chinese pound”, 16 liǎng	
dan or picul	50.00	110.2	“Chinese hundredweight”, 100 jīn	

(continued)

Table 7.2 (continued)

Region and unit	Equivalent kgs at 1 grav.	Equivalent lbs at 1 grav.	Notes	Era
Colombia (pre 1854 to about 1920, value of one libra set at 0.500 kg at the time of metrication, previous values varied)				Colonial to Metric
onza	0.0313	0.0689	Ounce, 1/16 libra, 2003 reference	
libra or libbra	0.500	1.10	Pound, also reported as 0.5435 kg, 2003 reference	
arroba	12.50	27.56	25 libra, 2003 reference	
quintal	50.00	110.2	100 libra, 2003 reference	
saco	62.50	137.8	Sack, 125 libra, 2003 reference	
carga	125.0	275.6	250 libra, 2003 reference	
tonelada	1000	2,205	Ton, 2000 libra, 2003 reference	
Costa Rica (See also Central America, local variations, primarily Spanish system, potential conflicts among references)				Colonial to Pre-metric
libra	0.4731	1.043	1891 value	
arroba	11.83	26.07	25 libras, 1891 value	
caja	16.0	35.3	2003 reference	
fanega (coffee)	46	101		
quintal	47.31	104.3	4 arrobas, 1891 value	
fanega	92.0	203	23/4 caja, 2003 reference	
carga	161	355	7/4 fanega, 2003 reference	
Crete (Or Candia, local variations)				Pre-metric
rottola	0.5288	1.166	1891 value	
oka	1.202	2.649	1891 value	
cantaro	52.88	116.6	44 oka, 100 rottoli, 1891 value	
Cuba (mostly Spanish basis, pre-1858, some additional 1920s units)				Colonial to Pre-metric
libra	0.461	1.02		
tercio	72.2	159		
tonelada or millier	1,016	2,239		
Cypress (Primarily British units and others, pre-1972)				Colonial to pre-metric
drachme	0.003175	0.007000	1/400 oke, 2003 reference	
rottolo	0.5588	1.232	176 drachme, 0.44 oke, 2003 reference	

(continued)

Table 7.2 (continued)

Region and unit	Equivalent kgs at 1 grav.	Equivalent lbs at 1 grav.	Notes	Era
oka (1891)	1.268	2.796	1891 value	
oke, oka, or uqqa	1.270	2.800	400 drachme, 2003 reference	
rotolo (1891)	2.378	5.242	1891 value, 1-7/8 oka	
mussa	6.350	14.00	5 okes, 2003 reference	
stone	50.80	112.0	Hundredweight, 8 mussas, 2008 reference	
moosa (1891)	50.80	112.0	1891 value	
kantar or cantaro	55.88	123.2	40 oke, 2003 reference	
kantar (Aleppo)	228.6	504.0	180 oke (local variation), 2003 reference	
kantar or cantaro (1891)	237.8	524.2	1891 value, 100 rotolos	
ton	1016	2,240	800 oke, 2003 reference	
Denmark (pre-1907)				Medieval to pre-metric
Ordinary measure				
es	0.0000546	0.000120	2003 reference	
ort	0.000977	0.00215	17-7/8 es, 2003 reference	
quintin	0.00391	0.00861	4 ort, 2003 reference	
ort	0.005000	0.01102	1891 value	
loth	0.0156	0.0344	4 quintin, 2003 reference	
unze	0.0313	0.0689	2 loth, 2003 reference	
quint	0.05000	0.1102	10 ort, 1891 value	
mark	0.250	0.551	8 unze, 2003 reference	
pund (old)	0.4994	1.101	Early 1800 s value?	
pund	0.4998	1.102	“Pound” from 1683, weight of 1/62 cubic fod (foot) of water	
pund	0.5000	1.102	Same as German Zollverein, 2 mark, 10 quint, 1891 value, consistent with 2003 reference	
bismerpund	6.00	13.2	12 pund, 2003 reference	
lispund (old)	7.990	17.61	16 old pund, early 1800s value?	

(continued)

Table 7.2 (continued)

Region and unit	Equivalent kgs at 1 grav.	Equivalent lbs at 1 grav.	Notes	Era
Ordinary measure (Continued)				
lispund	8.00	17.6	16 pund, 2003 reference	
waag	18.0	39.7	3 bismerpund, 2003 reference	
centner	50.00	110.2	100 pund, 1891 value, consistent with 2003 reference	
skippund (old)	159.8	352.3	20 old lispund, early 1800 s value?, consistent with 2003 reference	
skyplast	2,600	5,732	52 centner, 2003 reference	
Precious metals measure				
ort	0.0009123	0.002011	1891 value	
quintin	0.003649	0.008045	4 ort, 1891 value	
lod	0.01460	0.03218	4 quintin, 1891 value	
mark	0.2336	0.5149	16 lod, 1891 value	
Apothecaries' Measure				
gran	0.00006213	0.0001370	1891 value	
drachme	0.003728	0.008218	60 gran, 1891 value	
unze	0.02982	0.06575	8 drachme, 1891 value	
pund	0.3579	0.7890	12 unze, 1891 value	
Egypt (pre-metric, local variations)				Pre-metric
kamha	0.0000322	0.0000710	1891 value	
kérat	0.000129	0.000284	4 kamha, 1891 value	
kirat	0.000195	0.000430	1/6400 oke, alternate reference	
kirat	0.001755	0.00387	0.001406 oke, 2003 reference	
darhim or drachm	0.00309	0.00682	24 k�rat, 1891 value	
mitkal or metical (prec. Mtls)	0.00309	0.00682	For weighing precious metals, same as darhim, 1891 value	
dirhem	0.00312	0.00688	1/400 oke	
miskal	0.0125	0.0275	1/100 oke?	
dirhem	0.02808	0.06190	16 kirat, 2003 reference	
okieh	0.0374	0.0825	0.03 oke	
miskal	0.1123	0.2476	4 dirhem, 2003 reference	
okieh	0.3370	0.7429	3 miskal, 2003 reference	
rotl or rottolo	0.4454	0.9819	144 darhims, 1891 value	

(continued)

Table 7.2 (continued)

Region and unit	Equivalent kgs at 1 grav.	Equivalent lbs at 1 grav.	Notes	Era
rotoli	0.4493	0.9905	4 miskal, 2003 reference	
oke, oka, or occa	1.237	2.727	400 darhims, 1891 value	
harsela (silk)	1.237	2.727	Same as oke, 1891 value	
oke, oka, or uqqa	1.248	2.751	25/9 rotoli, 2003 reference	
harsela (silk)	1.248	2.751	Same as oke, alternate reference	
cantaro	44.54	98.19	100 rotl, 1891 value	
kantar	44.93	99.05	36 oke, 2003 reference	
helm	249.6	550.3	200 oke, 2003 reference	
Egypt—Ancient (wide variations over time and locally, approximate values)				Ancient
gerah or obol	0.0006825	0.001505	2003 reference	
grain	0.0009100	0.002006	1-1/3 gerah, 2003 reference	
shꜣts or shematy (Old and Mid)	0.00113	0.00250	1/12 deben	
qd.t, kite, or qedet (Old & Middle Kingdom)	0.00136	0.00300	1/10 deben, for silver & gold	
sep	0.001365	0.003009	2 gerah, 2003 reference	
shꜣts or shematy (New)	0.00758	0.0167	1/12 deben	
qd.t, kite, or qedet (New Kingdom)	0.00910	0.0201	1/10 deben, for silver & gold	
dbn or deben (Old & Middle Kingdom)	0.0136	0.0300	Base unit (Old and Middle Kingdom), for copper, silver & gold	
deben or sicles	0.01365	0.03009	10 sep, 2003 reference	
dbn or deben (New Kingdom)	0.0910	0.201	Base unit (New Kingdom), for copper, silver, and gold	
kedat	0.1365	0.3009	10 deben, 2003 reference	
mine	0.8190	1.806	6 kedet, 2003 reference	
talent	40.95	90.28	50 mine, 2003 reference	
Egypt (Capacity measures by weight, wide variations over time and locally, 2003 reference)				Ancient
outen	0.21	0.47	2003 reference	
maân or mine	0.85	1.9	4 outen, 2003 reference	

(continued)

Table 7.2 (continued)

Region and unit	Equivalent kgs at 1 grav.	Equivalent lbs at 1 grav.	Notes	Era
hecte	2.1	4.7	2.5 mine, 2003 reference	
apt	8.5	19	4 hecte, 2003 reference	
khar or keramion	34	75	4 apt, 2003 reference	
metretes of Heron	43	94	5 apt, 2003 reference	
artabe	51	112	6 apt, 2003 reference	
letech	143	316	675 outen, 2003 reference	
El Salvador (See also Central America, local variations, primarily Spanish system, potential conflicts among references)				Colonial to pre-metric
libra	0.4731	1.043	1891 value	
arroba	11.83	26.07	25 libras, 1891 value	
caja	16.0	35.3	2003 reference	
quintal	47.31	104.3	4 arrobas, 1891 value	
fanega	92.0	203	23/4 caja, 2003 reference	
carga	161	355	7/4 fanega, 2003 reference	
Eretria (early 20th Century, local variations)				Medieval to pre-metric
okia	0.0280	0.0617	Ounce, 1/16 rotolo, 2003 reference	
rotolo or rottolo	0.448	0.988	Pound, 16 okia, 2003 reference	
gisla	163	359	364 rottolo, 2003 reference	
Estonia (early 20th century, local variations)				Medieval to pre-metric
quent	0.00336	0.00741	1/128 pfund, 2003 reference	
loth	0.0134	0.0296	4 quent, 2003 reference	
pfund	0.460	1.01	Pound, 32 loth, 2003 reference	
liespfund	9.20	20.3	20 pfund, 2003 reference	
centner	55.2	122	120 pfund, 2003 reference	

(continued)

Table 7.2 (continued)

Region and unit	Equivalent kgs at 1 grav.	Equivalent lbs at 1 grav.	Notes	Era
tonne or ton	110	243	240 pfund, 2003 reference	
schiffspfund	184	406	400 pfund, 2003 reference	
Ethiopia (pre-1963, local variations)				Medieval to pre-metric
drachm or derime	0.00259	0.00571	1/120 rottolo	
kasm (rubber)	0.00390	0.00860	Based on rubber farasula, 2003 reference	
mutagalla (rubber)	0.007799	0.01719	2 kasm, based on rubber farasula, 2003 reference	
alada (rubber)	0.01560	0.03439	2 mutagalla, based on rubber farasula, 2003 reference	
wakea	0.0259	0.0571	1/12 rotto	
mocha	0.0311	0.0686	1/10 rotto	
wogiet (rubber)	0.03120	0.06878	2 alada, based on rubber farasula, 2003 reference	
rottolo	0.311	0.686		
neter (rubber)	0.3360	0.7407	140/13 wogiet, based on rubber farasula, 2003 reference	
farasula (ivory)	13.48	29.72	Ivory basis, 2003 reference	
farasula (coffee)	16.85	37.15	Coffee basis, 2003 reference	
farasula (rubber)	17.97	39.62	Rubber basis, 1152 alada, 2003 reference	
France (Several versions, local variations)				Medieval to metric
Pre 1790 and some after (Liver de Paris based)				
prime	0.000002213	0.000004879	1/24 ³ once, 2003 reference	
grain	0.00005311	0.0001171	1/24 ² once, “French grain”, 2003 reference	
felin (boullion)	0.0003824	0.0008430	2003 reference	
maille or obole (boullion)	0.000765	0.00169	2 filins, 2003 reference	
denier or scruple	0.001275	0.002811	1/24 once, 24 grains, 2003 reference	
esterlin or estelin (boullion)	0.00153	0.00337	2003 reference, 2 oboles	

(continued)

Table 7.2 (continued)

Region and unit	Equivalent kgs at 1 grav.	Equivalent lbs at 1 grav.	Notes	Era
gros or drachm	0.003824	0.008430	1/8 once, 3 denier, 2003 reference	
lot	0.01530	0.03373	4 gros, 2003 reference	
once	0.03059	0.06744	“French ounce”, 2 lot, 2003 reference	
quarteron	0.1224	0.2698	4 onces, 2003 reference	
marc or Mark	0.2448	0.5397	2 quarteron, 2003 reference	
livre	0.4895	1.079	“French pound”, 2 marc, 2003 reference	
poids-de-marce	0.4896	1.079	Ancient pound as reported 1891	
talent	34.28	75.57	Mass of one French cft water at 1 g/cm ³	
quintal	48.95	107.9	“French hundredweight”	
millier	489.5	1,079	“French thousand”, 10 quintal, 2003 reference	
tonneau de mer	979.0	2,158	2 millier, 2003 value	
Old units (Livre du Roi based, Charlemagne)				
grain	0.00006373	0.0001405	2003 reference	
obole	0.0007648	0.001686	12 grains, 2003 reference	
denier or scruple	0.001530	0.003372	2 obole, 2003 reference	
sol	0.01836	0.04047	12 denier, 2003 reference	
livre du roi (Charlemagne)	0.3671	0.8093	20 sol, 2003 reference	
Système usuel (1840 Compromise)				
grain	0.00005425	0.0001196		
gros	0.00391	0.00861	72 grains	
once	0.0313	0.0689	8 gros	
marc	0.250	0.551	8 onces	
livre	0.500	1.10	2 marcs	
Metric system (Early 1800s, values in 1891)				
milligramme	0.000001	0.000002205	1/10 centigramme	
centigramme	0.00001	0.00002205	1/10 decigramme	
decigramme	0.0001	0.0002205	1/10 gramme	
gramme (1891)	0.001	0.002205	Standard base	

(continued)

Table 7.2 (continued)

Region and unit	Equivalent kgs at 1 grav.	Equivalent lbs at 1 grav.	Notes	Era
decagram (1891)	0.01	0.02205	10 grammes	
hectogramme (1891)	0.1	0.2205	10 decagrammes	
kilogramme (1891)	1	2.205	10 hectogrammes	
myriagramme (1891)	10	22.05	10 kilogrammes	
quital (1891)	100	220.5	10 myrigrammes	
millier or tonneau (1891)	1,000	2,205	10 quitals	
Finland (pre-1861 except as noted, local variations)				Medieval to pre-metric
luoti	0.0140	0.0308	Weight of a musket ball, 1/16 markka	
unssi	0.0279	0.0615	1/8 markka	
markka	0.214	0.471	Finnish monetary unit 1861–2002	
naula	0.426	0.938	2 markka, metrinen naula (metric version) = 0.5 kg	
leiviskä	8.500	18.74	40 markka, metrinen leiviskä (metric version) = 10 kg	
sentneri	42.56	93.83	200 markka, metrinen sentneri (metric version) = 100 kg	
kippunta	170	375	800 markka	
Germany (pre-1868, local variations, values from 1891, see also Prussia)				Pre-metric
Ordinary measure				
ass (common, gold, silver)	0.00005000	0.0001102	1891 value	
ass (Baden)	5.000E-05	0.000110	1891 value	
gran (Saxony)	6.087E-05	0.000134		
gran (Austrian system)	6.090E-05	0.000134	2003 reference	
heller (Brunswick)	0.0004564	0.001006	1891 value	
heller (Frankfort)	0.000493	0.00109	1891 value	
pfennig or dekass (Baden)	0.0005000	0.001102	10 ass, 1891 value	
pfennig (Brunswick)	0.0009129	0.002013	2 heller, 1891 value	
pfennig (Saxony)	0.0009130	0.002013	15 gran	
pfennig (Austrian system)	0.0009135	0.002014	15 gran, 2003 reference	
pfennig (Hamburg)	0.0009461	0.002086	1891 value	
pfennige (Lubeck)	0.0009468	0.002087	1891 value	
örtche (Hanover)	0.0009563	0.002108	1891 value	

(continued)

Table 7.2 (continued)

Region and unit	Equivalent kgs at 1 grav.	Equivalent lbs at 1 grav.	Notes	Era
ort (Bremen)	0.0009737	0.002147	1891 value	
richtpfennig (Hesse-Darmstadt)	0.0009766	0.002153	1821 value, previously same as Frankfort	
pfennig (Frankfort)	0.000987	0.002176	2 heller, 1891 value	
quentchen (Brunswick)	0.003652	0.008050	4 pfennige, 1891 value	
quentlein (Saxony)	0.003652	0.008052	4 pfennige	
quint (Austrian system)	0.003654	0.008056	4 pfennig, 2003 reference	
quentchen (Hesse-Cassel)	0.003783	0.008340	1891 value	
quentchen (Hamburg)	0.003784	0.008343	4 pfennige, 1891 value	
quentchen (Lubeck)	0.003787	0.008350	4 pfennige, 1891 value	
quentchen (Hanover)	0.003825	0.008433	4 ortchen, 1891 value	
quentchen (Bremen)	0.003895	0.008586	4 ort, 1891 value	
quentchen (Bavaria)	0.00391	0.00861	1891 value	
quentchen (Hesse-Darmstadt)	0.003906	0.008612	4 richtpfennig, 1821 value, previously same as Frankfort	
quentchen (Frankfort)	0.00395	0.00870	4 pfennig, 1891 value	
quentchen (Bavaria, commercial)	0.00438	0.00965	1891 value	
quentchen (Austrian system)	0.004872	0.01074	80 gran, 2003 reference	
centass (Baden)	0.005000	0.01102	10 pfennig, 1891 value	
loth (Brunswick)	0.01461	0.03220	4 quentchen, 1891 value	
loth (Saxony)	0.01461	0.03221	4 quentlein	
loth (Austrian system)	0.01462	0.03222	3 quentchen, 2003 reference	
loth (Hesse-Cassel)	0.01513	0.03336	4 quentchen, 1891 value	
loth (Hamburg)	0.0151	0.0334	4 quentchen, 1891 value	
loth (Lubeck)	0.01515	0.03340	4 quentchen, 1891 value	
loth (Hanover)	0.01530	0.03373	4 quentchen, 1891 value	
loth (Bremen)	0.01558	0.03435	4 quentchen, 1891 value	
loth (Bavaria)	0.0156	0.0344	4 quentchen, 1891 value	
loth (Hesse-Darmstadt)	0.01563	0.03445	4 quentchen, 1821 value, previously same as Frankfort	

(continued)

Table 7.2 (continued)

Region and unit	Equivalent kgs at 1 grav.	Equivalent lbs at 1 grav.	Notes	Era
loth (Frankfort)	0.0158	0.0348	4 quentchen, 1891 value	
loth (Bavaria, commercial)	0.0175	0.0386	4 quentchen, 1891 value	
unze (Saxony)	0.02922	0.06441	2 loth	
unze (Austrian system)	0.02923	0.06444	1/16 pfund, 2003 reference	
unze (Hesse-Cassel)	0.03026	0.06672	2 loth, 1891 value	
unze (Hamburg)	0.03027	0.06674	2 loth, 1891 value	
unze (Lubeck)	0.03030	0.06680	2 loth, 1891 value	
unze (Hanover)	0.03060	0.06747	2 loth, 1891 value	
unze (Bremen)	0.03116	0.06869	2 loth, 1891 value	
unze (Frankfort)	0.0316	0.0696	2 loth, 1891 value	
unze (Bavaria, commercial)	0.0350	0.0772	2 loth, 1891 value	
zehning (Baden)	0.05000	0.1102	10 centass, 1891 value, post-metric	
halber vierling (Bavaria)	0.0625	0.138	4 loth, 1891 value	
vierling (Bavaria)	0.125	0.276	2 halbe vierling, 1891 value	
mark (Brunswick)	0.2337	0.5152	16 loth, 1891 value	
mark (Saxony)	0.2337	0.5153	8 unzen	
mark (Württemberg, gold, silver)	0.2339	0.5156	1891 value	
mark (Austrian system)	0.2339	0.5156	1/2 pfund, 2003 reference	
mark (Cologne, prec. mtl.)	0.234	0.516	1891 value, standard copy actually weighed 1 grain less	
mark (Hamburg)	0.2422	0.5339	8 unzen, 1891 value	
mark (Lubeck)	0.2424	0.5344	8 unzen, 1891 value	
mark (Hanover)	0.2448	0.5397	8 unzen, 1891 value	
mark (Bremen)	0.2493	0.5495	8 unzen, 1891 value	
mark (Frankfort)	0.253	0.557	8 unzen, 1891 value	
pfund (Württemberg, apothecary)	0.3576	0.7884	1891 value, divided further consistent with other apothecaries' measures	
pfund (Brunswick)	0.4674	1.030	2 mark, 1891 value	
pfund (Saxony)	0.4675	1.031	2 mark	
pfund (Austrian system)	0.4677	1.031	Pound, 32 loth, 2003 reference	
pfund (Hesse-Cassel)	0.4842	1.068	16 unzen, 1891 value	

(continued)

Table 7.2 (continued)

Region and unit	Equivalent kgs at 1 grav.	Equivalent lbs at 1 grav.	Notes	Era
pfund (Hamburg)	0.4844	1.068	2 mark, 1891 value	
pfund (Lubeck)	0.4848	1.069	2 mark, 1891 value	
pfund (Hanover)	0.4896	1.079	2 mark, 1891 value	
pfund (Bremen)	0.4985	1.099	2 mark, 1891 value	
pfund (Bavaria)	0.500	1.10	4 vierling, 1891 value, post-metric	
münzpfund (common, gold, silver)	0.5000	1.102	10000 ass, 1891 value, post metric	
pfund (Hesse-Darmstadt)	0.5000	1.102	32 loth, 1821 value, previously same as Frankfort, post-metric	
pfund (Württemberg)	0.5000	1.102	Zollverein units, 1891 value, post-metric	
pfund (Baden)	0.5000	1.102	10 zehning, 1891 value, post-metric	
pfund (Frankfort)	0.5053	1.114	2 mark, also a lighter mark reported at 92.6% of this value, 1891 value	
pfund (Bavaria, commercial)	0.560	1.23	16 unzen, 1891 value	
stein (Baden)	5.000	11.02	10 pfund, 1891 value, post-metric	
liespfund (Brunswick)	6.544	14.43	1891 value	
liespfund (Hamburg)	6.782	14.95	14 pfund, 1891 value	
liespfund (Bremen)	7.229	15.94	1891 value	
stein or stone (Austrian system)	10.29	22.68	22 pfund, 2003 reference	
centner (Hesse-Darmstadt)	50.00	110.2	100 pfund, 1821 value, previously same as Frankfort, post-metric	
centner (Baden)	50.00	110.2	10 stein, 1891 value, post-metric	
centner (Saxony)	51.42	113.4	110 pfund	
zentner or quintal (Austrian system)	51.45	113.4	5 stein, 2003 reference	
centner (Bremen)	57.83	127.5	116 pfund, 1891 value	
doppelzentner (Austrian system)	102.9	226.8	2 zentner, 2003 reference	
schiffpfund (Brunswick)	130.9	288.5	20 liespfund, 280 pfund, 1891 value	
schiffpfund (Hamburg)	135.6	299.0	20 liespfund, 1891 value	
schiffpfund (Bremen)	144.6	318.7	290 pfund, 20 liespfund, 1891 value	

(continued)

Table 7.2 (continued)

Region and unit	Equivalent kgs at 1 grav.	Equivalent lbs at 1 grav.	Notes	Era
frachtpfund or pfundschwer (Bremen)	149.6	329.7	300 pfund, 1891 value	
schiffspfund (Austrian system)	154.3	340.3	3 zentner, 2003 reference	
Apothecaries' weight (Used throughout Germany, Nuremberg basis)				
grain	0.0000621	0.000137		
scruple	0.00124	0.00274	20 gr	
drachm	0.00373	0.00822	3 scruples	
unze	0.0298	0.0657	480 grains	
pfund	0.3579	0.7890	12 unzen	
Metric measures (1891)				
milligramme	0.000001	0.000002205	1/1000 gramme, 1891 value	
zentigramme	0.00001	0.00002205	1/100 gramme, 1891 value	
dezigramme	0.0001	0.0002205	1/10 gramme, 1891 value	
gramme	0.001	0.002205	1891 value	
neu-loth or dekagramme	0.01	0.02205	10 grammes, 1891 value	
pfund	0.500	1.10	Metric pfund, 1891 value	
kilogramme	1.000	2.205	2 pfund, 1891 value	
zentner	50	110	1891 value	
tonne	1,000	2,205	1891 value	
Zollverein measures (1891 Customs Units, old names with metric definitions)				Post-metric
zollloth	0.0167	0.0367		
zollpfund	0.500	1.10	30 zollloth	
zollcentner	50.0	110	100 zollpfund	
zollstein	100	220	2 zollcentner	
Greece (Ancient, local variations, often associated with currency, values disputed)				Ancient
“barleycorn” (Attic/ Euboic)	0.00006	0.0001	1/12 obol, estimated	
chalque (Attic/Euboic)	0.00009000	0.0001984	1/8 obol, 2003 reference	
obol or obolus (Attic/ Euboic)	0.0007200	0.001587	2003 reference	
obol or obolus (Aeginetic)	0.0011	0.0023		
diobol (Attic/Euboic)	0.00144	0.00317	2 obols, 2003 reference	

(continued)

Table 7.2 (continued)

Region and unit	Equivalent kgs at 1 grav.	Equivalent lbs at 1 grav.	Notes	Era
drachma (Attic/Euboic)	0.004320	0.009524	6 obols, 2003 reference	
drachma (Aeginetic)	0.0063	0.014	6 obols	
mina or mine (Attic/ Euboic)	0.4320	0.9524	100 drachmae, 2003 reference	
mina (Aeginetic)	0.63	1.4	100 drachmae	
talent (Attic/Euboic)	25.92	57.14	60 minae, 2003 reference	
talent (Aeginetic)	37.8	83.3	60 minae	
Greece (Local variations, pre and post-metric values as noted)				Pre- and post-metric
drachme	0.001000	0.002205	Gram, 1891 value, post-metric	
dramme	0.003277	0.007224	Pre-metric, 2003 reference	
pound	0.5120	1.129	Pre-metric, 2003 reference	
drachm	0.544	1.20	1891 value	
mina	1.000	2.205	Kilogram, 1000 drachme, 1891 value, post-metric	
oke	1.24	2.73	1891 value, post metric	
oka	1.280	2.822	2.5 pounds, pre-metric, 2003 reference	
talanton	1.500	3.307	1.5 minae, 1891 value, post-metric	
mina	1.536	3.386	3 pounds, pre-metric, 2003 reference	
stater	51.20	112.9	100 pounds, pre-metric, 2003 reference	
cantaro	54.4	120	44 oke, 100 drachms, varied from 112–128 lbs avoirdupois, used 120 lb basis, 1891 value	
talanton	153.6	338.6	3 staters, pre-metric, 2003 reference	
Guatemala (See also Central America, local variations, primarily Spanish system, potential conflicts among references)				Colonial to pre-metric
libra	0.4731	1.043	1891 value	
arroba	11.83	26.07	25 libras, 1891 value	
caja	16.0	35.3	2003 reference	
quintal	47.31	104.3	4 arrobas, 1891 value	

(continued)

Table 7.2 (continued)

Region and unit	Equivalent kgs at 1 grav.	Equivalent lbs at 1 grav.	Notes	Era
fanega	92.0	203	23/4 caja, 2003 reference	
carga	161	355	7/4 fanega, 2003 reference	
Guinea				Medieval to pre-metric
akey	0.00100	0.00221	2003 reference	
akey	0.00134	0.00295	1/48 benda	
mediatabla or media-tabla	0.00201	0.00442	2 akey, 2003 reference	
aguirage	0.00401	0.00885	2 mediatabla, 2003 reference	
quinto or quito	0.00602	0.0133	3 mediatabla, 2003 reference	
uzan or piso	0.00803	0.0177	2 aguirage, 2003 reference	
seron	0.0120	0.0265	2 quinto, 2003 reference	
eggaba	0.0214	0.0472	1/3 benda	
offa or benda-offa	0.0321	0.0708	4 uzan, 2003 reference	
benda	0.0642	0.142	2 offa, 2003 reference	
gammell	0.195	0.431	1/5 kantar, conflict with 2003 reference	
rotl	0.433	0.954	0.9538 Avoirdupois pounds	
kantar	0.977	2.15	Conflict with 2003 reference	
gammell	195	431	2003 reference, conflict with other references	
kantar	977	2,154	5 gammell, 15,218 benda, 2003 reference, conflict with other references	
Hebrew (See also Biblical and Talmudic, Sacred system, local variations)				Ancient to pre-metric
gerah or obol	0.000708	0.00156	2003 reference	
rabah	0.00354	0.00781	5 gerah, 2003 reference	
bekah	0.00708	0.0156	2 rabah, 2003 reference	
shekel	0.0142	0.0312	2 bekah, 2003 reference	

(continued)

Table 7.2 (continued)

Region and unit	Equivalent kgs at 1 grav.	Equivalent lbs at 1 grav.	Notes	Era
mina	0.850	1.87	60 shekels, 2003 reference	
talent of Moses	42.5	93.7	50 minas, 2003 reference	
Hebrew (See also Biblical and Talmudic, Talmudic or Rabbinical system, local variations)				Ancient to pre-metric
pondiuscule	0.0002952	0.0006507	2003 reference	
mehah or obol	0.0005903	0.001301	2 pondiuses, 2003 reference	
zuzah or drachm	0.003542	0.007809	6 mehahs, 2003 reference	
shekel	0.01417	0.03123	4 zuzahs, 2003 reference	
mina	0.3542	0.7809	25 shekels, 2003 reference	
talent	21.25	46.85	60 minas, 2003 reference	
Hebrew (Capacity units by weight, see also Biblical and Talmudic, local variations)				Ancient to pre-metric
Dry measure				
log (new)	0.2975	0.6559	2003 reference	
log (old)	0.4080	0.8995	2003 reference	
cab (new)	1.190	2.623	4 log, 2003 reference	
cab (old)	1.632	3.598	4 log, 2003 reference	
gomor (new)	2.142	4.722	9/5 log, 2003 reference	
gomor (old)	2.938	6.476	9/5 log, 2003 reference	
sath or modius (new)	6.426	14.17	3 gomor, 2003 reference	
sath or modius (old)	8.813	19.43	3 gomor, 2003 reference	
ephah (new)	21.42	47.22	10 gomor, 2003 reference	
ephah (old)	29.38	64.76	10 gomor, 2003 reference	
cor (new)	214.2	472.2	10 ephah, 2003 reference	
cor (old)	293.8	647.6	10 ephah, 2003 reference	
Liquid measure				
log (new)	0.2975	0.6559	2003 reference	
log (old)	0.4080	0.8995	2003 reference	

(continued)

Table 7.2 (continued)

Region and unit	Equivalent kgs at 1 grav.	Equivalent lbs at 1 grav.	Notes	Era
hin (new)	3.570	7.870	12 log, 2003 reference	
hin (old)	4.896	10.79	12 log, 2003 reference	
bath (new)	21.42	47.22	6 hin, 2003 reference	
bath (old)	29.38	64.76	6 hin, 2003 reference	
cor (new)	214.2	472.2	10 bath, 2003 reference	
cor (old)	293.8	647.6	10 bath, 2003 reference	
Honduras (See also Central America, local variations, primarily Spanish system, potential conflicts among references)				Colonial to pre-metric
libra	0.4731	1.043	1891 value	
arroba	11.83	26.07	25 libras, 1891 value	
caja	16.0	35.3	2003 reference	
quintal	47.31	104.3	4 arrobas, 1891 value	
fanega	92.0	203	23/4 caja, 2003 reference	
carga	161	355	7/4 fanega, 2003 reference	
Hungary (pre-1874, local variations, see also Austria)				Medieval to pre-metric
oka	1.33	2.93	Varied from 2.78 to 3.082 lb av, used 2.92 lb, 1891 value	
Iceland (pre-1907, many other units)				Medieval to metric
pund	0.500	1.10	Pound, post-metric value, 2003 reference	
mark	1.00	2.20	2 pund, post-metric value, 2003 reference	
fisk	4.00	8.82	8 pund, post-metric value, 2003 reference	
fierding	20.0	44.1	40 pund, post-metric value, 2003 reference	
liespund	32.0	70.5	64 pund, post-metric value, 2003 reference	
tunna smjörs	112	247	224 pund, post-metric value, 2003 reference	
skipbund or batt	160	353	320 pund, post-metric value, 2003 reference	

(continued)

Table 7.2 (continued)

Region and unit	Equivalent kgs at 1 grav.	Equivalent lbs at 1 grav.	Notes	Era
India (Pre-metric, many units, many local variations, several systems used)				Medieval to pre-metric
Pre-Akbar Northern India				
dhan (wheat berries)	0.0000021	0.0000045		
jau (barleycorns)	0.0000029	0.0000064		
chawal	0.0000076	0.000017	Grain of rice	
dhan	0.000030	0.000067	4 chawal	
ratti	0.00012	0.00027	4 dhan, seed of the <i>abrus precatorius</i> plant	
masha	0.00097	0.0021	8 ratti	
tak	0.00292	0.0064	24 ratti	
bhari	0.0117	0.0257	12 masha	
Pre-Akbar commodity weights (Some of these are best interpretations)				
siki	0.00073	0.0016		
bhari	0.0029	0.0064	4 siki	
kancha	0.015	0.032	5 siki	
chhatank	0.058	0.13	4 kancha	
adh-pav	0.12	0.26	2 chhatank, 1/8 seer	
pav	0.23	0.51	2 adh-pav, 1/4 seer	
adher or adha (1/2) seer	0.47	1.0	2 pav, 1/2 seer	
ser or seer	0.933	2.06	2 adher, 4 pav, 16 chhatank, 80 tola	
savaser	1.2	2.6	1 ser + 1 pav, 100 Imperial rupees	
sava (1 1/4) seer or savaser 1 dhaser	1.5	3.2	2.25 seer	
dhai (2 1/2) seer or dhaser	2.3	5.1	2 adasari, 5 seer	
panch (5) seer or paseri	4.7	10	5 seer	
das (10) seer or daseri	9.3	21	10 seer	
maund	37.3	82.3	4 daseri, 8 pasri, 40 seer	
Akbar Period to Colonial (See also general units below)				
nello (Pondicherry, gold, silver)	0.000024	0.000053	0.37 grains, 1891 value	
grain	0.000065	0.00014	Before 1833	
rattis	0.00011	0.00025	1.75 grains, before 1833	
mangal (Madras, pearls)	0.00039	0.00086	6 grains, 1891 value	
rittee (Bombay, pearls)	0.00052	0.0011	8 grains, 1891 value	

(continued)

Table 7.2 (continued)

Region and unit	Equivalent kgs at 1 grav.	Equivalent lbs at 1 grav.	Notes	Era
māshā	0.00091	0.0020	8 rattīs, before 1833	
pagoda (Madras)	0.003544	0.007812	1891 value	
tank (Bombay)	0.00441	0.00972	1891 value	
misqal (gold, expensive spices)	0.0062	0.014		
pice (Bombay)	0.0106	0.0233	1891 value	
sicca (Bengal, factory)	0.0106	0.0233	1891 value	
tolā	0.011	0.024	12 māshās, before 1833, fixed at 180 grains after 1848	
sicca (Bengal, bazaar)	0.0116	0.0257	1891 value	
dam (spices)	0.020	0.044		
pollam (Madras)	0.03544	0.07812	10 pagodas, 1891 value	
chattack (Bengal, factory)	0.0529	0.117	5 siccas, 1891 value	
chattack (Bengal, bazaar)	0.0582	0.128	5 siccas, 1891 value	
seer (Madras)	0.2835	0.6250	8 pollams, 1891 value	
seer (Bombay)	0.318	0.700	30 pice, 72 tanks, 1891 value	
pao (Bengal, grain)	0.370	0.816	1891 value	
ser	0.64	1.4		
seer (Bengal, factory)	0.847	1.87	16 chattacks, 1891 value	
ser	0.87	1.9	80 tolas, before 1833	
seer (Bengal, bazaar)	0.931	2.05	16 chattacks, 1891 value	
vis or visay (Madras)	1.418	3.125	5 seers, 1891 value	
pussaree (Bengal)	4.66	10.3	1891 value	
maund (Goa)	11.2	24.7	1891 value	
maund (Madras)	11.34	25.00	8 vis, 1891 value	
maund (Pondicherry)	11.7	25.9	1891 value	
maund (Anjar)	11.9	26.2	40 seers, 1891 value	
maund (Maharatta country)	11.9	26.2	1891 value	
maund (Bombay)	12.7	28.0	40 seers, 1891 value	
maund (Gujerat)	12.7	28.0	40 seers, 1891 value	
maund (Bengal, factory)	33.9	74.7	40 seers, 1891 value	
maund (Aurangabad)	34.4	75.8	40 seers, 1891 value	

(continued)

Table 7.2 (continued)

Region and unit	Equivalent kgs at 1 grav.	Equivalent lbs at 1 grav.	Notes	Era
maund	34.84	76.80	40 sers, before 1833, after 1848 was defined as 37.32 kg, one maund is weight of goods that could be carried by pack animal or porter	
maund (Deccan)	36.2	79.8	40 seers, 1891 value	
maund (Bengal, bazaar)	37.3	82.1	40 seers, 1891 value	
maund (Malda)	45.6	100	1891 value	
candy (Surat)	154	340	20 maunds, 1891 value	
candy or baruay (Mysore, and Seringapatam)	220.2	485.4	20 maunds, 1891 value	
candy or barbar (Goa)	225	495	1891 value	
candy or baruay (Madras)	226.8	500.0	20 maunds, 1891 value	
candy (Bombay)	254	560	20 maunds, 1891 value	
candy (Pondicherry)	267	588	1891 value	
candy or baruay (Malabar coast)	315.5	695.5	20 maunds, 1891 value	
candy (Ahmednuggar)	715	1,576	20 maunds, 1891 value	
Akbar period—general units—1966 and 2003 references				
yava	0.0000147	0.0000324	1966 value	
ruttee	0.0001215	0.0002678	2003 reference	
retti or ratika	0.000147	0.000324	10 yava, 1966 value	
masha	0.000882	0.00194	6 retti, 1966 value	
masha	0.0009719	0.002143	8 ruttee, 2003 reference	
tank-sala	0.00265	0.00583	3 masha, 1966 value	
dharana	0.00470	0.0104	32 retti, 1966 value	
kona	0.00706	0.0156	8 masha, 1966 value	
tolah or sicca	0.01166	0.02571	12 masha, 2003 reference	
tola	0.0118	0.0259	80 retti, 1966 value	
tank	0.01296	0.02857	10/9 tolah, 2003 reference	
kharsha	0.0141	0.0311	2 kona, 1966 value	
parah or pince	0.03110	0.06857	32 masha, 2003 reference	
pala	0.0470	0.104	4 tola, 1966 value	
chittak	0.05832	0.1286	5 tolah, 2003 reference	

(continued)

Table 7.2 (continued)

Region and unit	Equivalent kgs at 1 grav.	Equivalent lbs at 1 grav.	Notes	Era
powa	0.2333	0.5142	4 chittak, 2003 reference	
seer	0.9330	2.057	4 powa, 2003 reference	
raik	1.166	2.571	5 powa, 2003 reference	
dhurra or pally	4.665	10.28	4 raik, 2003 reference	
tuba	4.70	10.4	100 pala, 1966 value	
hara	9.41	20.7	2 tuba, 1966 value	
maund or bazar	37.32	82.28	8 dhurra, 2003 reference	
bara	94.1	207	10 hara, 1966 value	
candy	746.4	1,646	20 maund, 2003 reference	
achita	941	2,074	10 bara, 1966 value	
British colonial system—gold measures				
wheat berry	0.00000456	0.0000101		
barleycorn	0.00000648	0.0000143		
carat	0.000259	0.000571	1/120 troy ounce	
tola	0.0117	0.0257	3.75/10 troy ounces	
troy ounce	0.0311	0.0686	480 barleycorns	
troy pound	0.373	0.823	12 troy ounces, abolished 1878	
British colonial system—commodity weights				
ounce avoirdupois	0.0283	0.0625		
pound avoirdupois	0.454	1.00	16 ounces av	
stone avoirdupois	6.35	14.0	14 pounds av	
bushel	25.40	56.00	4 stones, 56 pounds	
hundredweight (cwt)	50.80	112.0	112 pounds av, 2 bushels + 8 stones	
ton avoirdupois	1,016	2,240	20 hundredweight (cwt), 40 bushels, 160 stones	
Indonesia (pre-1923, local variations, Old Dutch and local units used)				Colonial to pre-metric
Ordinary or non-specific measures				
wang	0.0008042	0.001773	2003 reference	
mace (Amboyna)	0.0018	0.0041	28.5 grains, estimated	
tali	0.002413	0.005319	3 wang, 2003 reference	
soekoe	0.004825	0.01064	2 tali, 2003 reference	

(continued)

Table 7.2 (continued)

Region and unit	Equivalent kgs at 1 grav.	Equivalent lbs at 1 grav.	Notes	Era
real	0.01930	0.04255	4 soekoe, 2003 reference	
tael (Batavia)	0.03842	0.08470		
tael	0.03860	0.08510	2 real, 2003 reference	
thail	0.0386	0.0851	1/1600 pikol	
tael (Bantam)	0.069	0.151		
catti (Java)	0.6152	1.356		
catty, catti, or kabi	0.6176	1.362	16 tael, 2003 reference	
catty (Ternate)	0.70	1.5		
catty (Sumatra)	0.96	2.1	2.118 lb av	
ootan (Sumatra, camphor)	1.81	4.00	4 lb av	
kulack	4.48	9.87	0.0725 pikol	
gantang (Java, coffee)	6.15	13.6	10 catties	
maund (Sumatra)	34.9	77.0	77 lb av	
pecul (Sumatra)	60.5	133	133 1/3 lb av	
pecul (Java, Celebes, modern Sulawesi)	61.5	136	100 catties	
picol, pikol, or pecul	61.76	136.2	100 catty, 2003 reference	
amat	123.5	272.3	2 picul, 2003 reference	
bahar (Bantam)	180	396		
bahar (Bantam, pepper)	185	407		
bahar (short) or small bahar	185.3	408.5	3 picul, 2003 reference	
candil (Sumatra)	192.1	423.5	423 1/3 lb av	
bahar (Amboyna)	271	598		
bahar (Batavia)	277	610		
bahar (long) or large bahar	277.9	612.7	4.5 picul, 2003 reference	
timbang (Java, grain)	308	678		
timbang	308.8	680.8	5 picul, 2003 reference	
tael (Amboyna)	1,406	3,099	55.3371 bushels, estimated but seems high	
kojang (Batavia)	1,668	3,676	6 bahar (long), 2003 reference	
kojang (Semarang)	1,729	3,812	14 amat, 2003 reference	
kojang (Soerabaya)	1,853	4,085	6 timbang, 2003 reference	

(continued)

Table 7.2 (continued)

Region and unit	Equivalent kgs at 1 grav.	Equivalent lbs at 1 grav.	Notes	Era
Precious metals				
wang	0.00113	0.00248	1/48 thail	
tali	0.00338	0.00745	1/16 thail	
soekoe	0.00676	0.0149	1/8 thail	
reaal	0.0270	0.0596	1/2 thail	
thail	0.0541	0.119		
Opium				
hoen	0.0000386	0.0000851	1/1000 thail, consistent with 2003 reference	
tjembang Mata	0.000386	0.000851	1/100 thail	
tji	0.00386	0.00851	1/10 thail, <u>in</u> consistent with 2003 reference	
thail	0.0386	0.0851		
Ionian Islands (Mostly British with some Turkish and Italian units, local variations)				Pre-metric
libbra sottile	0.3732	0.8228	1 lb troy, 1891 value	
libbra grosso	0.4536	1.000	1 lb avoirdupois, 1891 value	
centinajo or talento	45.4	100	100 lb av, 1891 value	
oke	1.22	2.70	Old value	
cantaro	53.9	119	Old value	
Ireland (pre-metric, local variations)				Medieval to pre-metric
grain	0.00005	0.0001	1/8 penny	
pinginn or penny	0.0004	0.0009		
screpall or scruple	0.0012	0.0026	3 penny	
unga or ounce or mann	0.028	0.062	72 penny, from Latin	
Italy (pre-1862, local variations, sampling of units, by 1891 metric system was in use)				Medieval to pre-metric
Common measure				
granotino (Sardinia, Piedmont, Turin)	0.000002224	0.000004903	1891 value	
grano (typical)	0.0000444	0.0000979	Grain, Pre-1861, 2003 reference	
grano (Genoa)	0.00004595	0.0001013	1891 value	
grano (Bologna)	0.000047	0.00010	1891 value	
grano (Parma)	0.00004723	0.0001041	1891 value	
grano (Ancona)	0.00004776	0.0001053	1891 value	

(continued)

Table 7.2 (continued)

Region and unit	Equivalent kgs at 1 grav.	Equivalent lbs at 1 grav.	Notes	Era
grano (Rome, Roman States)	0.00004907	0.0001082	Based on Roman libbra	
grano (Tuscany)	0.00004913	0.0001083	1891 value	
grano (Sardinia, Piedmont, Turin)	0.00005337	0.0001177	24 granotini, 1891 value	
carato (Bologna)	0.00019	0.00042	4 grani, 1891 value	
denaro (typical)	0.00107	0.00235	Scruple, 24 grano, pre-1861, 2003 reference	
denaro (Genoa)	0.001103	0.002431	24 grani, 1891 value	
denaro (Parma)	0.001134	0.002499	24 grani, 1891 value	
denaro (Ancona)	0.001146	0.002527	24 grani, 1891 value	
denaro (Rome, Roman States)	0.001178	0.002596	24 grani, based on Roman libbra	
denaro (Tuscany)	0.001179	0.002599	24 grani, 1891 value	
denaro (Sardinia, Piedmont, Turin)	0.001281	0.002824	24 grani, 1891 value	
ferlina (Modena)	0.001664	0.003669	1891 value	
ferlino (Bologna)	0.0019	0.0042	10 carati, 1891 value	
ottavo (typical)	0.00320	0.00705	Drachm, 3 denaro, pre-1861, 2003 reference	
dramma (Tuscany)	0.003537	0.007798	3 denari, 1891 value	
ottavo (Bologna)	0.0038	0.0083	2 ferlini, 1891 value	
ottavo (Sardinia, Piedmont, Turin)	0.003843	0.008472	3 denari, 1891 value	
uncia (typical)	0.0256	0.0564	Ounce, 8 ottavo, pre-1861, 2003 reference	
once (Palermo)	0.0264	0.0582		
uncia grosso or sottile (Sicily)	0.02646	0.05833	1891 value	
uncia (Genoa)	0.02647	0.05835	24 denari, 1891 value	
uncia (Modena)	0.02663	0.05870	16 ferlini, 1891 value	
uncia (Sicily)	0.02673	0.05894	1891 value	
uncia (Parma)	0.02720	0.05997	24 denari, 1891 value	
uncia (Ancona)	0.02751	0.06064	24 denari, 1891 value	
uncia (Rome, Roman States)	0.02826	0.06231	24 denari, based on Roman libbra	
uncia (Tuscany)	0.02830	0.06238	8 dramme, 1891 value	
uncia (Bologna)	0.0302	0.0665	8 ottavi, 1891 value	
	0.03074	0.06778	8 ottavi, 1891 value	

(continued)

Table 7.2 (continued)

Region and unit	Equivalent kgs at 1 grav.	Equivalent lbs at 1 grav.	Notes	Era
oncia (Sardinia, Piedmont, Turin)				
libbra sottile (Venice)	0.301	0.664		
libbra (typical)	0.307	0.677	Pound, 12 onci, pre-1861, 2003 reference	
libbra (Palermo)	0.317	0.699	12 once	
libbra (Genoa)	0.3176	0.7002	12 oncie, 1891 value	
libbra or lira (Modena)	0.3195	0.7044	12 oncie, 1891 value	
libbra (Sicily)	0.3208	0.7072	12 oncie, 1891 value	
libbra (Parma)	0.3265	0.7197	12 oncie, 1891 value	
libbra (Ancona)	0.3301	0.7277	12 oncie, 1891 value	
libbra (Rome, Roman States)	0.3392	0.7477	12 oncie	
libbra (Florence)	0.340	0.748	12 once	
libbra (Tuscany)	0.3396	0.7486	12 oncie, 1891 value	
libbra (peso grosso, Genoa)	0.3494	0.7702	1/10 higher than ordinary libbra, 1891 value	
libbra (variation)	0.353	0.778	“Pound”, varied from 0.307 to 0.398 kg, used average	
libbra mercantile (Bologna)	0.362	0.798	12 once, 1891 value	
libbra (Sardinia, Piedmont, Turin)	0.3689	0.8133	12 oncie, 1891 value	
libbra (Turin)	0.369	0.813	12 once	
rotole (Genoa)	0.4764	1.050	1.5 libbre, 1891 value	
libbra grossa (Venice)	0.477	1.05	12 once	
libbra grossa (Milan)	0.763	1.68	28 once	
rotoli (Palermo)	0.793	1.75		
rotole sottile (Sicily)	0.7938	1.750	30 oncie sottile, 1891 value	
rotolo grosso (Sicily)	0.8732	1.925	33 oncie grosso, 1891 value	
rotolo (Naples)	0.8911	1.964	2-7/9 libbre, 1891 value	
rubbo (typical)	7.68	16.9	25 libbra, pre-1861, 2003 reference	
rubbo (Parma)	8.161	17.99	25 libbre, 1891 value	
rubbo (variation)	8.83	19.5	25 libbra	
cantaro (typical)	46.1	102	6 rubbo, pre-1861, 2003 reference	
cantaro (variation)	52.95	116.7	150 libbra	

(continued)

Table 7.2 (continued)

Region and unit	Equivalent kgs at 1 grav.	Equivalent lbs at 1 grav.	Notes	Era
cantaro (Palermo)	79.34	174.9	100 rotoli	
Apothecaries' measure				
accini (Naples, apothecaries' weight)	0.00004455	0.0000982	1891 value	
scrupolo (Naples, apothecaries' weight)	0.0008911	0.001964	20 accini, 1891 value	
drachma (Naples, apothecaries' weight)	0.002673	0.005893	3 scrupoli, 1891 value	
uncia (Naples, apothecaries' weight)	0.02673	0.05893	10 drachme, 1891 value	
libbra (Sardinia, Piedmont, Turin, apothecary)	0.3074	0.6778	1.25 marco, 1891 value	
libbra (Naples, apothecaries' weight)	0.3208	0.7072	12 oncie, 1891 value	
Precious metals and fine goods				
accini (Naples, gold, silver, drugs, pigments)	0.00004455	0.00009822	1891 value	
grano (Venetian Lombardy, gold, silver)	0.00005100	0.0001124	Pre-metric	
trapeso or scrupoli (Naples, gold, silver, drugs, pigments)	0.0008911	0.00196420 accini, 1891 value		
denaro (Venetian Lombardy, gold, silver)	0.001224	0.002699	24 grani, post-metric	
dramma or scrupoli (Naples, gold, silver, drugs, pigments)	0.002673	0.0058933 trapesi, 1891 value		
uncia (Naples, gold, silver, drugs, pigments)	0.02673	0.05893	10 dramme, 1891 value	
uncia (Venetian Lombardy, gold, silver)	0.02938	0.06477	24 denari, pre-metric	
marco (Venetian Lombardy, gold, silver)	0.2350	0.5181	8 oncie, 7.5562 troy ounces, pre-metric	
marco (Sardinia, Piedmont, Turin, gold, silver)	0.2459	0.5422	2/3 libbra, 1891 value	
libbra (Naples, gold, silver, drugs, pigments)	0.3208	0.7072	12 oncie, 1891 value	
Metric versions of traditional measures (Early 1800s)				
grano (Venetian Lombardy)	0.0001000	0.0002205	Post-metric	
denaro (Venetian Lombardy)	0.001000	0.002205	10 grani, post-metric	

(continued)

Table 7.2 (continued)

Region and unit	Equivalent kgs at 1 grav.	Equivalent lbs at 1 grav.	Notes	Era
grosso (Venetian Lombardy)	0.01000	0.02205	10 denari, post-metric	
oncia (Venetian Lombardy)	0.1000	0.2205	10 grossi, post-metric	
libbra metrica (Venetian Lombardy)	1.0000	2.2046	10 oncie, post-metric	
rubbio (Venetian Lombardy)	10.00	22.05	10 libbre, post-metric	
Japan (pre-1924, some units still used, these are metric versions)				Medieval to pre-metric
shî	0.000000375	0.000000827	2003 reference	
mô	0.00000375	0.00000827	10 shî, 2003 reference	
rin	0.0000375	0.0000827	10 mô, 2003 reference	
fun or candareen	0.000375	0.000827	10 rin, 2003 reference	
monme	0.00175	0.00386	1891 value, pre-metric	
mommé, momme, or monme	0.00375	0.00827	10 fun, used especially for pearls, 2003 reference	
rjoo	0.00753	0.0166	1891 value, pre-metric	
niyo	0.0150	0.0331	4 mommé, 2003 reference	
hyaku-mé or hyakume	0.375	0.827	25 niyo, 100 momme, 2003 reference	
kin	0.600	1.32	40 niyo, 2003 reference	
kwan, kan, or kanme	3.75	8.27	10 hyaku-mé, 1000 momme, 2003 reference	
ninsoku-ichi-nin	26.3	57.9	7 kwan, 2003 reference	
kiyak-kin	60.0	132	16 kwan, 2003 reference	
karus hiri-ichi-da	67.5	149	18 kwan, 2003 reference	
komma-ichi-da	150	331	40 kwan, 2003 reference	
Java (Primarily used old Dutch, but many local units and variations)				Colonial to pre-metric
tael (Batavia)	0.0384	0.0847	1891 value	
tael (Bantam)	0.0685	0.151	1891 value	
cattie	0.615	1.36	1891 value	
gantang (coffee)	6.15	13.6	10 catties, 1891 value	

(continued)

Table 7.2 (continued)

Region and unit	Equivalent kgs at 1 grav.	Equivalent lbs at 1 grav.	Notes	Era
pecul	61.5	136	100 catties, 1891 value	
bahar (Bantam)	180	396	1891 value	
bahar (Bantam, pepper)	185	407	1891 value	
bahar (Batavia)	277	610	1891 value	
timbang (grain)	308	678	1891 value	
Jewish				Ancient to modern
gerah or obulus	0.00071	0.0016	1/20 shekel	
drachma Attica	0.0035	0.0078	1/4 shekel	
bekab	0.0071	0.016	1/2 shekel	
drachma Alexandrina, darchmon, or adarchmon	0.0071	0.016	1/2 shekel	
stater, silus, shekel	0.014	0.031	Estimated	
maneh or mna	1.4	3.1	100 shekels, 21,900 troy grains	
talent (silver)	4.3	9.4	300 shekels	
Korea				Medieval to pre-metric
p'un	0.00038	0.00083	0.0075 US ounces roughly	
ton	0.0038	0.0083	10 p'un	
nyang	0.038	0.083	10 ton	
kun	0.60	1.3	16 nyang	
kwan	3.75	8.27		
Latvia				Medieval to pre-metric
quent	0.00327	0.00722	2003 reference	
loth	0.0131	0.0289	4 quent, 2003 reference	
pfund	0.419	0.924	32 loth, 2003 reference	
liespfund	8.38	18.5	20 pfund, 2003 reference	
centner	50.3	111	6 liespfund, 2003 reference	
ton	101	222	2 centner, 2003 reference	
schiffspfund	168	369	20 liespfund, 2003 reference	

(continued)

Table 7.2 (continued)

Region and unit	Equivalent kgs at 1 grav.	Equivalent lbs at 1 grav.	Notes	Era
Libya				Medieval to pre-metric
kharouba	0.0002003	0.0004416	1/6400 oka, carob seed, 2003 reference	
metrical (gold, silver)	0.00476	0.0105	Gold, silver measure	
dram	0.003205	0.007066	16 kharouba, 2003 reference	
termino	0.004006	0.008832	20 kharouba, 2003 reference	
uckin	0.03205	0.07066	8 termino, 2003 reference	
roto	0.5128	1.131	16 uckin, 2003 reference	
oka	1.282	2.826	40 uckin, 2003 reference	
mattaro	21.54	47.48	42 roto, 2003 reference	
cantar	51.28	113.1	100 roto, 2003 reference	
Madagascar (pre-1897, other units, local variations, estimated)				Pre-metric
nanki (gold, silver)	0.000648	0.00143	1891 value	
vari (gold, silver)	0.00194	0.00429	3 nanki, 1891 value	
sompi (gold, silver)	0.00389	0.00857	2 vari, 60 grains, 1891 value	
Madeira Islands (Primarily Portuguese based units, 1891 values)				Pre-metric
libra	0.4586	1.011		
Malacca (Including Straits settlements, 1891 values)				Pre-metric
mace or miam (common)	0.00291	0.00641	44.83 grains, 1891 value	
mace or miam (Singapore)	0.00337	0.00743	52 grains, 1891 value	
buncal (gold, Singapore)	0.0533	0.117	822 grains, 1891 value	
catty (common)	0.612	1.35	1891 value	
tampang (tin)	0.6151	1.356	Equivalent of catty for tin, 1891 value	
catty (gold, silver)	0.9295	2.049	1891 value	
kip (tin)	18.45	40.68	1891 value	
pecul	61.2	135	100 catties, 1891 value	
candy or bahar	184	405	3 peculs, 1891 value	

(continued)

Table 7.2 (continued)

Region and unit	Equivalent kgs at 1 grav.	Equivalent lbs at 1 grav.	Notes	Era
Malta (Pre-metric, also used British system, units re-defined in terms of Imperial measure in 1921, originally Arabic)				Medieval to pre-metric
parto	0.001772	0.003906	2003 reference	
ottav	0.003307	0.007291	1/8 uqija, “eighth”, 1921 act only	
kwart	0.006615	0.01458	1/4 uqija, “quarter”, 1921 act only	
uqija	0.02646	0.05833	“Maltese ounce”, 1/30 ratal	
ounce	0.02835	0.06250	16 partos, 2003 reference	
kwart	0.1984	0.4374	“Quarter” of a ratal, Aquilina reference	
libra	0.4536	1.000	16 ounces, 2003 reference	
rotoło	0.7938	1.750	7/4 libras, 2003 reference	
ratál, rotola, rotoło, or libbra	0.7938	1.750	Consistent with 1891 value	
qsima	0.9922	2.187	1.25 ratál, Aquilina reference	
wiżna	3.969	8.750	5 ratál, not mentioned in 1921 act	
qantar, cantarro, or cantaro	79.38	175.0	100 ratál, consistent with 2003 reference	
peżata	238.1	524.9	300 ratál, mentioned in 1921 act only	
Mesopotamia (Including Sumeria and Akkadia, EN system E—Mesopotamian designations used)				Ancient
še or uṭṭatu	0.00005	0.0001	Grain, 1/180 shekel	
gin ₂ or šiqlu	0.009	0.02	Shekel	
ma-na or manû	0.498	1.10	Pound, 60 shekels	
gun ₂ or biltu	30.0	66.1	Load, 3600 shekels	
Mexico (pre-1896, several units not listed, local variations, these values reported in 1891)				Colonial to pre-metric
tomin	0.0005993	0.001321	1/768 libra, 2003 reference	
adarme	0.001798	0.003963	1/256 libra, 3 tomin, 2003 reference	
ochava	0.003596	0.007927	1/128 libra, 2 adarme, 2003 reference	

(continued)

Table 7.2 (continued)

Region and unit	Equivalent kgs at 1 grav.	Equivalent lbs at 1 grav.	Notes	Era
onza	0.02877	0.06342	Ounce, 1/16 libra, 8 ochava, 2003 reference	
libra or libbra	0.4602	1.015	Pound, 16 onza, 2003 reference	
arroba	11.51	25.37	25 libra, 2003 reference	
quintal	46.02	101.5	100 libra, 4 arrobas, 2003 reference	
tercio	73.64	162.3	160 libra, 2003 reference	
Molucca (Dutch weights and measures somewhat used, several other standards, local variations)				Pre-metric
mace (Amboyna)	0.00185	0.00407	28.5 grains, 1891 value	
tael (Amboyna)	0.0296	0.0652	16 mace, 455.8 grains, 1891 value	
catty (Ternate)	0.617	1.36	1891 value	
bahar (Amboyna)	271.1	597.6	1891 value	
Morocco (pre-1923, local variations and units not listed, not rigidly defined)				Colonial to pre-metric
rotal, rotl, or artal	0.5075	1.119	2003 reference	
rotl (Commerce)	0.540	1.19	Variation, 1891 value	
rotl (Markets)	0.771	1.70	Variation, 1891 value	
gerbe	3.045	6.713	6 rotal, 2003 reference	
kula	11.17	24.63	22 rotal, 2003 reference	
kantar or cantarro	50.75	111.9	100 rotal, 1891 value, consistent with 2003 reference	
Muscat (1891 values, local variations)				Pre-metric
kotscha	0.165	0.365		
maund	3.97	8.75	24 kotschas	
candy	238	525	60 maunds	
Native America (Shoshone tribe, many other similar measures)				Pre-metric
General: Estimated by comparison of two things manually for normal quantities. E.g. quantity of grain might be estimated by holding a known weight in one hand and grain in the other. Very qualitative and individualized				
Netherlands (Includes Holland and Dutch units, local variations, pre-1800s, units from Holy Roman Empire period mostly)				Medieval to metric
Common weight measure				
grein (ordinary)	0.00006408	0.0001413	Grain, 2003 reference	
korrel or decigramme	0.0001000	0.0002205	1891 value, metric “re-purposed” unit	

(continued)

Table 7.2 (continued)

Region and unit	Equivalent kgs at 1 grav.	Equivalent lbs at 1 grav.	Notes	Era
vierling (ordinary)	0.0003845	0.0008477	6 grein, 2003 reference	
wigtje or gramme	0.001000	0.002205	1891 value, metric “re-purposed” unit	
engel (ordinary)	0.001538	0.003391	4 vierling, 2003 reference	
drachme (ordinary)	0.003845	0.008477	Drachm, 10 vierling, 2003 reference	
lood or decagramme	0.01000	0.02205	1891 value, metric “re-purposed” unit	
ons, unze, once (ordinary)	0.03076	0.06781	Ounce, 8 drachme, 2003 reference	
ons, unze, once (Amsterdam)	0.0309	0.0681	“Ounce”, Amsterdam basis, 1/16 pond, pre-1800	
ons or hectogramme	0.1000	0.2205	1891 value, metric “re-purposed” unit	
mark (ordinary)	0.2461	0.5425	8 unze, 2003 reference	
Gorinchem pond	0.466	1.03	Gorinchem basis, “pound”, pre-1800	
pond (ordinary)	0.4922	1.085	Ordinary pound, 2 mark, 2003 reference	
Amsterdam pond	0.494	1.09	Amsterdam basis, “pound”, pre-1800, consistent with 2003 reference	
Utrecht pond	0.498	1.10	Utrecht basis, “pound”, pre-1800	
pond	0.5000	1.102	2014 value, metric “re-purposed” unit, also referred to English pound until officially eliminated in 1937, but still used today	
Nederlandsch pond or kilogramme	1.000	2.205	1891 value, metric “re-purposed” unit	
centnaar	100.0	220.5	100 kilogrammes, 1891 value, metric “re-purposed” unit	
last or scheepslast	1,976	4,357	4000 Amsterdam ponds, “load”, referred to ship loads or loads of herring. Not used after herring business stopped. Pre-1800	
Apothecaries’ measure (Medicine, same as U.S. or English apothecary measures)				
grein	0.0000648	0.000143	“grain”	
scrupel	0.00130	0.00286	20 grains, “scruple”	
drachme	0.00389	0.00857	3 scrupels, 60 grains, “dram”	

(continued)

Table 7.2 (continued)

Region and unit	Equivalent kgs at 1 grav.	Equivalent lbs at 1 grav.	Notes	Era
medicinaal ons	0.0311	0.0686	8 drachmen, 480 grains, “medicinal ounce”	
medicinaal pond	0.373	0.823	12 ons, 5760 grains, “medicinal pound”, also reported as 0.3691 kg in 2003 reference	
Nicaragua (See also Central America, local variations, primarily Spanish system, potential conflicts among references)				Colonial to pre-metric
libra	0.4731	1.043	1891 value	
arroba	11.83	26.07	25 libras, 1891 value	
caja	16.0	35.3	2003 reference	
quintal	47.31	104.3	4 arrobas, 1891 value	
fanega	92.0	203	23/4 caja, 2003 reference	
carga	161	355	7/4 fanega, 2003 reference	
Norway (pre-1887, local variations and additional units, changes over time)				Medieval to pre-metric
Common measure				
as	0.00004805	0.0001059	1891 value	
ort	0.00097	0.00215	1/512 pund, “grain”	
qwintin	0.003322	0.007323	1891 value	
lod	0.01329	0.02929	4 qwintin, 1891 value	
untz	0.02657	0.05858	2 lod, 1891 value	
mark or merker	0.249	0.550	1/2 pund, 0.2187 kg before 1683	
skålpund	0.4252	0.9373	16 untz, 8848 as, 1891 value	
pund or skålpund	0.4981	1.098	2 merker, 0.4667 before 1683, “pound”, value is consistent with 2003 reference	
bismerpund	5.98	13.2	12 pund	
vette	6.30	13.9	28.8 merker	
lispund	8.503	18.75	20 skålpunds, 1891 value	
laup (butter)	17.93	39.53	36 pund, 72 merker	
spann (other commodities)	17.93	39.53	Same as laup	
våg	17.94	39.56	1/8 skippund	
skippund (1270)	151.0	332.9	“Ship’s pound”, 1270 value	

(continued)

Table 7.2 (continued)

Region and unit	Equivalent kgs at 1 grav.	Equivalent lbs at 1 grav.	Notes	Era
skippund (pre 1887)	159.5	351.6	“Ship’s pound”, pre-1887 value	
skippund (1891)	170.1	374.9	400 skälpunds, 1891 value	
Apothecaries’ Measure				
gran (Apothecary)	0.00006187	0.0001364	1891 value	
scrupel (Apothecary)	0.001237	0.002728	20 grans, 1891 value	
drachm (Apothecary)	0.003712	0.008183	3 scrupels, 1891 value	
untz (Apothecary)	0.02970	0.06547	8 drachmas, 1891 value	
pund (Apothecary)	0.3563	0.7856	7416 as, 12 untz, 1891 value	
Precious metals, fine goods				
qwintin (gold, silver)	0.003292	0.007256	1891 value	
lod (gold, silver)	0.01317	0.02903	4 qwintins, 1891 value	
untz (gold, silver)	0.02633	0.05805	2 lods, 1891 value	
mark (gold, silver)	0.2107	0.4644	8 untzes, 4384 as, 1891 value	
Oman (pre-Metric, local variations, additional units not listed)				Medieval to pre-metric
kotscha	0.165	0.365		
maund	3.97	8.75	24 kotschas	
candy	238.1	525.0	60 maunds	
Ottoman Empire (See also Turkey, pre-1933, local variations and additional units not listed)				Medieval to pre-metric
kırat	0.000200	0.000442	“Carat”	
dirhem	0.00321	0.00707	16 kırat, “drachma”	
miskal	0.00425	0.00937	1.5 dirhem	
okka	1.28	2.83	400 dirhem, “oka”	
batman	7.70	17.0	6 okka	
kantar	56.4	124	“weighbridge”	
çeki	225.8	497.8	4 kantar	
Paraguay (pre-1899, local variations and additional units not listed)				Colonial to pre-metric
once (new)	0.0287	0.0632	Ounce, 2003 reference	
once (old)	0.02876	0.06339	Ounce, 2003 reference	
libra or libbra (new)	0.459	1.01	Pound (new), 2003 reference	
libra or libbra (old)	0.4601	1.014	Pound (old), 16 once, 2003 reference	

(continued)

Table 7.2 (continued)

Region and unit	Equivalent kgs at 1 grav.	Equivalent lbs at 1 grav.	Notes	Era
arrobe (new)	11.5	25.3	25 libra, 2003 reference	
arrobe (old)	11.50	25.36	25 libra, 2003 reference	
quintal (new)	45.9	101	100 libra, 2003 reference	
quintal (old)	46.01	101.4	100 libra, 2003 reference	
tonne or tonelada (new)	918	2,024	Ton, 2000 libra, 2003 reference	
tonne or tonelada (old)	920.2	2,029	Ton, 2000 libra, 2003 reference	
Persia or Iran (Assyrio-Chaldean-Persian system, weights very inconsistent, local variations, examples and general values in 1891 for specific locations, additional values reported in 2003 reference)				Ancient to pre-metric
makhod	0.000256	0.000563	Carat, 2003 reference	
dung	0.000767	0.00169	3 makhod, 2003 reference	
dartung	0.00102	0.00225	1-1/3 dung, 2003 reference	
drachm	0.00326	0.00719	2003 value	
miskal	0.00460	0.0101	6 dung, 2003 reference	
mascai (Tauris)	0.00479	0.0106	1891 value	
miskal (Teheran)	0.00484	0.0107	1891 value	
dirhem	0.00920	0.0203	2 miskal, 2003 reference	
dirhem (Tauris)	0.00959	0.0211	2 mascais, 1891 value	
sir	0.0736	0.162	8 dirhem, 2003 reference	
pinar	0.0920	0.203	10 dirhem, 2003 reference	
danar	0.184	0.406	2 pinar, 2003 reference	
mine	0.326	0.719	100 drachm, 2003 value	
abbassi	0.368	0.811	4 pinar, 2003 reference	
rottell	0.460	1.01	5 pinar, 2003 reference	
rattel (Tauris)	0.479	1.06	50 dirhems, 1891 value	

(continued)

Table 7.2 (continued)

Region and unit	Equivalent kgs at 1 grav.	Equivalent lbs at 1 grav.	Notes	Era
tcheirek	0.736	1.62	2 abbassi, 2003 reference	
saddirham	1.47	3.25	2 tcheirek, 2003 reference	
batman (Tauris)	2.88	6.34	6 rattels, 1891 value	
batman (Tauris)	2.94	6.49	2 saddirham, 2003 reference	
batman (Shiraz)	5.75	12.7	1891 value	
batman (Shirez)	5.89	13.0	4 saddirham, 2003 reference	
mahnd shah (Ispahan)	6.20	13.7	1891 value	
rik (Teheran)	7.75	17.1	1600 miscals, 1891 value	
mahnd shah (Shiraz, Bushire, Gamri)	12.4	27.3	1891 value	
talent	32.6	71.9	100 mine, 2003 value	
karvar	589	1,298	400 saddirham, 2003 reference	
Persia or Iran (Assyrio-Chaldean-Persian system, capacity measures by weight, very inconsistent, local variations, examples and general values in 1891 for specific locations, additional values reported in 2003 reference)				Ancient to modern
cados	1.019	2.246	2003 reference	
makuk	4.075	8.984	4 cados, 2003 reference	
woëbe or modius	16.30	35.93	4 makuk, 2003 reference	
amphora	32.60	71.87	2 woëbe, 2003 reference	
short artaba	48.90	107.8	3 woëbe, 2003 reference	
long artaba	65.20	143.7	2 amphora, 2003 reference	
long amphora	97.80	215.6	3 amphora, 2003 reference	
gariba	260.8	575.0	4 long artaba, 2003 reference	
Peru (Orig Spanish Castilian, pre 1869, values are actually from 1891)				Colonial to pre-metric
libra or libbra	0.4601	1.014	Pound, still used in 1891, consistent with 2003 reference	
arroba	11.50	25.36	25 libra, still used in 1891, consistent with 2003 reference	

(continued)

Table 7.2 (continued)

Region and unit	Equivalent kgs at 1 grav.	Equivalent lbs at 1 grav.	Notes	Era
quintal	46.01	101.4	100 libra, 4 arroba, still used in 1891, consistent with 2003 reference	
fanega	64.41	142.0	140 libra, still used in 1891, consistent with 2003 reference	
Philippines (pre-1860, past Spanish, local variations and additional units not listed)				Medieval to pre-metric
punto	0.200	0.441	2003 reference	
catty	0.600	1.32	3 punto, 2003 reference	
chinanta	6.00	13.2	10 catty, 2003 reference	
lachsá	28.8	63.5	48 catty, 2003 reference	
caban (cocoa)	37.9	83.5	1891 value	
caban	58.2	128	97 catty, but varied with commodity, 2003 reference	
pecul	60.0	132	100 catty, 2003 reference	
caban (rice)	60.3	133	1891 value	
Poland (Local variations, values from 1891, see also Russia, Austria, and Prussia)				Pre-metric
gran	0.00004400	0.00009700	2003 reference	
skrupul	0.001056	0.002328	24 gran, 2003 reference	
drachma	0.003168	0.006984	3 skrupul, 2003 reference	
skoyciec	0.00846	0.0186	1891 value	
lut	0.01267	0.02794	4 drachma, 2003 reference	
uncja	0.02534	0.05587	2 lut, 2003 reference	
mark	0.203	0.447	24 skoyciec, 1891 value	
funt	0.4055	0.8940	16 uncja, 2003 reference	
funt	0.4060	0.8950	2 mark, 1891 value	
kamian	10.14	22.35	25 funt, 2003 reference	
centner	40.55	89.40	4 kamian, 2003 reference	

(continued)

Table 7.2 (continued)

Region and unit	Equivalent kgs at 1 grav.	Equivalent lbs at 1 grav.	Notes	Era
Portugal (pre-1862, consistent with 1891 values also, many systems were used, local variations and additional units not shown)				Medieval to pre-metric
grão or grao	0.0000498	0.000110	“Grain”, 1/9216 arratéis, 2003 reference	
escrópulo or scrupulo	0.00120	0.00264	“Scruple”, 24 grãos, 1/384 arratéis, 2003 reference	
oitava or outava	0.00359	0.00791	“Eighth”, or drachm, 3 escrópulos, 1/128 arratéis, 2003 reference	
onça	0.0287	0.0632	“Ounce”, 8 oitavas, 1/16 arratéis, 2003 reference	
quarta	0.115	0.253	“Fourth”, 4 onças, 1/4 arratéis	
marco (gold, silver)	0.230	0.506	1/2 arratel	
meio	0.230	0.507	Marco, 8 onça, 2003 reference	
libra (Apothecary)	0.344	0.759	12 onças	
arratel, arratéi, or libra	0.459	1.01	“Pound”, 16 onça, 2003 reference	
arroba	14.7	32.4	32 arratéis, 2003 reference	
quintal	58.8	130	4 arrobas, 128 arratéis, 2003 reference	
tonelada	793	1749	“Tonne”, 13.5 quintais, 1728 arratéis	
Prussia (See also Germany, pre- and post-1891 values, some are old names with metric definitions)				Pre- and post-metric
zent (new)	0.000167	0.000367	Post-metric value	
gran (gold, silver)	0.000812	0.00179	1891 value	
quentchen (new)	0.00167	0.00367	10 zent, post-metric value	
quentchen (old)	0.004	0.008	Pre-metric value	
loth (old)	0.0146	0.0322	4 quentchen, pre-metric value	
loth (gold, silver)	0.0146	0.0322	18 gran, 1891 value	
loth (new)	0.0167	0.0367	10 quentchen, post-metric value	
unze (old)	0.02923	0.06445	2 loth, pre-metric value	
mark (old)	0.2339	0.5156	8 unzen, pre-metric value	

(continued)

Table 7.2 (continued)

Region and unit	Equivalent kgs at 1 grav.	Equivalent lbs at 1 grav.	Notes	Era
mark (gold, silver)	0.234	0.516	16 loth, 1891 value	
pfund (old)	0.4677	1.031	2 mark, pre-metric value	
pfund (new)	0.500	1.10	30 loth, Zollverein pfund, post-metric value	
liespfund (old)	7.718	17.01	16.5 pfund, pre-metric value	
stein (old)	10.29	22.69	22 pfund, pre-metric value	
centner (new)	50.0	110	100 pfund, post-metric value	
centner (old)	51.45	113.4	5 stein, pre-metric value	
tonne (new)	150	331	3 centner, post-metric value	
schiffpfund (old)	154.4	340.3	20 liespfund, pre-metric value	
Roman Empire (Ancient, many systems were used, local variations and additional units not shown, for more recent units see Italy)				Ancient
siliqua	0.000190	0.000419	“Carat”, 1/144 uncia, “carob seed”	
obolus	0.000570	0.00126	1/48 uncia, “metal spit”	
scrupulum or scripulum	0.001135	0.002502	1/24 uncia, “small pebble” or “scruple”, 2003 reference	
semisextula	0.00228	0.00503	1/12 uncia, “half-little sixth”	
denier	0.00341	0.00751	1/8 uncia, 2003 reference	
denarius	0.00389	0.00858	1/7 uncia, 2003 reference	
sextula	0.004542	0.01001	1/6 uncia, “little sixth”, 2003 reference	
milaresium	0.005450	0.01201	1/5 uncia, 2003 reference	
sicilicus, sicilium, or siciliquus	0.006813	0.01502	1/4 uncia, “little sickle”, 2003 reference	
duella	0.009083	0.02002	1/3 uncia, “little double [sixths]”, 2003 reference	

(continued)

Table 7.2 (continued)

Region and unit	Equivalent kgs at 1 grav.	Equivalent lbs at 1 grav.	Notes	Era
semuncia	0.01363	0.03005	1/2 uncia, “Half-twelfth” or “half-ounce semuncia”, 2003 reference	
uncia	0.02725	0.06007	1/12 libra, “Roman ounce”, 2003 reference	
sescuncia or sescunx	0.0411	0.0906	1/8 libra, “One and 1/2 twelfths”	
sextans	0.05450	0.1201	1/6 libra, “sixth”, 2003 reference	
quadrans or teruncius	0.08175	0.1802	1/4 libra, “fourth” or “triple twelfth”, 2003 reference	
triens	0.1090	0.2403	1/3 libra, “third”, 2003 reference	
quincunx	0.1363	0.3005	5/12 libra, “five-twelfths”, 2003 reference	
semis or semissis	0.1635	0.3604	1/2 libra, “half”, 2003 reference	
septunx	0.191	0.421	7/12 libra, “seven-twelfths”	
bes or bessis	0.2180	0.4806	2/3 libra, “two of an as”, 2003 reference	
dodrans	0.2453	0.5408	3/4 libra, “less a fourth”, 2003 reference	
dextans	0.2725	0.6007	5/6 libra, “less a sixth”, 2003 reference	
deunx	0.2998	0.6609	11/12 libra, “less a twelfth”, 2003 reference	
libra	0.3270	0.7209	“Roman pound” or “balance”, estimates range from 0.322 to 0.329 kg, 2003 reference	
mina	0.5450	1.201	5/3 libra, 2003 reference	
centum podium	32.70	72.09	100 libra, 2003 reference	
as	Major variation		12 uncia prior to First Punic War. Reduced to 2 uncia until 2nd Punic War. Reduced to 1 uncia in 2nd Punic War. Reduced to 1/2 uncia before 191 BC	

(continued)

Table 7.2 (continued)

Region and unit	Equivalent kgs at 1 grav.	Equivalent lbs at 1 grav.	Notes	Era
Romania (Includes Moldavia and Wallachia, local variations, values reported in 1891)				Pre-metric
litra	0.3197	0.7047	1891 value	
oka or occha	1.279	2.819	4 litra, consistent with 2003 reference	
cantaro	56.26	124.0	44 okas, consistent with 2003 reference	
Russia (pre-1924, many systems were used, local variations and additional units not shown)				Medieval to pre-metric
Ordinary measure				
dolia or doli	0.00004444	0.00009796	Grain, 1891 value, consistent with 2003 reference	
zolotnik or solotnik	0.004266	0.009404	Golden one, 96 dolias, 1891 value, consistent with 2003 reference	
loth or lot	0.01280	0.02821	3 zolotnicks, 1891 value	
once or ounce	0.02559	0.05642	2 loth, 2003 reference	
lana	0.03413	0.07523	8 zolotnicks, 1891 value, consistent with 2003 reference	
funt or funte	0.4095	0.9028	Pound, 12 lanas, 1891 value, consistent with 2003 reference	
pood or pud	16.38	36.11	40 funts, 12th century, still found in used for agricultural products and bells, 1891 value, consistent with 2003 reference	
berkovets or berkowitz	163.8	361.1	10 poods, 1891 value, consistent with 2003 reference	
packen	491.4	1,083	3 berkovetz, 1891 value	
Apothecaries' measure				
dolia or doli	0.00004444	0.00009797	Grain, 1891 value, consistent with 2003 reference	
gran or grain	0.00006221	0.0001371	Grain, 1891 value, consistent with 2003 reference	
scrupul or scrupule	0.001244	0.002743	Scruple, 20 grains, 1891 value, consistent with 2003 reference	
drachma or drachme	0.003733	0.008229	Dram, 60 grains, 1891 value, consistent with 2003 reference	

(continued)

Table 7.2 (continued)

Region and unit	Equivalent kgs at 1 grav.	Equivalent lbs at 1 grav.	Notes	Era
uncia or once	0.02986	0.06583	Ounce, 480 grains, 1891 value, consistent with 2003 reference	
funt or funte	0.3583	0.7900	Pound, 5760 grains, 1891 value, consistent with 2003 reference	
Salvador (See El Salvador)				Colonial to pre-metric
Sandwich Islands (Hawaii, See U.S. Customary units)				Pre-metric
San Salvador (See El Salvador)				Colonial to pre-metric
Saudi Arabia (pre-Metric (1962), see also Arabia)				Pre-metric
coffilas	0.003375	0.007440	2003 reference	
tukeas or vakias	0.03375	0.07440	10 coffilas, 2003 reference	
ratl	0.4500	0.9921	13-1/3 tukeas, 2003 reference	
maund	1.350	2.976	3 ratl, 2003 reference	
farzil or farcella	13.50	29.76	10 maund, 2003 reference	
kantar or buhar	67.50	148.8	5 farzil, 2003 reference	
bokard or bahar	202.5	446.4	3 kantar, 2003 reference	
Scotland (pre-1824, many systems were used, local variations and additional units not shown)				Medieval to pre-metric
grain	0.00006480	0.0001429	2003 reference	
drop	0.001928	0.004250	2003 reference	
ounce	0.03084	0.06800	16 drops, 2003 reference	
pound	0.6169	1.360	Scottish pound, 20 ounces, 2003 reference	
stone	9.870	21.76	16 pounds, 2003 reference	
Serbia (Or Servia, pre-1873, varied locally and over time, values reported were 1891)				Medieval to pre-metric
drachm	0.003197	0.007047	“Dram”, 1891 value	
litra	0.3197	0.7047	“Pound”, 100 drachm, 1891 value	
oka	1.279	2.819	4 litra, 2.82 lbs av, 1891 value	

(continued)

Table 7.2 (continued)

Region and unit	Equivalent kgs at 1 grav.	Equivalent lbs at 1 grav.	Notes	Era
Siam (See Thailand)				Pre-metric
Siberia (See Russia)				Pre-metric
Singapore (pre-1968, varied, approximate values)				Colonial to pre-metric
mace or miam	0.0034	0.0074	52 grains	
buncal (gold)	0.053	0.12	822 grains	
Somalia (pre-1950, local variation, additional units not shown)				Medieval to pre-metric
okia	0.028	0.062	Ounce, 1/16 rottolo, 2003 reference	
rottolo	0.448	0.988	Pound, 16 okia, 2003 reference	
frasla	16.1	35.6	36 rottolo, 2003 reference	
gisla	161	356	10 frasla, 2003 reference	
Sooloo Archipelago (1891 values)				Pre-metric
mace	0.00378	0.00833	58.33 grains, 1891 value	
tael	0.0378	0.0833	1891 value	
lachsá	30.24	66.66	1891 value	
South Africa (Used Dutch, English, pre-1922)				Medieval to pre-metric
bundle	0.318	0.700	Equivalent to a pound roughly	
Spain (pre-Metric, local variation, additional units not shown)				Medieval to pre-metric
grano (ordinary)	0.00005001	0.0001103	1891 value, reported as 0.00004992 kg in 2003 reference	
arienzo (ordinary)	0.0001997	0.0004403	4 granos, 2003 reference	
tomin (ordinary)	0.0006001	0.001323	12 granos, 1891 value, reported as 0.0005991 kg in 2003 reference	
dinero (ordinary)	0.001198	0.002641	2 tomin, 2003 reference	
adarme or drachm (ordinary)	0.001800	0.003969	3 tomines, 1891 value, reported as 0.1797 kg in 2003 reference	
ochava or caracer (ordinary)	0.003601	0.007938	2 adarmes, 1891 value, reported as 0.003594 kg in 2003 reference	
escrupolo or scruple (ordinary)	0.007189	0.01585	2 ochavas, 2003 reference	

(continued)

Table 7.2 (continued)

Region and unit	Equivalent kgs at 1 grav.	Equivalent lbs at 1 grav.	Notes	Era
onza (ordinary)	0.02881	0.06351	8 ochavas, 1891 value, reported as 0.02876 kg in 2003 reference	
marco (ordinary)	0.2305	0.5080	8 onzas, 1891 value, reported as 0.2300 kg in 2003 reference	
libra (apothecary)	0.3454	0.7615	1891 value	
libra or pound (ordinary)	0.4609	1.016	2 marcos, 1891 value, reported as 0.4601 kg in 2003 reference	
arroba (ordinary)	11.52	25.40	25 libras, 1891 value, reported as 11.50 kg in 2003 reference	
quintal (ordinary)	46.09	101.6	4 arrobas, 1891 value, reported as 46.01 kg in 2003 reference	
tonelada or tonelada (ordinary)	921.8	2,032	20 quintals, 1891 value, reported as 920.2 kg in 2003 reference	
Sri Lanka (pre-1970s, local variation, additional units not shown, previously Ceylon)				Medieval to pre-metric
candy or bahar	226.8	500.0		
Small weights measured in seeds:				
tala				
amu				
vee ata			3 amu	
madati			8 vee ata	
majadi				
maditi				
kalanda				
manjadi				
Sumatra (Local variations, 1891 values)				Pre-metric
catty	0.9607	2.118	1891 value	
ootan (camphor)	1.8	4.0	1891 value	
maund	35	77	1891 value	
pecul	60.5	133	1891 value	
candil	192	423	1891 value	
Sweden (pre-1889, local variations and changes with time, additional units not shown)				Medieval to pre-metric
ass	0.00004804	0.0001059	2003 reference	
korn	0.0004251	0.0009371	1/10 ort, 2003 reference	
qvintin or kvintin	0.003321	0.007322	1/4 lod, 2003 reference	

(continued)

Table 7.2 (continued)

Region and unit	Equivalent kgs at 1 grav.	Equivalent lbs at 1 grav.	Notes	Era
ort	0.004236	0.009338	100 korns, 1891 value	
ort	0.004251	0.009371	10 korn, 2003 reference	
lod	0.013284	0.02929	4 qvintin, 2003 reference	
uns	0.026569	0.05857	2 lod, 2003 reference	
mark	0.203	0.448	1/2 skålpund, Viking era	
mark	0.213	0.468	50 ort, pre-metric	
skålpund	0.4236	0.9338	100 orts, 1891 value	
skålpund	0.4251	0.9372	16 uns, 2 mark, 2003 reference	
bismerpund	5.10	11.2	12 skålpund	
lispund or liespund	8.502	18.74	20 skålpund, 2003 reference	
sten	13.60	29.98	32 skålpund, 2003 reference	
centner	42.36	93.38	100 skålpund, 1891 value	
centner	42.51	93.72	5 liespund, 2003 reference	
waag	70.14	154.6	165 skålpund, 2003 reference	
skeppspund	170.0	374.8	20 liespund, 2003 reference	
last	4,236	9,338	100 centners, 1891 value	
nyläst	5,101	11,246	30 skeppspund, 2003 reference	
Switzerland (Names are pre-1868, local variations, additional units not shown, values based on definitions at time of metrification)				Medieval to metric
Ordinary measure				
loth	0.01563	0.03445	1891 value, consistent with 2003 reference	
once	0.03125	0.06889	2 loth, “ounce”, 1891 value, consistent with 2003 reference	
livre or pfund	0.5000	1.102	Defined at transition to metric, “Swiss pound”, Zollverein pfund, 16 onces, 1891 value, consistent with 2003 reference	
quintal	50.00	110.2	100 livres, 1891 value	

(continued)

Table 7.2 (continued)

Region and unit	Equivalent kgs at 1 grav.	Equivalent lbs at 1 grav.	Notes	Era
Apothecaries' Measure				
grain	0.0000651	0.000144	1891 value, consistent with 2003 reference	
scruple	0.00130	0.00287	20 grains, 1891 value, consistent with 2003 reference	
drachme	0.00391	0.00861	3 scruples, 1891 value, consistent with 2003 reference	
once	0.0313	0.0689	8 drachmes, 1891 value, consistent with 2003 reference	
livre	0.375	0.827	Defined at transition to metric, 12 ounces, 1891 value, consistent with 2003 reference	
Syria (pre-1935, local variations, additional units not shown, see also Turkey and Ottoman Empire)				Medieval to pre-metric
pesi	0.002975	0.006559	1/600 rottolo, 2003 reference	
metecali or mitcal	0.004463	0.009838	1/400 rottolo, 1.5 pesi, 2003 reference	
once	0.02975	0.06559	Ounce, 10 pesi, 2003 reference	
rottolo	1.785	3.935	60 once, 2003 reference	
zurbo	49.09	108.2	1650 once, 2003 reference	
cola	62.48	137.7	35 rottolo, 2003 reference	
cantar	178.5	393.5	100 rottolo, 2003 reference	
Taiwan (local variations, similar names to Chinese but different values, still used for bulk goods, metric definitions, formerly Formosa)				Pre-metric
cash or li	0.0000375	0.0000827		
candareen, fēn, hun	0.000375	0.000827	10 cash	
mace, qián, chí ⁿ	0.00375	0.00827	10 candareens	
tael, liǎng, niú	0.0375	0.0827	10 mace	
catty, jīn, kīn, kūn	0.600	1.32	16 taels	
picul, dàn, tà ⁿ	60.0	132	100 catties	
Tanzania (pre-1967, many units used, local variations, only some listed)				Pre-metric
rotoli	0.445	0.980		
mane	0.91	2.0		
bazla	15.53	34.23		
franzella	16.0	35.3	36 rotoli	

(continued)

Table 7.2 (continued)

Region and unit	Equivalent kgs at 1 grav.	Equivalent lbs at 1 grav.	Notes	Era
Tatar (pre-1924, many variations and changes over time)				Medieval to pre-metric
öleş	0.0000444	0.0000980		
misqal	0.00427	0.00940	96 öleş	
loth	0.0128	0.0282	3 misqal	
qadaq or göränkä	0.4095	0.9028	96 misqal, 32 lot	
pot	16.4	36.1	40 qadaq	
qantar	41.0	90.3	2-1/2 pot	
berkovets	163.8	361.1	10 pot	
Thailand (Formerly Siam, 1891 values, local variations, some values are pre-metric names and post-metric values)				Pre- and post-metric
klom	0.000117	0.000258	2003 reference	
klam	0.000234	0.000517	2 klom, 2003 reference	
pai	0.000469	0.00103	2 klam, 2003 reference	
sompay or grani	0.000938	0.00207	2 pai, 2003 reference	
fuang	0.00188	0.00413	2 sompay, 2003 reference	
salung	0.00375	0.00827	2 fuang, 2003 reference	
baht	0.0150	0.0331	4 salung, 2003 reference	
tical	0.01512	0.0333	1891 value	
tamlung	0.0600	0.132	4 baht, 2003 reference	
tael	0.06049	0.1334	4 ticals, 1891 value	
tchang	1.200	2.646	20 tamlung, 2003 reference	
catty	1.210	2.667	20 tael, 1891 value	
doon	24.0	52.9	20 tchang, 2003 reference	
hap	60.0	132	50 tchang, 2003 reference	
pecul	60.49	133.4	50 catties, 1891 value	
bara	480	1,058	8 hap, 2003 reference	
Tripoli (See also Libya, 1891 values, local variations)				Pre-metric
kharouba	0.0001944	0.0004286	1891 value	
drachma	0.003110	0.006857	16 kharoubas, 1891 value	
metical (gold, silver)	0.00477	0.0105	73.6 grains, 1891 value	

(continued)

Table 7.2 (continued)

Region and unit	Equivalent kgs at 1 grav.	Equivalent lbs at 1 grav.	Notes	Era
uckia	0.03110	0.06857	10 drachmas, 1891 value	
rotl	0.4977	1.097	16 unkias, 1891 value	
oke	1.244	2.743	1/40 cantaro, 1891 value	
cantaro or kantar	49.77	109.7	100 rotls, 40 oke, 1891 value	
Tunisia (varied, many used, approximate values)				Ancient to pre-metric
Common measure				
uckir or unkia	0.03150	0.06943	Ounce, nominal value, 2003 reference, varies with commodity	
rotoilo attari or rotl attari	0.5039	1.111	16 uckir, 2003 reference, reported as 0.5069 kg in 1891	
rotoilo sucki or rotl sucky (meat, etc.)	0.5669	1.250	18 uckir, meat, etc., 2003 reference, reported as 0.5685 kg in 1891	
rotoilo khaddari (vegetables)	0.6299	1.389	20 uckir, vegetables, 2003 reference	
cantaro (attari)	50.39	111.1	1600 uckir, 2003 reference	
cantaro (sucki)	56.69	125.0	1800 uckir, meat, etc., 2003 reference	
cantaro (khaddari)	62.99	138.9	2000 uckir, vegetables, 2003 reference	
Precious metals, fine goods				
metical (gold, silver)	0.0039	0.0085	59.7 gr, 1891 value	
Turkmenistan (See also Russia, values reported in 1891 and 2003)				Pre-metric
mimtscha	0.494	1.09	2003 reference	
tscharik	1.98	4.36	4 mimtscha, 2003 reference	
sir or seer	15.67	34.55	1891 value	
sir or seer	15.8	34.9	8 tscharik, 2003 reference	
batmann or batman	125.4	276.4	8 seer, 1891 value	
batmann or batman	127	279	8 sir, 2003 reference, varied 125–128 kg, used average	
Turkey (See also Ottoman Empire, major local variations, mixed units from other countries)				Medieval to pre-metric
karat	0.0002005	0.0004420	2003 reference	
karat	0.0002008	0.0004428	1891 value	

(continued)

Table 7.2 (continued)

Region and unit	Equivalent kgs at 1 grav.	Equivalent lbs at 1 grav.	Notes	Era
denke	0.0008019	0.001768	4 karat, 2003 reference	
deuke	0.0008034	0.001771	4 karats, 1891 value	
dirham or drachm	0.003208	0.007071	4 denke, 2003 reference	
dirhem or drachm	0.003214	0.007084	4 deukes, 1891 value	
miskal	0.004811	0.01061	6 denke, 2003 reference	
yusdrum or cequi	0.3208	0.7071	100 dirham, 2003 reference	
chequi	0.3214	0.7084	100 dirhem, 1891 value	
rottel	0.5645	1.245	176 dirham, 2003 reference	
rotoolo	0.65	1.4	Wildly variable, from 0.57 to 2.3 kg in 1891, average shown	
oka	1.283	2.828	4 yusdrum, 2003 reference	
oke or occa	1.285	2.834	4 chequis, 1891 value	
batman	7.698	16.97	6 oka, 2003 reference	
batman (Asia Minor, Syria)	7.7	17	6 okes, 1891 value	
kantar	56.45	124.5	44 oka, 2003 reference	
kantar or cantaro	56.56	124.7	44 okes, 1891 value	
tcheki	225.8	497.8	4 kantar, 2003 reference	
United Kingdom (Includes England, Great Britain, and former possessions, customary units, major local variations and changes over time)				Medieval to pre-metric
Avoirdupois				
grain (gr)	0.00006480	0.0001429	Originally weight of grain seed from middle of ear of barley	
dram or drachm (dr)	0.001772	0.003906	1/16 ounce, possibly from drachma	
poundal (pdl)	0.01410	0.03108	Unit of mass, equivalent kg force	
ounce (oz)	0.02835	0.06250	16 dram, 437.5 grains	
pound (lb)	0.4536	1.000	7000 grains, 16 ounces	
nail	3.175	7.000	1/16 cwt, 7 pounds	
clove (wool)	3.175	7.000	7 pounds	
clove (cheese)	3.629	8.000	8 pounds	

(continued)

Table 7.2 (continued)

Region and unit	Equivalent kgs at 1 grav.	Equivalent lbs at 1 grav.	Notes	Era
stone (st)	6.350	14.00	14 pounds	
quarter or tod	12.70	28.00	1/4 hundredweight, 2 stone	
slug (slug)	14.59	32.17	Unit of mass	
hundredweight (cwt)	50.80	112.0	112 pounds, 4 quarters	
ton	1,016	2,240	20 hundredweight	
Troy (coins and precious metals, after 1526)				
grain (gr t)	0.00006490	0.0001431		
pennyweight (dwt t)	0.001558	0.003434	24 grains	
ounce (oz t)	0.03115	0.06867	480 grains, 20 pennyweight	
mark	0.2492	0.5494	8 oz t	
pound (lb t)	0.3738	0.8241	12 oz t, 5760 gr	
Tower (coins and precious metals, pre-1526)				
grain (gr T)	0.0000455	0.000100	45/64 gr t	
pennyweight (dwt T)	0.00146	0.00322	22.5 gr t, 32 gr T	
ounce (oz T)	0.0290	0.0639	24 dwt T, 640 gr T	
mark	0.232	0.511	8 oz T	
pound (lb T)	0.349	0.770	12 oz T, 7680 gr T	
Apothecaries Measure (Purchase of drugs used avoirdupois measures)				
grain (gr ap)	0.0000648	0.000143		
scruple (s ap)	0.00130	0.00286	20 gr ap	
dram or drachm (dr ap)	0.00389	0.00857	3 s ap, 60 gr ap	
ounce (oz ap)	0.0311	0.0686	480 gr ap, 8 drachms	
pound (lb ap)	0.373	0.823	1 lb t, 12 oz ap	
Miscellaneous				
diamond grain	0.0000519	0.000114	4/5 troy grain	
carat	0.000259	0.000571	4 grains	
ounce (wool)	0.02835	0.06250		
merchants or mercantile pound	0.437	0.964	~ 15 oz T	
pound (wool)	0.4536	0.9999	16 ounces (wool), same as avoirdupois pound	
pound (Suffolk, butter, cheese)	0.4536	1.000	Avoirdupois basis	
pound (coal)	0.4536	1.000	Same as avoirdupois pound	
pound (new hay)	0.454	1.00		

(continued)

Table 7.2 (continued)

Region and unit	Equivalent kgs at 1 grav.	Equivalent lbs at 1 grav.	Notes	Era
London or mercantile pound	0.467	1.03	~ 15 oz t, ~ 16 oz T, ~ 7200 gr	
pound (old hay)	0.486	1.07	1.071 pounds (new hay)	
roll (Suffolk, butter, cheese)	0.6804	1.500	24 oz av	
pound (straw)	0.756	1.67	1-2/3 lbs (new hay)	
clove (Suffolk, butter, cheese)	3.629	8.000	8 lbs	
butcher's stone	3.63	8.00	8 lb	
mercantile stone	5.60	12.3	12 lb L	
stone (wool)	6.350	14.00	14 lbs (wool)	
stone (coal)	6.350	14.00	14 lbs	
quarter (coal)	12.70	28.00	2 stones	
firkin (Suffolk, butter, cheese)	25.40	56.00	7 cloves	
truss (hay or straw)	27.2	60.0	36 lbs (straw)	
tub (Suffolk, butter, cheese)	38.10	84.00	1.5 firkins	
hundredweight (coal)	50.80	112.0	4 quarters	
sack (coal)	50.80	112.0	1 hundredweight	
Dutch cask (Suffolk, butter, cheese)	58.06	128.0	16 cloves	
large sack (coal)	101.6	224.0	2 sacks	
wey (wool)	114.3	252.0	18 stones (wool)	
barrel (Suffolk, butter, cheese)	116.1	256.0	32 cloves	
whey (Essex, butter, cheese)	122.3	269.7	236 lbs	
sack	165	364	26 stone, 364 lbs	
sack (wool)	165.1	364.0	26 stones (wool)	
wey (Suffolk, butter, cheese)	184.6	406.9	356 lbs	
load (hay or straw)	980	2,160	36 truss (hay or straw)	
long ton (coal)	1,016	2,240	10 large sacks	
load (wool)	1,372	3,024	12 wey (wool)	
room (coal)	7,112	15,680	7 long tons	
keel (coal)	21,541	47,488	212 large sacks	
ship load (coal)	430,811	949,760	20 keels	

(continued)

Table 7.2 (continued)

Region and unit	Equivalent kgs at 1 grav.	Equivalent lbs at 1 grav.	Notes	Era
United States (Customary units, based on English units before 1824)				Colonial to modern
Avoirdupois measure (most common use)				
grain (gr)	0.0000648	0.000143		
carat	0.000200	0.000441		
dram (dr)	0.00177	0.00391	8.859 carats or 27-11/32 gr	
poundal (pdl)	0.0141	0.0311	Unit of mass, equivalent kg force	
ounce (oz)	0.0283	0.0625	16 dr	
pound (lb)	0.4536	1.000	Base unit, technically a unit of mass	
slug (slug)	14.59	32.17	Unit of mass	
US hundredweight (cwt) or quintal	45.36	100.0	100 lb	
long hundredweight	50.80	112.0	112 lb	
ton or short ton	907.2	2,000	20 US cwt, 2000 lbs	
long ton	1,016	2,240	20 long hundredweight or 2240 lbs	
Apothecaries' Measure				
grain (apoth)	0.00002939	0.00006480		
scruple (scr apoth)	0.0005879	0.001296	20 gr apoth	
drachm (dr apoth)	0.001764	0.003888	3 scr apoth	
ounce (oz apoth)	0.01411	0.03110	8 dr apoth	
pound (lb apoth)	0.1693	0.3732	12 oz apoth	
Troy measure (precious metals)				
grain (gr)	0.0000648	0.000143	Same as Avoirdupois measure	
pennyweight (dwt)	0.00156	0.00343	7.776 carats, 24 gr	
troy ounce (oz t)	0.0311	0.0686	20 dwt	
troy pound (lb t)	0.3732	0.8228	12 oz t	
Commodity measure (based on typical density)				
metric carat (gems)	0.0002	0.0004	1932 value	
carat (gems)	0.000205	0.000452	3.164 grains	
bushel (barley)	21.8	48.1	2150.42 cu in	
bushel (corn)	25.4	56.0	2150.42 cu in	
bushel (wheat)	27.2	60.0	2150.42 cu in	

(continued)

Table 7.2 (continued)

Region and unit	Equivalent kgs at 1 grav.	Equivalent lbs at 1 grav.	Notes	Era
Uruguay (pre-1866, local variations, additional units not shown, older Spanish Castilian)				Colonial to pre-metric
libra	0.4601	1.014	1891 value	
Venezuela (pre-1857, local variations, additional units not shown, older Spanish Castilian, values indicated were set at time metric system was adopted, 2003 reference)				Colonial to pre-metric
onza	0.031	0.069	1/16 libra, older value estimated at 0.029 kg	
libra or libbra	0.50	1.1	16 onza, older value estimated at 0.46 kg	
arroba	12.5	27.6	25 libra, older value estimated at 11.5 kg	
quintal	50.0	110	100 libra, older value reported as 46.0 kg	
bag or saco	62.5	138	125 libra, older value estimated at 57.5 kg	
carga	125	276	250 libra, older value estimated at 115 kg	
tonelada	1,000	2,205	2000 libra, older value estimated at 920 kg	
Vietnam (Formerly Annam, pre-metric, early 20th Century traditional values with some re-defined metric values, local variations, additional units not shown)				Medieval to pre-metric
vi	3.780E-09	8.333E-09		
hốt	3.780E-08	8.333E-08	10 vi	
ti	3.780E-07	8.333E-07	10 hốt	
hao	3.775E-06	8.322E-06	2003 reference	
hào	3.780E-06	8.333E-06	10 ti	
li	0.00003775	0.00008322	10 hao, 2003 reference	
ly or li	0.0000378	0.0000833	10 hào	
fan	0.0003775	0.0008322	10 li, 2003 reference	
phân	0.000378	0.000833	10 ly	
chi (precious metals)	0.00375	0.00827		
dong	0.003775	0.008322	10 fan, 2003 reference	
đồng, tiền, or đồng cân	0.00378	0.00833	10 phân, differs from monetary unit	
lạng, cây, or lượng (precious metals)	0.0375	0.0827		
luong	0.03775	0.08322	10 dong, 2003 reference	

(continued)

Table 7.2 (continued)

Region and unit	Equivalent kgs at 1 grav.	Equivalent lbs at 1 grav.	Notes	Era
lạng, đỉnh, or lượng	0.0378	0.0833	10 đồng, under metric = 0.1 kg, later 2 names are French colonial units	
thoi	0.189	0.417	French colonial unit	
neu	0.3775	0.8322	10 luong, 2003 reference	
nén	0.378	0.833	10 lạng	
can	0.6040	1.332	16 luong, 2003 reference	
cân or cân tạ	0.6045	1.333	16 lạng, under metric = 1 kg and is called cân tây or “Western scale”	
yen	6.040	13.32	10 can, 2003 reference	
yến	6.045	13.33	10 cân, under metric = 10 kg	
bình	30.20	66.58	5 yen, 2003 reference	
bình	30.23	66.63	5 yến, under metric = 50 kg, in Annam bình was 31 kg	
ta or picul	60.40	133.2	2 bình, 2003 reference	
tạ	60.45	133.3	10 yến, under metric = 100 kg	
kwan	67.95	149.8	180 neu, 2003 reference	
quân	302.3	666.3	5 tạ, under metric = 500 kg	
tấn	604.5	1,333	10 tạ, under metric = 1000 kg, when used for ship capacity = 2.83 or 1.13 cu meters	
West Indies				Colonial to pre-metric
Spanish units used in: Cuba, Puerto Rico, Isle of Pines, Curacao, and Culebra				
French units used in: Martinique, Deseada, Guadeloupe, Marie Galante, Le Saintes, and part of St. Martin				
Swedish units used in St. Bartholomew				
Dutch (Netherlands) units used in: Part of St. Martin, Buen Ayre, Oruba (Aruba), and Tortuga				
Danish units used in: Santa Cruz, St. Thomas, and St. Jan or St. John, but also use English standards for length				
English units used in: Jamaica, Barbados, Grenada, Santa Lucia, St. Vincent, Trinidad, Tobago, Antigua, Bermuda, Dominica, Nevis, Montserrat, St. Kitt's, Tortola, Bahamas, and minor islands. Units are essentially US Customary				

(continued)

Table 7.2 (continued)

Region and unit	Equivalent kgs at 1 grav.	Equivalent lbs at 1 grav.	Notes	Era
Independent units used in: Haiti and Santo Domingo				
livre (Martinique)	0.4895	1.079	Used old French units in 1891	
Yugoslavia (Pre-metric units, pre-1873 primarily, 2003 reference)				Pre-metric
dramm	0.003200	0.007055	2003 reference	
litra or satlijk	0.3200	0.7055	100 drammm, 2003 reference	
oka	1.280	2.822	4 litra, 2003 reference	
akov	51.20	112.9	40 oka, 2003 reference	
tovar	128.0	282.2	100 oka, 2003 reference	
Zanzibar				Pre-metric
bazla	15.52	34.23	1891 value	
mane	1.36	3.01	1891 value	
franzella	16.00	35.28	36 franzella, 1891 value	
rotolo	0.4446	0.9801	1891 value	x

Table 7.3 Alphabetical table of historical volume/capacity measurement conversion factors. Multiple sources, see References

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
abbassi	0.368	0.811	Persia, Iran	Ancient to pre-metric	General	4 pinar, 2003 reference
accini (Naples)	0.00004455	0.0000982	Italy	Medieval to pre-metric	Apothecaries'	1891 value
accini (Naples)	0.00004455	0.00009822	Italy	Medieval to pre-metric	Prec. Mils., Drugs, Pigments	1891 value
achita	941	2,074	India	Akbar to Colonial	General	10 bara, 1966 value
adachmon	0.0071	0.016	Jewish, Israel	Ancient to Modern	General	1/2 shekel
adarme	0.001795	0.003956	Argentina	Colonial to pre-metric	General	1/256 libra, 36 granos, 2003 reference
adarme	0.001797	0.003962	Chile	Colonial to pre-metric	General	1/256 libra, 36 granos, 2003 reference
adarme	0.001798	0.003963	Mexico	Colonial to pre-metric	General	1/256 libra, 3 tomin, 2003 reference
adarme	0.001800	0.003969	Spain	Medieval to pre-metric	General	3 tomines, 1891 value, reported as 0.1797 kg in 2003 reference
adha (1/2) seer	0.47	1.0	India	Medieval to Akbar	General	2 pav, 1/2 seer
adher	0.47	1.0	India	Medieval to Akbar	General	2 pav, 1/2 seer
adh-pav	0.12	0.26	India	Medieval to Akbar	General	2 chhatank, 1/8 seer
aguirage	0.00401	0.00885	Guinea	Medieval to pre-metric	General	2 mediatabla, 2003 reference
akey	0.00100	0.00221	Guinea	Medieval to pre-metric	General	2003 reference
akey	0.00134	0.00295	Guinea	Medieval to pre-metric	General	1/48 benda
akov	51.20	112.9	Yugoslavia	Pre-metric	General	40 oka, 2003 reference
alada	0.01560	0.03439	Ethiopia	Medieval to Pre-metric	Rubber	2 mutagalla, based on rubber farasula, 2003 reference
amat	123.5	272.3	Indonesia	Colonial to pre-metric	General	2 picul, 2003 reference
amphora	32.60	71.87	Persia, Iran	Ancient to modern	Capacity	2 woöbe, 2003 reference

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
amphora	65.28	143.9	Arabia	Ancient	Capacity	2 cafiz, 2003 reference, capacity measure
Amsterdam pond	0.494	1.09	Netherlands, Holland	Medieval to metric	General	Amsterdam basis, "pound", pre-1800, consistent with 2003 reference
amu			Sri Lanka, Ceylon	Medieval to pre-metric	General	Small weight measured in seeds
apt	8.5	19	Egypt	Ancient	Capacity	4 hecte, 2003 reference
ariento	0.0001997	0.0004403	Spain	Medieval to pre-metric	General	4 granos, 2003 reference
arratêi	0.459	1.01	Portugal	Medieval to pre-metric	General	"Pound", 16 onça, 2003 reference
arratel	0.459	1.01	Portugal	Medieval to pre-metric	General	"Pound", 16 onça, 2003 reference
arroba	10.6	23.4	Balearic Islands	Pre-metric	General	26 rottolos, 2003 reference
arroba	11.48	25.32	Argentina	Colonial to pre-metric	General	25 libras, 1891 value, consistent with 2003 reference
arroba	11.50	25.35	Bolivia	Pre-metric	General	1891 value
arroba	11.50	25.36	Peru	Colonial to pre-metric	General	25 libra, still used in 1891, consistent with 2003 reference
arroba	11.50	25.36	Chile	Colonial to pre-metric	General	25 libra, 2003 reference
arroba	11.51	25.37	Mexico	Colonial to pre-metric	General	25 libra, 2003 reference
arroba	11.52	25.40	Spain	Medieval to pre-metric	General	25 libras, 1891 value, reported as 11.50 kg in 2003 reference
arroba	11.83	26.07	Central America	Colonial to pre-metric	General	25 libras, 1891 value
arroba	11.83	26.07	Costa Rica	Colonial to pre-metric	General	25 libras, 1891 value
arroba	11.83	26.07	El Salvador	Colonial to pre-metric	General	25 libras, 1891 value

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
arroba	11.83	26.07	Guatemala	Colonial to pre-metric	General	25 libras, 1891 value
arroba	11.83	26.07	Honduras	Colonial to pre-metric	General	25 libras, 1891 value
arroba	11.83	26.07	Nicaragua	Colonial to pre-metric	General	25 libras, 1891 value
arroba	12.50	27.56	Colombia	Colonial to metric	General	25 libra, 2003 reference
arroba	12.5	27.6	Venezuela	Post-metric	General	25 libra, older value estimated at 11.5 kg, old name, metric definition
arroba	14.7	32.4	Portugal	Medieval to pre-metric	General	32 arratéis, 2003 reference
arroba	14.69	32.38	Brazil	Colonial to pre-metric	General	32 libras, 2003 reference
arroba (Buenos Aires)	11.50	25.36	Argentina	Colonial to pre-metric	General	25.3583 lbs, 1891 value
arrobe (new)	11.5	25.3	Paraguay	Colonial to pre-metric	General	25 libra, 2003 reference
arrobe (old)	11.50	25.36	Paraguay	Colonial to pre-metric	General	25 libra, 2003 reference
artabe	51	112	Egypt	Ancient	Capacity	6 apt, 2003 reference
artabe	65.28	143.9	Arabia	Ancient	Capacity	2 cafiz, 2003 reference, capacity measure
artal	0.5075	1.119	Morocco	Colonial to pre-metric	General	2003 reference
as	0.00004805	0.0001059	Norway	Medieval to pre-metric	General	1891 value
as	Major variation		Roman Empire	Ancient	General	12 uncia prior to First Punic War. Reduced to 2 uncia until 2nd Punic War. Reduced to 1 uncia in 2nd Punic War. Reduced to 1/2 uncia before 191 BC
ass	0.00004804	0.0001059	Sweden	Medieval to pre-metric	General	2003 reference
ass	0.00005000	0.0001102	Germany, Prussia	Medieval to pre-metric	Prec. Mtls.	1891 value

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
ass (Baden)	5.000E-05	0.000110	Germany, Prussia	Medieval to pre-metric	General	1891 value
bag	62.5	138	Venezuela	Post-metric	General	125 libra, older value estimated at 57.5 kg, old name, metric definition
bahar	184	405	Malacca	Pre-metric	General	3 peculs, 1891 value
bahar	202.5	446.4	Saudi Arabia	Pre-metric	General	3 kantar, 2003 reference
bahar	204	450	Arabia	Ancient to Pre-metric	General	15 frazils, 1891 value
bahar	226.8	500.0	Ceylon, Sri Lanka	Pre-metric	General	20 maund, 18,891 value, consistent with 2003 reference
bahar	226.8	500.0	Sri Lanka, Ceylon	Medieval to pre-metric	General	
bahar (Amboyna)	271	598	Indonesia	Colonial to pre-metric	General	
bahar (Amboyna)	271.1	597.6	Molucca	Pre-metric	General	1891 value
bahar (Bantam)	180	396	Indonesia	Colonial to pre-metric	General	
bahar (Bantam)	180	396	Java	Colonial to pre-metric	General	1891 value
bahar (Bantam)	185	407	Indonesia	Colonial to pre-metric	Pepper	
bahar (Bantam)	185	407	Java	Colonial to pre-metric	Pepper	1891 value
bahar (Batavia)	277	610	Indonesia	Colonial to pre-metric	General	
bahar (Batavia)	277	610	Java	Colonial to pre-metric	General	1891 value
bahar (Bet-el-faki)	370	816	Arabia	Ancient to pre-metric	General	400 maunds, 1891 value
bahar (Jidda)	83.0	183	Arabia	Ancient to pre-metric	General	100 maunds, 1891 value
bahar (long)	277.9	612.7	Indonesia	Colonial to pre-metric	General	4.5 picul, 2003 reference
bahar (short)	185.3	408.5	Indonesia	Colonial to pre-metric	General	3 picul, 2003 reference

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
baht	0.0150	0.0331	Thailand, Siam	Pre- and post-metric	General	4 salung, 2003 reference
balle	97.90	215.8	Belgium	Pre-metric	General	2 quintal, 2003 reference
bara	94.1	207	India	Akbar to colonial	General	10 hara, 1966 value
bara	480	1,058	Thailand, Siam	Pre- and post-metric	Shipping	8 hap, 2003 reference
barbar (Goa)	225	495	India	Akbar to colonial	General	1891 value
barleycorn	0.00000648	0.0000143	India	Colonial to pre-metric	Gold	
barleycorn (Attic/ Euboic)	0.00006	0.0001	Greece	Ancient	General	1/12 obol, estimated
barrel (Suffolk)	116.1	256.0	United Kingdom, England	Medieval to pre-metric	Butter, Cheese	32 cloves, Suffolk
baruay (Madras)	226.8	500.0	India	Akbar to colonial	General	20 maunds, 1891 value
baruay (Malabar coast)	315.5	695.5	India	Akbar to colonial	General	20 maunds, 1891 value
baruay (Mysore, Seringapatam)	220.2	485.4	India	Akbar to colonial	General	20 maunds, 1891 value
bath (new)	21.42	47.22	Hebrew	Ancient to pre-metric	Liquid capacity	6 hin, 2003 reference
bath (old)	29.38	64.76	Hebrew	Ancient to pre-metric	Liquid capacity	6 hin, 2003 reference
batman	7.70	17.0	Ottoman Empire, Turkey	Medieval to pre-metric	General	6 okka

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
batman	7.698	16.97	Turkey, Ottoman Empire	Medieval to pre-metric	General	6 oka, 2003 reference
batman	125.4	276.4	Turkmenistan	pre-metric	General	8 seer, 1891 value
batman	127	279	Turkmenistan	pre-metric	General	8 sir, 2003 reference, varied 125-128 kg, used average
batman (Asia Minor, Syria)	7.7	17	Turkey, Ottoman Empire	Medieval to pre-metric	General	6 okes, 1891 value
batman (Shiraz)	5.75	12.7	Persia, Iran	Ancient to pre-metric	General	1891 value
batman (Shirez)	5.89	13.0	Persia, Iran	Ancient to pre-metric	General	4 saddirham, 2003 reference
batman (Tauris)	2.88	6.34	Persia, Iran	Ancient to pre-metric	General	6 rattels, 1891 value
batman (Tauris)	2.94	6.49	Persia, Iran	Ancient to pre-metric	General	2 saddirham, 2003 reference
batmann	125.4	276.4	Turkmenistan	Pre-metric	General	8 seer, 1891 value
batmann	127	279	Turkmenistan	Pre-metric	General	8 sir, 2003 reference, varied 125- 128 kg, used average
batt	160	353	Iceland	Medieval to metric	General	320 pund, post-metric value, 2003 reference
bazar	37.32	82.28	India	Akbar to colonial	General	8 dhurra, 2003 reference
bazla	15.52	34.23	Zanzibar	Pre-metric	General	1891 value
bazla	15.53	34.23	Tanzania	Pre-metric	General	
beka	0.00571	0.0126	Biblical, Talmudic	Ancient	General	10 gerah (half a shekel), based on Oxford Biblical Studies Online
bekab	0.0071	0.016	Jewish, Israel	Ancient to modern	General	1/2 shekel

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
bekah	0.00571	0.0126	Biblical, Talmudic	Ancient	General	10 gerah (half a shekel), based on Oxford Biblical Studies Online
bekah	0.00708	0.0156	Hebrew, Sacred System	Ancient to pre-metric	General	2 rahah, 2003 reference
benda	0.0642	0.142	Guinea	Medieval to pre-metric	General	2 offa, 2003 reference
benda-offa	0.0321	0.0708	Guinea	Medieval to pre-metric	General	4 uzan, 2003 reference
beqa	0.00571	0.0126	Biblical, Talmudic	Ancient	General	10 gerah (half a shekel), based on Oxford Biblical Studies Online
berkovets	163.8	361.1	Tatar	Medieval to pre-metric	General	10 pot
berkovets	163.8	361.1	Russia	Medieval to pre-metric	General	10 poods, 1891 value, consistent with 2003 reference
berkowitz	163.8	361.1	Russia	Medieval to pre-metric	General	10 poods, 1891 value, consistent with 2003 reference
bes	0.2180	0.4806	Roman Empire	Ancient	General	2/3 libra, "two of an as", 2003 reference
bessis	0.2180	0.4806	Roman Empire	Ancient	General	2/3 libra, "two of an as", 2003 reference
bhari	0.0029	0.0064	India	Medieval to Akbar	General	4 siki
bhari	0.0117	0.0257	India, Northern	Medieval to Akbar	General	12 masha
biltu	30.0	66.1	Mesopotamia, Sumer, Akkadia	Ancient (EN system E)	General	Load, 3600 shekels
binh	30.20	66.58	Viet Nam, Annam	Medieval to pre-metric	General	5 yen, 2003 reference

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
binh	31.24	68.88	Annam, Viet Nam	Pre-metric	General	5 yen, 1891 value
binh	30.23	66.63	Viet Nam, Annam	Medieval to pre-metric	General	5 yén, under metric = 50 kg, in Annam binh was 31 kg
bismerpund	5.10	11.2	Sweden	Medieval to pre-metric	General	12 skålpund
bismerpund	5.98	13.2	Norway	Medieval to pre-metric	General	12 pund
bismerpund	6.00	13.2	Denmark	Medieval to pre-metric	General	12 pund, 2003 reference
bokard	202.5	446.4	Saudi Arabia	Pre-metric	General	3 kantar, 2003 reference
buhar	67.50	148.8	Saudi Arabia	Pre-metric	General	5 farzil, 2003 reference
buncal	0.053	0.12	Singapore	Colonial to pre-metric	Gold	822 grains
buncal (Singapore)	0.0533	0.117	Malacca	Pre-metric	Prec. Mils.	822 grains, 1891 value
bundle	0.318	0.700	South Africa	Colonial to pre-metric	General	Equivalent to a pound roughly
bushel	21.8	48.1	United States	Colonial to modern	Barley	2150.42 cu in
bushel	25.4	56.0	United States	Colonial to modern	Corn	2150.42 cu in
bushel	25.40	56.00	India	Colonial to pre-metric	General	4 stones, 56 pounds
bushel	27.2	60.0	United States	Colonial to modern	Wheat	2150.42 cu in
butcher's stone	3.63	8.00	United Kingdom, England	Medieval to pre-metric	Meat	8 lb
cab (new)	1.190	2.623	Hebrew	Ancient to pre-metric	Dry capacity	4 log, 2003 reference
cab (old)	1.632	3.598	Hebrew	Ancient to pre-metric	Dry capacity	4 log, 2003 reference
caban	37.9	83.5	Philippines	Medieval to pre-metric	Cocoa	1891 value

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
caban	58.2	128	Philippines	Medieval to pre-metric	General	97 catty, but varied with commodity, 2003 reference
caban	60.3	133	Philippines	Medieval to pre-metric	Rice	1891 value
cados	1.019	2.246	Persia, Iran	Ancient to modern	Capacity	2003 reference
cafiz	32.64	71.96	Arabia	Ancient	Capacity	2 khoul, 2003 reference, capacity measure
caja	16.0	35.3	Central America	Colonial to pre-metric	General	2003 reference
caja	16.0	35.3	Costa Rica	Colonial to pre-metric	General	2003 reference
caja	16.0	35.3	El Salvador	Colonial to pre-metric	General	2003 reference
caja	16.0	35.3	Guatemala	Colonial to pre-metric	General	2003 reference
caja	16.0	35.3	Honduras	Colonial to pre-metric	General	2003 reference
caja	16.0	35.3	Nicaragua	Colonial to pre-metric	General	2003 reference
can	0.6040	1.332	Viet Nam, Annam	Medieval to pre-metric	General	16 luong, 2003 reference
cân	0.6045	1.333	Viet Nam, Annam	Medieval to pre-metric	General	16 lang, under metric = 1 kg and is called cân tây or “Western scale”
cân	0.6248	1.378	Annam, Viet Nam	Pre-metric	General	1.6 nen, 1891 value
cân ta	0.6045	1.333	Viet Nam, Annam	Medieval to pre-metric	General	16 lang, under metric = 1 kg and is called cân tây or “Western scale”
candareen	0.000313	0.000689	China	Post-metric (1930–1958)	General	1/1600 jin, old name, metric definition
candareen	0.000373	0.0008223	China	Pre-metric (1915–1929)	General	1/100 liang
candareen	0.000375	0.000827	Japan	Post-metric	General	10 rin, 2003 reference

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
candareen	0.000375	0.000827	Taiwan, Formosa	Pre-metric	General	10 cash
candareen	0.000500	0.001110	China	Post-metric (Since 1959)	General	1/1600 jin, old name, metric definition
candil	192	423	Sumatra	Pre-metric	General	1891 value
candil (Sumatra)	192.1	423.5	Indonesia	Colonial to Pre-metric	General	423 1/3 lb av
candy	184	405	Malacca	Pre-metric	General	3 peculs, 1891 value
candy	226.8	500.0	Ceylon, Sri Lanka	Pre-metric	General	20 maund, 18891 value, consistent with 2003 reference
candy	226.8	500.0	Sri Lanka, Ceylon	Medieval to Pre-metric	General	
candy	226.8	500.0	Burma, Birmah, Rangoon, Myanmar	Pre-metric	General	150 vis, 1891 value
candy	238	525	Muscat	Pre-metric	General	60 maunds
candy	238.1	525.0	Oman	Medieval to Pre-metric	General	60 maunds
candy	245	540	Burma, Birmah, Rangoon, Myanmar	Pre-metric	General	150 viss, 2003 reference
candy	746.4	1,646	India	Akbar to colonial	General	20 maund, 2003 reference
candy (Ahmednuggar)	715	1,576	India	Akbar to colonial	General	20 maunds, 1891 value
candy (Bombay)	254	560	India	Akbar to colonial	General	20 maunds, 1891 value
candy (Goa)	225	495	India	Akbar to colonial	General	1891 value

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
candy (Madras)	226.8	500.0	India	Akbar to colonial	General	20 maunds, 1891 value
candy (Malabar coast)	315.5	695.5	India	Akbar to colonial	General	20 maunds, 1891 value
candy (Mysore, Seringapatam)	220.2	485.4	India	Akbar to colonial	General	20 maunds, 1891 value
candy (older value)	236.2	520.7	Ceylon, Sri Lanka	Pre-metric	General	Older value (pre 1891)
candy (Pondicherry)	267	588	India	Akbar to colonial	General	1891 value
candy (Surat)	154	340	India	Akbar to colonial	General	20 maunds, 1891 value
cantar	51.28	113.1	Libya	Medieval to pre-metric	General	100 rottolo, 2003 reference
cantar	178.5	393.5	Syria	Medieval to pre-metric	General	100 rottolo, 2003 reference
cantar à kebyr	81.91	180.6	Algeria	Medieval to pre-metric	General	100 rottolo à kebyr
cantar à khaldary	61.43	135.4	Algeria	Medieval to pre-metric	General, Fruit	100 rottolo à khadhary
cantar à thary	54.61	120.4	Algeria	Medieval to pre-metric	General	100 rottolo à thary
cantaro	42.4	93.5	Balearic Islands	Pre-metric	General	4 arrobas, 2003 reference
cantaro	44.54	98.19	Egypt	Pre-metric	General	100 rotl, 1891 value
cantaro	49.77	109.7	Tripoli, Libya	Pre-metric	General	100 rotls, 40 oke, 1891 value
cantaro	52.88	116.6	Crete, Candia	Pre-metric	General	44 oka, 100 rottoli, 1891 value
cantaro	53.9	119	Ionian Islands	Pre-metric	General	Old value
cantaro	54.4	120	Greece	Pre- and post-metric	General	44 oke, 100 drachms, varied from 112-128 lbs avoirdupois, used 120 lb basis, 1891 value

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
cantaro	55.88	123.2	Cyprus	Colonial to pre-metric	General	40 okes, 2003 reference
cantaro	56.26	124.0	Romania, Roumania	Pre-metric	General	44 okas, consistent with 2003 reference
cantaro	56.56	124.7	Turkey, Ottoman Empire	Medieval to pre-metric	General	44 okes, 1891 value
cantaro	79.38	175.0	Malta	Medieval to pre-metric	General	100 ratal, consistent with 2003 reference
cantaro	237.8	524.2	Cyprus	Colonial to pre-metric	General	1891 value, 100 rotolos
cantaro (Palermo)	79.34	174.9	Italy	Medieval to pre-metric	General	100 rotoli
cantaro (typical)	46.1	102	Italy	Medieval to pre-metric	General	6 rubbo, pre-1861, 2003 reference
cantaro (variation)	52.95	116.7	Italy	Medieval to pre-metric	General	150 libbra
cantaro attari	50.39	111.1	Tunisia	Ancient to pre-metric	General	1600 uckir, 2003 reference
cantaro attari	54.6	120	Algeria	Medieval to pre-metric	Spices	100 rotl, 1891 value
cantaro barbaresco	40.8	89.9	Balearic Islands	Pre-metric	General	100 rottolos, 2003 reference
cantaro feuddi	49.7	110	Algeria	Medieval to pre-metric	Gold, silver	100 rotl, 1891 value
cantaro gheddari	61.43	135.4	Algeria	Medieval to pre-metric	General, fruit	100 rottolo à khadhary
cantaro khaddari	62.99	138.9	Tunisia	Ancient to pre-metric	General, vegetables	2000 uckir, vegetables, 2003 reference
cantaro khebir	81.91	180.6	Algeria	Medieval to pre-metric	General	100 rottolo à kebyr
cantaro sucki	56.69	125.0	Tunisia	Ancient to pre-metric	General, Meat	1800 uckir, meat, etc., 2003 reference
cantaro	50.75	111.9	Morocco	Colonial to pre-metric	General	100 rotal, 1891 value, consistent with 2003 reference

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
cantarro	79.38	175.0	Malta	Medieval to pre-metric	General	100 ratal, consistent with 2003 reference
caphite	1.360	2.998	Arabia	Ancient	Capacity	2 mudd, 2003 reference, capacity measure
caracter	0.003601	0.007938	Spain	Medieval to pre-metric	General	2 adarmes, 1891 value, reported as 0.003594 kg in 2003 reference
carat	0.000200	0.000441	United States	Colonial to modern	General, Avoirdupois	
carat	0.000205	0.000452	United States	Colonial to modern	Gems	3.164 grains
carat	0.000259	0.000571	United Kingdom, England	Medieval to pre-metric	Gems	4 grains
carat	0.000259	0.000571	India	Colonial to pre-metric	Gold	1/120 troy ounce
carato (Bologna)	0.00019	0.00042	Italy	Medieval to pre-metric	General	4 grani, 1891 value
carga	125.0	275.6	Colombia	Colonial to metric	General	250 libra, 2003 reference
carga	125	276	Venezuela	Post-metric	General	250 libra, older value estimated at 115 kg, old name, metric definition
carga	161	355	Central America	Colonial to pre-metric	General	7/4 fanega, 2003 reference
carga	161	355	Costa Rica	Colonial to pre-metric	General	7/4 fanega, 2003 reference
carga	161	355	El Salvador	Colonial to pre-metric	General	7/4 fanega, 2003 reference
carga	161	355	Guatemala	Colonial to pre-metric	General	7/4 fanega, 2003 reference
carga	161	355	Honduras	Colonial to pre-metric	General	7/4 fanega, 2003 reference
carga	161	355	Nicaragua	Colonial to pre-metric	General	7/4 fanega, 2003 reference
carga	1,146	2,526	Balearic Islands	Pre-metric	General	27 cantaros, 2003 reference

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
cash	0.0000313	0.0000689	China	Post-metric (1930–1958)	General	1/16000 jīn, old name, metric definition
cash	0.0000373	0.00008223	China	Pre-metric (1915–1929)	General	1/1000 liǎng
cash	0.0000375	0.0000827	Taiwan, Formosa	Pre-metric	General	
cash	0.0000500	0.000110	China	Post-metric (Since 1959)	General	1/10000 jīn, old name, metric definition
castellano	0.004601	0.01014	Chile	Colonial to pre-metric	General	1/100 libra, 2003 reference
catti	0.6176	1.362	Indonesia	Colonial to pre-metric	General	16 tael, 2003 reference
catti (Java)	0.6152	1.356	Indonesia	Colonial to pre-metric	General	
cattie	0.615	1.36	Java	Colonial to pre-metric	General	1891 value
catty	0.500	1.102	China	Post-metric (1930–1958)	General	Chinese pound, old name, metric definition
catty	0.500	1.10	China	Post-metric (Since 1959)	General	“Chinese pound”, 16 liǎng, old name, metric definition
catty	0.5040	1.111	Burma, Birmah, Rangoon, Myanmar	Pre-metric	General	1891 value
catty	0.544	1.20	Burma, Birmah, Rangoon, Myanmar	Pre-metric	General	33-1/3 tical, 2003 reference
catty	0.5968	1.316	China	Pre-metric (1915–1929)	General	Chinese pound, 16 liǎng
catty	0.600	1.32	Philippines	Medieval to pre-metric	General	3 punto, 2003 reference

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
catty	0.600	1.32	Taiwan, Formosa	Pre-metric	General	16 taels
catty	0.6048	1.333	China	Medieval to pre-metric	General	16 tael, 1891 value
catty	0.612	1.35	Malacca	Pre-metric	General	1891 value
catty	0.6176	1.362	Indonesia	Colonial to pre-metric	General	16 tael, 2003 reference
catty	0.9295	2.049	Malacca	Pre-metric	Prec. Mtls.	1891 value
catty	0.9607	2.118	Sumatra	Pre-metric	General	1891 value
catty	1.210	2.667	Thailand, Siam	Pre- and post-metric	General	20 taels, 1891 value
catty (Sumatra)	0.96	2.1	Indonesia	Colonial to pre-metric	General	2.118 lb av
catty (Ternate)	0.617	1.36	Molucca	Pre-metric	General	1891 value
catty (Ternate)	0.70	1.5	Indonesia	Colonial to pre-metric	General	
cây	0.0375	0.0827	Viet Nam, Annam	Medieval to pre-metric	Prec. Mtls.	
çeki	225.8	497.8	Ottoman Empire, Turkey	Medieval to pre-metric	General	4 kantar
centass (Baden)	0.005000	0.01102	Germany, Prussia	Medieval to pre-metric	General	10 pfennig, 1891 value
centigramme	0.00001	0.00002205	France	Post-metric	General	1/10 decigramme
centinajo	45.4	100	Ionian Islands	Pre-metric	General	100 lb av, 1891 value
centnaar	100.0	220.5	Netherlands, Holland	Medieval to metric	General	100 kilogrammes, 1891 value, metric “re-purposed” unit
centner	40.55	89.40	Poland	Pre-metric	General	4 kamian, 2003 reference

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
centner	42.36	93.38	Sweden	Medieval to pre-metric	General	100 skålpund, 1891 value
centner	42.51	93.72	Sweden	Medieval to pre-metric	General	5 liespund, 2003 reference
centner	50.00	110.2	Denmark	Medieval to pre-metric	General	100 pund, 1891 value, consistent with 2003 reference
centner	50.3	111	Latvia	Medieval to pre-metric	General	6 liespund, 2003 reference
centner	55.2	122	Estonia	Medieval to pre-metric	General	120 pfund, 2003 reference
centner	56.00	123.5	Austrian Empire	Pre-metric	General	5 stein, 1891 value, consistent with 2003 reference
centner (Baden)	50.00	110.2	Germany, Prussia	Medieval to pre-metric	General	10 stein, 1891 value, post-metric
centner (Bohemia, Prague)	67.2	148	Austrian Empire	Pre-metric	General	6 stein, 1891 value, approximate, local variation, pfund is slightly lighter
centner (Bremen)	57.83	127.5	Germany, Prussia	Medieval to pre-metric	General	116 pfund, 1891 value
centner (Hesse-Darmstadt)	50.00	110.2	Germany, Prussia	Medieval to pre-metric	General	100 pfund, 1821 value, previously same as Frankfurt, post-metric
centner (new)	50.0	110	Prussia, Germany	Post-metric	General	100 pfund, post-metric value
centner (old)	51.45	113.4	Prussia, Germany	Pre-metric	General	5 stein, pre-metric value
centner (Saxony)	51.42	113.4	Germany, Prussia	Medieval to pre-metric	General	110 pfund
centum podium	32.70	72.09	Roman Empire	Ancient	General	100 libra, 2003 reference

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
cequi	0.3208	0.7071	Turkey, Ottoman Empire	Medieval to pre-metric	General	100 dirham, 2003 reference
chalque (Attic/ Euboic)	0.00009000	0.0001984	Greece	Ancient	General	1/8 obol, 2003 reference
charge	195.8	431.7	Belgium	Pre-metric	General	2 balle, 2003 reference
chariot	80.77	178.1	Belgium	Pre-metric	General	165 livre, 2003 reference
chattack (Bengal)	0.0529	0.117	India	Akbar to colonial	General, Factory	5 siccas, 1891 value
chattack (Bengal)	0.0582	0.128	India	Akbar to colonial	General, Bazaar	5 siccas, 1891 value
chawal	0.0000076	0.000017	India, Northern	Medieval to Akbar	General	Grain of rice
chequi	0.3214	0.7084	Turkey, Ottoman Empire	Medieval to pre-metric	General	100 dirhem, 1891 value
chhatank	0.058	0.13	India	Medieval to Akbar	General	4 kancha
chi	0.00375	0.00827	Viet Nam, Annam	Medieval to pre-metric	Prec. Mills.	
chin	0.00375	0.00827	Cambodia	Post-metric	General	25 lin, 2003 reference
chîn	0.00375	0.00827	Taiwan, Formosa	Pre-metric	General	10 candareens
chinanta	6.00	13.2	Philippines	Medieval to pre-metric	General	10 catty, 2003 reference
chittak	0.05832	0.1286	India	Akbar to colonial	General	5 tolah, 2003 reference
chong	30.00	66.14	Cambodia	Post-metric	General	30,000 muoi, 30 pram roi, 2003 reference

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
clove	3.175	7.000	United Kingdom, England	Medieval to pre-metric	Wool	7 pounds
clove	3.629	8.000	United Kingdom, England	Medieval to pre-metric	Cheese	8 pounds
clove (Suffolk)	3.629	8.000	United Kingdom, England	Medieval to pre-metric	Butter, Cheese	8 lbs, Suffolk
coffala (Mocha)	0.00311	0.00686	Arabia	Ancient to pre-metric	Gold, Silver	48 grains, 1891 value
coffilas	0.003375	0.007440	Saudi Arabia	Pre-metric	General	2003 reference
cola	62.48	137.7	Syria	Medieval to pre-metric	General	35 rottolo, 2003 reference
copang	0.000622	0.00137	Borneo	Pre-metric	General	1.5 tica
cor (new)	214.2	472.2	Hebrew	Ancient to pre-metric	Dry Capacity	10 ephah, 2003 reference
cor (new)	214.2	472.2	Hebrew	Ancient to pre-metric	Liquid Capacity	10 bath, 2003 reference
cor (old)	293.8	647.6	Hebrew	Ancient to pre-metric	Dry Capacity	10 ephah, 2003 reference
cor (old)	293.8	647.6	Hebrew	Ancient to pre-metric	Liquid Capacity	10 bath, 2003 reference
corta	3.67	8.10	Balearic Islands	Pre-metric	General	3 libra mayors, 2003 reference
cwt	45.36	100.0	United States	Colonial to modern	General, Avoirdupois	100 lb
cwt	50.80	112.0	United Kingdom, England	Medieval to pre-metric	Shipping, Avoirdupois	112 pounds, 4 quarters

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
dam	0.020	0.044	India	Akbar to colonial	Spices	
dan	50.00	110.2	China	Post-metric (1930–1958)	General	“Chinese hundredweight”, 100 jīn, old name, metric definition
dan	50.00	110.2	China	Post-metric (Since 1959)	General	“Chinese hundredweight”, 100 jīn, old name, metric definition
dan	71.62	157.9	China	Pre-metric (1915–1929)	General	4 jun
dán	60.0	132	Taiwan, Formosa	Pre-metric	General	100 catties
danar	0.184	0.406	Persia, Iran	Ancient to pre-metric	General	2 pinar, 2003 reference
danik (Mocha)	0.000509	0.00112	Arabia	Ancient to pre-metric	General	7.86 grains, 1891 value
darchmon	0.0071	0.016	Jewish, Israel	Ancient to modern	General	1/2 shekel
darhim	0.00309	0.00682	Egypt	Pre-metric	General	24 kērat, 1891 value
dartung	0.00102	0.00225	Persia, Iran	Ancient to pre-metric	General	1–1/3 dung, 2003 reference
das (10) seer	9.3	21	India	Medieval to Akbar	General	10 seer
daseri	9.3	21	India	Medieval to Akbar	General	10 seer
dbn	0.0136	0.0300	Egypt	Ancient – Old & Mid Kingdom	General, Copper, Prec. Mtls.	Base unit (Old and Middle Kingdom), for copper, silver & gold
dbn	0.0910	0.201	Egypt	Ancient – New Kingdom	General, Copper, Prec. Mtls.	Base unit (New Kingdom), for copper, silver, and gold
deben	0.0136	0.0300	Egypt	Ancient – Old & Mid Kingdom	General, Copper, Prec. Mtls.	Base unit (Old and Middle Kingdom), for copper, silver & gold
deben	0.01365	0.03009	Egypt	Ancient	General	10 sep, 2003 reference

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
deben	0.0910	0.201	Egypt	Ancient - New Kingdom	General, Copper, Prec. Mtls.	Base unit (New Kingdom), for copper, silver, and gold
decagram (1891)	0.01	0.02205	France	Post-metric	General	10 grammes
decagramme	0.01000	0.02205	Netherlands, Holland	Medieval to metric	General	1891 value, metric “re-purposed” unit
decigramme	0.0001	0.0002205	France	Post-metric	General	1/10 gramme
decigramme	0.0001000	0.0002205	Netherlands, Holland	Medieval to metric	General	1891 value, metric “re-purposed” unit
dekagramme	0.01	0.02205	Germany, Prussia	Medieval to pre-metric	General	10 grammes, 1891 value
dekass (Baden)	0.0005000	0.001102	Germany, Prussia	Medieval to pre-metric	General	10 ass, 1891 value
den	261.1	575.6	Arabia	Ancient	Capacity	4 artabe, 2003 reference, capacity measure
denarius	0.00389	0.00858	Roman Empire	Ancient	General	1/7 uncia, 2003 reference
denaro (Ancona)	0.001146	0.002527	Italy	Medieval to pre-metric	General	24 grani, 1891 value
denaro (Genoa)	0.001103	0.002431	Italy	Medieval to pre-metric	General	24 grani, 1891 value
denaro (Parma)	0.001134	0.002499	Italy	Medieval to pre-metric	General	24 grani, 1891 value
denaro (Rome, Roman States)	0.001178	0.002596	Italy	Medieval to pre-metric	General	24 grani, based on Roman libbra
denaro (Sardinia, Piedmont, Turin)	0.001281	0.002824	Italy	Medieval to pre-metric	General	24 grani, 1891 value
denaro (Tuscany)	0.001179	0.002599	Italy	Medieval to pre-metric	General	24 grani, 1891 value

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
denaro (typical)	0.00107	0.00235	Italy	Medieval to pre-metric	General	Scruple, 24 grano, pre-1861, 2003 reference
denaro (Venetian Lombardy)	0.001000	0.002205	Italy	Post-metric	General	10 grani, post-metric, old name, metric definition
denaro (Venetian Lombardy)	0.001224	0.002699	Italy	Medieval to Pre-metric	Prec. Mtls.	24 grani, post-metric
denier	0.001275	0.002811	France	Medieval to pre-metric	General	1/24 once, 24 grains, 2003 reference
denier	0.001530	0.003372	France	Medieval to pre-metric	General	2 obole, 2003 reference
denier	0.00341	0.00751	Roman Empire	Ancient	General	1/8 uncia, 2003 reference
denke	0.0008019	0.001768	Turkey, Ottoman Empire	Medieval to pre-metric	General	4 karat, 2003 reference
derime	0.00259	0.00571	Ethiopia	Medieval to pre-metric	General	1/120 rottolo
derime	0.00259	0.00571	Abyssinia	Pre-metric	General	Drachm, 1891 value, consistent with 2003 reference
dermat	0.001094	0.002411	Austrian Empire	Pre-metric	General	1891 value, consistent with 2003 reference
deuke	0.0008034	0.001771	Turkey, Ottoman Empire	Medieval to pre-metric	General	4 karats, 1891 value
deunx	0.2998	0.6609	Roman Empire	Ancient	General	11/12 libra, "less a twelfth", 2003 reference
dextans	0.2725	0.6007	Roman Empire	Ancient	General	5/6 libra, "less a sixth", 2003 reference

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
dezigramme	0.0001	0.0002205	Germany, Prussia	Medieval to pre-metric	General	1/10 gramme, 1891 value
dhai (2 1/2) seer	2.3	5.1	India	Medieval to Akbar	General	2 adasari, 5 seer
dhan	0.0000021	0.0000045	India, Northern	Medieval to Akbar	General	Wheat berry
dhan	0.000030	0.000067	India, Northern	Medieval to Akbar	General	4 chawal
dharana	0.00470	0.0104	India	Akbar to Colonial	General	32 retti, 1966 value
dhaser	2.3	5.1	India	Medieval to Akbar	General	2 adasari, 5 seer
dhurra	4.665	10.28	India	Akbar to colonial	General	4 raik, 2003 reference
dihrem	0.00283	0.00624	Arabia	Ancient to pre-metric	General	2003 reference
dinar	0.00571	0.0126	Biblical, Talmudic	Ancient	General	10 gerah (half a shekel), based on Oxford Biblical Studies Online
dinar	0.00982	0.0217	Biblical, Talmudic	Ancient	General	10 gerah, based on heavy common talent
dinar	0.0101	0.0223	Biblical, Talmudic	Ancient	General	10 gerah, based on heavy royal talent
dinero	0.001198	0.002641	Spain	Medieval to pre-metric	General	2 tomin, 2003 reference
dinh	0.0378	0.0833	Viet Nam, Annam	Medieval to pre-metric	General	10 đồng, under metric = 0.1 kg, later 2 names are French colonial units
diobol (Attic/ Euboic)	0.00144	0.00317	Greece	Ancient	General	2 obols, 2003 reference
dirham	0.003208	0.007071	Turkey, Ottoman Empire	Medieval to pre-metric	General	4 denke, 2003 reference

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
dirhem	0.00259	0.00571	Abyssinia	Pre-metric	General	Drachm, 1891 value, consistent with 2003 reference
dirhem	0.00312	0.00688	Egypt	Pre-metric	General	1/400 oke
dirhem	0.00321	0.00707	Ottoman Empire, Turkey	Medieval to pre-metric	General	16 kīrat, “drachma”
dirhem	0.003214	0.007084	Turkey, Ottoman Empire	Medieval to pre-metric	General	4 deukes, 1891 value
dirhem	0.00920	0.0203	Persia, Iran	Ancient to pre-metric	General	2 miskal, 2003 reference
dirhem	0.02808	0.06190	Egypt	Pre-metric	General	16 kīrat, 2003 reference
dirhem (Tauris)	0.00959	0.0211	Persia, Iran	Ancient to pre-metric	General	2 mascais, 1891 value
dodrans	0.2453	0.5408	Roman Empire	Ancient	General	3/4 libra, “less a fourth”, 2003 reference
doli	0.00004444	0.00009796	Russia	Medieval to pre-metric	General	Grain, 1891 value, consistent with 2003 reference
doli	0.00004444	0.00009797	Russia	Medieval to pre-metric	Apothecaries’	Grain, 1891 value, consistent with 2003 reference
dolia	0.00004444	0.00009796	Russia	Medieval to pre-metric	General	Grain, 1891 value, consistent with 2003 reference
dolia	0.00004444	0.00009797	Russia	Medieval to pre-metric	Apothecaries’	Grain, 1891 value, consistent with 2003 reference
dong	0.003775	0.008322	Viet Nam, Annam	Medieval to pre-metric	General	10 fan, 2003 reference
dong	0.00391	0.00861	Annam, Viet Nam	Pre-metric	General	10 phan, 1891 value

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
đồng	0.00378	0.00833	Viet Nam, Annam	Medieval to pre-metric	General	10 phân, differs from monetary unit
đồng cân	0.00378	0.00833	Viet Nam, Annam	Medieval to pre-metric	General	10 phân, differs from monetary unit
doon	24.0	52.9	Thailand, Siam	Pre- and post-metric	General	20 tchang, 2003 reference
doppelzentner (Austrian system)	102.9	226.8	Germany, Prussia	Medieval to pre-metric	General	2 zentner, 2003 reference
dr	0.00177	0.00391	United States	Colonial to modern	General, Avoirdupois	8.859 carats or 27-11/32 gr
dr	0.001772	0.003906	United Kingdom, England	Medieval to pre-metric	General, Avoirdupois	1/16 ounce, possibly from drachma
dr ap	0.00389	0.00857	United Kingdom, England	Medieval to pre-metric	Apothecaries'	3 s ap, 60 gr ap
dr apoth	0.001764	0.003888	United States	Colonial to modern	Apothecaries'	3 scr apoth
drachm	0.001764	0.003888	United States	Colonial to modern	Apothecaries'	3 scr apoth
drachm	0.001772	0.003906	United Kingdom, England	Medieval to pre-metric	General, Avoirdupois	1/16 ounce, possibly from drachma
drachm	0.001800	0.003969	Spain	Medieval to pre-metric	General	3 tomines, 1891 value, reported as 0.1797 kg in 2003 reference
drachm	0.00259	0.00571	Ethiopia	Medieval to pre-metric	General	1/120 rottolo
drachm	0.00309	0.00682	Egypt	Pre-metric	General	24 kērat, 1891 value

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
drachm	0.003197	0.007047	Serbia, Serbia	Medieval to Pre-metric	General	"Dram", 1891 value
drachm	0.003208	0.007071	Turkey, Ottoman Empire	Medieval to pre-metric	General	4 denke, 2003 reference
drachm	0.003214	0.007084	Turkey, Ottoman Empire	Medieval to pre-metric	General	4 deukes, 1891 value
drachm	0.00326	0.00719	Persia, Iran	Ancient to pre-metric	General	2003 value
drachm	0.003542	0.007809	Hebrew, Talmudic, Rabbinical	Ancient to pre-metric	General	6 mehahs, 2003 reference
drachm	0.003712	0.008183	Norway	Medieval to pre-metric	Apothecaries'	3 scrupels, 1891 value
drachm	0.00373	0.00822	Germany, Prussia	Medieval to pre-metric	Apothecaries'	3 scrupels
drachm	0.003824	0.008430	France	Medieval to pre-metric	General	1/8 once, 3 denier, 2003 reference
drachm	0.00389	0.00857	United Kingdom, England	Medieval to pre-metric	Apothecaries'	3 s ap, 60 gr ap
drachm	0.544	1.20	Greece	Pre- and post-metric	General	1891 value
drachma	0.003110	0.006857	Tripoli, Libya	Pre-metric	General	16 kharoubas, 1891 value
drachma	0.003168	0.006984	Poland	Pre-metric	General	3 skrupul, 2003 reference
drachma	0.003733	0.008229	Russia	Medieval to pre-metric	Apothecaries'	Dram, 60 grains, 1891 value, consistent with 2003 reference
drachma (Aegimetic)	0.0063	0.014	Greece	Ancient	General	6 obols

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
drachma (Attic/ Euboic)	0.004320	0.009524	Greece	Ancient	General	6 obols, 2003 reference
drachma (Naples)	0.002673	0.005893	Italy	Medieval to pre-metric	Apothecaries'	3 scrupoli, 1891 value
drachma Alexandrina	0.0071	0.016	Jewish, Israel	Ancient to Modern	General	1/2 shekel
drachma Attica	0.0035	0.0078	Jewish, Israel	Ancient to modern	General	1/4 shekel
drachme	0.001000	0.002205	Greece	Pre- and post-metric	General	Gram, 1891 value, post-metric
drachme	0.003175	0.007000	Cyprus	Colonial to pre-metric	General	1/400 oke, 2003 reference
drachme	0.003728	0.008218	Denmark	Medieval to pre-metric	Apothecaries'	60 gran, 1891 value
drachme	0.003733	0.008229	Russia	Medieval to pre-metric	Apothecaries'	Dram, 60 grains, 1891 value, consistent with 2003 reference
drachme	0.00389	0.00857	Netherlands, Holland	Medieval to metric	Apothecaries'	3 scrupels, 60 grains, "dram"
drachme	0.00391	0.00861	Switzerland	Medieval to metric	Apothecaries'	3 scrupels, 1891 value, consistent with 2003 reference
drachme	0.004388	0.009673	Austrian Empire	Pre-metric	Apothecaries'	3 scrupel, 1891 value, also reported as 0.004375 kg in 2003 reference
drachme	0.003845	0.008477	Netherlands, Holland	Medieval to metric	General	Drachm, 10 vierling, 2003 reference
dram	0.00177	0.00391	United States	Colonial to modern	General, Avoirdupois	8.859 carats or 27-11/32 gr
dram	0.001772	0.003906	United Kingdom, England	Medieval to pre-metric	General, Avoirdupois	1/16 ounce, possibly from drachma
dram	0.003205	0.007066	Libya	Medieval to pre-metric	General	16 kharouba, 2003 reference

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
dram	0.00389	0.00857	United Kingdom, England	Medieval to pre-metric	Apothecaries'	3 s ap, 60 gr ap
dramm	0.003200	0.007055	Yugoslavia	Pre-metric	General	2003 reference
dramma (Naples)	0.002673	0.005893	Italy	Medieval to pre-metric	Prec. Mtls., Drugs, Pigments	3 trapesi, 1891 value
dramma (Tuscany)	0.003537	0.007798	Italy	Medieval to pre-metric	General	3 denari, 1891 value
dramme	0.003277	0.007224	Greece	Pre- and post-metric	General	Pre-metric, 2003 reference
drop	0.001928	0.004250	Scotland	Medieval to pre-metric	General	2003 reference
duella	0.009083	0.02002	Roman Empire	Ancient	General	1/3 uncia, "little double [sixths]"; 2003 reference
dung	0.000767	0.00169	Persia, Iran	Ancient to pre-metric	General	3 makhod, 2003 reference
Dutch cask (Suffolk)	58.06	128.0	United Kingdom, England	Medieval to pre-metric	Butter, Cheese	16 cloves, Suffolk
dwt	0.00156	0.00343	United States	Colonial to modern	Prec. Mtls.	7.776 carats, 24 gr
dwt T	0.00146	0.00322	United Kingdom, England	Medieval to 1526	Prec. Mtls., Coins	22.5 gr t, 32 gr T, Tower
dwt t	0.001558	0.003434	United Kingdom, England	1526 to pre-metric	Prec. Mtls., Coins	24 grains, troy
eggaba	0.0214	0.0472	Guinea	Medieval to pre-metric	General	1/3 benda

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
engel	0.001538	0.003391	Netherlands, Holland	Medieval to metric	General	4 vierling, 2003 reference
ephah (new)	21.42	47.22	Hebrew	Ancient to pre-metric	Dry Capacity	10 gomor, 2003 reference
ephah (old)	29.38	64.76	Hebrew	Ancient to pre-metric	Dry Capacity	10 gomor, 2003 reference
es	0.0000546	0.000120	Denmark	Medieval to pre-metric	General	2003 reference
escrópulo	0.00120	0.00264	Portugal	Medieval to pre-metric	General	"Scruple", 24 grãos, 1/384 arratéis, 2003 reference
escrupolo	0.007189	0.01585	Spain	Medieval to pre-metric	General	2 ochavas, 2003 reference
estelin	0.00153	0.00337	France	Medieval to pre-metric	Prec. Mtls.	2003 reference, 2 oboles
esterlin	0.00153	0.00337	France	Medieval to pre-metric	Prec. Mtls.	2003 reference, 2 oboles
fan	0.0003775	0.0008322	Viet Nam, Annam	Medieval to pre-metric	General	10 li, 2003 reference
fanam	0.0001969	0.0004340	Ceylon, Sri Lanka	Pre-metric	General	2003 reference
fanaga	46	101	Costa Rica	Colonial to pre-metric	Coffee	
fanaga	64.41	142.0	Peru	Colonial to pre-metric	General	140 libra, still used in 1891, consistent with 2003 reference
fanaga	92.0	203	Central America	Colonial to pre-metric	General	23/4 caja, 2003 reference
fanaga	92.0	203	Costa Rica	Colonial to pre-metric	General	23/4 caja, 2003 reference
fanaga	92.0	203	El Salvador	Colonial to pre-metric	General	23/4 caja, 2003 reference
fanaga	92.0	203	Guatemala	Colonial to pre-metric	General	23/4 caja, 2003 reference
fanaga	92.0	203	Honduras	Colonial to pre-metric	General	23/4 caja, 2003 reference
fanaga	92.0	203	Nicaragua	Colonial to pre-metric	General	23/4 caja, 2003 reference

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
farasula	13.48	29.72	Ethiopia	Medieval to pre-metric	Ivory	Ivory basis, 2003 reference
farasula	16.85	37.15	Ethiopia	Medieval to pre-metric	Coffee	Coffee basis, 2003 reference
farasula	17.97	39.62	Ethiopia	Medieval to pre-metric	Rubber	Rubber basis, 1152 alada, 2003 reference
farcella	13.50	29.76	Saudi Arabia	Pre-metric	General	10 maund, 2003 reference
farzil	13.50	29.76	Saudi Arabia	Pre-metric	General	10 maund, 2003 reference
felin	0.0003824	0.0008430	France	Medieval to Pre-metric	Prec. Mils.	2003 reference
fēn	0.000313	0.000689	China	Post-metric (1930-1958)	General	1/1600 jīn, old name, metric definition
fēn	0.000373	0.0008223	China	Pre-metric (1915-1929)	General	1/100 liǎng
fēn	0.000375	0.000827	Taiwan, Formosa	Pre-metric	General	10 cash
fēn	0.000500	0.00110	China	Post-metric (Since 1959)	General	1/1600 jīn, old name, metric definition
ferk	8.160	17.99	Arabia	Ancient	Capacity	2 makuk, 2003 reference, capacity measure
ferlina (Modena)	0.001664	0.003669	Italy	Medieval to pre-metric	General	1891 value
ferlino (Bologna)	0.0019	0.0042	Italy	Medieval to pre-metric	General	10 carati, 1891 value
fierding	20.0	44.1	Iceland	Medieval to metric	General	40 pund, post-metric value, 2003 reference
firkin (Suffolk)	25.40	56.00	United Kingdom, England	Medieval to pre-metric	Butter, Cheese	7 cloves, Suffolk
fisk	4.00	8.82	Iceland	Medieval to metric	General	8 pund, post-metric value, 2003 reference
frachtpfund (Bremen)	149.6	329.7	Germany, Prussia	Medieval to pre-metric	General	300 pfund, 1891 value

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
franzella	16.0	35.3	Tanzania	Pre-metric	General	36 rotoli
franzella	16.00	35.28	Zanzibar	Pre-metric	General	36 franzella, 1891 value
frasla	16.1	35.6	Somalia	Medieval to pre-metric	General	36 rottolo, 2003 reference
frazil	13.6	30.0	Arabia	Ancient to pre-metric	General	10 maunds, 1891 value
fuang	0.00188	0.00413	Thailand, Siam	Pre- and post-metric	General	2 sompay, 2003 reference
fun	0.000375	0.000827	Japan	Post-metric	General	10 rin, 2003 reference
funt	0.3583	0.7900	Russia	Medieval to Pre-metric	Apothecaries'	Pound, 5760 grains, 1891 value, consistent with 2003 reference
funt	0.4055	0.8940	Poland	Pre-metric	General	16 uncia, 2003 reference
funt	0.4060	0.8950	Poland	Pre-metric	General	2 mark, 1891 value
funt	0.4095	0.9028	Russia	Medieval to pre-metric	General	Pound, 12 lanas, 1891 value, consistent with 2003 reference
funte	0.3583	0.7900	Russia	Medieval to pre-metric	Apothecaries'	Pound, 5760 grains, 1891 value, consistent with 2003 reference
funte	0.4095	0.9028	Russia	Medieval to pre-metric	General	Pound, 12 lanas, 1891 value, consistent with 2003 reference
gammell	0.195	0.431	Guinea	Medieval to pre-metric	General	1/5 kantar, conflict with 2003 reference
gammell	195	431	Guinea	Medieval to pre-metric	General	2003 reference, conflict with other references
gantang	6.15	13.6	Java	Colonial to pre-metric	Coffee	10 catties, 1891 value
gantang (Java)	6.15	13.6	Indonesia	Colonial to pre-metric	Coffee	10 catties
gariba	260.8	575.0	Persia, Iran	Ancient to modern	Capacity	4 long artaba, 2003 reference

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
gariba	261.1	575.6	Arabia	Ancient	Capacity	4 artabe, 2003 reference, capacity measure
gerah	0.000571	0.00126	Biblical, Talmudic	Ancient	General	Based on Oxford Biblical Studies Online
gerah	0.0006825	0.001505	Egypt	Ancient	General	2003 reference
gerah	0.000708	0.00156	Hebrew, Sacred system	Ancient to pre-metric	General	2003 reference
gerah	0.00071	0.0016	Jewish, Israel	Ancient to modern	General	1/20 shekel
gerah	0.000982	0.00217	Biblical, Talmudic	Ancient	General	Based on Heavy Common Talent
gerah	0.00101	0.00223	Biblical, Talmudic	Ancient	General	Based on Heavy royal talent
gerbe	3.045	6.713	Morocco	Colonial to pre-metric	General	6 rotal, 2003 reference
gin ₂	0.009	0.02	Mesopotamia, Sumer, Akkadia	Ancient (EN system E)	General	Shekel
giru	0.000571	0.00126	Biblical, Talmudic	Ancient	General	Based on Oxford Biblical Studies Online
giru	0.000982	0.00217	Biblical, Talmudic	Ancient	General	Based on Heavy Common Talent
giru	0.00101	0.00223	Biblical, Talmudic	Ancient	General	Based on Heavy royal talent
gisla	161	356	Somalia	Medieval to pre-metric	General	10 frasila, 2003 reference
gisla	163	359	Eretria	Medieval to pre-metric	General	364 rottolo, 2003 reference
gomor (new)	2.142	4.722	Hebrew	Ancient to pre-metric	Dry Capacity	9/5 log, 2003 reference

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
gomor (old)	2.938	6.476	Hebrew	Ancient to pre-metric	Dry Capacity	9/5 log. 2003 reference
gööränkä	0.4095	0.9028	Tatar	Medieval to pre-metric	General	96 misqal, 32 lot
Gorinchem pond	0.466	1.03	Netherlands, Holland	Medieval to metric	General	Gorinchem basis, "pound", pre-1800
gr	0.00006480	0.0001429	United Kingdom, England	Medieval to pre-metric	General, Avoirdupois	Originally weight of grain seed from middle of ear of barley
gr	0.0000648	0.000143	United States	Colonial to modern	Prec. Mils.	Same as Avoirdupois measure
gr ap	0.0000648	0.000143	United Kingdom, England	Medieval to pre-metric	Apothecaries'	
gr apoth	0.00002939	0.00006480	United States	Colonial to modern	Apothecaries'	
gr T	0.0000455	0.000100	United Kingdom, England	Medieval to 1526	Prec. Mils., Coins	45/64 gr t, Tower
gr t	0.00006490	0.0001431	United Kingdom, England	1526 to pre-metric	Prec. Mils., Coins	Troy
grain	0.00002939	0.00006480	United States	Colonial to modern	Apothecaries'	
grain	0.00005	0.0001	Ireland	Medieval to pre-metric	General	1/8 penny
grain	0.00005311	0.0001171	France	Medieval to pre-metric	General	1/24 ² once, "French grain", 2003 reference
grain	0.00005425	0.0001196	France	Post-metric (1840)	General	Old name, metric definition
grain	0.0000621	0.000137	Germany, Prussia	Medieval to pre-metric	Apothecaries'	

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
grain	0.00006221	0.0001371	Russia	Medieval to pre-metric	Apothecaries'	Grain, 1891 value, consistent with 2003 reference
grain	0.00006373	0.0001405	France	Medieval to pre-metric	General	2003 reference
grain	0.00006480	0.0001429	Scotland	Medieval to pre-metric	General	2003 reference
grain	0.00006480	0.0001429	United Kingdom, England	Medieval to pre-metric	General, Avoirdupois	Originally weight of grain seed from middle of ear of barley
grain	0.0000648	0.000143	United Kingdom, England	Medieval to pre-metric	Apothecaries'	
grain	0.0000648	0.000143	United States	Colonial to modern	General, Avoirdupois	
grain	0.000065	0.00014	India	Akbar to colonial	General	Before 1833
grain	0.0000648	0.000143	Algeria	Medieval to pre-metric	General	Calculated from 1891 reference
grain	0.0000651	0.000144	Switzerland	Medieval to metric	Apothecaries'	1891 value, consistent with 2003 reference
grain	0.0009100	0.002006	Egypt	Ancient	General	1-1/3 gerah, 2003 reference
grain (Diamond)	0.0000519	0.000114	United Kingdom, England	Medieval to pre-metric	Diamond	4/5 troy grain
grain Tower	0.0000455	0.000100	United Kingdom, England	Medieval to 1526	Prec. Mtls., Coins	45/64 gr t
grain troy	0.00006490	0.0001431	United Kingdom, England	1526 to pre-metric	Prec. Mtls., Coins	

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
gramme	0.001	0.002205	Germany, Prussia	Medieval to pre-metric	General	1891 value
gramme	0.001000	0.002205	Netherlands, Holland	Medieval to metric	General	1891 value, metric “re-purposed” unit
gramme (1891)	0.001	0.002205	France	Post-metric	General	Standard base
gran	0.00004400	0.00009700	Poland	Pre-metric	General	2003 reference
gran	0.00006187	0.0001364	Norway	Medieval to pre-metric	Apothecaries’	1891 value
gran	0.00006213	0.0001370	Denmark	Medieval to pre-metric	Apothecaries’	1891 value
gran	0.00006221	0.0001371	Russia	Medieval to pre-metric	Apothecaries’	Grain, 1891 value, consistent with 2003 reference
gran	0.00007313	0.0001612	Austrian Empire	Pre-metric	Apothecaries’	1891 value, also reported as 0.00007292 kg in 2003 reference
gran	0.000812	0.00179	Prussia, Germany	Pre-metric	Prec. Mtls.	1891 value
gran (Austrian system)	6.090E-05	0.000134	Germany, Prussia	Medieval to pre-metric	General	2003 reference
gran (Saxony)	6.087E-05	0.000134	Germany, Prussia	Medieval to pre-metric	General	
grani	0.000938	0.00207	Thailand, Siam	Pre- and post-metric	General	2 pai, 2003 reference
grano	0.00004985	0.0001099	Argentina	Colonial to pre-metric	General	1/9216 libra, 2003 reference
grano	0.00005001	0.0001103	Spain	Medieval to pre-metric	General	1891 value, reported as 0.00004992 kg in 2003 reference
grano (Ancona)	0.00004776	0.0001053	Italy	Medieval to pre-metric	General	1891 value
grano (Bologna)	0.000047	0.00010	Italy	Medieval to pre-metric	General	1891 value

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
grano (Genoa)	0.00004595	0.0001013	Italy	Medieval to pre-metric	General	1891 value
grano (Parma)	0.00004723	0.0001041	Italy	Medieval to pre-metric	General	1891 value
grano (Rome, Roman States)	0.00004907	0.0001082	Italy	Medieval to pre-metric	General	Based on Roman libbra
grano (Sardinia, Piedmont, Turin)	0.00005337	0.0001177	Italy	Medieval to pre-metric	General	24 granotini, 1891 value
grano (Tuscany)	0.00004913	0.0001083	Italy	Medieval to pre-metric	General	1891 value
grano (typical)	0.0000444	0.0000979	Italy	Medieval to pre-metric	General	Grain, Pre-1861, 2003 reference
grano (Venetian Lombardy)	0.00005100	0.0001124	Italy	Medieval to pre-metric	Prec. Mtls.	Pre-metric
grano (Venetian Lombardy)	0.0001000	0.0002205	Italy	post-metric	General	Post-metric, old name, metric definition
granos	0.00004985	0.0001099	Argentina	Colonial to pre-metric	General	1/9216 libra, 2003 reference
granos	0.00004992	0.0001101	Chile	Colonial to pre-metric	General	Grain, 1/9216 libra, 2003 reference
granotino (Sardinia, Piedmont, Turin)	0.000002224	0.000004903	Italy	Medieval to pre-metric	General	1891 value
grao	0.0000498	0.000110	Portugal	Medieval to pre-metric	General	“Grain”, 1/9216 arratéis, 2003 reference
grão	0.0000498	0.000110	Portugal	Medieval to pre-metric	General	“Grain”, 1/9216 arratéis, 2003 reference
grein	0.00006408	0.0001413	Netherlands, Holland	Medieval to metric	General	Grain, 2003 reference
grein	0.0000648	0.000143	Netherlands, Holland	Medieval to metric	Apothecaries'	“grain”

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
gros	0.003824	0.008430	France	Medieval to pre-metric	General	1/8 once, 3 denier, 2003 reference
gros	0.00391	0.00861	France	Post-metric (1840)	General	72 grains, old name, metric definition
grosso (Venetian Lombardy)	0.01000	0.02205	Italy	Post-metric	General	10 denari, post-metric, old name, metric definition
gun ₂	30.0	66.1	Mesopotamia, Sumer, Akkadia	Ancient (EN system E)	General	Load, 3600 shekels
gyral	0.000207	0.000456	Algeria	Medieval to pre-metric	General	2003 reference
halber vierling (Bavaria)	0.0625	0.138	Germany, Prussia	Medieval to pre-metric	General	4 loth, 1891 value
hao	3.775E-06	8.322E-06	Viet Nam, Annam	Medieval to pre-metric	General	2003 reference
háo	0.00000313	0.00000689	China	Post-metric (1930–1958)	General	1/160000 jīn, old name, metric definition
háo	0.000003730	0.000008223	China	Pre-metric (1915-1929)	General	1/10,000 liǎng
háo	3.780E-06	8.333E-06	Viet Nam, Annam	Medieval to pre-metric	General	10 ti
hap	60.00	132.3	Cambodia	Post-metric	General	600,000 muoi, 2 chong, 2003 reference
hap	60.0	132	Thailand, Siam	Pre- and post-metric	General	50 tchang, 2003 reference
hara	9.41	20.7	India	Akbar to colonial	General	2 tuba, 1966 value
harsela	1.237	2.727	Egypt	Pre-metric	Silk	Same as oke, 1891 value
harsela	1.248	2.751	Egypt	Pre-metric	Silk	Same as oke, alternate reference
hecte	2.1	4.7	Egypt	Ancient	Capacity	2.5 mine, 2003 reference

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
hectogramme	0.1000	0.2205	Netherlands, Holland	Medieval to metric	General	1891 value, metric “re-purposed” unit
hectogramme (1891)	0.1	0.2205	France	Post-metric	General	10 decagrammes
heller (Brunswick)	0.0004564	0.001006	Germany, Prussia	Medieval to pre-metric	General	1891 value
heller (Frankfort)	0.000493	0.00109	Germany, Prussia	Medieval to pre-metric	General	1891 value
helm	249.6	550.3	Egypt	Pre-metric	General	200 oke, 2003 reference
hin (new)	3.570	7.870	Hebrew	Ancient to pre-metric	Liquid Capacity	12 log, 2003 reference
hin (old)	4.896	10.79	Hebrew	Ancient to pre-metric	Liquid Capacity	12 log, 2003 reference
hoen	0.0000386	0.0000851	Indonesia	Colonial to pre-metric	Opium	1/1000 thail, consistent with 2003 reference
hót	3.780E-08	8.333E-08	Viet Nam, Annam	Medieval to pre-metric	General	10 vi
hun	0.000375	0.000827	Cambodia	Post-metric	General	3/8 muoi, 10 lin, 2003 reference
hun	0.000375	0.000827	Taiwan, Formosa	Pre-metric	General	10 cash
hundredweight	45.36	100.0	United States	Colonial to modern	General, Avoirdupois	100 lb
hundredweight	50.80	112.0	United Kingdom, England	Medieval to pre-metric	Shipping, Avoirdupois	112 pounds, 4 quarters

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
hundredweight	50.80	112.0	United Kingdom, England	Medieval to pre-metric	Coal	4 quarters
hundredweight (cwt)	50.80	112.0	India	Colonial to pre-metric	General	112 pounds av, 2 bushels + 8 stones
hyakume	0.375	0.827	Japan	Post-metric	General	25 niyo, 100 momme, 2003 reference
hyaku-mé	0.375	0.827	Japan	Post-metric	General	25 niyo, 100 momme, 2003 reference
jau	0.0000029	0.0000064	India, Northern	Medieval to Akbar	General	Barleycorn
jīn	0.5968	1.316	China	Pre-metric (1915–1929)	General	Chinese pound, 16 liǎng
jīn	0.500	1.102	China	Post-metric (1930–1958)	General	Chinese pound, old name, metric definition
jīn	0.500	1.10	China	Post-metric (Since 1959)	General	“Chinese pound”, 16 liǎng, old name, metric definition
jīn	0.600	1.32	Taiwan, Formosa	Pre-metric	General	16 taels
jūn	17.90	39.46	China	Pre-metric (1915–1929)	General	30 jīn
kabi	0.6176	1.362	Indonesia	Colonial to pre-metric	General	16 tael, 2003 reference
kalanda			Sri Lanka, Ceylon	Medieval to pre-metric	General	Small weight measured in seeds
kamha	0.0000322	0.0000710	Egypt	Pre-metric	General	1891 value
kamian	10.14	22.35	Poland	Pre-metric	General	25 funt, 2003 reference
kan	0.6048	1.333	China	Medieval to pre-metric	General	16 tael, 1891 value
kan	3.75	8.27	Japan	Post-metric	General	10 hyaku-mé, 1000 momme, 2003 reference

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
kancha	0.015	0.032	India	Medieval to Akbar	General	5 siki
kanne	3.75	8.27	Japan	Post-metric	General	10 hyaku-mé, 1000 momme, 2003 reference
kantar	0.977	2.15	Guinea	Medieval to Pre-metric	General	Conflict with 2003 reference
kantar	44.93	99.05	Egypt	Pre-metric	General	36 oke, 2003 reference
kantar	49.77	109.7	Tripoli, Libya	Pre-metric	General	100 rotls, 40 oke, 1891 value
kantar	50.75	111.9	Morocco	Colonial to pre-metric	General	100 rotal, 1891 value, consistent with 2003 reference
kantar	55.88	123.2	Cyprus	Colonial to pre-metric	General	40 oke, 2003 reference
kantar	56.4	124	Ottoman Empire, Turkey	Medieval to pre-metric	General	“weighbridge”
kantar	56.45	124.5	Turkey, Ottoman Empire	Medieval to pre-metric	General	44 oka, 2003 reference
kantar	56.56	124.7	Turkey, Ottoman Empire	Medieval to pre-metric	General	44 okes, 1891 value
kantar	67.50	148.8	Saudi Arabia	Pre-metric	General	5 farzil, 2003 reference
kantar	237.8	524.2	Cyprus	Colonial to pre-metric	General	1891 value, 100 rotolos
kantar	977	2,154	Guinea	Medieval to pre-metric	General	5 gammell, 15218 benda, 2003 reference, conflict with other references
kantar (Aleppo)	228.6	504.0	Cyprus	Colonial to pre-metric	General	180 oke (local variation), 2003 reference

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
karat	0.0002005	0.0004420	Turkey, Ottoman Empire	Medieval to pre-metric	General	2003 reference
karat	0.0002008	0.0004428	Turkey, Ottoman Empire	Medieval to pre-metric	General	1891 value
karat	0.0002061	0.0004543	Austrian Empire	Pre-metric	Gems	3.1799 grains, 1891 value
karch	224.0	493.8	Austrian Empire	Pre-metric	General	4 centner, 1891 value, consistent with 2003 reference
karob	0.000194	0.000429	Algeria	Medieval to pre-metric	General	3 grains, 1891 value
karus hiri-ichi-da	67.5	149	Japan	Post-metric	General	18 kwan, 2003 reference
karvar	589	1,298	Persia, Iran	Ancient to pre-metric	General	400 saddirham, 2003 reference
kasm	0.00390	0.00860	Ethiopia	Medieval to pre-metric	Rubber	Based on rubber farasula, 2003 reference
kedat	0.1365	0.3009	Egypt	Ancient	General	10 deben, 2003 reference
keel	21,541	47,488	United Kingdom, England	Medieval to pre-metric	Coal	212 large sacks
keramion	34	75	Egypt	Ancient	Capacity	4 apt, 2003 reference
kérat	0.000129	0.000284	Egypt	Pre-metric	General	4 kamha, 1891 value
khaltar	7.00	15.4	Afghanistan	Colonial to modern	Narcotics	Approx. Narcotics
kharr	34	75	Egypt	Ancient	Capacity	4 apt, 2003 reference
kharruba	0.0001944	0.0004286	Tripoli, Libya	Pre-metric	General	1891 value

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
kharouba	0.0002003	0.0004416	Libya	Medieval to pre-metric	General	1/6400 oka, carob seed, 2003 reference
kharsha	0.0141	0.0311	India	Akbar to colonial	General	2 kona, 1966 value
kharvar	454.5	1.002	Afghanistan	Colonial to modern	Narcotics	~1,000 lbs US
khoul	16.32	35.98	Arabia	Ancient	Capacity	2 ferk, 2003 reference, capacity measure
kikar	34.3	75.6	Biblical, Talmudic	Ancient	General	60 maneh, based on Oxford Biblical Studies Online
kikar	58.9	130	Biblical, Talmudic	Ancient	General	60 maneh, based on heavy common talent
kikar	60.6	134	Biblical, Talmudic	Ancient	General	60 maneh, based on heavy royal talent
kikkar	34.3	75.6	Biblical, Talmudic	Ancient	General	60 maneh, based on Oxford Biblical Studies Online
kikkar	42.5	93.7	Arabia	Ancient to pre-metric	General	125 rotl, 2003 reference
kikkar	58.9	130	Biblical, Talmudic	Ancient	General	60 maneh, based on heavy common talent
kikkar	60.6	134	Biblical, Talmudic	Ancient	General	60 maneh, based on heavy royal talent
kiladja	1.360	2.998	Arabia	Ancient	Capacity	2 mudd, 2003 reference, capacity measure
kilogramme	1.000	2.205	Germany, Prussia	Medieval to pre-metric	General	2 pfund, 1891 value
kilogramme	1.000	2.205	Netherlands, Holland	Medieval to metric	General	1891 value, metric “re-purposed” unit

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
kilogramme (1891)	1	2.205	France	Post-metric	General	10 hectogrammes
kin	0.600	1.32	Japan	Post-metric	General	40 niyo, 2003 reference
kin	0.600	1.32	Taiwan, Formosa	Pre-metric	General	16 taels
kip	18.45	40.68	Malacca	Pre-metric	Tin	1891 value
kippunta	170	375	Finland	Medieval to pre-metric	General	800 markka
kirat	0.000195	0.000430	Egypt	Pre-metric	General	1/6400 oke, alternate reference
kirat	0.001755	0.00387	Egypt	Pre-metric	General	0.001406 oke, 2003 reference
kirat	0.000200	0.000442	Ottoman Empire, Turkey	Medieval to pre-metric	General	“Carat”
kist	1.360	2.998	Arabia	Ancient	Capacity	2 mudd, 2003 reference, capacity measure
kite	0.00136	0.00300	Egypt	Ancient—Old & Mid Kingdom	Prec. Mtls.	1/10 deben, for silver & gold
kite	0.00910	0.0201	Egypt	Ancient—New Kingdom	Prec. Mtls.	1/10 deben, for silver & gold
kiyak-kin	60.0	132	Japan	Post-metric	General	16 kwan, 2003 reference
klam	0.000234	0.000517	Thailand, Siam	Pre- and post-metric	General	2 klon, 2003 reference
klom	0.000117	0.000258	Thailand, Siam	Pre- and post-metric	General	2003 reference
kojang (Batavia)	1,668	3,676	Indonesia	Colonial to pre-metric	General	6 bahar (long), 2003 reference
kojang (Semarang)	1,729	3,812	Indonesia	Colonial to pre-metric	General	14 amat, 2003 reference

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
kojang (Soerabaya)	1.853	4.085	Indonesia	Colonial to pre-metric	General	6 timbang, 2003 reference
komma-ichi-da	150	331	Japan	Post-metric	General	40 kwan, 2003 reference
kona	0.00706	0.0156	India	Akbar to colonial	General	8 masha, 1966 value
korn	0.0004251	0.0009371	Sweden	Medieval to pre-metric	General	1/10 ort, 2003 reference
korrel	0.0001000	0.0002205	Netherlands, Holland	Medieval to metric	General	1891 value, metric “re-purposed” unit
kotscha	0.165	0.365	Muscat	Pre-metric	General	
kotscha	0.165	0.365	Oman	Medieval to pre-metric	General	
kula	11.17	24.63	Morocco	Colonial to pre-metric	General	22 rotal, 2003 reference
kulack	4.48	9.87	Indonesia	Colonial to pre-metric	General	0.0725 pikol
kun	0.60	1.3	Korea	Medieval to pre-metric	General	16 nyang
kun	0.600	1.32	Taiwan, Formosa	Pre-metric	General	16 tael
kvintin	0.003321	0.007322	Sweden	Medieval to pre-metric	General	1/4 lod, 2003 reference
kwan	3.75	8.27	Japan	Post-metric	General	10 hyaku-mé, 1000 momme, 2003 reference
kwan	3.75	8.27	Korea	Medieval to pre-metric	General	
kwan	17.90	39.46	China	Pre-metric (1915–1929)	General	30 jin
kwan	67.95	149.8	Viet Nam, Annam	Medieval to pre-metric	General	180 neu, 2003 reference
kwart	0.006615	0.01458	Malta	Medieval to pre-metric	General	1/4 uqija, “quarter”, 1921 act only
kwart	0.1984	0.4374	Malta	Medieval to pre-metric	General	“Quarter” of a ratal, Aquilina reference
lachsa	28.8	63.5	Philippines	Medieval to pre-metric	General	48 catty, 2003 reference

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
lachsa	30.24	66.66	Sooloo Archipelago	Colonial to pre-metric	General	1891 value
lägel	70.00	154.3	Austrian Empire	Pre-metric	Steel	1891 value
lana	0.03413	0.07523	Russia	Medieval to pre-metric	General	8 zolotnicks, 1891 value, consistent with 2003 reference
lång	0.0375	0.0827	Viet Nam, Annam	Medieval to pre-metric	Prec. Mtls.	
lång	0.0378	0.0833	Viet Nam, Annam	Medieval to pre-metric	General	10 đồng, under metric = 0.1 kg, later 2 names are French colonial units
large bahar	277.9	612.7	Indonesia	Colonial to pre-metric	General	4.5 picul, 2003 reference
large sack	101.6	224.0	United Kingdom, England	Medieval to pre-metric	Coal	2 sacks
last	1,976	4,357	Netherlands, Holland	Medieval to metric	Shipping	4,000 Amsterdam ponds, "load", referred to ship loads or loads of herring. Not used after herring business stopped. Pre-1800
last	2,240	4,938	Austrian Empire	Pre-metric	General	40 centner, 1891 value
last	4,236	9,338	Sweden	Medieval to pre-metric	Shipping	100 centners, 1891 value
laup	17.93	39.53	Norway	Medieval to pre-metric	Butter	36 pund, 72 merker
lb	0.4536	1.000	United Kingdom, England	Medieval to pre-metric	General, Avoirdupois	7000 grains, 16 ounces

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
lb	0.4536	1.000	United States	Colonial to modern	General, Avoirdupois	Base unit, technically a unit of mass
lb ap	0.373	0.823	United Kingdom, England	Medieval to pre-metric	Apothecaries'	1 lb t, 12 oz ap
lb apoth	0.1693	0.3732	United States	Colonial to modern	Apothecaries'	12 oz apoth
lb T	0.349	0.770	United Kingdom, England	Medieval to 1526	Prec. Mtls., Coins	12 oz T, 7680 gr T, Tower
lb t	0.3732	0.8228	United States	Colonial to modern	Prec. Mtls.	12 oz t
lb t	0.3738	0.8241	United Kingdom, England	1526 to pre-metric	Prec. Mtls., Coins	12 oz t, 5760 gr, troy
leiviskä	8.500	18.74	Finland	Medieval to pre-metric	General	40 markka, metrinen leiviskä (metric version) = 10 kg
letech	143	316	Egypt	Ancient	Capacity	675 outen, 2003 reference
li	0.0000313	0.0000689	China	Post-metric (1930–1958)	General	1/16000 jīn, old name, metric definition
li	0.0000373	0.00008223	China	Pre-metric (1915–1929)	General	1/1000 liǎng
li	0.0000375	0.0000827	Taiwan, Formosa	Pre-metric	General	
li	0.00003775	0.00008322	Viet Nam, Annam	Medieval to pre-metric	General	10 hao, 2003 reference
li	0.0000378	0.0000833	Viet Nam, Annam	Medieval to pre-metric	General	10 hào

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
li	0.0000500	0.000110	China	Post-metric (Since 1959)	General	1/10000 jīn, old name, metric definition
liǎng	0.0313	0.0689	China	Post-metric (1930–1958)	General	Chinese ounce, 1/16 jīn, old name, metric definition
liǎng	0.03730	0.08223	China	Pre-metric (1915–1929)	General	Chinese ounce, 24 zhu
liǎng	0.0375	0.0827	Taiwan, Formosa	Pre-metric	General	10 mace
liǎng	0.050	0.110	China	Post-metric (Since 1959)	General	“Chinese ounce”, old name, metric definition
libbra	0.4601	1.014	Peru	Colonial to pre-metric	General	Pound, still used in 1891, consistent with 2003 reference
libbra	0.4601	1.014	Chile	Colonial to pre-metric	General	Pound, 16 onza, 2003 reference, also reported as 0.473 kg in 1891
libbra	0.4602	1.015	Mexico	Colonial to pre-metric	General	Pound, 16 onza, 2003 reference
libbra	0.500	1.10	Colombia	Colonial to metric	General	Pound, also reported as 0.5435 kg, 2003 reference
libbra	0.50	1.1	Venezuela	Post-metric	General	16 onza, older value estimated at 0.46 kg, old name, metric definition
libbra	0.7938	1.750	Malta	Medieval to pre-metric	General	Consistent with 1891 value
libbra (Ancona)	0.3301	0.7277	Italy	Medieval to pre-metric	General	12 oncie, 1891 value
libbra (Florence)	0.340	0.748	Italy	Medieval to pre-metric	General	12 once
libbra (Genoa)	0.3176	0.7002	Italy	Medieval to pre-metric	General	12 oncie, 1891 value
libbra (Genoa)	0.3494	0.7702	Italy	Medieval to pre-metric	General	1/10 higher than ordinary libbra, 1891 value
libbra (Modena)	0.3195	0.7044	Italy	Medieval to pre-metric	General	12 oncie, 1891 value

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
libbra (Naples)	0.3208	0.7072	Italy	Medieval to pre-metric	Apothecaries'	12 oncie, 1891 value
libbra (Naples)	0.3208	0.7072	Italy	Medieval to pre-metric	Prec. Mils., Drugs, Pigments	12 oncie, 1891 value
libbra (new)	0.459	1.01	Paraguay	Colonial to pre-metric	General	Pound (new), 2003 reference
libbra (old)	0.4601	1.014	Paraguay	Colonial to pre-metric	General	Pound (old), 16 once, 2003 reference
libbra (Palermo)	0.317	0.699	Italy	Medieval to pre-metric	General	12 once
libbra (Parma)	0.3265	0.7197	Italy	Medieval to pre-metric	General	12 oncie, 1891 value
libbra (Rome, Roman States)	0.3392	0.7477	Italy	Medieval to pre-metric	General	12 oncie
libbra (Sardinia, Piedmont, Turin)	0.3074	0.6778	Italy	Medieval to pre-metric	Apothecaries'	1.25 marco, 1891 value
libbra (Sardinia, Piedmont, Turin)	0.3689	0.8133	Italy	Medieval to pre-metric	General	12 oncie, 1891 value
libbra (Sicily)	0.3208	0.7072	Italy	Medieval to pre-metric	General	12 oncie, 1891 value
libbra (Turin)	0.369	0.813	Italy	Medieval to pre-metric	General	12 once
libbra (Tuscany)	0.3396	0.7486	Italy	Medieval to pre-metric	General	12 oncie, 1891 value
libbra (typical)	0.307	0.677	Italy	Medieval to pre-metric	General	Pound, 12 onci, pre-1861, 2003 reference
libbra (variation)	0.353	0.778	Italy	Medieval to pre-metric	General	"Pound", varied from 0.307 to 0.398 kg, used average
libbra grossa (Milan)	0.763	1.68	Italy	Medieval to pre-metric	General	28 once
libbra grossa (Venice)	0.477	1.05	Italy	Medieval to pre-metric	General	12 once

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
libbra grosso	0.4536	1.000	Ionian Islands	Pre-metric	General	1 lb avoirdupois, 1891 value
libbra mercantile (Bologna)	0.362	0.798	Italy	Medieval to pre-metric	General	12 once, 1891 value
libbra metrica (Venetian Lombardy)	1.0000	2.2046	Italy	Post-metric	General	10 oncie, post-metric, old name, metric definition
libbra sottile	0.3732	0.8228	Ionian Islands	Pre-metric	General	1 lb troy, 1891 value
libbra sottile (Venice)	0.301	0.664	Italy	Medieval to pre-metric	General	
libra	0.326	0.720	Biblical, Talmudic	Ancient	General	Based on Oxford Biblical Studies Online
libra	0.3270	0.7209	Roman Empire	Ancient	General	“Roman pound” or “balance”, estimates range from 0.322 to 0.329 kg, 2003 reference
libra	0.344	0.759	Portugal	Medieval to pre-metric	Apothecaries’	12 onças
libra	0.3454	0.7615	Spain	Medieval to pre-metric	Apothecaries’	1891 value
libra	0.400	0.882	Balearic Islands	Pre-metric	General	1891 value
libra	0.4536	1.000	Malta	Medieval to pre-metric	General	16 ounces, 2003 reference
libra	0.4586	1.011	Madeira Islands	Pre-metric	General	
libra	0.459	1.01	Portugal	Medieval to pre-metric	General	“Pound”, 16 onça, 2003 reference
libra	0.4591	1.012	Brazil	Colonial to pre-metric	General	Pound, 2 marco, 2003 reference
libra	0.4594	1.013	Argentina	Colonial to pre-metric	General	16 onza, 1891 value, consistent with 2003 reference

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
libra	0.4601	1.014	Uruguay	Colonial to pre-metric	General	1891 value
libra	0.4601	1.014	Peru	Colonial to pre-metric	General	Pound, still used in 1891, consistent with 2003 reference
libra	0.4601	1.014	Chile	Colonial to pre-metric	General	Pound, 16 onza, 2003 reference, also reported as 0.473 kg in 1891
libra	0.4602	1.015	Mexico	Colonial to pre-metric	General	Pound, 16 onza, 2003 reference
libra	0.4603	1.015	Canary Islands	Pre-metric	General	
libra	0.4609	1.016	Spain	Medieval to pre-metric	General	2 marcos, 1891 value, reported as 0.4601 kg in 2003 reference
libra	0.461	1.02	Cuba	Colonial to pre-metric	General	
libra	0.4731	1.043	Central America	Colonial to pre-metric	General	1891 value
libra	0.4731	1.043	Costa Rica	Colonial to pre-metric	General	1891 value
libra	0.4731	1.043	El Salvador	Colonial to pre-metric	General	1891 value
libra	0.4731	1.043	Guatemala	Colonial to pre-metric	General	1891 value
libra	0.4731	1.043	Honduras	Colonial to pre-metric	General	1891 value
libra	0.4731	1.043	Nicaragua	Colonial to pre-metric	General	1891 value
libra	0.500	1.10	Colombia	Colonial to metric	General	Pound, also reported as 0.5435 kg, 2003 reference
libra	0.50	1.1	Venezuela	Post-metric	General	16 onza, older value estimated at 0.46 kg, old name, metric definition
libra (new)	0.459	1.01	Paraguay	Colonial to pre-metric	General	Pound (new), 2003 reference
libra (old)	0.4601	1.014	Paraguay	Colonial to pre-metric	General	Pound (old), 16 once, 2003 reference
libra de farmacia	0.3445	0.7595	Argentina	Colonial to pre-metric	General	3/4 libra, 1891 value

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
libra mayor	1.22	2.70	Balearic Islands	Pre-metric	General	3 rottolos, 2003 reference
liespfund	8.38	18.5	Latvia	Medieval to pre-metric	General	20 pfund, 2003 reference
liespfund	9.20	20.3	Estonia	Medieval to pre-metric	General	20 pfund, 2003 reference
liespfund (Bremen)	7.229	15.94	Germany, Prussia	Medieval to pre-metric	General	1891 value
liespfund (Brunswick)	6.544	14.43	Germany, Prussia	Medieval to pre-metric	General	1891 value
liespfund (Hamburg)	6.782	14.95	Germany, Prussia	Medieval to pre-metric	General	14 pfund, 1891 value
liespfund (old)	7.718	17.01	Prussia, Germany	Pre-metric	General	16.5 pfund, pre-metric value
liespund	8.502	18.74	Sweden	Medieval to pre-metric	General	20 skålpund, 2003 reference
liespund	32.0	70.5	Iceland	Medieval to metric	General	64 pund, post-metric value, 2003 reference
lii	0.0000373	0.00008223	China	Pre-metric (1915–1929)	General	1/1000 liàng
lin	0.0000375	0.0000827	Cambodia	Post-metric	General	3/80 muoi, 2003 reference
lira (Modena)	0.3195	0.7044	Italy	Medieval to pre-metric	General	12 oncie, 1891 value
lispund	8.00	17.6	Denmark	Medieval to pre-metric	General	16 pund, 2003 reference
lispund	8.502	18.74	Sweden	Medieval to pre-metric	General	20 skålpund, 2003 reference
lispund	8.503	18.75	Norway	Medieval to pre-metric	General	20 skålpunds, 1891 value
lispund (old)	7.990	17.61	Denmark	Medieval to pre-metric	General	16 old pund, early 1800 s value?
liter	0.311	0.686	Abyssinia	Pre-metric	General	Pound, 12 wakeas, 4800 grains, 1891 value, consistent with 2003 reference

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
lira	0.3197	0.7047	Romania, Roumania	Pre-metric	General	1891 value
lira	0.3197	0.7047	Serbia, Servia	Medieval to pre-metric	General	"Pound", 100 drachm, 1891 value
lira	0.3200	0.7055	Yugoslavia	Pre-metric	General	100 dramm, 2003 reference
lira	0.326	0.720	Biblical, Talmudic	Ancient	General	Based on Oxford Biblical Studies Online
lira	0.3276	0.7222	Byzantine Empire	Ancient	General	72 gold solidi, circa 309 AD, reduced over time to 0.319 kg by 9th century
lira	0.9824	2.166	Biblical, Talmudic	Ancient	General	2 tartimar, based on heavy royal talent
lira	1.01	2.23	Biblical, Talmudic	Ancient	General	2 tartimar, based on heavy royal talent
livre	0.375	0.827	Switzerland	Medieval to metric	Apothecaries'	Defined at transition to metric, 12 onces, 1891 value, consistent with 2003 reference
livre	0.4895	1.079	Belgium	Pre-metric	General	2 marc, 2003 reference
livre	0.4895	1.079	France	Medieval to pre-metric	General	"French pound", 2 marc, 2003 reference
livre	0.500	1.10	France	Post-metric (1840)	General	2 marcs, old name, metric definition
livre	0.5000	1.102	Switzerland	Medieval to metric	General	Defined at transition to metric, "Swiss pound", Zollverein pfund, 16 onces, 1891 value, consistent with 2003 reference
livre	1.000	2.205	Belgium		General	1891 value
livre (Martinique)	0.4895	1.079	West Indies	Colonial to pre-metric	General	Used old French units in 1891 (continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
livre du roi (Charlemagne)	0.3671	0.8093	France	Medieval to pre-metric	General	20 sol, 2003 reference
load	980	2,160	United Kingdom, England	Medieval to pre-metric	Hay, Straw	36 truss (hay or straw)
load	1,372	3,024	United Kingdom, England	Medieval to pre-metric	Wool	12 wey (wool)
lod	0.013284	0.02929	Sweden	Medieval to pre-metric	General	4 qvintin, 2003 reference
lod	0.01329	0.02929	Norway	Medieval to pre-metric	General	4 qvintin, 1891 value
lod	0.01460	0.03218	Denmark	Medieval to pre-metric	Prec. Mtls.	4 quintin, 1891 value
lod	0.01317	0.02903	Norway	Medieval to pre-metric	Prec. Mtls., Fine Goods	4 qvintins, 1891 value
log (new)	0.2975	0.6559	Hebrew	Ancient to pre-metric	Dry Capacity	2003 reference
log (new)	0.2975	0.6559	Hebrew	Ancient to pre-metric	Liquid Capacity	2003 reference
log (old)	0.4080	0.8995	Hebrew	Ancient to pre-metric	Liquid Capacity	2003 reference
log (old)	0.4080	0.8995	Hebrew	Ancient to pre-metric	Dry Capacity	2003 reference
London pound	0.467	1.03	United Kingdom, England	Medieval to pre-metric	Commercial	~ 15 oz t, ~ 16 oz T, ~ 7200 gr
long amphora	97.80	215.6	Persia, Iran	Ancient to modern	Capacity	3 amphora, 2003 reference
long artaba	65.20	143.7	Persia, Iran	Ancient to modern	Capacity	2 amphora, 2003 reference

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
long hundredweight	50.80	112.0	United States	Colonial to modern	General, Avoirdupois	112 lb
long ton	1,016	2,240	United States	Colonial to modern	General, Avoirdupois	20 long hundredweight or 2240 lbs
long ton	1,016	2,240	United Kingdom, England	Medieval to pre-metric	Coal	10 large sacks
load	0.01000	0.02205	Netherlands, Holland	Medieval to metric	General	1891 value, metric “re-purposed” unit
lot	0.01280	0.02821	Russia	Medieval to pre-metric	General	3 zolotnicks, 1891 value
lot	0.01530	0.03373	France	Medieval to pre-metric	General	4 gros, 2003 reference
loth	0.0128	0.0282	Tatar	Medieval to pre-metric	General	3 misqal
loth	0.01280	0.02821	Russia	Medieval to pre-metric	General	3 zolotnicks, 1891 value
loth	0.0131	0.0289	Latvia	Medieval to pre-metric	General	4 quent, 2003 reference
loth	0.0134	0.0296	Estonia	Medieval to pre-metric	General	4 quent, 2003 reference
loth	0.0146	0.0322	Prussia, Germany	Pre-metric	Prec. Mils.	18 gran, 1891 value
loth	0.01530	0.03372	Belgium	Pre-metric	General	2003 reference
loth	0.0156	0.0344	Denmark	Medieval to pre-metric	General	4 quintin, 2003 reference
loth	0.01563	0.03445	Switzerland	Medieval to metric	General	1891 value, consistent with 2003 reference
loth	0.01750	0.03858	Austrian Empire	Pre-metric	General	4 quentchen, 1891 value, consistent with 2003 reference
loth	0.01750	0.03858	Austrian Empire	Pre-metric	Prec. Mils.	4 quentchen, 1891 value

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
loth (Austrian system)	0.01462	0.03222	Germany, Prussia	Medieval to pre-metric	General	3 quentchen, 2003 reference
loth (Bavaria)	0.0156	0.0344	Germany, Prussia	Medieval to pre-metric	General	4 quentchen, 1891 value
loth (Bavaria)	0.0175	0.0386	Germany, Prussia	Medieval to pre-metric	General	4 quentchen, 1891 value
loth (Bremen)	0.01558	0.03435	Germany, Prussia	Medieval to pre-metric	General	4 quentchen, 1891 value
loth (Brunswick)	0.01461	0.03220	Germany, Prussia	Medieval to pre-metric	General	4 quentchen, 1891 value
loth (Frankfort)	0.0158	0.0348	Germany, Prussia	Medieval to pre-metric	General	4 quentchen, 1891 value
loth (Hamburg)	0.0151	0.0334	Germany, Prussia	Medieval to pre-metric	General	4 quentchen, 1891 value
loth (Hanover)	0.01530	0.03373	Germany, Prussia	Medieval to pre-metric	General	4 quentchen, 1891 value
loth (Hesse-Cassel)	0.01513	0.03336	Germany, Prussia	Medieval to pre-metric	General	4 quentchen, 1891 value
loth (Hesse-Darmstadt)	0.01563	0.03445	Germany, Prussia	Medieval to pre-metric	General	4 quentchen, 1821 value, previously same as Frankfurt
loth (Lubeck)	0.01515	0.03340	Germany, Prussia	Medieval to pre-metric	General	4 quentchen, 1891 value
loth (new)	0.0167	0.0367	Prussia, Germany	Post-metric	General	10 quentchen, post-metric value
loth (old)	0.0146	0.0322	Prussia, Germany	Pre-metric	General	4 quentchen, pre-metric value

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
loth (Saxony)	0.01461	0.03221	Germany, Prussia	Medieval to pre-metric	General	4 quentlein
luong	0.03775	0.08322	Viet Nam, Annam	Medieval to pre-metric	General	10 dong, 2003 reference
luong	0.0391	0.0861	Annam, Viet Nam	Pre-metric	General	10 dong, 1891 value
lượng	0.0375	0.0827	Viet Nam, Annam	Medieval to pre-metric	Prec. Mtls.	
lượng	0.0378	0.0833	Viet Nam, Annam	Medieval to pre-metric	General	10 đồng, under metric = 0.1 kg, later 2 names are French colonial units
luoti	0.0140	0.0308	Finland	Medieval to pre-metric	General	Weight of a musket ball, 1/16 markka
lut	0.01267	0.02794	Poland	Pre-metric	General	4 drachma, 2003 reference
ly	0.0000378	0.0000833	Viet Nam, Annam	Medieval to pre-metric	General	10 hào
ly	0.0000391	0.0000861	Annam, Viet Nam	Pre-metric	General	Subdivided by factors of 10 to 1/ 100000 (largely imaginary), 1891 value
maan	4.50	9.92	Afghanistan	Colonial to modern	Narcotics	Cannabis, opium, heroin
maân	0.85	1.9	Egypt	Ancient	Capacity	4 ouden, 2003 reference
mace	0.00249	0.00548	Borneo	Pre-metric	General	4 copang
mace	0.00291	0.00641	Malacca	Pre-metric	General	44.83 grains, 1891 value
mace	0.00313	0.00689	China	Post-metric (1930–1958)	General	1/160 jīn, old name, metric definition
mace	0.0034	0.0074	Singapore	Colonial to pre-metric	General	52 grains
mace	0.003730	0.008223	China	Pre-metric (1915–1929)	General	1/10 liàng

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
mace	0.00375	0.00827	Taiwan, Formosa	Pre-metric	General	10 candareens
mace	0.003780	0.008333	China	Medieval to pre-metric	General	1891 value
mace	0.00378	0.00833	Sooloo Archipelago	Colonial to pre-metric	General	58.33 grains, 1891 value
mace	0.00500	0.0110	China	Post-metric (Since 1959)	General	1/160 jin, old name, metric definition
mace (Amboyna)	0.0018	0.0041	Indonesia	Colonial to pre-metric	General	28.5 grains, estimated
mace (Amboyna)	0.00185	0.00407	Molucca	Pre-metric	General	28.5 grains, 1891 value
mace (Singapore)	0.00337	0.00743	Malacca	Pre-metric	General	52 grains, 1891 value
madati			Sri Lanka, Ceylon	Medieval to pre-metric	General	8 vee ata, small weight measured in seeds
maditi			Sri Lanka, Ceylon	Medieval to pre-metric	General	Small weight measured in seeds
mahnd shah (Isfahan)	6.20	13.7	Persia, Iran	Ancient to pre-metric	General	1891 value
mahnd shah (Shiraz, Bushire, Gamri)	12.4	27.3	Persia, Iran	Ancient to pre-metric	General	1891 value
maile	0.000765	0.00169	France	Medieval to pre-metric	Prec. Mtls.	2 filins, 2003 reference
majadi			Sri Lanka, Ceylon	Medieval to pre-metric	General	Small weight measured in seeds
makhod	0.000256	0.000563	Persia, Iran	Ancient to pre-metric	General	Carat, 2003 reference
makuk	4.075	8.984	Persia, Iran	Ancient to modern	Capacity	4 cados, 2003 reference
makuk	4.080	8.995	Arabia	Ancient	Capacity	3 caphite, 2003 reference, capacity measure

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
malaborong	0.000138	0.000305	Borneo	Pre-metric	General	1891 value
man	0.680	1.50	Arabia	Ancient to pre-metric	General	2 rotl, 2003 reference
ma-na	0.498	1.10	Mesopotamia, Sumer, Akkadia	Ancient (EN system E)	General	Pound, 60 shekels
mane	0.91	2.0	Tanzania	Pre-metric	General	
mane	1.36	3.01	Zanzibar	Pre-metric	General	1891 value
maneh	0.571	1.26	Biblical, Talmudic	Ancient	General	2 tartimar, based on Oxford Biblical Studies Online
maneh	0.9824	2.166	Biblical, Talmudic	Ancient	General	2 tartimar, based on heavy royal talent
maneh	1.01	2.23	Biblical, Talmudic	Ancient	General	2 tartimar, based on heavy royal talent
maneh	1.4	3.1	Jewish, Israel	Ancient to modern	General	100 shekels, 21900 troy grains
mangal (Madras)	0.00039	0.00086	India	Akbar to colonial	General, Pearls	6 grains, 1891 value
manjadi			Sri Lanka, Ceylon	Medieval to pre-metric	General	Small weight measured in seeds
mann	0.028	0.062	Ireland	Medieval to pre-metric	General	72 penny, from Latin
manū	0.498	1.10	Mesopotamia, Sumer, Akkadia	Ancient (EN system E)	General	Pound, 60 shekels
maon	1.36	3.00	Arabia	Ancient to pre-metric	General	40 vakias, 1891 value
maon (Bet-el-faki)	0.925	2.04	Arabia	Ancient to pre-metric	General	1891 value
maon (Jidda)	0.830	1.83	Arabia	Ancient to pre-metric	General	1891 value

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
mare	0.2448	0.5396	Belgium	Pre-metric	General	8 once, 2003 reference
mare	0.2448	0.5397	France	Medieval to pre-metric	General	2 quarteron, 2003 reference
mare	0.250	0.551	France	Post-metric (1840)	General	8 onces, old name, metric definition
marco	0.230	0.506	Portugal	Medieval to pre-metric	Prec. Mtls.	1/2 arratel
marco	0.2295	0.5060	Brazil	Colonial to pre-metric	General	Half-pound, 8 onza, 2003 reference
marco	0.2297	0.5063	Argentina	Colonial to pre-metric	Gold, Silver	3544.4 grains, 1891 value
marco	0.2305	0.5080	Spain	Medieval to pre-metric	General	8 onzas, 1891 value, reported as 0.2300 kg in 2003 reference
marco (Sardinia, Piedmont, Turin)	0.2459	0.5422	Italy	Medieval to pre-metric	Prec. Mtls.	2/3 libbra, 1891 value
marco (Venetian Lombardy)	0.2350	0.5181	Italy	Medieval to pre-metric	Prec. Mtls.	8 oncie, 7.5562 troy ounces, pre-metric
mark	0.203	0.447	Poland	Pre-metric	General	24 skoyciec, 1891 value
mark	0.203	0.448	Sweden	Medieval to pre-metric	General	1/2 skålpund, Viking era
mark	0.2107	0.4644	Norway	Medieval to pre-metric	Prec. Mtls., Fine Goods	8 untzes, 4384 as, 1891 value
mark	0.213	0.468	Sweden	Medieval to pre-metric	General	50 ort, pre-metric
mark	0.2336	0.5149	Denmark	Medieval to pre-metric	Prec. Mtls.	16 lod, 1891 value
mark	0.234	0.516	Prussia, Germany	Pre-metric	Prec. Mtls.	16 loth, 1891 value
mark	0.2448	0.5397	France	Medieval to pre-metric	General	2 quarteron, 2003 reference
mark	0.2461	0.5425	Netherlands, Holland	Medieval to metric	General	8 unze, 2003 reference
mark	0.249	0.550	Norway	Medieval to pre-metric	General	1/2 pund, 0.2187 kg before 1683 (continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
mark	0.250	0.551	Denmark	Medieval to pre-metric	General	8 unze, 2003 reference
mark	0.2800	0.6173	Austrian Empire	Pre-metric	General	2 vierding, 1891 value, consistent with 2003 reference
mark	0.2800	0.6173	Austrian Empire	Pre-metric	Prec. Mtls.	4333 grains, 16 loth, 1891 value
mark	1.00	2.20	Iceland	Medieval to metric	General	2 pund, post-metric value, 2003 reference
mark (Austrian system)	0.2339	0.5156	Germany, Prussia	Medieval to pre-metric	General	1/2 pfund, 2003 reference
mark (Bremen)	0.2493	0.5495	Germany, Prussia	Medieval to pre-metric	General	8 unzen, 1891 value
mark (Brunswick)	0.2337	0.5152	Germany, Prussia	Medieval to pre-metric	General	16 loth, 1891 value
mark (Cologne)	0.234	0.516	Germany, Prussia	Medieval to pre-metric	General, Prec. Mtls.	1891 value, standard copy actually weighed 1 grain less
mark (Frankfort)	0.253	0.557	Germany, Prussia	Medieval to pre-metric	General	8 unzen, 1891 value
mark (Hamburg)	0.2422	0.5339	Germany, Prussia	Medieval to pre-metric	General	8 unzen, 1891 value
mark (Hanover)	0.2448	0.5397	Germany, Prussia	Medieval to pre-metric	General	8 unzen, 1891 value
mark (Lubeck)	0.2424	0.5344	Germany, Prussia	Medieval to pre-metric	General	8 unzen, 1891 value
mark (old)	0.2339	0.5156	Prussia, Germany	Pre-metric	General	8 unzen, pre-metric value

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
mark (Saxony)	0.2337	0.5153	Germany, Prussia	Medieval to pre-metric	General	8 unzen
mark (Württemberg)	0.2339	0.5156	Germany, Prussia	Medieval to pre-metric	General, Prec. Mtls.	1891 value
mark Tower	0.232	0.511	United Kingdom, England	Medieval to 1526	Prec. Mtls., Coins	8 oz T
mark troy	0.2492	0.5494	United Kingdom, England	1526 to pre-metric	Prec. Mtls., Coins	8 oz t
markka	0.214	0.471	Finland	Medieval to pre-metric	General	Finnish monetary unit 1861-2002
mascai (Tauris)	0.00479	0.0106	Persia, Iran	Ancient to pre-metric	General	1891 value
masha	0.000882	0.00194	India	Akbar to colonial	General	6 rehti, 1966 value
masha	0.0009719	0.002143	India	Akbar to colonial	General	8 ruttee, 2003 reference
masha	0.00097	0.0021	India, Northern	Medieval to Akbar	General	8 ratti
māshā	0.00091	0.0020	India	Akbar to colonial	General	8 rattis, before 1833
mat	0.00408	0.00899	Burma, Birmah, Rangoon, Myanmar	Pre-metric	General	2 moo, 2003 reference
mattaro	21.54	47.48	Libya	Medieval to pre-metric	General	42 rotollo, 2003 reference
maund	1.350	2.976	Saudi Arabia	Pre-metric	General	3 ratl, 2003 reference
maund	3.97	8.75	Muscat	Pre-metric	General	24 kotschas
maund	3.97	8.75	Oman	Medieval to pre-metric	General	24 kotschas

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
maund	9.95	21.9	Abyssinia	Pre-metric	General	32 rotl, 1891 value
maund	11.34	25.00	Ceylon, Sri Lanka	Pre-metric	General	8 vis, 2003 reference
maund	34.84	76.80	India	Akbar to colonial	General	40 sers, before 1833, after 1848 was defined as 37.32 kg, one maund is weight of goods that could be carried by pack animal or porter
maund	35	77	Sumatra	Pre-metric	General	1891 value
maund	37.32	82.28	India	Akbar to colonial	General	8 dhurra, 2003 reference
maund	37.3	82.3	India	Medieval to Akbar	General	4 daseri, 8 pasri, 40 seer
maund	1.36	3.00	Arabia	Ancient to pre-metric	General	40 vakias, 1891 value
maund (Anjar)	11.9	26.2	India	Akbar to colonial	General	40 seers, 1891 value
maund (Aurangabad)	34.4	75.8	India	Akbar to colonial	General	40 seers, 1891 value
maund (Bengal)	33.9	74.7	India	Akbar to colonial	General, Factory	40 seers, 1891 value
maund (Bengal)	37.3	82.1	India	Akbar to colonial	General, Bazaar	40 seers, 1891 value
maund (Bet-el-faki)	0.925	2.04	Arabia	Ancient to pre-metric	General	1891 value
maund (Bombay)	12.7	28.0	India	Akbar to colonial	General	40 seers, 1891 value
maund (Deccan)	36.2	79.8	India	Akbar to colonial	General	40 seers, 1891 value
maund (Goa)	11.2	24.7	India	Akbar to colonial	General	1891 value
maund (Gujerat)	12.7	28.0	India	Akbar to colonial	General	40 seers, 1891 value

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
maund (Jidda)	0.830	1.83	Arabia	Ancient to pre-metric	General	1891 value
maund (Madras)	11.34	25.00	India	Akbar to colonial	General	8 vis, 1891 value
maund (Maharatta country)	11.9	26.2	India	Akbar to colonial	General	1891 value
maund (Malda)	45.6	100	India	Akbar to colonial	General	1891 value
maund (Pondicherry)	11.7	25.9	India	Akbar to colonial	General	1891 value
maund (Sumatra)	34.9	77.0	Indonesia	Colonial to pre-metric	General	77 lb av
mediatabla	0.00201	0.00442	Guinea	Medieval to pre-metric	General	2 akey, 2003 reference
media-tabla	0.00201	0.00442	Guinea	Medieval to pre-metric	General	2 akey, 2003 reference
medicinaal ons	0.0311	0.0686	Netherlands, Holland	Medieval to metric	Apothecaries'	8 drachmen, 480 grains, "medicinal ounce"
medicinaal pond	0.373	0.823	Netherlands, Holland	Medieval to metric	Apothecaries'	12 ons, 5760 grains, "medicinal pound", also reported as 0.3691 kg in 2003 reference
mehah	0.0005903	0.001301	Hebrew, Talmudic, Rabbinical	Ancient to pre-metric	General	2 pondiuscules, 2003 reference
meio	0.230	0.507	Portugal	Medieval to pre-metric	General	Marco, 8 onca, 2003 reference
mercantile pound	0.437	0.964	United Kingdom, England	Medieval to pre-metric	Commercial	~15 oz T
mercantile pound	0.467	1.03	United Kingdom, England	Medieval to pre-metric	Commercial	~15 oz t, ~16 oz T, ~7200 gr

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
mercantile stone	5.60	12.3	United Kingdom, England	Medieval to pre-metric	Commercial	12 lb L
merchants pound	0.437	0.964	United Kingdom, England	Medieval to pre-metric	Commercial	~ 15 oz T
marker	0.249	0.550	Norway	Medieval to pre-metric	General	1/2 pund, 0.2187 kg before 1683
metecali	0.004463	0.009838	Syria	Medieval to pre-metric	General, Prec. Mtls.	1/400 rottolo, 1.5 pesi, 2003 reference
metical	0.00309	0.00682	Egypt	pre-metric	Prec. Mtls.	For weighing precious metals, same as darhim, 1891 value
metical	0.004708	0.01038	Algeria	Medieval to pre-metric	General	2003 reference
metical	0.00477	0.0105	Tripoli, Libya	Pre-metric	Prec. Mtls.	73.6 grains, 1891 value
metical	0.0039	0.0085	Tunisia	Ancient to pre-metric	Prec. Mtls.	59.7 gr, 1891 value
metretres of Heron	43	94	Egypt	Ancient	Capacity	5 apt, 2003 reference
metric carat	0.0002	0.0004	United States	Colonial to modern	Gems	1932 value
metrical	0.00467	0.0103	Algeria	Medieval to pre-metric	Gold	72.06 gr, 1891 value
metrical	0.00476	0.0105	Libya	Medieval to pre-metric	Prec. Mtls.	Gold, silver measure
metquat	0.004708	0.01038	Algeria	Medieval to pre-metric	General	2003 reference
miam	0.00291	0.00641	Malacca	Pre-metric	General	44.83 grains, 1891 value
miam	0.0034	0.0074	Singapore	Colonial to pre-metric	General	52 grains
miam (Singapore)	0.00337	0.00743	Malacca	Pre-metric	General	52 grains, 1891 value
milaresium	0.005450	0.01201	Roman Empire	Ancient	General	1/5 uncia, 2003 reference

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
millier	489.5	1,079	France	Medieval to pre-metric	General	"French thousand", 10 quintal, 2003 reference
millier	1,000	2,205	France	Post-metric	Shipping	10 quintals
millier	1,016	2,239	Cuba	Colonial to pre-metric	General	
milligramme	0.000001	0.000002205	Germany, Prussia	Medieval to pre-metric	General	1/1000 gramme, 1891 value
milligramme	0.000001	0.000002205	France	Post-metric	General	1/10 centigramme
mimtscha	0.494	1.09	Turkmenistan	Pre-metric	General	2003 reference
mina	0.3542	0.7809	Hebrew, Talmudic, Rabbinical	Ancient to pre-metric	General	25 shekels, 2003 reference
mina	0.5450	1.201	Roman Empire	Ancient	General	5/3 libra, 2003 reference
mina	0.571	1.26	Biblical, Talmudic	Ancient	General	2 tartimar, based on Oxford Biblical Studies Online
mina	0.850	1.87	Hebrew, Sacred system	Ancient to pre-metric	General	60 shekels, 2003 reference
mina	0.9824	2.166	Biblical, Talmudic	Ancient	General	2 tartimar, based on heavy royal talent
mina	1.000	2.205	Greece	Pre- and post-metric	General	Kilogram, 1000 drachme, 1891 value, post-metric
mina	1.01	2.23	Biblical, Talmudic	Ancient	General	2 tartimar, based on heavy royal talent
mina	1.536	3.386	Greece	Pre- and post-metric	General	3 pounds, pre-metric, 2003 reference
mina (Aeginetic)	0.63	1.4	Greece	Ancient	General	100 drachmae

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
mina (Attic/ Euboic)	0.4320	0.9524	Greece	Ancient	General	100 drachmae, 2003 reference
mine	0.326	0.719	Persia, Iran	Ancient to pre-metric	General	100 drachm, 2003 value
mine	0.680	1.50	Arabia	Ancient to pre-metric	General	2 rotl, 2003 reference
mine	0.8190	1.806	Egypt	Ancient	General	6 kedet, 2003 reference
mine	0.85	1.9	Egypt	Ancient	Capacity	4 outen, 2003 reference
mine (Attic/ Euboic)	0.4320	0.9524	Greece	Ancient	General	100 drachmae, 2003 reference
misal (Mocha)	0.00467	0.0103	Arabia	Ancient to pre-metric	General	72 grains, 1891 value
misal	0.00425	0.00937	Ottoman Empire, Turkey	Medieval to pre-metric	General	1.5 dirhem
misal	0.00460	0.0101	Persia, Iran	Ancient to pre-metric	General	6 dung, 2003 reference
misal	0.004811	0.01061	Turkey, Ottoman Empire	Medieval to pre-metric	General	6 denke, 2003 reference
misal	0.0125	0.0275	Egypt	Pre-metric	General	1/100 oke?
misal	0.1123	0.2476	Egypt	Pre-metric	General	4 dirhem, 2003 reference
misal (Teheran)	0.00484	0.0107	Persia, Iran	Ancient to pre-metric	General	1891 value
misal	0.00427	0.00940	Tatar	Medieval to pre-metric	General	96 öleş
misal	0.0062	0.014	India	Akbar to colonial	General, Prec. Mtls., Spices	
misura	14.7	32.4	Balearic Islands	Pre-metric	General	4 quartanos, 2003 reference
mitcal	0.004463	0.009838	Syria	Medieval to pre-metric	General, Prec. Mtls.	1/400 rottolo, 1.5 pesi, 2003 reference

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
mitkal	0.00309	0.00682	Egypt	Pre-metric	Prec. Mils.	For weighing precious metals, same as darhim, 1891 value
mitkal	0.00467	0.0103	Algeria	Medieval to pre-metric	Gold	72.06 gr, 1891 value
mna	0.571	1.26	Biblical, Talmudic	Ancient	General	2 tartimar, based on Oxford Biblical Studies Online
mna	1.4	3.1	Jewish, Israel	Ancient to modern	General	100 shekels, 21900 troy grains
mô	0.00000375	0.00000827	Japan	Post-metric	General	10 shi, 2003 reference
mocha	0.0311	0.0686	Ethiopia	Medieval to pre-metric	General	1/10 rotto
mocha	0.0311	0.0686	Abyssinia	Pre-metric	General	12 dirhems, 1 troy ounce, consistent with 2003 reference
modius	16.30	35.93	Persia, Iran	Ancient to modern	Capacity	4 makuk, 2003 reference
modius	40.80	89.95	Arabia	Ancient	Capacity	5 ferk, 2003 reference, capacity measure
modius (new)	6.426	14.17	Hebrew	Ancient to pre-metric	Dry Capacity	3 gomor, 2003 reference
modius (old)	8.813	19.43	Hebrew	Ancient to pre-metric	Dry Capacity	3 gomor, 2003 reference
momme	0.00375	0.00827	Japan	Post-metric	General, Pearls	10 fun, used especially for pearls, 2003 reference
mommé	0.00375	0.00827	Japan	Post-metric	General, Pearls	10 fun, used especially for pearls, 2003 reference
mon	50.0	110	Afghanistan	Colonial to modern	Narcotics	Used in Quetta
mond	9.95	21.9	Abyssinia	Pre-metric	General	32 rotl, 1891 value
monme	0.00175	0.00386	Japan	Pre-metric	General	1891 value, pre-metric
monme	0.00375	0.00827	Japan	Post-metric	General, Pearls	10 fun, used especially for pearls, 2003 reference

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
moo	0.00204	0.00450	Burma, Birmah, Rangoon, Myanmar	Pre-metric	General	2 pai, 2003 reference
moosa	50.80	112.0	Cyprus	Colonial to pre-metric	General	1891 value
mot can tay	1.00	2.20	Cambodia	Post-metric	General	1000 muoi, 2003 reference
mot dong can tay	0.00100	0.00220	Cambodia	Post-metric	General	2-2/3 hun, 2003 reference
mudd	0.6800	1.499	Arabia	Ancient	Capacity	2003 reference, capacity measure
münzpfund	0.5000	1.102	Austrian Empire	Pre-metric	General	1891 value, post-metric
münzpfund	0.5000	1.102	Germany, Prussia	Medieval to pre-metric	General, Prec. Mtls.	10000 ass, 1891 value, post metric
muoi	0.00100	0.00220	Cambodia	Post-metric	General	2-2/3 hun, 2003 reference
mussa	6.350	14.00	Cyprus	Colonial to pre-metric	General	5 okes, 2003 reference
mutagalla	0.007799	0.01719	Ethiopia	Medieval to pre-metric	Rubber	2 kasm, based on rubber farasula, 2003 reference
myriagramme (1891)	10	22.05	France	Post-metric	General	10 kilogrammes
nail	3.175	7.000	United Kingdom, England	Medieval to pre-metric	General, Avoirdupois	1/16 cwt, 7 pounds
nanki	0.000648	0.00143	Madagascar	Pre-metric	Prec. Mtls.	1891 value
nasch	0.0567	0.125	Arabia	Ancient to Pre-metric	General	4 nevat, 2003 reference
naula	0.426	0.938	Finland	Medieval to pre-metric	General	2 markka, metrinen naula (metric version) = 0.5 kg

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
neal	0.600	1.32	Cambodia	Post-metric	General	600 muoi, 16 tael, 2003 reference
nello (Pondicherry)	0.000024	0.000053	India	Akbar to colonial	General, Prec. Mtls.	0.37 grains, 1891 value
nen	0.3905	0.8609	Annam, Viet Nam	Pre-metric	General	10 luong, 1891 value
nén	0.378	0.833	Viet Nam, Annam	Medieval to pre-metric	General	10 lạng
neter	0.3360	0.7407	Ethiopia	Medieval to pre-metric	Rubber	140/13 wogiet, based on rubber farasula, 2003 reference
neu	0.3775	0.8322	Viet Nam, Annam	Medieval to pre-metric	General	10 luong, 2003 reference
neu-loth	0.01	0.02205	Germany, Prussia	Medieval to pre-metric	General	10 grammes, 1891 value
nevat	0.0142	0.0313	Arabia	Ancient to pre-metric	General	5 dihrem, 2003 reference
Niederlandsch pond	1.000	2.205	Netherlands, Holland	Medieval to metric	General	1891 value, metric "re-purposed" unit
ninsoku-ichi-nin	26.3	57.9	Japan	Post-metric	General	7 kwan, 2003 reference
niú	0.0375	0.0827	Taiwan, Formosa	Pre-metric	General	10 mace
niyo	0.0150	0.0331	Japan	Post-metric	General	4 mommé, 2003 reference
nomisma	0.00455	0.0100	Byzantine Empire	Ancient	General	1/6 Greek ounce
nyang	0.038	0.083	Korea	Medieval to pre-metric	General	10 ton
nyläst	5,101	11,246	Sweden	Medieval to pre-metric	Shipping	30 skeppsund, 2003 reference

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
obol	0.0005903	0.001301	Hebrew, Talmudic, Rabbinical	Ancient to pre-metric	General	2 pondiuses, 2003 reference
obol	0.0006825	0.001505	Egypt	Ancient	General	2003 reference
obol	0.000708	0.00156	Hebrew, Sacred system	Ancient to pre-metric	General	2003 reference
obol (Aeginetic)	0.0011	0.0023	Greece	Ancient	General	
obol (Attic/ Euboic)	0.0007200	0.001587	Greece	Ancient	General	2003 reference
obole	0.0007648	0.001686	France	Medieval to pre-metric	General	12 grains, 2003 reference
obole	0.000765	0.00169	France	Medieval to pre-metric	Prec. Mils.	2 filins, 2003 reference
obolus	0.000570	0.00126	Roman Empire	Ancient	General	1/48 uncia, "metal spit"
obolus (Aeginetic)	0.0011	0.0023	Greece	Ancient	General	
obolus (Attic/ Euboic)	0.0007200	0.001587	Greece	Ancient	General	2003 reference
obulus	0.00071	0.0016	Jewish, Israel	Ancient to modern	General	1/20 shekel
occa	1.237	2.727	Egypt	Pre-metric	General	400 darhims, 1891 value
occa	1.285	2.834	Turkey, Ottoman Empire	Medieval to pre-metric	General	4 chequis, 1891 value
occha	1.279	2.819	Romania, Roumania	Pre-metric	General	4 litra, consistent with 2003 reference
ochava	0.003596	0.007927	Mexico	Colonial to pre-metric	General	1/128 libra, 2 adarme, 2003 reference

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
ochava	0.003601	0.007938	Spain	Medieval to pre-metric	General	2 adammes, 1891 value, reported as 0.003594 kg in 2003 reference
ocque	1.36	3.00	Arabia	Ancient to pre-metric	General	2 man, 2003 reference
offa	0.0321	0.0708	Guinea	Medieval to pre-metric	General	4 uzan, 2003 reference
oitava	0.00359	0.00791	Portugal	Medieval to pre-metric	General	"Eighth" or drachm, 3 escrúpulos, 1/128 arratéis, 2003 reference
oka	1.202	2.649	Crete, Candia	Pre-metric	General	1891 value
oka	1.237	2.727	Egypt	Pre-metric	General	400 darhims, 1891 value
oka	1.248	2.751	Egypt	Pre-metric	General	25/9 rotoli, 2003 reference
oka	1.268	2.796	Cyprus	Colonial to pre-metric	General	1891 value
oka	1.270	2.800	Cyprus	Colonial to pre-metric	General	400 drachme, 2003 reference
oka	1.279	2.819	Romania, Roumania	Pre-metric	General	4 litra, consistent with 2003 reference
oka	1.279	2.819	Serbia, Servia	Medieval to pre-metric	General	4 litra, 2.82 lbs av, 1891 value
oka	1.280	2.822	Greece	Pre- and post-metric	General	2.5 pounds, pre-metric, 2003 reference
oka	1.280	2.822	Yugoslavia	Pre-metric	General	4 litra, 2003 reference
oka	1.282	2.826	Libya	Medieval to pre-metric	General	40 uckin, 2003 reference
oka	1.283	2.828	Turkey, Ottoman Empire	Medieval to pre-metric	General	4 yusdrum, 2003 reference
oka	1.33	2.93	Hungary	Medieval to pre-metric	General	Varied from 2.78 to 3.082 lb av, used 2.92 lb, 1891 value
oka	1.36	3.00	Arabia	Ancient to pre-metric	General	2 man, 2003 reference
oke	1.22	2.70	Ionian Islands	Pre-metric	General	Old value

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
oke	1.237	2.727	Egypt	Pre-metric	General	400 darhims, 1891 value
oke	1.24	2.73	Greece	Pre- and post-metric	General	1891 value, post metric
oke	1.244	2.743	Tripoli, Libya	Pre-metric	General	1/40 cantaro, 1891 value
oke	1.248	2.751	Egypt	Pre-metric	General	25/9 rotoli, 2003 reference
oke	1.270	2.800	Cyprus	Colonial to pre-metric	General	400 drachme, 2003 reference
oke	1.285	2.834	Turkey, Ottoman Empire	Medieval to pre-metric	General	4 chequis, 1891 value
okia	0.0280	0.0617	Eretria	Medieval to pre-metric	General	Ounce, 1/16 rotolo, 2003 reference
okia	0.028	0.062	Somalia	Medieval to pre-metric	General	Ounce, 1/16 rottolo, 2003 reference
okieh	0.0374	0.0825	Egypt	Pre-metric	General	0.03 oke
okieh	0.3370	0.7429	Egypt	Pre-metric	General	3 miskal, 2003 reference
okka	1.28	2.83	Ottoman Empire, Turkey	Medieval to pre-metric	General	400 dirhem, "oka"
öleş	0.0000444	0.0000980	Tatar	Medieval to pre-metric	General	
onça	0.02869	0.06325	Brazil	Colonial to pre-metric	General	Ounce, 2003 reference
once	0.02559	0.05642	Russia	Medieval to pre-metric	General	2 loth, 2003 reference
once	0.02975	0.06559	Syria	Medieval to pre-metric	General	Ounce, 10 pesi, 2003 reference
once	0.02986	0.06583	Russia	Medieval to pre-metric	Apothecaries'	Ounce, 480 grains, 1891 value, consistent with 2003 reference
once	0.03059	0.06744	France	Medieval to pre-metric	General	"French ounce", 2 lot, 2003 reference
once	0.03059	0.06745	Belgium	Pre-metric	General	2 loth, 2003 reference

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
once	0.03076	0.06781	Netherlands, Holland	Medieval to metric	General	Ounce, 8 drachme, 2003 reference
once	0.0313	0.0689	France	Post-metric (1840)	General	8 gros, old name, metric definition
once	0.03125	0.06889	Switzerland	Medieval to metric	General	2 loth, "ounce", 1891 value, consistent with 2003 reference
once	0.0313	0.0689	Switzerland	Medieval to metric	Apothecaries'	8 drachmes, 1891 value, consistent with 2003 reference
once (Amsterdam)	0.0309	0.0681	Netherlands, Holland	Medieval to metric	General	"Ounce", Amsterdam basis, 1/16 pond, pre-1800
once (new)	0.0287	0.0632	Paraguay	Colonial to pre-metric	General	Ounce, 2003 reference
once (old)	0.02876	0.06339	Paraguay	Colonial to pre-metric	General	Ounce, 2003 reference
once (Palermo)	0.0264	0.0582	Italy	Medieval to pre-metric	General	
uncia (Ancona)	0.02751	0.06064	Italy	Medieval to pre-metric	General	24 denari, 1891 value
uncia (Bologna)	0.0302	0.0665	Italy	Medieval to pre-metric	General	8 ottavi, 1891 value
uncia (Genoa)	0.02647	0.05835	Italy	Medieval to pre-metric	General	24 denari, 1891 value
uncia (Modena)	0.02663	0.05870	Italy	Medieval to pre-metric	General	16 ferlini, 1891 value
uncia (Naples)	0.02673	0.05893	Italy	Medieval to pre-metric	Apothecaries'	10 drachme, 1891 value
uncia (Naples)	0.02673	0.05893	Italy	Medieval to pre-metric	Prec. Mtls., Drugs, Pigments	10 dramme, 1891 value
uncia (Parma)	0.02720	0.05997	Italy	Medieval to pre-metric	General	24 denari, 1891 value
uncia (Rome, Roman States)	0.02826	0.06231	Italy	Medieval to pre-metric	General	24 denari, based on Roman libbra
uncia (Sardinia, Piedmont, Turin)	0.03074	0.06778	Italy	Medieval to pre-metric	General	8 ottavi, 1891 value

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
uncia (Sicily)	0.02673	0.05894	Italy	Medieval to pre-metric	General	1891 value
uncia (Tuscany)	0.02830	0.06238	Italy	Medieval to pre-metric	General	8 dramme, 1891 value
uncia (typical)	0.0256	0.0564	Italy	Medieval to pre-metric	General	Ounce, 8 ottavo, pre-1861, 2003 reference
uncia (Venetian Lombardy)	0.02938	0.06477	Italy	Medieval to pre-metric	Prec. Mils.	24 denari, pre-metric
uncia (Venetian Lombardy)	0.1000	0.2205	Italy	Post-metric	General	10 grossi, post-metric, old name, metric definition
uncia grosso (Sicily)	0.02646	0.05833	Italy	Medieval to pre-metric	General	1891 value
uncia sottile (Sicily)	0.02646	0.05833	Italy	Medieval to pre-metric	General	1891 value
ons	0.03076	0.06781	Netherlands, Holland	Medieval to metric	General	Ounce, 8 drachme, 2003 reference
ons	0.1000	0.2205	Netherlands, Holland	Medieval to metric	General	1891 value, metric "re-purposed" unit
ons (Amsterdam)	0.0309	0.0681	Netherlands, Holland	Medieval to metric	General	"Ounce", Amsterdam basis, 1/16 pond, pre-1800
onza	0.02869	0.06325	Brazil	Colonial to pre-metric	General	Ounce, 2003 reference
onza	0.02871	0.06330	Argentina	Colonial to pre-metric	General	1/16 libra, 16 adarme, 2003 reference
onza	0.02876	0.06339	Chile	Colonial to pre-metric	General	Ounce, 16 adarme, 2003 reference
onza	0.02877	0.06342	Mexico	Colonial to pre-metric	General	Ounce, 1/16 libra, 8 ochava, 2003 reference
onza	0.0313	0.0689	Colombia	Colonial to metric	General	Ounce, 1/16 libra, 2003 reference

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
onza	0.031	0.069	Venezuela	Post-metric	General	1/16 libra, older value estimated at 0.029 kg, old name, metric definition
onza	0.02881	0.06351	Spain	Medieval to pre-metric	General	8 ochavas, 1891 value, reported as 0.02876 kg in 2003 reference
onça	0.0287	0.0632	Portugal	Medieval to pre-metric	General	“Ounce”, 8 oitavas, 1/16 arratéis, 2003 reference
ootan (camphor)	1.8	4.0	Sumatra	Pre-metric	Camphor	1891 value
ootan (Sumatra)	1.81	4.00	Indonesia	Colonial to pre-metric	Camphor	4 lb av
ort	0.0009123	0.002011	Denmark	Medieval to pre-metric	Prec. Mtls.	1891 value
ort	0.00097	0.00215	Norway	Medieval to pre-metric	General	1/512 pund, “grain”
ort	0.000977	0.00215	Denmark	Medieval to pre-metric	General	17-7/8 es, 2003 reference
ort	0.004236	0.009338	Sweden	Medieval to pre-metric	General	100 korns, 1891 value
ort	0.004251	0.009371	Sweden	Medieval to pre-metric	General	10 korn, 2003 reference
ort	0.005000	0.01102	Denmark	Medieval to pre-metric	General	1891 value
ort (Bremen)	0.0009737	0.002147	Germany, Prussia	Medieval to pre-metric	General	1891 value
örtche (Hanover)	0.0009563	0.002108	Germany, Prussia	Medieval to pre-metric	General	1891 value
ottav	0.003307	0.007291	Malta	Medieval to pre-metric	General	1/8 uqija, “eighth”, 1921 act only
ottavo (Bologna)	0.0038	0.0083	Italy	Medieval to pre-metric	General	2 ferlini, 1891 value
ottavo (Sardinia, Piedmont, Turin)	0.003843	0.008472	Italy	Medieval to pre-metric	General	3 denari, 1891 value
ottavo (typical)	0.00320	0.00705	Italy	Medieval to pre-metric	General	Drachm, 3 denaro, pre-1861, 2003 reference

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
oukia	0.113	0.249	Arabia	Ancient to pre-metric	General	2 nasch, 2003 reference
ounce	0.01411	0.03110	United States	Colonial to modern	Apothecaries'	8 dr apoth
ounce	0.02559	0.05642	Russia	Medieval to pre-metric	General	2 loth, 2003 reference
ounce	0.0273	0.0602	Byzantine Empire	Ancient	General	= Roman uncia
ounce	0.028	0.062	Ireland	Medieval to pre-metric	General	72 penny, from Latin
ounce	0.02835	0.06250	United Kingdom, England	Medieval to pre-metric	Wool	
ounce	0.0283	0.0625	United States	Colonial to modern	General, Avoirdupois	16 dr
ounce	0.02835	0.06250	United Kingdom, England	Medieval to pre-metric	General, Avoirdupois	16 dram, 437.5 grains
ounce	0.02835	0.06250	Malta	Medieval to pre-metric	General	16 partos, 2003 reference
ounce	0.03084	0.06800	Scotland	Medieval to pre-metric	General	16 drops, 2003 reference
ounce	0.0311	0.0686	United Kingdom, England	Medieval to pre-metric	Apothecaries'	480 gr ap, 8 drachms
ounce avoirdupois	0.0283	0.0625	India	Colonial to pre-metric	General	
ounce Tower	0.0290	0.0639	United Kingdom, England	Medieval to 1526	Prec. Mtls., Coins	24 dwt T, 640 gr T
ounce troy	0.03115	0.06867	United Kingdom, England	1526 to pre-metric	Prec. Mtls., Coins	480 grains, 20 pennyweight

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
outava	0.00359	0.00791	Portugal	Medieval to pre-metric	General	"Eighth" or drachm, 3 escrúpulos, 1/128 arratéis, 2003 reference
outava	0.003705	0.008167	Brazil	Colonial to pre-metric	Topaz	57.17 grains
outen	0.21	0.47	Egypt	Ancient	Capacity	2003 reference
oz	0.0283	0.0625	United States	Colonial to modern	General, Avoirdupois	16 dr
oz	0.02835	0.06250	United Kingdom, England	Medieval to pre-metric	General, Avoirdupois	16 dram, 437.5 grains
oz ap	0.0311	0.0686	United Kingdom, England	Medieval to pre-metric	Apothecaries'	480 gr ap, 8 drachms
oz apoth	0.01411	0.03110	United States	Colonial to modern	Apothecaries'	8 dr apoth
oz T	0.0290	0.0639	United Kingdom, England	Medieval to 1526	Prec. Mtls., Coins	24 dwt T, 640 gr T, Tower
oz t	0.0311	0.0686	United States	Colonial to Modern	Prec. Mtls.	20 dwt
oz t	0.03115	0.06867	United Kingdom, England	1526 to pre-metric	Prec. Mtls., Coins	480 grains, 20 pennyweight, troy
packen	491.4	1.083	Russia	Medieval to pre-metric	General	3 berkovetz, 1891 value
pagoda	0.007087	0.01562	Ceylon, Sri Lanka	Pre-metric	General	36 fanam, 2003 reference
pagoda (Madras)	0.003544	0.007812	India	Akbar to colonial	General	1891 value
pahaw	0.00995	0.0219	Borneo	Pre-metric	General	4 mace

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
pai	0.000469	0.00103	Thailand, Siam	Pre- and post-metric	General	2 klam, 2003 reference
pai	0.00102	0.00225	Burma, Birmah, Rangoon, Myanmar	Pre-metric	General	4 ruay, 2003 reference
pala	0.0470	0.104	India	Akbar to colonial	General	4 tola, 1966 value
pally	4.665	10.28	India	Akbar to colonial	General	4 raik, 2003 reference
panch (5) seer	4.7	10	India	Medieval to Akbar	General	5 seer
pao (Bengal)	0.370	0.816	India	Akbar to colonial	General, Grain	1891 value
parah	0.03110	0.06857	India	Akbar to colonial	General	32 masha, 2003 reference
parto	0.001772	0.003906	Malta	Medieval to pre-metric	General	2003 reference
paseri	4.7	10	India	Medieval to Akbar	General	5 seer
pav	0.23	0.51	India	Medieval to Akbar	General	2 adh-pav, 1/4 seer
payim	0.00762	0.0168	Biblical, Talmudic	Ancient	General	1-1/3 dinar, based on Oxford Biblical Studies Online
pdl	0.01410	0.03108	United Kingdom, England	Medieval to pre-metric	General, Avoirdupois	Unit of mass, equivalent kg force
pdl	0.0141	0.0311	United States	Colonial to modern	General, Avoirdupois	Unit of mass, equivalent kg force
pecul	60.0	132	Philippines	Medieval to pre-metric	General	100 catty, 2003 reference
pecul	60.5	133	Sumatra	Pre-metric	General	1891 value
pecul	60.48	133.3	China	Medieval to pre-metric	General	50 yin, 1891 value

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
pecul	60.49	133.4	Thailand, Siam	Pre- and post-metric	General	50 catties, 1891 value
pecul	61.2	135	Malacca	Pre-metric	General	100 catties, 1891 value
pecul	61.5	136	Java	Colonial to pre-metric	General	100 catties, 1891 value
pecul	61.52	135.6	Borneo	Pre-metric	General	
pecul	61.53	135.6	Celebes	Pre-metric	General	
pecul	61.76	136.2	Indonesia	Colonial to pre-metric	General	100 catty, 2003 reference
pecul (Java, Celebes, modern Sulawesi)	61.5	136	Indonesia	Colonial to pre-metric	General	100 catties
pecul (Sumatra)	60.5	133	Indonesia	Colonial to pre-metric	General	133 1/3 lb av
penny	0.0004	0.0009	Ireland	Medieval to pre-metric	General	
pennyweight Tower	0.00146	0.00322	United Kingdom, England	Medieval to 1526	Prec. Mtls., Coins	22.5 gr t, 32 gr T
pennyweight troy	0.001558	0.003434	United Kingdom, England	1526 to pre-metric	Prec. Mtls., Coins	24 grains
pesi	0.002975	0.006559	Syria	Medieval to pre-metric	General	1/600 rottolo, 2003 reference
peso grosso (Genoa)	0.3494	0.7702	Italy	Medieval to pre-metric	General	1/10 higher than ordinary libbra, 1891 value
pežata	238.1	524.9	Malta	Medieval to pre-metric	General	300 ratat, mentioned in 1921 act only
pfenig	0.001094	0.002411	Austrian Empire	Pre-metric	General	1891 value, consistent with 2003 reference

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
pfennig	0.001094	0.002411	Austrian Empire	Pre-metric	Prec. Mils.	1891 value
pfennig (Austrian system)	0.0009135	0.002014	Germany, Prussia	Medieval to pre-metric	General	15 gran, 2003 reference
pfennig (Baden)	0.0005000	0.001102	Germany, Prussia	Medieval to pre-metric	General	10 ass, 1891 value
pfennig (Brunswick)	0.0009129	0.002013	Germany, Prussia	Medieval to pre-metric	General	2 heller, 1891 value
pfennig (Frankfort)	0.000987	0.002176	Germany, Prussia	Medieval to pre-metric	General	2 heller, 1891 value
pfennig (Hamburg)	0.0009461	0.002086	Germany, Prussia	Medieval to pre-metric	General	1891 value
pfennig (Saxony)	0.0009130	0.002013	Germany, Prussia	Medieval to pre-metric	General	15 gran
pfennige	0.001094	0.002411	Austrian Empire	Pre-metric	General	1891 value, consistent with 2003 reference
pfennige (Lubeck)	0.0009468	0.002087	Germany, Prussia	Medieval to pre-metric	General	1891 value
pfund	0.3579	0.7890	Germany, Prussia	Medieval to pre-metric	Apothecaries'	12 unzen
pfund	0.419	0.924	Latvia	Medieval to pre-metric	General	32 loth, 2003 reference
pfund	0.4212	0.9286	Austrian Empire	Pre-metric	Apothecaries'	6499 troy grains, 12 unzen, 1891 value, also reported as 0.4200 kg in 2003 reference
pfund	0.460	1.01	Estonia	Medieval to pre-metric	General	Pound, 32 loth, 2003 reference

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
pfund	0.500	1.10	Germany, Prussia	Medieval to pre-metric	General	Metric pfund, 1891 value
pfund	0.5000	1.102	Switzerland	Medieval to metric	General	Defined at transition to metric, "Swiss pound", Zollverein pfund, 16 ounces, 1891 value, consistent with 2003 reference
pfund	0.5600	1.235	Austrian Empire	Pre-metric	General	2 mark, 1891 value, slightly less in Bohemia, consistent with 2003 reference
pfund (Austrian system)	0.4677	1.031	Germany, Prussia	Medieval to pre-metric	General	Pound, 32 loth, 2003 reference
pfund (Baden)	0.5000	1.102	Germany, Prussia	Medieval to pre-metric	General	10 zehning, 1891 value, post-metric
pfund (Bavaria)	0.500	1.10	Germany, Prussia	Medieval to pre-metric	General	4 vierling, 1891 value, post-metric
pfund (Bavaria)	0.560	1.23	Germany, Prussia	Medieval to pre-metric	General	16 unzen, 1891 value
pfund (Bremen)	0.4985	1.099	Germany, Prussia	Medieval to pre-metric	General	2 mark, 1891 value
pfund (Brunswick)	0.4674	1.030	Germany, Prussia	Medieval to pre-metric	General	2 mark, 1891 value
pfund (Frankfort)	0.5053	1.114	Germany, Prussia	Medieval to pre-metric	General	2 mark, also a lighter mark reported at 92.6% of this value, 1891 value
pfund (Hamburg)	0.4844	1.068	Germany, Prussia	Medieval to pre-metric	General	2 mark, 1891 value

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
pfund (Hanover)	0.4896	1.079	Germany, Prussia	Medieval to pre-metric	General	2 mark, 1891 value
pfund (Hesse-Cassel)	0.4842	1.068	Germany, Prussia	Medieval to pre-metric	General	16 unzen, 1891 value
pfund (Hesse-Darmstadt)	0.5000	1.102	Germany, Prussia	Medieval to pre-metric	General	32 loth, 1821 value, previously same as Frankfurt, post-metric
pfund (Lubeck)	0.4848	1.069	Germany, Prussia	Medieval to pre-metric	General	2 mark, 1891 value
pfund (new)	0.500	1.10	Prussia, Germany	Post-metric	General	30 loth, Zollverein pfund, post-metric value
pfund (old)	0.4677	1.031	Prussia, Germany	Pre-metric	General	2 mark, pre-metric value
pfund (Saxony)	0.4675	1.031	Germany, Prussia	Medieval to pre-metric	General	2 mark
pfund (Württemberg)	0.5000	1.102	Germany, Prussia	Medieval to pre-metric	General	Zollverein units, 1891 value, post-metric
pfund (Württemberg, apothecary)	0.3576	0.7884	Germany, Prussia	Medieval to pre-metric	General	1891 value, divided further consistent with other apothecaries' measures
pfundschwer (Bremen)	149.6	329.7	Germany, Prussia	Medieval to pre-metric	General	300 pfund, 1891 value
phan	0.000391	0.000861	Annam, Viet Nam	Pre-metric	General	10 ly, 1891 value
phân	0.000378	0.000833	Viet Nam, Annam	Medieval to pre-metric	General	10 ly
pice (Bombay)	0.0106	0.0233	India	Akbar to colonial	General	1891 value

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
picul	50.00	110.2	China	Post-metric (1930–1958)	General	“Chinese hundredweight”, 100 jīn, old name, metric definition
picul	50.00	110.2	China	Post-metric (Since 1959)	General	“Chinese hundredweight”, 100 jīn, old name, metric definition
picul	60.00	132.3	Cambodia	Post-metric	General	600,000 muoi, 2 chong, 2003 reference
picul	60.0	132	Taiwan, Formosa	Pre-metric	General	100 catties
picul	60.40	133.2	Viet Nam, Annam	Medieval to Pre-metric	General	2 binh, 2003 reference
picul	61.76	136.2	Indonesia	Colonial to Pre-metric	General	100 catty, 2003 reference
pikol	61.76	136.2	Indonesia	Colonial to Pre-metric	General	100 catty, 2003 reference
pim	0.00762	0.0168	Biblical, Talmudic	Ancient	General	1-1/3 dinar, based on Oxford Biblical Studies Online
pim	0.0131	0.0289	Biblical, Talmudic	Ancient	General	1-1/3 dinar, based on heavy common talent
pim	0.0135	0.0297	Biblical, Talmudic	Ancient	General	1-1/3 dinar, based on heavy royal talent
pinar	0.0920	0.203	Persia, Iran	Ancient to pre-metric	General	10 dirhem, 2003 reference
pince	0.03110	0.06857	India	Akbar to Colonial	General	32 masha, 2003 reference
pinginn	0.0004	0.0009	Ireland	Medieval to pre-metric	General	
piso	0.00803	0.0177	Guinea	Medieval to pre-metric	General	2 aguirage, 2003 reference
poids-de-marce	0.4896	1.079	France	Medieval to pre-metric	General	Ancient pound as reported 1891
pollam	0.03544	0.07812	Ceylon, Sri Lanka	Pre-metric	General	5 pagoda, 2003 reference

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
pollam (Madras)	0.03544	0.07812	India	Akbar to colonial	General	10 pagodas, 1891 value
pond	0.5000	1.102	Netherlands, Holland	Medieval to metric	General	2014 value, metric “re-purposed” unit, also referred to English pound until officially eliminated in 1937, but still used today.
pond	0.4922	1.085	Netherlands, Holland	Medieval to metric	General	Ordinary pound, 2 mark, 2003 reference
pondiuscule	0.0002952	0.0006507	Hebrew, Talmudic, Rabbinical	Ancient to pre-metric	General	2003 reference
pood	16.38	36.11	Russia	Medieval to pre-metric	General	40 funts, 12th century, still found in used for agricultural products and bells, 1891 value, consistent with 2003 reference
pot	16.4	36.1	Tatar	Medieval to pre-metric	General	40 qadaq
pound	0.1693	0.3732	United States	Colonial to modern	Apothecaries’	12 oz apoth
pound	0.373	0.823	United Kingdom, England	Medieval to pre-metric	Apothecaries’	1 lb t, 12 oz ap
pound	0.4536	0.9999	United Kingdom, England	Medieval to pre-metric	Wool	16 ounces (wool), same as avoirdupois pound
pound	0.4536	1.000	United Kingdom, England	Medieval to pre-metric	General, Avoirdupois	7000 grains, 16 ounces
pound	0.4536	1.000	United States	Colonial to modern	General, Avoirdupois	Base unit, technically a unit of mass

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
pound	0.4536	1.000	United Kingdom, England	Medieval to pre-metric	Coal	Same as avoirdupois pound
pound	0.454	1.00	United Kingdom, England	Medieval to pre-metric	New Hay	
pound	0.4609	1.016	Spain	Medieval to pre-metric	General	2 marcos, 1891 value, reported as 0.4601 kg in 2003 reference
pound	0.486	1.07	United Kingdom, England	Medieval to pre-metric	Old Hay	1.071 pounds (new hay)
pound	0.5120	1.129	Greece	Pre- and post-metric	General	Pre-metric, 2003 reference
pound	0.6169	1.360	Scotland	Medieval to pre-metric	General	Scottish pound, 20 ounces, 2003 reference
pound	0.756	1.67	United Kingdom, England	Medieval to pre-metric	Straw	1-2/3 lbs (new hay)
pound (Suffolk)	0.4536	1.000	United Kingdom, England	Medieval to pre-metric	Butter, Cheese	Avoirdupois basis, Suffolk
pound avoirdupois	0.454	1.00	India	Colonial to pre-metric	General	16 ounces av
pound Tower	0.349	0.770	United Kingdom, England	Medieval to 1526	Prec. Mils., Coins	12 oz T, 7680 gr T
pound troy	0.3738	0.8241	United Kingdom, England	1526 to pre-metric	Prec. Mils., Coins	12 oz t, 5760 gr

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
poundal	0.01410	0.03108	United Kingdom, England	Medieval to pre-metric	General, Avoirdupois	Unit of mass, equivalent kg force
poundal	0.0141	0.0311	United States	Colonial to modern	General, Avoirdupois	Unit of mass, equivalent kg force
powa	0.07087	0.1562	Ceylon, Sri Lanka	Pre-metric	General	2 pollam, 2003 reference
powa	0.2333	0.5142	India	Akbar to colonial	General	4 chittak, 2003 reference
pram roi	1.00	2.20	Cambodia	Post-metric	General	1000 muoi, 2003 reference
prime	0.000002213	0.000004879	France	Medieval to pre-metric	General	1/24 ³ once, 2003 reference
pud	16.38	36.11	Russia	Medieval to pre-metric	General	40 funts, 12th century, still found in used for agricultural products and bells, 1891 value, consistent with 2003 reference
p'un	0.00038	0.00083	Korea	Medieval to pre-metric	General	0.0075 US ounces roughly
pund	0.3563	0.7856	Norway	Medieval to pre-metric	Apothecaries'	7416 as, 12 untz, 1891 value
pund	0.3579	0.7890	Denmark	Medieval to pre-metric	Apothecaries'	12 unze, 1891 value
pund	0.4981	1.098	Norway	Medieval to pre-metric	General	2 merker, 0.4667 before 1683, "pound", value is consistent with 2003 reference
pund	0.4998	1.102	Denmark	Medieval to pre-metric	General	"Pound" from 1683, weight of 1/62 cubic fod (foot) of water
pund	0.500	1.10	Iceland	Medieval to metric	General	Pound, post-metric value, 2003 reference

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
pund	0.5000	1.102	Denmark	Medieval to pre-metric	General	Same as German Zollverein, 2 mark, 10 quint, 1891 value, consistent with 2003 reference
pund (old)	0.4994	1.101	Denmark	Medieval to pre-metric	General	Early 1800s value?
punto	0.200	0.441	Philippines	Medieval to pre-metric	General	2003 reference
puri	1	2.2	Afghanistan	Colonial to modern	Narcotics	Slightly less, approx, Narcotics
pussaree (Bengal)	4.66	10.3	India	Akbar to colonial	General	1891 value
qadaq	0.4095	0.9028	Tatar	Medieval to pre-metric	General	96 misqal, 32 lot
qantar	41.0	90.3	Tatar	Medieval to pre-metric	General	2-1/2 pot
qantar	79.38	175.0	Malta	Medieval to pre-metric	General	100 ratat, consistent with 2003 reference
qd.t	0.00136	0.00300	Egypt	Ancient—Old & Mid Kingdom	Prec. Mtls.	1/10 deben, for silver & gold
qd.t	0.00910	0.0201	Egypt	Ancient—New Kingdom	Prec. Mtls.	1/10 deben, for silver & gold
qedet	0.00136	0.00300	Egypt	Ancient—Old & Mid Kingdom	Prec. Mtls.	1/10 deben, for silver & gold
qedet	0.00910	0.0201	Egypt	Ancient—New Kingdom	Prec. Mtls.	1/10 deben, for silver & gold
qián	0.00313	0.00689	China	Post-metric (1930–1958)	General	1/160 jīn, old name, metric definition
qián	0.003730	0.008223	China	Pre-metric (1915–1929)	General	1/10 liǎng
qián	0.00375	0.00827	Taiwan, Formosa	Pre-metric	General	10 candareens
qián	0.00500	0.0110	China	Post-metric (Since 1959)	General	1/160 jīn, old name, metric definition
qisma	0.9922	2.187	Malta	Medieval to pre-metric	General	1.25 ratat, Aquilina reference

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
quadrans	0.08175	0.1802	Roman Empire	Ancient	General	1/4 libra, “fourth” or “triple twelfth”, 2003 reference
quân	302.3	666.3	Viet Nam, Annam	Medieval to pre-metric	General	5 tạ, under metric = 500 kg
quần	312.4	688.8	Annam, Viet Nam	Pre-metric	General	5 tạ, 1891 value
quanthar	34.0	75.0	Arabia	Ancient to pre-metric	General	25 oka, 2003 reference
quarta	0.115	0.253	Portugal	Medieval to pre-metric	General	“Fourth”, 4 onças, 1/4 arratéis
quartano	3.67	8.10	Balearic Islands	Pre-metric	General	3 libra mayors, 2003 reference
quarter	12.70	28.00	United Kingdom, England	Medieval to pre-metric	General, Avoirdupois	1/4 hundredweight, 2 stone
quarter	12.70	28.00	United Kingdom, England	Medieval to pre-metric	Coal	2 stones
quarteron	0.1224	0.2698	France	Medieval to pre-metric	General	4 onces, 2003 reference
quent	0.00327	0.00722	Latvia	Medieval to pre-metric	General	2003 reference
quent	0.00336	0.00741	Estonia	Medieval to pre-metric	General	1/128 pfund, 2003 reference
quentchen	0.004375	0.009645	Austrian Empire	Pre-metric	General	4 pfennige, 1891 value, consistent with 2003 reference
quentchen	0.004375	0.009645	Austrian Empire	Pre-metric	Prec. Mils.	4 pfennig, 1891 value
quentchen (Austrian system)	0.004872	0.01074	Germany, Prussia	Medieval to pre-metric	General	80 gran, 2003 reference

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
quentchen (Bavaria)	0.00391	0.00861	Germany, Prussia	Medieval to pre-metric	General	1891 value
quentchen (Bavaria, commercial)	0.00438	0.00965	Germany, Prussia	Medieval to pre-metric	General	1891 value
quentchen (Bremen)	0.003895	0.008586	Germany, Prussia	Medieval to pre-metric	General	4 ort, 1891 value
quentchen (Brunswick)	0.003652	0.008050	Germany, Prussia	Medieval to pre-metric	General	4 pfennige, 1891 value
quentchen (Frankfort)	0.00395	0.00870	Germany, Prussia	Medieval to pre-metric	General	4 pfennig, 1891 value
quentchen (Hamburg)	0.003784	0.008343	Germany, Prussia	Medieval to pre-metric	General	4 pfennige, 1891 value
quentchen (Hanover)	0.003825	0.008433	Germany, Prussia	Medieval to pre-metric	General	4 ortchen, 1891 value
quentchen (Hesse-Cassel)	0.003783	0.008340	Germany, Prussia	Medieval to pre-metric	General	1891 value
quentchen (Hesse-Darmstadt)	0.003906	0.008612	Germany, Prussia	Medieval to pre-metric	General	4 richtpfennig, 1821 value, previously same as Frankfort
quentchen (Lubeck)	0.003787	0.008350	Germany, Prussia	Medieval to pre-metric	General	4 pfennige, 1891 value
quentchen (new)	0.00167	0.00367	Prussia, Germany	Post-metric	General	10 zent, post-metric value
quentchen (old)	0.004	0.008	Prussia, Germany	Pre-metric	General	Pre-metric value

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
quentein (Saxony)	0.003652	0.008052	Germany, Prussia	Medieval to pre-metric	General	4 pfennige
quilate	0.0001993	0.0004393	Brazil	Colonial to pre-metric	Gems	3.075 grains
quincunx	0.1363	0.3005	Roman Empire	Ancient	General	5/12 libra, "five-twelfths", 2003 reference
quint	0.05000	0.1102	Denmark	Medieval to pre-metric	General	10 ort, 1891 value
quint (Austrian system)	0.003654	0.008056	Germany, Prussia	Medieval to pre-metric	General	4 pfennig, 2003 reference
quintal	45.36	100.0	United States	Colonial to modern	General, Avoirdupois	100 lb
quintal	45.94	101.3	Argentina	Colonial to Pre-metric	General	4 arrobas, 100 libra, 1891 value, consistent with 2003 reference
quintal	46.00	101.4	Bolivia	Pre-metric	General	4 arrobas, 1891 value
quintal	46.01	101.4	Peru	Colonial to pre-metric	General	100 libra, 4 arroba, still used in 1891, consistent with 2003 reference
quintal	46.02	101.5	Mexico	Colonial to pre-metric	General	100 libra, 4 arrobas, 2003 reference
quintal	46.09	101.6	Spain	Medieval to pre-metric	General	4 arrobas, 1891 value, reported as 46.01 kg in 2003 reference
quintal	47.31	104.3	Central America	Colonial to pre-metric	General	4 arrobas, 1891 value
quintal	47.31	104.3	Costa Rica	Colonial to pre-metric	General	4 arrobas, 1891 value
quintal	47.31	104.3	El Salvador	Colonial to pre-metric	General	4 arrobas, 1891 value
quintal	47.31	104.3	Guatemala	Colonial to pre-metric	General	4 arrobas, 1891 value
quintal	47.31	104.3	Honduras	Colonial to pre-metric	General	4 arrobas, 1891 value

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
quintal	47.31	104.3	Nicaragua	Colonial to pre-metric	General	4 arrobas, 1891 value
quintal	48.95	107.9	Belgium	Pre-metric	General	100 livre, 2003 reference
quintal	48.95	107.9	France	Medieval to pre-metric	General	“French hundredweight”
quintal	50.00	110.2	Colombia	Colonial to metric	General	100 libra, 2003 reference
quintal	50.00	110.2	Switzerland	Medieval to metric	General	100 livres, 1891 value
quintal	50.0	110	Venezuela	Post-metric	General	100 libra, older value reported as 46.0 kg, old name, metric definition
quintal	58.8	130	Portugal	Medieval to pre-metric	General	4 arrobas, 128 arratéis, 2003 reference
quintal	58.76	129.5	Brazil	Colonial to pre-metric	General	128 libras, 4 arroba, 2003 reference
quintal (Austrian system)	51.45	113.4	Germany, Prussia	Medieval to pre-metric	General	5 stein, 2003 reference
quintal (new)	45.9	101	Paraguay	Colonial to pre-metric	General	100 libra, 2003 reference
quintal (old)	46.01	101.4	Paraguay	Colonial to pre-metric	General	100 libra, 2003 reference
quintale	46.01	101.4	Chile	Colonial to pre-metric	General	100 libra, 4 arroba, 2003 reference
quintin	0.003649	0.008045	Denmark	Medieval to pre-metric	Prec. Mills.	4 ort, 1891 value
quintin	0.00391	0.00861	Denmark	Medieval to pre-metric	General	4 ort, 2003 reference
quinto	0.00602	0.0133	Guinea	Medieval to pre-metric	General	3 mediatabla, 2003 reference
quital (1891)	100	220.5	France	Post-metric	General	10 myrigrammes
quito	0.00602	0.0133	Guinea	Medieval to pre-metric	General	3 mediatabla, 2003 reference
quontar attari	54.6	120	Algeria	Medieval to pre-metric	Spices	100 rotl, 1891 value
quontar feuddi	49.7	110	Algeria	Medieval to pre-metric	Gold, Silver	100 rotl, 1891 value
quontar gheddari	61.43	135.4	Algeria	Medieval to pre-metric	General, Fruit	100 rottolo à khadhary
quontar khebir	81.91	180.6	Algeria	Medieval to pre-metric	General	100 rottolo à kebyr

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
qwintin	0.003321	0.007322	Sweden	Medieval to pre-metric	General	1/4 lod, 2003 reference
qwintin	0.003292	0.007256	Norway	Medieval to pre-metric	Prec. Mtls., Fine Goods	1891 value
qwintin	0.003322	0.007323	Norway	Medieval to pre-metric	General	1891 value
rabah	0.00354	0.00781	Hebrew, Sacred system	Ancient to pre-metric	General	5 gerah, 2003 reference
raik	1.166	2.571	India	Akbar to colonial	General	5 powa, 2003 reference
ratat	0.7938	1.750	Malta	Medieval to pre-metric	General	Consistent with 1891 value
ratata	0.000147	0.000324	India	Akbar to colonial	General	10 yava, 1966 value
ratl	0.4500	0.9921	Saudi Arabia	Pre-metric	General	13-1/3 tukeas, 2003 reference
rattal (Tauris)	0.479	1.06	Persia, Iran	Ancient to pre-metric	General	50 dirhems, 1891 value
ratti	0.00012	0.00027	India, Northern	Medieval to Akbar	General	4 dhan, seed of the <i>abrus precatorius</i> plant
rattis	0.00011	0.00025	India	Akbar to colonial	General	1.75 grains, before 1833
reaal	0.0270	0.0596	Indonesia	Colonial to pre-metric	Prec. Mtls.	1/2 thail
real	0.01930	0.04255	Indonesia	Colonial to pre-metric	General	4 soekoe, 2003 reference
retti	0.000147	0.000324	India	Akbar to colonial	General	10 yava, 1966 value
richpfennig (Hesse-Darmstadt)	0.0009766	0.002153	Germany, Prussia	Medieval to pre-metric	General	1821 value, previously same as Frankfort
rik (Teheran)	7.75	17.1	Persia, Iran	Ancient to pre-metric	General	1600 miscals, 1891 value
rin	0.0000375	0.0000827	Japan	Post-metric	General	10 mō, 2003 reference
rittee (Bombay)	0.00052	0.0011	India	Akbar to colonial	General, Pearls	8 grains, 1891 value
rijo	0.00753	0.0166	Japan	Pre-metric	General	1891 value, pre-metric

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
roll	0.6804	1.500	United Kingdom, England	Medieval to pre-metric	Butter, Cheese	24 oz av, Suffolk
Roman pound	0.3276	0.7222	Byzantine Empire	Ancient	General	72 gold solidi, circa 309 AD, reduced over time to 0.319 kg by 9th century
room	7,112	15,680	United Kingdom, England	Medieval to pre-metric	Coal	7 long tons
rotal	0.5075	1.119	Morocco	Colonial to pre-metric	General	2003 reference
rotl	0.311	0.686	Abyssinia	Pre-metric	General	Pound, 12 wakeas, 4800 grains, 1891 value, consistent with 2003 reference
rotl	0.340	0.750	Arabia	Ancient to pre-metric	General	3 oukia, 2003 reference
rotl	0.433	0.954	Guinea	Medieval to pre-metric	General	0.9538 Avoirdupois pounds
rotl	0.4454	0.9819	Egypt	Pre-metric	General	144 darhims, 1891 value
rotl	0.4977	1.097	Tripoli, Libya	Pre-metric	General	16 unkias, 1891 value
rotl	0.5075	1.119	Morocco	Colonial to pre-metric	General	2003 reference
rotl	0.540	1.19	Morocco	Colonial to pre-metric	General, Commercial	Variation, 1891 value
rotl	0.771	1.70	Morocco	Colonial to pre-metric	General, Market	Variation, 1891 value
rotl (Bet-el-faki)	0.462	1.02	Arabia	Ancient to pre-metric	General	1891 value
rotl (Jidda)	0.166	0.366	Arabia	Ancient to pre-metric	General	1891 value
rotl attari	0.5039	1.111	Tunisia	Ancient to pre-metric	General	16 uckir, 2003 reference, reported as 0.5069 kg in 1891
rotl attari	0.546	1.20	Algeria	Medieval to pre-metric	Spices	1891 value

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
rotl feuddi	0.497	1.10	Algeria	Medieval to pre-metric	Gold, Silver	1891 value
rotl gheddari	0.6143	1.354	Algeria	Medieval to pre-metric	General, Fruit	2, 2003 reference, consistent with 1891 value, applied to fruits
rotl khebir	0.8191	1.806	Algeria	Medieval to pre-metric	General	24 ukkia, also reported as 0.922 kg in 1891
rotl sucky	0.5669	1.250	Tunisia	Ancient to pre-metric	General, Meat	18 uckir, meat, etc., 2003 reference, reported as 0.5685 kg in 1891
rotola	0.7938	1.750	Malta	Medieval to pre-metric	General	Consistent with 1891 value
rotoli	0.445	0.980	Tanzania	Pre-metric	General	
rotoli	0.4493	0.9905	Egypt	Pre-metric	General	4 miskal, 2003 reference
rotoli (Palermo)	0.793	1.75	Italy	Medieval to pre-metric	General	
rotollo grosso (Sicily)	0.8732	1.925	Italy	Medieval to pre-metric	General	33 oncie grosso, 1891 value
rotolo	0.340	0.750	Arabia	Ancient to pre-metric	General	3 oukia, 2003 reference
rotolo	0.4446	0.9801	Zanzibar	Pre-metric	General	1891 value
rotolo	0.448	0.988	Eretria	Medieval to pre-metric	General	Pound, 16 okia, 2003 reference
rotolo	2.378	5.242	Cyprus	Colonial to pre-metric	General	1891 value, 1-7/8 oka
rotolo (Naples)	0.8911	1.964	Italy	Medieval to pre-metric	General	2-7/9 libbre, 1891 value
rottel	0.460	1.01	Persia, Iran	Ancient to pre-metric	General	5 pinar, 2003 reference
rottel	0.5645	1.245	Turkey, Ottoman Empire	Medieval to pre-metric	General	176 dirham, 2003 reference
rottola	0.5288	1.166	Crete, Candia	Pre-metric	General	1891 value
rottollo	0.311	0.686	Ethiopia	Medieval to pre-metric	General	

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
rottolo	0.311	0.686	Abyssinia	Pre-metric	General	Pound, 12 wakeas, 4800 grains, 1891 value, consistent with 2003 reference
rottolo	0.408	0.899	Balearic Islands	Pre-metric	General	2003 reference
rottolo	0.4454	0.9819	Egypt	Pre-metric	General	144 darhims, 1891 value
rottolo	0.448	0.988	Eretria	Medieval to pre-metric	General	Pound, 16 okia, 2003 reference
rottolo	0.448	0.988	Somalia	Medieval to pre-metric	General	Pound, 16 okia, 2003 reference
rottolo	0.5128	1.131	Libya	Medieval to pre-metric	General	16 uckin, 2003 reference
rottolo	0.5588	1.232	Cyprus	Colonial to pre-metric	General	176 drachme, 0.44 oke, 2003 reference
rottolo	0.65	1.4	Turkey, Ottoman Empire	Medieval to pre-metric	General	Wildly variable, from 0.57 to 2.3 kg in 1891, average shown
rottolo	0.7938	1.750	Malta	Medieval to pre-metric	General	7/4 libras, 2003 reference
rottolo	0.7938	1.750	Malta	Medieval to pre-metric	General	Consistent with 1891 value
rottolo	1.785	3.935	Syria	Medieval to pre-metric	General	60 once, 2003 reference
rottolo (Genoa)	0.4764	1.050	Italy	Medieval to pre-metric	General	1.5 libbre, 1891 value
rottolo à kebyr	0.8191	1.806	Algeria	Medieval to pre-metric	General	24 ukkia, also reported as 0.922 kg in 1891
rottolo à khalday	0.6143	1.354	Algeria	Medieval to pre-metric	General, Fruit	2, 2003 reference, consistent with 1891 value, applied to fruits
rottolo à thary	0.5461	1.204	Algeria	Medieval to pre-metric	General	16 ukkia, 2003 reference
rottolo attari	0.5039	1.111	Tunisia	Ancient to pre-metric	General	16 uckir, 2003 reference, reported as 0.5069 kg in 1891
rottolo khaddari	0.6299	1.389	Tunisia	Ancient to pre-metric	General, Vegetables	20 uckir, vegetables, 2003 reference

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
rotolo sottile (Sicily)	0.7938	1.750	Italy	Medieval to pre-metric	General	30 oncie sottile, 1891 value
rotolo sucki	0.5669	1.250	Tunisia	Ancient to pre-metric	General, Meat	18 uckir, meat, etc., 2003 reference, reported as 0.5685 kg in 1891
ruay	0.000255	0.000562	Burma, Birmah, Rangoon, Myanmar	Pre-metric	General	2003 reference
rubbio (Parma)	8.161	17.99	Italy	Medieval to pre-metric	General	25 libbre, 1891 value
rubbio (Venetian Lombardy)	10.00	22.05	Italy	Post-metric	General	10 libbre, post-metric, old name, metric definition
rubbo (typical)	7.68	16.9	Italy	Medieval to pre-metric	General	25 libbra, pre-1861, 2003 reference
rubbo (variation)	8.83	19.5	Italy	Medieval to pre-metric	General	25 libbra
ruttee	0.0001215	0.0002678	India	Akbar to colonial	General	2003 reference
s ap	0.00130	0.00286	United Kingdom, England	Medieval to pre-metric	Apothecaries'	20 gr ap
sâa	2.720	5.996	Arabia	Ancient	Capacity	2 caphite, 2003 reference, capacity measure
sack	50.80	112.0	United Kingdom, England	Medieval to pre-metric	Coal	1 hundredweight
sack	165	364	United Kingdom, England	Medieval to pre-metric		26 stone, 364 lbs

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
sack	165.1	364.0	United Kingdom, England	Medieval to pre-metric	Wool	26 stones (wool)
saco	62.50	137.8	Colombia	Colonial to metric	General	Sack, 125 libra, 2003 reference
saco	62.5	138	Venezuela	Post-metric	General	125 libra, older value estimated at 57.5 kg, old name, metric definition
saddirham	1.47	3.25	Persia, Iran	Ancient to pre-metric	General	2 tcheirek, 2003 reference
salung	0.00375	0.00827	Thailand, Siam	Pre- and post-metric	General	2 fuang, 2003 reference
sath (new)	6.426	14.17	Hebrew	Ancient to pre-metric	Dry Capacity	3 gomor, 2003 reference
sath (old)	8.813	19.43	Hebrew	Ancient to pre-metric	Dry Capacity	3 gomor, 2003 reference
satijk	0.3200	0.7055	Yugoslavia	Pre-metric	General	100 dram, 2003 reference
saum	140.0	308.6	Austrian Empire	Pre-metric	Steel	250 pfund, 2 lägel, 1891 value
saum	154.0	339.5	Austrian Empire	Pre-metric	General	275 pfund, 1891 value, consistent with 2003 reference
sava (1 1/4) seer	1.5	3.2	India	Medieval to Akbar	General	2.25 seer
savaser	1.2	2.6	India	Medieval to Akbar	General	1 ser + 1 pav, 100 Imperial rupees
savaser 1 dhaser	1.5	3.2	India	Medieval to Akbar	General	2.25 seer
scheepslast	1,976	4,357	Netherlands, Holland	Medieval to Metric	Shipping	4,000 Amsterdam ponds, "load", referred to ship loads or loads of herring. Not used after herring business stopped. Pre-1800
schiffpfund (Bremen)	144.6	318.7	Germany, Prussia	Medieval to pre-metric	General	290 pfund, 20 liespfund, 1891 value

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
schiffpfund (Brunswick)	130.9	288.5	Germany, Prussia	Medieval to pre-metric	General	20 liespfund, 280 pfund, 1891 value
schiffpfund (Hamburg)	135.6	299.0	Germany, Prussia	Medieval to pre-metric	General	20 liespfund, 1891 value
schiffpfund (old)	154.4	340.3	Prussia, Germany	Pre-metric	General	20 liespfund, pre-metric value
schiffslast	1,120	2,469	Austrian Empire	Pre-metric	Shipping	20 centner, 1891 value, shipping ton
schiffspfund	168	369	Latvia	Medieval to pre-metric	General	20 liespfund, 2003 reference
schiffspfund	184	406	Estonia	Medieval to pre-metric	General	400 pfund, 2003 reference
scr apoth	0.0005879	0.001296	United States	Colonial to modern	Apothecaries'	20 gr apoth
scrapall	0.0012	0.0026	Ireland	Medieval to pre-metric	General	3 penny
scripulum	0.001135	0.002502	Roman Empire	Ancient	General	1/24 uncia, "small pebble" or "scruple", 2003 reference
scrupel	0.001237	0.002728	Norway	Medieval to pre-metric	Apothecaries'	20 grans, 1891 value
scrupel	0.00130	0.00286	Netherlands, Holland	Medieval to metric	Apothecaries'	20 grains, "scruple"
scrupel	0.001463	0.003224	Austrian Empire	Pre-metric	Apothecaries'	20 gran, 1891 value, also reported as 0.001458 kg in 2003 reference
scruple	0.0005879	0.001296	United States	Colonial to modern	Apothecaries'	20 gr apoth
scruple	0.0012	0.0026	Ireland	Medieval to pre-metric	General	3 penny
scruple	0.00124	0.00274	Germany, Prussia	Medieval to pre-metric	Apothecaries'	20 gr
scruple	0.001275	0.002811	France	Medieval to pre-metric	General	1/24 once, 24 grains, 2003 reference

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
scruple	0.00130	0.00286	United Kingdom, England	Medieval to pre-metric	Apothecaries'	20 gr ap
scruple	0.00130	0.00287	Switzerland	Medieval to metric	Apothecaries'	20 grains, 1891 value, consistent with 2003 reference
scruple	0.001530	0.003372	France	Medieval to pre-metric	General	2 obole, 2003 reference
scruple	0.00155	0.00342	Byzantine Empire	Ancient	General	1/24 Greek ounce
scruple	0.007189	0.01585	Spain	Medieval to pre-metric	General	2 ochavas, 2003 reference
scrupoli (Naples)	0.0008911	0.001964	Italy	Medieval to pre-metric	Prec. Mils., Drugs, Pigments	20 accini, 1891 value
scrupoli (Naples)	0.002673	0.005893	Italy	Medieval to pre-metric	Prec. Mils., Drugs, Pigments	3 trapesi, 1891 value
scrupolo (Naples)	0.0008911	0.001964	Italy	Medieval to pre-metric	Apothecaries'	20 accini, 1891 value
scrupul	0.001244	0.002743	Russia	Medieval to pre-metric	Apothecaries'	Scruple, 20 grains, 1891 value, consistent with 2003 reference
scrupule	0.001244	0.002743	Russia	Medieval to pre-metric	Apothecaries'	Scruple, 20 grains, 1891 value, consistent with 2003 reference
scrupulo	0.00120	0.00264	Portugal	Medieval to pre-metric	General	"Scruple", 24 grãos, 1/384 arratéis, 2003 reference
scrupulum	0.001135	0.002502	Roman Empire	Ancient	General	1/24 uncia, "small pebble" or "scruple", 2003 reference

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
še	0.00005	0.0001	Mesopotamia, Sumer, Akkadia	Ancient (EN system E)	General	Grain, 1/180 shekel
seer	0.2835	0.6250	Ceylon, Sri Lanka	Pre-metric	General	4 powa, 2003 reference
seer	0.9330	2.057	India	Akbar to colonial	General	4 powa, 2003 reference
seer	0.933	2.06	India	Medieval to Akbar	General	2 adher, 4 pav, 16 chhatank, 80 tola
seer	15.67	34.55	Turkmenistan	Pre-metric	General	1891 value
seer	15.8	34.9	Turkmenistan	Pre-metric	General	8 tscharik, 2003 reference
seer (Bengal)	0.847	1.87	India	Akbar to colonial	General, Factory	16 chattaacks, 1891 value
seer (Bengal)	0.931	2.05	India	Akbar to colonial	General, Bazaar	16 chattaacks, 1891 value
seer (Bombay)	0.318	0.700	India	Akbar to colonial	General	30 pice, 72 tanks, 1891 value
seer (Madras)	0.2835	0.6250	India	Akbar to colonial	General	8 pollams, 1891 value
sela	0.02285	0.05037	Biblical, Talmudic	Ancient	General	2 shekel, based on Oxford Biblical Studies Online
sela	0.03930	0.0866	Biblical, Talmudic	Ancient	General	2 shekel, based on heavy common talent
sela	0.0404	0.0891	Biblical, Talmudic	Ancient	General	2 shekel, based on heavy royal talent
semis	0.1635	0.3604	Roman Empire	Ancient	General	1/2 libra, "half", 2003 reference
semisextula	0.00228	0.00503	Roman Empire	Ancient	General	1/12 uncia, "half-little sixth"

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
semissis	0.00227	0.00500	Byzantine Empire	Ancient	General	1/12 Greek ounce
semissis	0.1635	0.3604	Roman Empire	Ancient	General	1/2 libra, "half", 2003 reference
semuncia	0.01363	0.03005	Roman Empire	Ancient	General	1/2 uncia, "Half-twelfth" or "half-ounce semuncia", 2003 reference
sentneri	42.56	93.83	Finland	Medieval to pre-metric	General	200 markka, metrinen sentneri (metric version) = 100 kg
sep	0.001365	0.003009	Egypt	Ancient	General	2 gerah, 2003 reference
septunx	0.191	0.421	Roman Empire	Ancient	General	7/12 libra, "seven-twelfths"
ser	0.64	1.4	India	Akbar to colonial	General	
ser	0.87	1.9	India	Akbar to colonial	General	80 tolas, before 1833
ser	0.933	2.06	India	Medieval to Akbar	General	2 adher, 4 pav, 16 chhatank, 80 tola
seron	0.0120	0.0265	Guinea	Medieval to pre-metric	General	2 quinto, 2003 reference
sescuncia	0.0411	0.0906	Roman Empire	Ancient	General	1/8 libra, "One and 1/2 twelfths"
sescunx	0.0411	0.0906	Roman Empire	Ancient	General	1/8 libra, "One and 1/2 twelfths"
sextans	0.05450	0.1201	Roman Empire	Ancient	General	1/6 libra, "sixth", 2003 reference
sextula	0.004542	0.01001	Roman Empire	Ancient	General	1/6 uncia, "little sixth", 2003 reference
shekel	0.0114	0.0252	Biblical, Talmudic	Ancient	General	1.5 pim, based on Oxford Biblical Studies Online

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
shekel	0.0142	0.0312	Hebrew, Sacred system	Ancient to pre-metric	General	2 bekah, 2003 reference
shekel	0.01417	0.03123	Hebrew, Talmudic, Rabbinical	Ancient to pre-metric	General	4 zuzahs, 2003 reference
shekel	0.014	0.031	Jewish, Israel	Ancient to modern	General	Estimated
shekel	0.0196	0.0433	Biblical, Talmudic	Ancient	General	1.5 pim, based on heavy common talent
shekel	0.0202	0.0445	Biblical, Talmudic	Ancient	General	1.5 pim, based on heavy royal talent
shematy	0.00113	0.00250	Egypt	Ancient—Old & Mid Kingdom	General	1/12 deben
shematy	0.00758	0.0167	Egypt	Ancient—New Kingdom	General	1/12 deben
shī	0.000000375	0.000000827	Japan	Post-metric	General	2003 reference
shiffpfund	146.9	323.7	Belgium	Pre-metric	General	3 quintal, 2003 reference
shiffspfund (Austrian system)	154.3	340.3	Germany, Prussia	Medieval to pre-metric	General	3 zentner, 2003 reference
shih	71.62	157.9	China	Pre-metric (1915–1929)	General	4 jun
shik	72.6	160	China	Medieval to pre-metric	General	1891 value
ship load	430,811	949,760	United Kingdom, England	Medieval to pre-metric	Coal	20 keels
short artaba	48.90	107.8	Persia, Iran	Ancient to modern	Capacity	3 woëbe, 2003 reference
short ton	907.2	2,000	United States	Colonial to modern	General, Avoirdupois	20 US cwt, 2000 lbs

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
shu	0.00001554	0.00003426	China	Pre-metric (1915–1929)	General	
sh ₃ ts	0.00113	0.00250	Egypt	Ancient—Old & Mid Kingdom	General	1/12 deben
sh ₃ ts or	0.00758	0.0167	Egypt	Ancient—New Kingdom	General	1/12 deben
sī	0.00000313	0.000000689	China	Post-metric (1930–1958)	General	1/160000 jīn, old name, metric definition
sicca	0.01166	0.02571	India	Akbar to colonial	General	12 masha, 2003 reference
sicca (Bengal)	0.0106	0.0233	India	Akbar to colonial	General, Factory	1891 value
sicca (Bengal)	0.0116	0.0257	India	Akbar to colonial	General, Bazaar	1891 value
sicilicus	0.006813	0.01502	Roman Empire	Ancient	General	1/4 uncia, “little sickle”, 2003 reference
siciliquus	0.006813	0.01502	Roman Empire	Ancient	General	1/4 uncia, “little sickle”, 2003 reference
sicilium	0.006813	0.01502	Roman Empire	Ancient	General	1/4 uncia, “little sickle”, 2003 reference
sicles	0.01365	0.03009	Egypt	Ancient	General	10 sep, 2003 reference
siki	0.00073	0.0016	India	Medieval to Akbar	General	
siliqua	0.000190	0.000419	Roman Empire	Ancient	General	“Carat”, 1/144 uncia, “carob seed”
silus	0.014	0.031	Jewish, Israel	Ancient to modern	General	Estimated
šiqu	0.009	0.02	Mesopotamia, Sumer, Akkadia	Ancient (EN system E)	General	Shekel

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
sir	0.0736	0.162	Persia, Iran	Ancient to pre-metric	General	8 dirhem, 2003 reference
sir	15.67	34.55	Turkmenistan	Pre-metric	General	1891 value
sir	15.8	34.9	Turkmenistan	Pre-metric	General	8 tscharik, 2003 reference
skälpund	0.4252	0.9373	Norway	Medieval to pre-metric	General	16 untz, 8848 as, 1891 value
skälpund	0.4236	0.9338	Sweden	Medieval to pre-metric	General	100 ortz, 1891 value
skälpund	0.4251	0.9372	Sweden	Medieval to pre-metric	General	16 uns, 2 mark, 2003 reference
skälpund	0.4981	1.098	Norway	Medieval to pre-metric	General	2 merker, 0.4667 before 1683, “pound”, value is consistent with 2003 reference
skeppspund	170.0	374.8	Sweden	Medieval to pre-metric	Shipping	20 liespund, 2003 reference
skippund	160	353	Iceland	Medieval to metric	General	320 pund, post-metric value, 2003 reference
skippund (1270)	151.0	332.9	Norway	Medieval to pre-metric	Shipping	“Ship’s pound”, 1270 value
skippund (1891)	170.1	374.9	Norway	Medieval to pre-metric	Shipping	400 skälpunds, 1891 value
skippund (old)	159.8	352.3	Denmark	Medieval to pre-metric	General	20 old lispund, early 1800s value?, consistent with 2003 reference
skippund (pre 1887)	159.5	351.6	Norway	Medieval to pre-metric	Shipping	“Ship’s pound”, pre-1887 value
skoyciec	0.00846	0.0186	Poland	Pre-metric	General	1891 value
skrupul	0.001056	0.002328	Poland	Pre-metric	General	24 gran, 2003 reference
skyplast	2,600	5,732	Denmark	Medieval to Pre-metric	Shipping	52 centner, 2003 reference
slug	14.59	32.17	United Kingdom, England	Medieval to Pre-metric	General, Avoirdupois	Unit of mass

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
slug	14.59	32.17	United States	Colonial to modern	General, Avoirdupois	Unit of mass
small bahar	185.3	408.5	Indonesia	Colonial to pre-metric	General	3 picul, 2003 reference
soekoe	0.004825	0.01064	Indonesia	Colonial to pre-metric	General	2 tali, 2003 reference
soekoe	0.00676	0.0149	Indonesia	Colonial to pre-metric	Prec. Mtls.	1/8 thail
sol	0.01836	0.04047	France	Medieval to pre-metric	General	12 denier, 2003 reference
solidi	0.00455	0.0100	Byzantine Empire	Ancient	General	Circa 309 AD, reduced over time to 0.00443 kg by 9th century
solotnik	0.004266	0.009404	Russia	Medieval to pre-metric	General	Golden one, 96 dolias, 1891 value, consistent with 2003 reference
sompay	0.000938	0.00207	Thailand, Siam	Pre- and post-metric	General	2 pai, 2003 reference
sompi	0.00389	0.00857	Madagascar	Pre-metric	Prec. Mtls.	2 vari, 60 grains, 1891 value
spann	17.93	39.53	Norway	Medieval to pre-metric	General	Same as laup
st	6.350	14.00	United Kingdom, England	Medieval to pre-metric	General, Avoirdupois	14 pounds
stater	0.014	0.031	Jewish, Israel	Ancient to modern	General	Estimated
stater	51.20	112.9	Greece	Pre- and post-metric	General	100 pounds, pre-metric, 2003 reference
stein	3.916	8.633	Belgium	Pre-metric	General	8 livre, 2003 reference
stein	11.20	24.69	Austrian Empire	Pre-metric	General	20 pfund, 1891 value, consistent with 2003 reference
stein (Austrian system)	10.29	22.68	Germany, Prussia	Medieval to pre-metric	General	22 pfund, 2003 reference

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
stein (Baden)	5.000	11.02	Germany, Prussia	Medieval to pre-metric	General	10 pfund, 1891 value, post-metric
stein (old)	10.29	22.69	Prussia, Germany	Pre-metric	General	22 pfund, pre-metric value
sten	13.60	29.98	Sweden	Medieval to pre-metric	General	32 skålpund, 2003 reference
stone	6.350	14.00	United Kingdom, England	Medieval to pre-metric	Wool	14 lbs (wool)
stone	6.350	14.00	United Kingdom, England	Medieval to pre-metric	General, Avoirdupois	14 pounds
stone	6.350	14.00	United Kingdom, England	Medieval to pre-metric	Coal	14 lbs
stone	9.870	21.76	Scotland	Medieval to pre-metric	General	16 pounds, 2003 reference
stone	50.80	112.0	Cyprus	Colonial to pre-metric	General	Hundredweight, 8 musses, 2008 reference
stone (Austrian system)	10.29	22.68	Germany, Prussia	Medieval to pre-metric	General	22 pfund, 2003 reference
stone avoirdupois	6.35	14.0	India	Colonial to pre-metric	General	14 pounds av
ta	60.40	133.2	Viet Nam, Annam	Medieval to pre-metric	General	2 binh, 2003 reference
ta	62.48	137.8	Annam, Viet Nam	Pre-metric	General	2 binh, 1891 value
tạ	60.45	133.3	Viet Nam, Annam	Medieval to pre-metric	General	10 yén, under metric = 100 kg

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
tael	0.0313	0.0689	China	Post-metric (1930–1958)	General	Chinese ounce, 1/16 jīn, old name, metric definition
tael	0.03730	0.08223	China	Pre-metric (1915–1929)	General	Chinese ounce, 24 zhu
tael	0.0375	0.0827	Cambodia	Post-metric	General	75/2 muoi, 10 chin, 2003 reference
tael	0.0375	0.0827	Taiwan, Formosa	Pre-metric	General	10 mace
tael	0.0378	0.0833	Sooloo Archipelago	Colonial to pre-metric	General	1891 value
tael	0.03780	0.08333	China	Medieval to pre-metric	General	10 mace, 1891 value
tael	0.03860	0.08510	Indonesia	Colonial to PRE-metric	General	2 real, 2003 reference
tael	0.0398	0.0877	Borneo	Pre-metric	General	4 pahaws, 614 troy grains
tael	0.050	0.110	China	Post-metric (Since 1959)	General	“Chinese ounce”, old name, metric definition
tael	0.06049	0.1334	Thailand, Siam	Pre- and post-metric	General	4 ticals, 1891 value
tael (Amboyna)	0.0296	0.0652	Molucca	Pre-metric	General	16 mace, 455.8 grains, 1891 value
tael (Amboyna)	1.406	3.099	Indonesia	Colonial to pre-metric	General	55.3371 bushels, estimated but seems high
tael (Bantam)	0.069	0.151	Indonesia	Colonial to pre-metric	General	
tael (Bantam)	0.0685	0.151	Java	Colonial to pre-metric	General	1891 value
tael (Batavia)	0.03842	0.08470	Indonesia	Colonial to pre-metric	General	
tael (Batavia)	0.0384	0.0847	Java	Colonial to pre-metric	General	1891 value
tael (Cochin China)	0.0383	0.0844	Annam, Viet Nam	Pre-metric	General	1891 value

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
tak	0.00292	0.0064	India, Northern	Medieval to Akbar	General	24 ratti
tala			Sri Lanka, Ceylon	Medieval to pre-metric	General	Small weight measured in seeds
talanton	1.500	3.307	Greece	Pre- and post-metric	General	1.5 minae, 1891 value, post-metric
talanton	153.6	338.6	Greece	Pre- and post-metric	General	3 staters, pre-metric, 2003 reference
talent	4.3	9.4	Jewish, Israel	Ancient to modern	General, Silver	300 shekels
talent	21.25	46.85	Hebrew, Talmudic, Rabbinical	Ancient to pre-metric	General	60 minas, 2003 reference
talent	32.6	71.9	Persia, Iran	Ancient to pre-metric	General	100 mine, 2003 value
talent	32.64	71.96	Arabia	Ancient	Capacity	2 khoull, 2003 reference, capacity measure
talent	34.0	75.0	Arabia	Ancient to pre-metric	General	25 oka, 2003 reference
talent	34.28	75.57	France	Medieval to pre-metric	General	Mass of one French cft water at 1 g/ cm ³
talent	34.3	75.6	Biblical, Talmudic	Ancient	General	60 maneh, based on Oxford Biblical Studies Online
talent	40.95	90.28	Egypt	Ancient	General	50 mine, 2003 reference
talent	58.9	130	Biblical, Talmudic	Ancient	General	60 maneh, based on heavy common talent
talent	60.6	134	Biblical, Talmudic	Ancient	General	60 maneh, based on heavy royal talent
talent (Aeginetic)	37.8	83.3	Greece	Ancient	General	60 minae

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
talent (Attic/ Euboic)	25.92	57.14	Greece	Ancient	General	60 minae, 2003 reference
talent of Moses	42.5	93.7	Hebrew, Sacred system	Ancient to pre-metric	General	50 minas, 2003 reference
talento	45.4	100	Ionian Islands	Pre-metric	General	100 lb av, 1891 value
tali	0.002413	0.005319	Indonesia	Colonial to pre-metric	General	3 wang, 2003 reference
tali	0.00338	0.00745	Indonesia	Colonial to pre-metric	Prec. Mtls.	1/16 thail
tam	60.48	133.3	China	Medieval to pre-metric	General	50 yin, 1891 value
tamlung	0.0600	0.132	Thailand, Siam	Pre- and post-metric	General	4 baht, 2003 reference
tampang	0.6151	1.356	Malacca	Pre-metric	Tin	Equivalent of catty for tin, 1891 value
tan	59.68	131.6	China	Pre-metric (1915–1929)	General	100 jin
tân	60.0	132	Taiwan, Formosa	Pre-metric	General	100 catties
tán	604.5	1,333	Viet Nam, Annam	Medieval to pre-metric	General	10 tạ, under metric = 1000 kg, when used for ship capacity = 2.83 or 1.13 cu meters
tank	0.01296	0.02857	India	Akbar to colonial	General	10/9 tolah, 2003 reference
tank (Bombay)	0.00441	0.00972	India	Akbar to colonial	General	1891 value
tank-sala	0.00265	0.00583	India	Akbar to colonial	General	3 masha, 1966 value
tartimar	0.286	0.630	Biblical, Talmudic	Ancient	General	6-1/4 unkeya, based on Oxford Biblical Studies Online
tartimar	0.491	1.08	Biblical, Talmudic	Ancient	General	6-1/4 unkeya, based on heavy common talent

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
tartimar	0.505	1.11	Biblical, Talmudic	Ancient	General	6-1/4 unkeya, based on heavy royal talent
tchang	1.200	2.646	Thailand, Siam	Pre- and post-metric	General	20 tamlung, 2003 reference
tcheirek	0.736	1.62	Persia, Iran	Ancient to pre-metric	General	2 abbassi, 2003 reference
tcheki	225.8	497.8	Turkey, Ottoman Empire	Medieval to pre-metric	General	4 kantar, 2003 reference
tchin	0.5968	1.316	China	Pre-metric (1915–1929)	General	Chinese pound, 16 liàng
tercio	72.2	159	Cuba	Colonial to pre-metric	General	
tercio	73.64	162.3	Mexico	Colonial to pre-metric	General	160 libra, 2003 reference
termino	0.004006	0.008832	Libya	Medieval to pre-metric	General	20 kharouba, 2003 reference
teruncius	0.08175	0.1802	Roman Empire	Ancient	General	1/4 libra, “fourth” or “triple twelfth”, 2003 reference
thail	0.0386	0.0851	Indonesia	Colonial to pre-metric	General	1/1600 pikol
thail	0.0386	0.0851	Indonesia	Colonial to pre-metric	Opium	
thail	0.0541	0.119	Indonesia	Colonial to pre-metric	Prec. Mils.	
thoi	0.189	0.417	Viet Nam, Annam	Medieval to pre-metric	General	French colonial unit
ti	3.780E-07	8.333E-07	Viet Nam, Annam	Medieval to pre-metric	General	10 hót
tica	0.000415	0.000914	Borneo	Pre-metric	General	3 malaborong
tical	0.01512	0.03333	Burma, Birmah, Rangoon, Myanmar	Pre-metric	General	1891 value

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
tical	0.01512	0.0333	Thailand, Siam	Pre- and post-metric	General	1891 value
tical	0.0163	0.0360	Burma, Birmah, Rangoon, Myanmar	Pre-metric	General	4 mat, 2003 reference
tiền	0.00378	0.00833	Viet Nam, Annam	Medieval to pre-metric	General	10 phán, differs from monetary unit
timbang	308	678	Java	Colonial to pre-metric	Grain	1891 value
timbang	308.8	680.8	Indonesia	Colonial to pre-metric	General	5 picul, 2003 reference
timbang (Java)	308	678	Indonesia	Colonial to pre-metric	Grain	
timbang Mata	0.000386	0.000851	Indonesia	Colonial to pre-metric	Opium	1/100 thail
tji	0.00386	0.00851	Indonesia	Colonial to pre-metric	Opium	1/10 thail, <u>inconsistent</u> with 2003 reference
tod	12.70	28.00	United Kingdom, England	Medieval to pre-metric	General, Avoirdupois	1/4 hundredweight, 2 stone
tola	0.0117	0.0257	India	Colonial to pre-metric	Gold	3.75/10 troy ounces
tola	0.0118	0.0259	India	Akbar to Colonial	General	80 retti, 1966 value
tolā	0.011	0.024	India	Akbar to Colonial	General	12 māshās, before 1833, fixed at 180 grains after 1848
tolah	0.01166	0.02571	India	Akbar to Colonial	General	12 masha, 2003 reference
tomin	0.0005993	0.001321	Mexico	Colonial to pre-metric	General	1/768 libra, 2003 reference
tomin	0.0006001	0.001323	Spain	Medieval to pre-metric	General	12 granos, 1891 value, reported as 0.0005991 kg in 2003 reference

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
ton	0,0038	0,0083	Korea	Medieval to pre-metric	General	10 p'un
ton	101	222	Latvia	Medieval to pre-metric	General	2 centner, 2003 reference
ton	110	243	Estonia	Medieval to pre-metric	General	240 pfund, 2003 reference
ton	907.2	2,000	United States	Colonial to Modern	General, Avoirdupois	20 US cwt, 2000 lbs
ton	1,016	2,240	United Kingdom, England	Medieval to pre-metric	Shipping, Avoirdupois	20 hundredweight
ton	1016	2,240	Cyprus	Colonial to pre-metric	General	800 oke, 2003 reference
ton avoirdupois	1,016	2,240	India	Colonial to pre-metric	General	20 hundredweight (cwt), 40 bushels, 160 stones
tonelada	793	1749	Portugal	Medieval to pre-metric	General	“Tonne”, 13.5 quintais, 1728 arratéis
tonelada	793.2	1,749	Brazil	Colonial to pre-metric	General	1,728 libras, 54 arroba, 2003 reference
tonelada	918.7	2,025	Argentina	Colonial to pre-metric	General	20 quintals, 2000 libras, 1891 value, consistent with 2003 reference
tonelada	921.8	2,032	Spain	Medieval to pre-metric	General	20 quintals, 1891 value, reported as 920.2 kg in 2003 reference
tonelada	1000	2,205	Colombia	Colonial to Metric	General	Ton, 2000 libra, 2003 reference
tonelada	1,000	2,205	Venezuela	Post-metric	Shipping	2000 libra, older value estimated at 920 kg, old name, metric definition
tonelada	1,016	2,239	Cuba	Colonial to pre-metric	General	
tonne	110	243	Estonia	Medieval to pre-metric	General	240 pfund, 2003 reference
tonne	1,000	2,205	Germany, Prussia	Medieval to pre-metric	General	1891 value

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
tonne (new)	150	331	Prussia, Germany	Post-metric	General	3 centner, post-metric value
tonne (new)	918	2,024	Paraguay	Colonial to pre-metric	General	Ton, 2000 libra, 2003 reference
tonne (old)	920.2	2,029	Paraguay	Colonial to pre-metric	General	Ton, 2000 libra, 2003 reference
tonneau (1891)	1,000	2,205	France	Post-metric	Shipping	10 quitals
tonneau de mer	979.0	2,158	France	Medieval to pre-metric	Shipping	2 millier, 2003 value
tonnelada	921.8	2,032	Spain	Medieval to pre-metric	General	20 quintals, 1891 value, reported as 920.2 kg in 2003 reference
tonnelada (new)	918	2,024	Paraguay	Colonial to pre-metric	General	Ton, 2000 libra, 2003 reference
tonnelada (old)	920.2	2,029	Paraguay	Colonial to pre-metric	General	Ton, 2000 libra, 2003 reference
tovar	128.0	282.2	Yugoslavia	Pre-metric	General	100 oka, 2003 reference
trapeso (Naples)	0.0008911	0.001964	Italy	Medieval to pre-metric	Prec. Mils., Drugs, Pigments	20 accini, 1891 value
triens	0.1090	0.2403	Roman Empire	Ancient	General	1/3 libra, “third”, 2003 reference
troy grain	0.0000648	0.000143	United States	Colonial to Modern	Prec. Mils.	Same as Avoirdupois measure
troy ounce	0.0311	0.0686	United States	Colonial to Modern	Prec. Mils.	20 dwt
troy ounce	0.0311	0.0686	India	Colonial to pre-metric	Gold	480 barleycorns
troy pennyweight	0.00156	0.00343	United States	Colonial to Modern	Prec. Mils.	7.776 carats, 24 gr
troy pound	0.3732	0.8228	United States	Colonial to Modern	Prec. Mils.	12 oz t
troy pound	0.373	0.823	India	Colonial to pre-metric	Gold	12 troy ounces, abolished 1878
truss	27.2	60.0	United Kingdom, England	Medieval to pre-metric	Hay, Straw	36 lbs (straw)

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
tscharik	1.98	4.36	Turkmenistan	Pre-metric	General	4 mintscha, 2003 reference
tsouen	0.003730	0.008223	China	Pre-metric (1915-1929)	General	1/10 liäng
tub (Suffolk)	38.10	84.00	United Kingdom, England	Medieval to pre-metric	Butter, Cheese	1.5 firkins, Suffolk
tuba	4.70	10.4	India	Akbar to Colonial	General	100 pala, 1966 value
tukeas	0.03375	0.07440	Saudi Arabia	Pre-metric	General	10 coffilas, 2003 reference
tulee	0.01	0.02	Afghanistan	Colonial to modern	Narcotics	Varies, Narcotics
tunna smjörs	112	247	Iceland	Medieval to metric	General	224 pund, post-metric value, 2003 reference
uckia	0.03110	0.06857	Tripoli, Libya	Pre-metric	General	10 drachmas, 1891 value
uckin	0.03205	0.07066	Libya	Medieval to pre-metric	General	8 termino, 2003 reference
uckir	0.03150	0.06943	Tunisia	Ancient to pre-metric	General	Ounce, nominal value, 2003 reference, varies with commodity
ukkia	0.03413	0.07524	Algeria	Medieval to pre-metric	General	Ounce, 7.25 metical, 2003 reference
uncia	0.02725	0.06007	Roman Empire	Ancient	General	1/12 libra, "Roman ounce", 2003 reference
uncia	0.02986	0.06583	Russia	Medieval to pre-metric	Apothecaries'	Ounce, 480 grains, 1891 value, consistent with 2003 reference
uncja	0.02534	0.05587	Poland	Pre-metric	General	2 lut, 2003 reference
unga	0.028	0.062	Ireland	Medieval to pre-metric	General	72 penny, from Latin
unkeya	0.0457	0.101	Biblical, Talmudic	Ancient	General	2 sela, based on Oxford Biblical Studies Online
unkeya	0.0786	0.173	Biblical, Talmudic	Ancient	General	2 sela, based on heavy common talent

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
unkeya	0.0808	0.178	Biblical, Talmudic	Ancient	General	2 sela, based on heavy royal talent
unkia	0.03150	0.06943	Tunisia	Ancient to pre-metric	General	Ounce, nominal value, 2003 reference, varies with commodity
uns	0.026569	0.05857	Sweden	Medieval to pre-metric	General	2 lod, 2003 reference
unssi	0.0279	0.0615	Finland	Medieval to pre-metric	General	1/8 markka
untz	0.02633	0.05805	Norway	Medieval to pre-metric	Prec. Mtls., Fine Goods	2 lods, 1891 value
untz	0.02657	0.05858	Norway	Medieval to pre-metric	General	2 lod, 1891 value
untz	0.02970	0.06547	Norway	Medieval to pre-metric	Apothecaries'	8 drachmas, 1891 value
unze	0.02982	0.06575	Denmark	Medieval to pre-metric	Apothecaries'	8 drachme, 1891 value
unze	0.0298	0.0657	Germany, Prussia	Medieval to pre-metric	Apothecaries'	480 grains
unze	0.03076	0.06781	Netherlands, Holland	Medieval to Metric	General	Ounce, 8 drachme, 2003 reference
unze	0.0313	0.0689	Denmark	Medieval to pre-metric	General	2 loth, 2003 reference
unze	0.03500	0.07716	Austrian Empire	Pre-metric	General	2 loth, 1891 value, consistent with 2003 reference
unze	0.03510	0.07738	Austrian Empire	Pre-metric	Apothecaries'	8 drachmen, 1891 value, also reported as 0.03500 kg in 2003 reference
unze (Amsterdam)	0.0309	0.0681	Netherlands, Holland	Medieval to metric	General	"Ounce", Amsterdam basis, 1/16 pond, pre-1800
unze (Austrian system)	0.02923	0.06444	Germany, Prussia	Medieval to pre-metric	General	1/16 pfund, 2003 reference

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
unze (Bavaria)	0.0350	0.0772	Germany, Prussia	Medieval to pre-metric	General	2 loth, 1891 value
unze (Bremen)	0.03116	0.06869	Germany, Prussia	Medieval to pre-metric	General	2 loth, 1891 value
unze (Frankfort)	0.0316	0.0696	Germany, Prussia	Medieval to pre-metric	General	2 loth, 1891 value
unze (Hamburg)	0.03027	0.06674	Germany, Prussia	Medieval to pre-metric	General	2 loth, 1891 value
unze (Hanover)	0.03060	0.06747	Germany, Prussia	Medieval to pre-metric	General	2 loth, 1891 value
unze (Hesse-Cassel)	0.03026	0.06672	Germany, Prussia	Medieval to pre-metric	General	2 loth, 1891 value
unze (Lubeck)	0.03030	0.06680	Germany, Prussia	Medieval to pre-metric	General	2 loth, 1891 value
unze (old)	0.02923	0.06445	Prussia, Germany	Pre-metric	General	2 loth, pre-metric value
unze (Saxony)	0.02922	0.06441	Germany, Prussia	Medieval to pre-metric	General	2 loth
uqija	0.02646	0.05833	Malta	Medieval to pre-metric	General	“Maltese ounce”, 1/30 ratat
uqqa	1.248	2.751	Egypt	Pre-metric	General	25/9 rotoli, 2003 reference
uqqa	1.270	2.800	Cyprus	Colonial to pre-metric	General	400 drachme, 2003 reference
Utrecht pond	0.498	1.10	Netherlands, Holland	Medieval to metric	General	Utrecht basis, “pound”, pre-1800
uʃʃatu	0.00005	0.0001	Mesopotamia, Sumer, Akkadia	Ancient (EN system E)	General	Grain, 1/180 shekel

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
uzan	0.00803	0.0177	Guinea	Medieval to pre-metric	General	2 aguirage, 2003 reference
våg	17.94	39.56	Norway	Medieval to pre-metric	General	1/8 skippund
vakia	0.0340	0.0750	Arabia	Ancient to Pre-metric	General	1891 value
vakias	0.03375	0.07440	Saudi Arabia	Pre-metric	General	10 coffilas, 2003 reference
varahan	0.03544	0.07812	Ceylon, Sri Lanka	Pre-metric	General	5 pagoda, 2003 reference
vari	0.00194	0.00429	Madagascar	Pre-metric	Prec. Mils.	3 nanki, 1891 value
vee ata			Sri Lanka, Ceylon	Medieval to pre-metric	General	3 amu, small weight measured in seeds
vette	6.30	13.9	Norway	Medieval to pre-metric	General	28.8 merker
vi	3.780E-09	8.333E-09	Viet Nam, Annam	Medieval to pre-metric	General	
vierding	0.1400	0.3086	Austrian Empire	Pre-metric	General	4 unzen, 1891 value, consistent with 2003 reference
vierling	0.1400	0.3086	Austrian Empire	Pre-metric	General	4 unzen, 1891 value, consistent with 2003 reference
vierling	0.0003845	0.0008477	Netherlands, Holland	Medieval to Metric	General	6 grein, 2003 reference
vierling (Bavaria)	0.125	0.276	Germany, Prussia	Medieval to pre-metric	General	2 halbe vierling, 1891 value
vis	1.417	3.125	Ceylon, Sri Lanka	Pre-metric	General	5 seer, 2003 reference
vis	1.512	3.333	Burma, Birmah, Rangoon, Myanmar	Pre-metric	General	3 catties, 100 ticals, 1891 value

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
vis	1.63	3.60	Burma, Birmah, Rangoon, Myanmar	Pre-metric	General	3 catty, 2003 reference
vis (Madras)	1.418	3.125	India	Akbar to Colonial	General	5 seers, 1891 value
visay (Madras)	1.418	3.125	India	Akbar to Colonial	General	5 seers, 1891 value
viss	1.417	3.125	Ceylon, Sri Lanka	Pre-metric	General	5 seer, 2003 reference
viss	1.512	3.333	Burma, Birmah, Rangoon, Myanmar	Pre-metric	General	3 catties, 100 ticals, 1891 value
viss	1.63	3.60	Burma, Birmah, Rangoon, Myanmar	Pre-metric	General	3 catty, 2003 reference
waag	18.0	39.7	Denmark	Medieval to pre-metric	General	3 bismerpund, 2003 reference
waag	70.14	154.6	Sweden	Medieval to pre-metric	General	165 skålpund, 2003 reference
wakea	0.0259	0.0571	Ethiopia	Medieval to pre-metric	General	1/12 rotto
wakea	0.0259	0.0571	Abyssinia	Pre-metric	General	Ounce, 10 dirhems, 1891 value, consistent with 2003 reference
wakea	0.341	0.752	Algeria	Medieval to pre-metric	General	12.04 oz, 1891 value
wakega (Mocha)	0.311	0.686	Arabia	Ancient to Pre-metric	Gold, Silver	1891 value
wakega (Mocha)	0.4536	1.00	Arabia	Ancient to Pre-metric	General	1891 value
wang	0.0008042	0.001773	Indonesia	Colonial to pre-metric	General	2003 reference

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
wang	0.00113	0.00248	Indonesia	Colonial to pre-metric	Prec. Mils.	1/48 thail
wey	114.3	252.0	United Kingdom, England	Medieval to pre-metric	Wool	18 stones (wool)
wey (Suffolk)	184.6	406.9	United Kingdom, England	Medieval to pre-metric	Butter, Cheese	356 lbs
wheat berry	0.00000456	0.0000101	India	Colonial to pre-metric	Gold	
wey (Essex)	122.3	269.7	United Kingdom, England	Medieval to pre-metric	Butter, Cheese	236 lbs, Essex
wigtje	0.001000	0.002205	Netherlands, Holland	Medieval to Metric	General	1891 value, metric “re-purposed” unit
wizna	3.969	8.750	Malta	Medieval to pre-metric	General	5 ratal, not mentioned in 1921 act
woëbe	16.30	35.93	Persia, Iran	Ancient to Modern	Capacity	4 makuk, 2003 reference
woëbe	16.32	35.98	Arabia	Ancient	Capacity	2 ferk, 2003 reference, capacity measure
wogiet	0.03120	0.06878	Ethiopia	Medieval to pre-metric	Rubber	2 alada, based on rubber farasula, 2003 reference
yava	0.0000147	0.0000324	India	Akbar to Colonial	General	1966 value
yen	6.040	13.32	Viet Nam, Annam	Medieval to pre-metric	General	10 can, 2003 reference
yen	6.25	13.8	Annam, Viet Nam	Pre-metric	General	10 cân, 1891 value
yén	6.045	13.33	Viet Nam, Annam	Medieval to pre-metric	General	10 cân, under metric = 10 kg

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
yin	1.210	2.667	China	Medieval to pre-metric	General	2 catties, 1891 value
yusdram	0.3208	0.7071	Turkey, Ottoman Empire	Medieval to pre-metric	General	100 dirham, 2003 reference
zehnlng (Baden)	0.05000	0.1102	Germany, Prussia	Medieval to pre-metric	General	10 centass, 1891 value, post-metric
zent (new)	0.000167	0.000367	Prussia, Germany	Post-metric	General	Post-metric value
zentigramme	0.00001	0.00002205	Germany, Prussia	Medieval to pre-metric	General	1/100 gramme, 1891 value
zentner	50	110	Germany, Prussia	Medieval to pre-metric	General	1891 value
zentner	56.00	123.5	Austrian Empire	Pre-metric	General	5 stein, 1891 value, consistent with 2003 reference
zentner (Austrian system)	51.45	113.4	Germany, Prussia	Medieval to pre-metric	General	5 stein, 2003 reference
zhu	0.001554	0.003426	China	Pre-metric (1915-1929)	General	100 shu
zollcentner	50.0	110	Germany, Prussia	Post-metric	General	100 zollpfund, old name, metric definition
zollloth	0.0167	0.0367	Germany, Prussia	Post-metric	General	Old name, metric definition
zollpfund	0.500	1.10	Germany, Prussia	Post-metric	General	30 zollloth, old name, metric definition
zollpfund (Zollverein)	0.5000	1.102	Austrian Empire	Pre-metric	General	For customs, 1891 value, post-metric

(continued)

Table 7.3 (continued)

Unit (Qualifiers)	Equivalent kg at 1 grav.	Equivalent lbs at 1 grav.	Region	Era	Common application	Notes
zollstein	100	220	Germany, Prussia	Post-metric	General	2 zollcentner, old name, metric definition
zolotnik	0.004266	0.009404	Russia	Medieval to pre-metric	General	Golden one, 96 dolias, 1891 value, consistent with 2003 reference
zurbo	49.09	108.2	Syria	Medieval to pre-metric	General	1650 once, 2003 reference
zuzah	0.003542	0.007809	Hebrew, Talmudic, Rabbinical	Ancient to pre-metric	General	6 mehahs, 2003 reference

Conclusion

Weight was an historical, base measurement unit representing the apparent “heaviness” of a physical object under the influence of gravity. The concept of mass was a somewhat later development than weight. For practical, daily applications in a terrestrial frame of reference, weight can be converted to mass with small error. Weight is normally what is measured by available devices, such as balances and weighing scales. The “operational weight” measured this way is close to the actual weight, for normal purposes. Weight standards have evolved from rough standards based on rocks, through standards based on the weights of various grains, to a standard based on the International Prototype Kilogram. This is the only base unit of measurement that still uses a physical artifact as the international standard. The methods of measurement for weight and mass have been discussed, along with their sources and magnitudes of errors. Extensive listings of conversion factors for historical units to modern volume units are provided for various locales and eras in world history.

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“Imperial units” x. “Canadian units” y. “English units” z. “Eritrean units of measurement” aa. “Estonian units of measurement” bb. “Ethiopian units of measurement” cc. “Finnish obsolete units of measurement” dd. “Units of measurement in France before the French Revolution” ee. “Units of measurement in France” ff. “German obsolete units of measurement” gg. “Ancient Greek units of measurement” hh. “Greek units of measurement” ii. “Guinean units of measurement” jj. “Haitian units of measurement” kk. “Honduran units of measurement” ll. “Hungarian units of measurement” mm. “Hong Kong units of measurement” nn. “Icelandic units of measurement” oo. “Inca Empire” pp. “Hindu units of time” qq. “Indian weights and measures” rr. “History of measurement systems in India” ss. “Indonesian units of measurement” tt. “Old Irish units of measurement” uu. “Italian units of measurement” vv. “Japanese units of measurement” ww. “Latvian units of measurement” xx. “Libyan units of measurement” yy. “Luxembourgian units of measurement” zz. “Maltese units of measurement” aaa. “Malagasy units of measurement” bbb. “Mauritian units of measurement” ccc. “Ancient Mesopotamian units of measurement” ddd. “Mexican units of measurement” eee. “Moroccan units of measurement” fff. “Nicaraguan units of measurement” ggg. “Norwegian units of measurement” hhh. “Omani units of measurement” iii. “Ottoman units of measurement” jjj. “Paraguayan units of measurement” kkk. “Persian units of measurement” ll. “Peruvian units of measurement” mmm. “Philippine units of measurement” nnn. “Obsolete Polish units of measurement” ooo. “Portuguese customary units” ppp. “Puerto Rican units of measurement” qq. “Ancient Roman units of measurement” rr. “Obsolete Russian units of measurement” sss. “Scottish units” tt. “Serbian units of measurement” uu. “Seychellois units of measurement” vv. “Singaporean units of measurement” www. “Slovak units of measurement” xxx. “Somalian units of measurement” yyy. “South African units of measurement” zzz. “Spanish customary units” aaa. “Sri Lankan units of measurement” bbbb. “Swedish units of measurement” cccc. “Swiss units of measurement” dddd. “Syrian units of measurement” eeee. “Taiwanese units of measurement” ffff. “Tanzanian units of measurement” gggg. “Obsolete Tatar units of measurement” hhhh. “Thai units of measurement” iii. “Tunisian units of measurement” jjjj. “Uruguayan units of measurement” kkkk. “Venezuelan units of measurement” ll. “Vietnamese units of measurement” mmmm. “Welsh units”

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Chapter 8

Historical Time



Abstract This chapter explores the development of the concept and the measurement of time throughout history. Recognition of time philosophically as a “thing” that could be measured and the methods for performing that measurement required several millennia to develop. Measurement has moved from recognizing a consistent daily solar cycle to longer term measures that are synchronized with other celestial events. Shorter measures began as divisions of day and night into what amounted to hours and progressed to smaller and smaller increments to current abilities to measure in units like picoseconds (10^{-12} seconds). Relativity throws a bit of a monkey wrench into simple time measurement, although the impact is not detailed here. Methods have been and are being developed to account for the effects of relativity on time measurement that will be needed in the future. Interestingly, time is the one measurement that has become fairly standardized throughout the world, regardless of the metric or English systems. The modern standard in the metric SI system is, oddly enough, based on the ancient Mesopotamian method of measurement starting with the second. Attempts to develop a decimal approach to time measurement have not been successful. A number of time measurement units and conversions are provided, along with their historical context.

Introduction

This chapter deals with the historical development of understanding and measuring time, as well as providing the factors for interconverting among historical systems where possible.

Time is one of the more interesting fundamental or base properties because it is more difficult to define than things like length or volume or mass, which you can physically experience and measure directly. Time is primarily an artificial, intellectual construct to explain the apparent differences or separations in occurrences of events. Understanding it really requires the concepts of events and “simultaneity” to differentiate time. Many definitions are circular.

We use time as a structure in which events are placed in order and by which events are separated. We observe that events happen in specific order, with cause and effect. Events do not happen out of order. For instance, you could not be born before you were conceived or before your parents met (neglecting any ideas about time travel).

Hence there is a progression of events that we consider to occur over time. If we didn't have time to separate events, everything would happen at once. We observe that everything does not happen at once—we can experience separate events. In perspective, on a very large time scale, events may appear to happen all at once, but at a fine-enough resolution, they do not. For instance, the entirety of human existence on the time scale of the universe might appear to happen at once, but on the time scale we humans experience, human events require notable time periods. From a practical standpoint, we experience a sequence of events in a specific order that are separated by a measurable thing we define as time.

An “event” could be considered to be a specific arrangement and condition of matter in space that occurs simultaneously at a specific instant. Due to movement or changes, one instantaneous event evolves into another instantaneous event, which becomes another one, and so on. We can observe each of these arrangements, so we would say that they do not all exist simultaneously, but are instead separated by something. That something is essentially time.

In dimensional analysis, there are seven fundamental “dimensions” described. Time is one of the fundamental dimensions, along with length, mass, electrical charge, temperature, amount of substance, and luminous intensity. You can describe something using dimensions, like an event, but that description is only valid within a specific frame of reference at a specific point in time.

For us to function and understand the world around us, there must be some understanding of time, although it doesn't need to be a very deep understanding for most everyday purposes.

Time is one of the fundamental measurement properties or base units in both the SI and U.S. Customary (English) systems of measurement. The units happen to be identical in both of these systems after an interesting, and ultimately futile, foray into metric time in the 18th century, but the roots of time measurement and understanding go far back in “time”.

Much of this chapter is concerned with mankind's struggle to understand and quantify time. We will explore the concepts of time as they have evolved through history. We will talk about how the passage of time has been measured or inferred and the different systems of units that have been applied. We'll compare and contrast the time units, ending with conversion factors between time units.

We will start with a brief exploration of the nature of time.

Nature of Time

Regimes

Time units can be divided conceptually into two distinct regimes or durations for definitions:

- *Short times* are considered to be those of less than one day in duration. Short times are measured by devices such as clocks. Modern units for short time periods would include hours, minutes, seconds, microseconds, nanoseconds, and picoseconds.
- *Long times* are periods of one day or more in duration. Long times are measured by devices such as calendars. Examples of long time measurement units would be days, weeks, months, seasons, solar years, lunar cycles, decades, centuries, millennia, eons, and epochs.

We chose the daily (diurnal) cycle of the earth's rotation only as a convenient dividing line, but we could choose any consistent cyclic event that appears to occur with predictable regularity. In development of standards for time measurement, other cyclic events have been used as a basis and time periods are defined over a continuum.

Historical developments of time concepts and measurements in these two regimes have taken separate paths which we will address in discussion.

Historical Concepts of Time [16, 34]

Evolution of Concepts

Time has long played a role in philosophy and religion in addition to practical application and scientific study. We will look briefly at how time has been viewed in each of these realms.

Philosophy

There have traditionally been two philosophical views of time. In one view, time is a real "structure" within which events occur in order, one after another. It allows time to be considered as a definable dimension. This is sort of a practical, realist's view.

The second view is that time is only an intellectual construct that allows us to understand events in combination with order and space. This is a bit harder to get your arms around. In this view, the concept of time is all about our human perceptions of events. It is a little hard to quantify time in this concept.

Both views, as well as all sorts of combinations and ideas, have been argued and put forth. Some of the ideas expressed on both sides and in the middle of this philosophical discussion have included:

- Parmenides of Elea (5th–6th centuries BC), Antiphon the Sophist (5th century BC), John McTaggart (1866–1925 AD), Julian Barbour (1937 AD–Present), and others have argued that time is not real, but is instead an illusion along with space. They maintain it is “unreal”.
- Aristotle (384–322 BC), paraphrasing, saw time as a measure of motion which could be divided into units. The concept is addressed in Book IV of his writings on physics. This is one of the more useful concepts because it gives us a chance to measure time.
- St. Augustine of Hippo (354–430 AD) saw time as a human perception that related the past, present, and future. This is similar to the second view.
- Isaac Newton (1642–1726 AD) subscribed to the first view of time as an absolute part of the universe. He viewed it as a real dimension.
- Gottfried Leibniz (1646–1716 AD) advocated the second approach to understanding time. He anticipates the understanding of time in relativistic terms—i.e. time is relative to one’s frame of reference.
- Immanuel Kant (1724–1804 AD) also advocated the view of time as a way we comprehend and sense experiences—again a mental construct.

While these philosophical arguments are interesting and engaging, they ultimately don’t help us much. If something isn’t somewhat “real”, how can we hope to quantify it and do anything useful with it. Since this work is focused on measuring and converting units, we will assume the view that time (and space, too) is a real, measurable dimension. It may be a mental construct, but so are most of the ways we perceive the world around us.

Operational/Practical

For our normal, everyday use of time, it is possible to parse the passage of time by comparing other events against a cyclic event that we experience as requiring exactly the same amount of time per cycle. For instance, a pendulum of a specific weight and arm length appears to take exactly the same amount of time to complete one swing within our local frame of reference. We measure and standardize time durations based on this type of event—either fractions or multiples of defined events.

This approach provides a practical and useful approach to quantifying and using time, without having to fret over the nature of time. This still works for us in our normal experiences and normal frames of reference. We will see that this perception of time is not always valid, but we will use it anyway. This approach is consistent with that of Isaac Newton.

It is interesting to note that the division of the day into smaller partitions has not necessarily been consistent. In ancient Greece and Rome, for example, the daylight time (from sunrise to sunset) was separated into 12 “hours”. Because the actual length of the daylight varied during the year, the quantity of time represented by one hour also varied. The Greeks and Romans divided the dark time (from sunset to sunrise) into four “watches” which also varied in length. Water clocks or oil lamps could be used to time the watches during the dark hours. The variation of the amount of time represented by these divisions continued in common use throughout most of human history until mechanical clocks became more common around the 14th century AD.

In the meantime, however, astronomers and others recognized that it would be best if the time divisions were consistent throughout the year. Hipparchus of Nicaea (~190–120 BC), a Greek, proposed dividing the day into 24 equinoctial hours (i.e. hours of equal length). There would be 12 daylight hours and 12 night hours on the days of the equinoxes in Spring and Autumn when the lengths of day and night are equal. The reasons for the 12 divisions of day or night probably were related to the way people of the time counted, but this is not well-established. This is essentially the system we use today.

Impact of Theory of Relativity

Albert Einstein (1879–1955 AD) published his Special Theory of Relativity around 1905. In this modified view, he related space and time perception with the observer’s frame of reference. In this view, space-time could appear to change depending on speed relative to an observer. This dilation of space and time was significant only at more extreme speeds approaching the speed of light.

We won’t go into this concept in any depth since it does not relate to normal perception and measurement of time (and I’m sure I could not do an adequate treatment of the topic, anyway), but it does mean that the simple conversions of time units from one system to another that are presented here are only valid for nominal speeds (far lower than the speed of light) and with the other conditions common to our normal frames of reference.

Historical Time Measurement Methods

[5, 6, 15, 26, 28, 29, 34]

A number of methods for measuring the passage of time have been applied over the millennia in which time has been important to us. The earliest methods were applied to long time periods, with days (or maybe day/night) being the shortest time durations of interest to centuries or millennia for long durations. These were

normally based on naturally occurring events and were often tied to events in religion or agriculture.

It was not until around 4000 BC that the means for actually quantifying time durations shorter than about one day (or daylight and night) were developed. These shorter periods could be measured by sundials, water clocks, hourglasses, and candles. As technology and needs developed, more accurate and finer time measurements were required, which led to the development of mechanical, electronic, and atomic clocks.

We will examine each of these approaches in the following discussion.

Natural Cycle Observations

The most common method for measuring the passage of time has been simple observation of the cyclic events of the “natural” world and the universe. This approach works best for time durations in the longer scale (one day or longer).

The day (or diurnal cycle) is the first and most obvious natural cycle we can observe. A day, on average, is the same length all the time, although there may be variations between the amounts of light and dark within a day. The position of the sun in the sky was used to define when one day ended and another began. In many cases, the maximum angle of the sun in the sky would separate one day from another. In other cases, sunrise or sunset defined the start and end of a day.

Another observed phenomenon that has been used for time keeping is the lunar cycle. It was observed that the moon goes through a regular cycle from a “new moon” which is completely dark through a “full moon” and back to a new moon every roughly 29 days. Hence longer times could be reckoned by the “phases” of the moon. This is the basis for “lunar” calendars. We have Native Americans stereotypically referring to this sort of cycle when tracking time—e.g. an event was said to have occurred so many “moons” ago.

The annual orbit of the earth around the sun, lasting roughly 365.24 days, was observable by carefully tracking the sun’s location each day—the year. This is a “solar” or “sidereal” year. Observers could see that the elevation of the sun at the same time in each day changed in a cyclic pattern. The elevation of the sun above the horizon would move higher at noon each day during the summer and lower during the winter, but always returning to the same location before starting a new cycle. The ability to accurately determine the length of a year by solar observation was limited by the tools available at the time. In various societies and times, the length of a solar year has been calculated to be 360 or 364 or 365 days, with periodic adjustments as necessary to keep the year in sync with the actual orbital time of the earth around the sun. The extra day in every fourth year (Leap Year) that we use today is an example of one of these “intercalary” adjustments to keep the calendar year consistent with a solar year.

Celestial observations of the stars and planets were also used for determining long time periods. It was noted that the arrangement of stars in the sky went through

cycles. Astronomers and astrologers named the star arrangements for ease of recognition or to attach some meaning to the shapes they saw. Thus the “constellations” were defined. The appearance of the various constellations in the sky was observed to have a cycle that was more or less consistent with a year. However, the constellations also exhibit a longer cycle of roughly 26,000 years due to the precession or wobble of the earth on its axis of rotation. This longer cycle was first observed early, with early calculation of the precession period about 160 BC by Hipparchus of Nicaea (~190–120 BC).

The planets presented another sort of cycle that was not consistent with a year, but instead, each had a different sort of movement which would remain unexplained for many centuries until planetary orbits around the sun were understood.

People could also observe that certain types of events corresponded to certain parts of the yearly cycle. These were convenient subdivisions of the year and had specific meanings to agricultural or hunter-gatherer civilization. In Egypt, for example, they noted that the year could be divided into three roughly equal numbers of days based on the Nile River flow and the agriculture that depended on that flow:

- *Inundation Season (Akhet)* when the river filled and overflowed its banks into the surrounding land, bringing needed nutrients and moisture to the dry land
- *Emergence Season (Peret)* when the crops could be grown on the moist, fertilized land
- *Harvest Season (Shemu)* when the river level was low and the crops were harvested—typically summer

Our four seasons today are a northern hemisphere version of this type of division that is rooted in an agricultural economy:

- *Spring* when crops are planted and begin growing
- *Summer* when crops grow to maturity
- *Autumn or Fall* when crops are harvested
- *Winter* when it is too cold for agriculture

Hunter-gatherer societies have similar divisions of a year that would be based on when specific plants would yield food and the migration and availability of various game animals. They still follow a roughly annual cycle.

Today, of course, we know that the lengths of a year and a day have been changing very slowly for all of history. A year today is 365 days (and change), but 900 million years ago, a year was about 486 days. The length of a day or one complete rotation of the earth has increased by about 0.0015 hours (current basis) per million years.

The actual time the earth needs to make one complete orbit of the sun has similarly changed over the life of the earth. Today, a year is about 3 minutes longer than it was 4000 years ago or about 12.5 hours (current basis) longer per million years.

For practical purposes, we won't notice these differences in our lifetimes, but they can factor in over history.

Tally Stick (Before 30,000 BC) [22]

Probably the oldest device for measuring the passage of time was the tally stick or various equivalent forms. A tally stick is just a simple stick on which a mark or notch is made to count items. Equivalent alternatives would include making a mark on any sort of relatively durable source, like the wall of a cave. This sort of device was used for, as an example, counting the number of days as they passed. Evidence for use of these devices exists from the Paleolithic Era as early as 30,000 BC. They were used for other purposes also.

The tally stick endured into the middle ages, primarily for commercial purposes.

Oil Lamp (Before 4500 BC) [15]

Oil lamps have been used since well before 4000 BC. Their primary purposes were for lighting and heating; but they were easily adapted for use as timers. You simply measured a time period by how long it took for the lamp to burn up a specific, measured amount of oil.

The oldest lamps were made of terra cotta, but many materials, including metals, have been used. The key parts of an oil lamp included a reservoir to hold the oil, an opening for filling the reservoir, and a hole from which a wick protruded or which had a small channel to conduct oil to support a flame. See Fig. 8.1.

Fig. 8.1 A replica oil lamp in its simplest form—Canaanite style of about 1500–1200 BC. A specific amount of olive oil would burn for a known time when used as a “clock”. Lamp could be made simply from a round clay “pancake” and then fired



Accuracy of this type of device could vary significantly. Factors affecting the accuracy could include drafts, quality and consistency of the oil, and fabrication of the lamp. An oil lamp could show errors in timing of several minutes or hours.

Water Clock (Before 4000 BC) [15, 21, 28, 29]

A water clock or clepsydra allows measurement of the passage of time by monitoring the level of water in a container that is either losing or accumulating water at a controlled rate. See Fig. 8.2. China has evidence of the use of water clocks as early as 4000 BC. There is also evidence that this type of time keeping device was used in India as far back as 2800 BC. Water clocks were used for astronomical calculation in Babylon as early as 2000 BC. Documentation of these devices has been found in Egypt dating back to the 16th century BC.

A major advantage of a water clock is that it does not depend on the sun, like a sundial does. They could be used, for instance, during the night to time the watches stood by soldiers. In Babylon, the timing of a clepsydra was used as a basis for paying soldiers for standing watch. The Greeks used these devices for timing speeches and for visits to brothels.



Fig. 8.2 Model of outflow water clock 0.99 mm hole in basin allows water to drip out at controlled rate Markings in basin indicate water level at 3 minute intervals

A simple water clock would consist of a bowl with a hole near the bottom from which water leaked at a controlled rate. The inside of the bowl would be calibrated to some time scale of interest. Figure 8.2 is an example of an outflow type of water clock. An outflow clock would be non-linear as the outflow rate would vary with level; but the shape of the vessel could be controlled to minimize this effect.

An inflow type of water clock accumulated water from a steady, regulated inflowing water stream. The accumulated level of water in the clock would indicate the time. In this type of clock, it would be possible to have a linear relationship between level and the time reading by ensuring a stable inflow rate.

Advances to the accuracy and methods for reading these devices were made by several civilizations which included the addition of mechanical ways to display the time reading with greater accuracy than you could read by simple inspection. In Babylon, the weight of water in a vessel was used to determine the time instead of the water level. Some clocks have had animation of characters indicating the time. There are modern-day versions of water clocks that are more art than practical time keeping devices, employing multiple siphons and trip systems to track time.

Accuracy of water clocks is affected by several factors: fluid used (normally water, but could be any liquid), temperature, viscosity, fluid purity, erosion, fouling, nozzle size and shape, level, evaporation, and so on. At best, the error in a water clock is probably several minutes to an hour per day. This accuracy was good enough for the times and purposes for which they were used, however.

Sundial (Before 3500 BC) [15, 23]

The apparent motion of the sun through the sky was noted to cast a shadow from any stationary device. That shadow would move in a predictable, steady manner from sun up to sun down. Rough time passage could be judged just by observing the shadow's length or location.

At some point, people decided to divide the shadow location into segments which would correspond to specific elevations of the sun during a day to get smaller readings. The sundial developed from a simple stick in the ground to a more precise device for the measurement of time passage.

The earliest sundials found to date are obelisks from Egypt (3500 BC) used for astronomy. Shadow clocks dating to 1500 BC have also been found in Babylon. References or instructions for making sundials can be found in the writings of Marcus Vitruvius Pollio (~75 BC–15 AD), Giovanni Padovani (~1512–???? AD), and Giuseppe Biancani (1566–1624 AD).

Sundials persisted as one of the common and inexpensive time keeping devices until the development of the mechanical clock in the Middle Ages. Figure 8.3a shows a sundial from the Middle Ages in Nuremberg, Germany, and Fig. 8.3b shows a more modern sundial from the Public Garden in Halifax, Nova Scotia. You still find sundials used primarily for decorative purposes today.



Fig. 8.3 **a** Medieval sundial on side of building in Nuremberg, Germany (left), **b** Sundial in Public Gardens at Halifax, Nova Scotia, Canada (right)

The chief disadvantage of a sundial is that you need the sun to obtain a reading. A cloudy day and nighttime totally confound a sundial. If you want to measure time during one of these conditions, you need another type of device.

Hourglass (Before 150 BC) [15, 20]

An hourglass is a device for measuring the passage of time using the rate at which a fine particulate, like sand, passes through a narrow neck or orifice connecting one sealed container to another vertically. It is best applied as a timer with a fixed time duration. The hourglass is really an evolution from a water clock in its general principles.

The sides of the hourglass containers or bulbs are steep enough that the material inside cannot reach its angle of repose, so that the material continues to drain smoothly and completely from the upper container into the lower container. See Fig. 8.4.

A specific amount of time is required for all the sand (or other material) to drain from the top container into the bottom container. The container sizes, the quantity of sand, and the size of the orifice relative to the sand determine the amount of time indicated by the hourglass. Once set, the time period indicated by emptying of the top container into the bottom will be almost exactly the same each time the hourglass is inverted.

The material used in the hourglass has traditionally been fine, dry, fluidizable sand or a mixture of powdered marble, oxides, and pulverized eggshell; but it can be any material that acts like a fluid. The sand nominal particle size is in the range of $1/12$ to $1/2$ of the size of the narrow neck or orifice. The bulbs that contain the

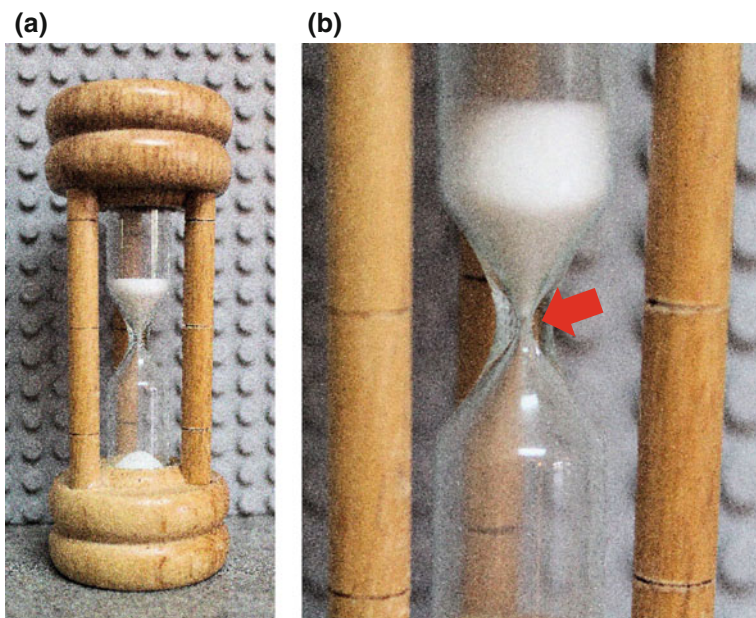


Fig. 8.4 **a** An inexpensive kitchen timer hourglass (left), **b** Orifice for regulating sand flow in hourglass (right)

sand are normally glass, so development of a good hourglass actually followed the development of glass blowing.

The earliest hourglasses consisted of two teardrop-shaped bulbs with openings at the small end of each tear-drop. The openings were connected together by wax and string, with the sand sealed inside. This was the construction used until about 1760 when the two bulbs were blown together.

The chief differences between an hourglass and a water clock are:

- (1) Use of a dry medium that will not freeze
- (2) Ability to be used repeatedly and indefinitely because the medium is sealed in the hourglass, so that inverting the hourglass allows you to start measuring the next increment of time without having to refill a container
- (3) Improved accuracy and precision with fewer sources of error

At least one version of the hourglass was invented around 150 BC in Alexandria and was called the clepsammia or sand-glass. They were used in Rome for timing events. By the 4th century AD, they were well known and were used as symbols for the passage of time. We find mention of the hourglass in the 8th century AD and common use of this device in the 14th century AD.

Hourglasses found an important application in ships where they could be used as an accurate, dependable way of measuring time before the invention of the mechanical chronometer in the 18th century AD. A ship would carry several

hourglasses on an extended voyage, with each showing a different time increment. A crew member, usually the page, was assigned to turn the hourglasses. Knowing the exact time was required for accurate celestial navigation. They have been used for this purpose since at least the 14th century AD.

Widespread use of hourglasses for timing events (like speeches, sermons, cooking, etc.) has persisted even after the invention of the mechanical clock, although use did taper off after the 15th century due to the ready availability of clocks. Today you seldom find hourglasses used for tracking time, except for timing the boiling of an egg or a turn when playing “Pictionary” or while you are waiting for a download on your computer. For practical uses, even in these applications, hourglasses are being replaced by electronic timers.

Candle Clock (Before 600 AD) [15]

A candle clock is primarily used for roughly timing an event, but could also be used for indicating a rough time of day or night. This is really just another form of oil lamp, based on a solid hydrocarbon wax rather than liquid oil as fuel.

This type of clock uses the uniform burning rate of a straight candle made from consistent materials. The candle length is reduced by burning of the candle wax at a relatively constant rate. The height of the remaining candle stub at any time indicates the time or duration of the burn. The candle itself could be marked or an indirect reading scale could be created. An example of a candle alarm clock is shown in Fig. 8.5.

Fig. 8.5 Example of a candle clock with an alarm. Marks on the candle indicate hours of burning time. Nail in candle falls and hits metal base, creating an alarm. Nail set for 1 hour time and it fell at 58 minutes



Candle clocks were used in China beginning in the 6th century AD, but are likely to have been used much earlier. They were probably independently invented in many other areas of the world. They were primarily useful only for event timing and not telling the time of day. They would be used for timing a sermon, for instance.

This type of time-keeping method is subject to a number of errors, including the effects of drafts and differences in wax quality and uniformity of the candle. If you had a day-long burning candle, the best accuracy would be to an hour or so per day.

Mechanical Clocks and Watches (~725 AD) [15, 19]

A mechanical clock keeps track of time by measuring beats or oscillations of a regulating mechanism and translating that movement into an indication of current time. There are five key elements involved in a mechanical clock:

1. *Energy source*: This can be any method for storing energy for a reasonable period of time and delivering it as the driving force for the clock. Energy sources used in the past have included falling liquids, falling weights, springs, and electricity.
2. *Cyclic timing (or beat) mechanism*: This is a device which is capable of dividing time into specific, predictable units. Timing mechanisms have included fluid rates (e.g. droplets per unit time), pendulums, foliots, balance wheels, and magnetic oscillators. The most common timing mechanisms have been the pendulum and the oscillating balance wheel. The rate at which the timing device oscillates has an effect on the accuracy of the clock. Pendulums may have periods of several seconds per beat whereas a watch and many clocks typically have periods of 3–4 cycles per second or higher. Your time-keeping device can't indicate finer time divisions than the oscillation frequency of the timing or beat mechanism.
3. *Regulation mechanism*: This is a mechanical system which senses the cyclic beat and uses that beat to control the speed at which energy is released from the energy source to the gear train. The regulation mechanism is normally an "escapement". This is probably the key development that enabled the construction of reasonable mechanical clocks. We will look at these mechanisms in more detail later.
4. *Gear train*: The controlled energy release through the escapement is used to drive a gear train where the speed of the escapement, which is normally relatively fast, is reduced to the slow movements required for indicating longer time divisions (minutes, hours, days, etc.).
5. *Indication mechanism*: Eventually the movements created by the gear train must be translated into an indication of time. This has usually been accomplished by mounting a calibrated dial over the final gear and providing hands that rotate with the final gear to indicate the time (usually hours). Additional hands that

indicate shorter or longer time periods are tied to other gears (e.g. minutes, seconds, moon phases, days). Many clocks have other associated mechanisms that play tunes, ring bells, and trigger other mechanical devices (e.g. moving figures).

The first primarily mechanical clock appears to have been that developed by Yi Xing and Liang Lingzan about 725 AD. The escapement mechanism applied was well-known prior to this time, having been described by Philo of Byzantium in the 3rd century BC. Xing and Lingzan's clock used water as the energy source that was regulated through an orifice, so this could still have been considered a sort of "water clock". Similar hydraulic mechanisms provided the motive force to drive the escapement in subsequent Chinese devices. The fluid was not always water. In 979 AD, for example, liquid mercury was used and this type of working fluid was applied in other areas of the world subsequently.

Sometime in the late 13th century AD, in Europe, it is believed that the driving force for the escapement mechanism was converted to the use of falling weights for the energy source and the first purely mechanical clocks were born. This made for a cleaner and simpler drive that would be influenced much less by temperature. Weights applied a relatively constant force. The verge and foliot escapement was the most common form, with its swinging counterweights to regulate speed using the inertia of the weights; but there are many types of escapements. The verge and foliot escapement was the standard for mechanical clocks for around 400 years.

Accuracies of the early mechanical clocks were limited by friction and the inability to consistently maintain a beat, thus the available devices for timing were rough at best. This situation changed in 1657 AD with the development of the pendulum and balance spring. These created the ability to produce a precisely measured beat to drive new types of escapements that were relatively insensitive to the force applied. The force could be applied by weights, but other forms of stored mechanical energy were usable, such as coiled springs (earliest surviving example dated 1450 AD). The improvement in accuracy resulted in errors of less than a one minute per day. Prior to this time, clocks would only indicate hours; after the development of pendulum clocks, indications of minutes were worth adding.

The demands for accurate time when at sea drove further accuracy increases in clocks. John Harrison, in 1761, made improvements to reducing friction and compensating for temperature to yield an accurate chronometer for navigation. This improvement in accuracy enabled mariners to determine their longitude to within $\frac{1}{2}$ degree ($\pm$ about 30 miles at the equator) for long periods of time.

As mechanical clocks developed, their accuracy improved. The most accurate commercial clocks of this type used the electromechanical Shortt-Synchronome mechanism (by W. H. Shortt, 1921 AD) and were accurate to within 1 second per year. Higher accuracy devices have been built, but were not produced commercially. These devices are electromechanical in the sense that electricity is used to provide the driving force in place of weights or springs. This is not the same as the types of clocks discussed in the next section.

The use of mechanical clocks driven by springs, weights, or electricity continues to this day, but the evolution of knowledge about electricity and electronics have led to new ways of driving the clock mechanisms and totally new types of clocks which we will explore in the next section.

As noted above, the key to the development of the mechanical clock was a reliable escapement mechanism. Table 8.1 lists many of the escapement systems that have been used over the years.

Referring to Fig. 8.6, an escapement usually has some sort of escapement wheel (A) (sometimes a crown wheel) with specially shaped teeth or pins. The wheel is connected to the energy source. Without the escapement, the energy source would simply turn the wheel at an increasing speed until it was limited by friction. This would not track the passage of time or it would use too much energy; so the speed of the escapement wheel is controlled by two (or more) pallets (B1, B2) mounted on an oscillating lever (C) (or a rod in some designs) so that the pallets alternately engage, lock, and release teeth on the escapement wheel.

Now the escapement wheel would still increase in speed if the oscillation of the lever with the pallets was not controlled, so the timing or beat device enters the picture. The timing device is connected to the pallet lever and limits the rate at which the lever can move. The timing device can exert a very large force relative to the forces on the pallets so that the speed of the escapement wheel is finally controlled. From this point, the escapement wheel movement is simply translated through a gear train into the indicated time.

Mechanical clock movements can be simple or very complex. Figure 8.7 illustrates a wooden, complex, chiming movement.

Electric and Electronic Clocks (Beginning ~1814 AD) **[15, 18]**

The first electric clock was developed by Sir Francis Ronalds (1788–1873 AD) in England around 1814 AD. Its reliability varied significantly with weather, but he was eventually able to improve the reliability. Giuseppe Zamboni (1776–1846 AD) developed an electrostatic clock in 1815 AD that was battery powered and extremely energy efficient. He continued to produce these clocks for some years.

Alexander Bain (1811–1877 AD) patented the first electromechanical clock in 1840 AD. His design used electromagnets to provide the periodic timing pulses in place of a pendulum or other device. There were several inventors that followed with similar concepts. Matthias Hipp (1813–1893 AD) was the first clock maker to mass produce electromagnetic clocks in Switzerland beginning about 1843 AD. A traditional movement was driven by the magnetic pulses to indicate the time, but an escapement mechanism was not necessarily used. You still find this type of movement in some large clocks for display.

Table 8.1 Some historical escapement mechanisms [19]

Name	Inventor(s)	First use	Key features	Uses	Advantages	Disadvantages	Accuracy
Verge or crown wheel	Unknown	~1275 AD	Crown wheel, pallets connected to rod, rod oscillation controlled by foliot (weights on ends of an oscillating beam) or other timing device	Large clocks, wall clocks, watches	Simple, capable of being made using technology of the time	Poor accuracy, recoil causes wear & inaccuracy, rate varied with driving force	Hour(s) per day
Cross beat	Jost Bürgi	1584 AD	Similar to verge escapement with two foliots used to regulate movement	Wall clocks, large clocks	Slight increase in accuracy, better fabrication practices	Same as verge escapement	Hour per day
Anchor	Robert Hooke	~1657 AD	Toothed escapement wheel engaged by oscillating anchor-shaped piece holding the pallets and connected to timing device	Large clocks, wall clocks, floor clocks, grandfather clock	Much better accuracy, very simple, works well with pendulum	Slight variation with driving force, still has recoil and wear limiting accuracy	Minutes per day
Deadbeat or Graham	Thomas Tompion, George Graham	~1675 AD	Similar to anchor escapement with improved shapes to avoid recoil	Large clocks, floor and wall clocks	Good accuracy	Still some variation with driving force	Minute per day
Pin wheel, Amant, or Mannheim	Louis Amant	~1741 AD	Used pins in place of a toothed wheel with a scissors-like anchor	Tower clocks, wall clocks	Good accuracy	Still some variation with driving force	Minute per day

(continued)

Table 8.1 (continued)

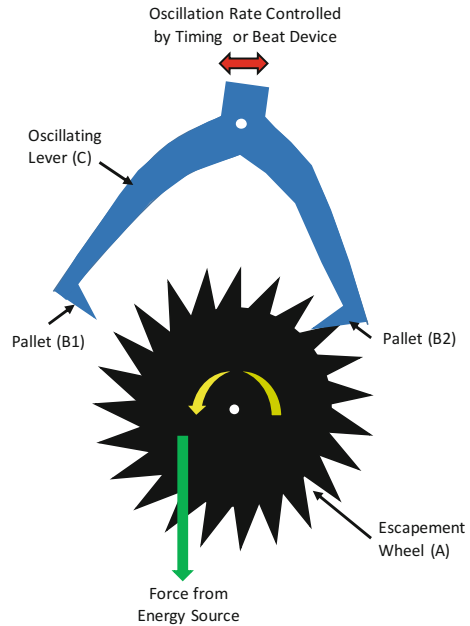
Name	Inventor(s)	First use	Key features	Uses	Advantages	Disadvantages	Accuracy
Detent or chronometer balance wheel	Pierre Le Roy, John Arnold, Thomas Earnshaw	~1748 AD	Oscillating balance wheel (with spring) moved pallets which engaged escapement wheel teeth	Precision Watches, marine chronometers	High accuracy, small	Fragile, skilled maintenance needed, not self-starting, sensitive to shock, hard to mfr. in volume	Seconds per day
Cylinder	Thomas Tompion, George Graham	1695 AD	Oscillating, cutaway cylinder connected to balance wheel acts as the pallets to engage escapement wheel with wedge-shaped teeth	Pocket watches after 1700	Good accuracy, can be made very thin	High friction, wear, requires frequent cleaning	Minute per day
Duplex	Robert Hooke, Jean Baptiste Dutertre, Pierre Le Roy, Thomas Tyrer	~1700 AD	Two stacked, toothed escapement wheels alternately engaging two types of oscillating pallet shapes coordinated together	Pocket watches	High accuracy, small	Hard to make, some friction effects, sensitive to shock, not self-starting	Seconds per day
Lever	Thomas Mudge	~1750 AD	Oscillating balance wheel moves a lever containing two pallets back and forth. Pallets engage and release teeth on escapement wheel	Majority of watches since 1800s	High accuracy, cheap, simple, reliable, small	Friction, wear	Seconds per day

(continued)

Table 8.1 (continued)

Name	Inventor(s)	First use	Key features	Uses	Advantages	Disadvantages	Accuracy
Pin pallet, Roskopf, or pin lever	Georges Fredric Roskopf	1867 AD	Pins mounted together on oscillating pallet engaged by balance wheel. Pins alternately engage and release teeth on escapement wheel	Watches, timers, smaller users	Cheap, simple to make, fairly good accuracy	Friction, less accurate than lever on pins, throwaway mechanism when broken	Minutes per day
Grasshopper	John Harrison	1722 AD	Two hinged arms hold pallets that engage and release balance wheel. Hinged arms connected to timing device	Clocks, rarely used	Interesting, fairly good accuracy	Recoil, rapid wear to mechanism, not energy efficient	Minutes per day
Gravity	Various	Mid 1700s AD	Two long arms with pallets on either side of pendulum. Arms alternately pushed out to engage & release teeth on two, stacked escapement wheels. Complex action	Tower or turret clocks (e.g. Big Ben)	High accuracy, not affected by driving force	Poor energy efficiency, complex	Second per day
Coaxial	George Daniels	1974	Multiple wheels and pallets in complex mechanism	Watches	High accuracy, low friction	Complex, not significant improvement over lever escapement	Second per day
Constant	Nicolas Déhone	2008	Flexing silicon blade oscillates back & forth between “S” and its mirror image as controlled by balance wheel	Precision watches	Excellent accuracy		<1 second per day

Fig. 8.6 Simple anchor escapement mechanism [19]

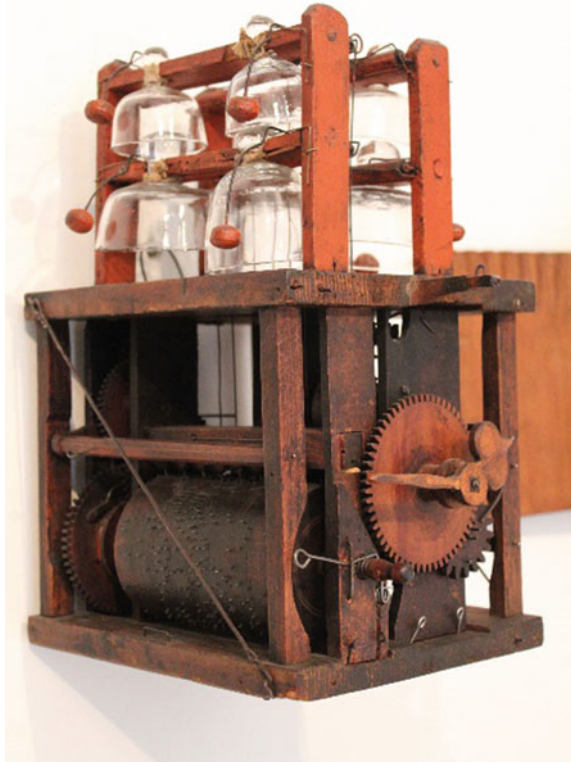


Electromechanical clocks used an electric motor or electromagnet to wind a mainspring that then supplied the power for a traditional mechanical escapement movement. This concept is merely a modification of the power source for a traditional clock. These are less common today.

In 1918 AD, Henry Warren (1872–1957 AD) developed the first synchronous electric clock. Beginning in the 1930s AD, these became common, with the first mass production of the clocks beginning in 1931. This type of clock used a synchronous motor as the timing device to drive a traditional gear train. The synchronous motor was locked into the 50 or 60 Hz alternating current (AC) supplied by the power company. Today, the power companies regulate the AC cycle very accurately using the Coordinated Universal Time (UTC) atomic clock maintained by the U.S. National Institute of Standards and Technology (NIST) and other entities as a reference, so the clocks have similar high accuracy. They require an AC power supply, so they are limited to fixed locations. These clocks have been replaced by quartz electronic clocks beginning in the 1980s, but inexpensive alarm clocks still use this principle.

Tuning fork clocks appeared about the 1960s AD. These clocks used an electrically excited tuning fork as a timing device. The clock movement sensed the specific vibration frequency of the fork and, through a gear train, translated the movement into time indication. This principle was primarily only used in watches because the mechanism could be very small and could be battery powered.

Fig. 8.7 A chiming mechanical clock movement in Clock Museum, Vienna, Austria



Today's clocks and watches are largely electronic. Stand-alone electronic clocks are based on counting the vibrations of a quartz crystal that is excited electrically by a battery or an AC power supply. The vibrations are counted electronically and translated into time digitally. The time displays can be digital or they can be converted into an analog display through an electromechanical movement. Some watches have both. Most clocks and watches today use this type of timing. Errors for this type of clock are only a few seconds per week. The cost of a quartz movement for a typical clock is less than \$10 US in 2016 for a movement with accuracy of $\pm$ less than 1 second per day. Better movements are available for higher accuracy, with higher cost. See Fig. 8.8.

A newer development is the radio-controlled clock. This clock uses a quartz movement for time keeping, but the time is periodically synchronized with the UTC atomic clock via a continuously broadcast radio transmission. These clocks can be battery or AC powered. The radio link reduces the error significantly.

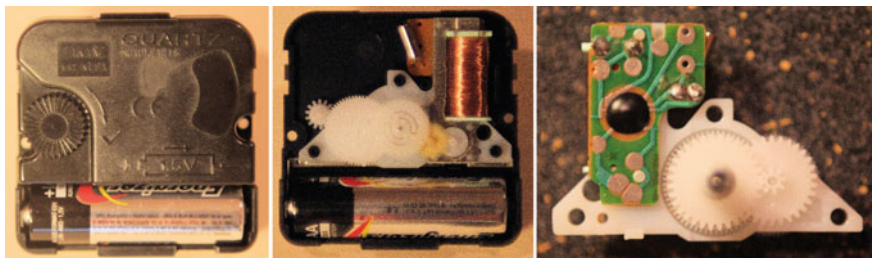


Fig. 8.8 Inexpensive battery-operated quartz clock movement. Left to right: Back of movement with battery; Electromagnet and nylon gear train for turning clock hands; Quartz clock circuit board and front side of gear train. Size of clock drive is about 2 inches (51 mm) square and 5/8 inch (15 mm) deep. Quartz timer itself is very small (Photos by the author)

Atomic Clock (1949 AD) [15, 17]

All clocks depend on some timing device to generate a consistent, detectable, and measurable frequency or beat. Pendulum clocks do this using the swing of a pendulum. Mechanical watches do this using a rotating balance wheel. Quartz clocks and watches make use of the vibrations of a quartz crystal or a tuning fork. The accuracy of these timing mechanisms is limited by the frequency of the beat. An atomic clock increases accuracy using a far higher frequency than any of the current alternatives, which enables it to divide time into very fine increments.

The concept of using an atomic scale phenomenon as the basis for time measurement was first proposed by William Thomson, 1st Baron Kelvin (AKA Lord Kelvin, 1824–1907 AD) as knowledge of transition states within atoms was beginning to be understood in 1879 AD. Measuring these transition states remained an obstacle until the 1930s AD, when Isidor Rabi (1898–1988 AD) developed a method for measuring magnetic resonance. The atomic clock became a reality in 1949 AD when the U.S. National Bureau of Standards built a clock based on an ammonia maser. The accuracy was not as good as alternatives, but the viability of the concept was established.

In 1955 AD, a clock based on a specific transition frequency of Cs^{133} was constructed by the National Physical Laboratory in the U.K. This approach led eventually to the current standard definition of a second in the International System of Units (SI): one second is equal to the duration of 9,192,631,770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the Cs^{133} atom. This then uses a frequency in the microwave range. Other atomic clocks have used different elements for the frequency standard, including H^1 and Rb^{87} , but the standard today remains Cs^{133} .

The early atomic clocks were bulky, roughly the size of a work bench. Work continued to develop commercial, smaller clocks. These became available in the 1960s AD and were rack-mountable. The 1990s AD saw further technology

advances that have led to atomic clocks that are the size of an integrated circuit chip (starting about 2004 AD) and require very little power input, making them feasible for battery-operated devices.

Improvements to atomic clocks continue. Higher accuracy would have several advantages, notably improved Global Positioning System (GPS) applications. The capability to meter time in the nanosecond range is necessary for high speed computing and communications. Current clocks have errors of less than 0.1 nanosecond per day or less than 32 seconds per 1000 years. This is accurate enough for most of us, but we don't know what the future holds.

Development of Standards for Time

[1, 8, 9, 11–14, 16, 25, 26, 34]

Early in history, it was not necessary to standardize the measurement of time. An agrarian or hunter-gatherer only needed to recognize days and seasons. This knowledge does not need to be very exact. An error of a few days or weeks in planting or game hunting would make little difference. The vagaries of weather would have been more important to our ancestors.

As civilization developed, the need for measuring finer as well as longer increments of time increased. The day and night were split into smaller increments. The year was divided into seasons which were standardized. Religious rites and ceremonies were performed at defined times of the year, so tracking time during the year became important. This was often done using the motions of the stars and planets.

Before the invention of clocks, the absolute length of hours in a day or night varied with the seasons. In many cases (like the Romans), the lengths of time increments during the day and night were not the same. With the development of the mechanical clock beginning around 725 AD, it became necessary to fix the length of time increments, regardless of day or night. This synchronized time-keeping with the earth's rotation. Of course, not all societies adopted the same increments for several centuries.

An hour was once the finest division of time available and measurable. With the implementation of better time keeping devices, minutes could be determined (starting in the Middle Ages) and seconds could be measured (starting in the 1500s) with enough accuracy and precision to make them worth measuring. The age of exploration in the 15th through 20th centuries AD required methods for precisely determining an explorer's location on the planet, which required time keeping to the nearest second or better. Improvements to clocks allowed this level of accuracy, whereas previous navigation often used various hourglasses.

Specialization that arose in civilization created new types of activities that depended less on seasonal considerations, culminating in our present, heavily industrialized society where work is often measured in increments of time. We are

expected to keep appointments at specific times. Machines are controlled by computers which perform operations in extremely small increments of time that must be, in turn, metered.

As we reach out toward the planets and stars, we will need increasingly accurate time measurement. Time measurement technology will develop as needs arise. At some point, we might expect to have to deal with the impacts and implications of relativity on time. New standardization concepts will be needed.

For a couple of generic definitions, we would note:

- Day—This is a single rotation of a heavenly body around its axis.
- Year—This refers to a single orbit of one body around another body, such as the earth around the sun. It may also refer to a single orbit of a group of bodies around a central point, such as the entire solar system's orbit around the center of the Milky Way Galaxy.

Since organized societies have dominated human culture, efforts have been made to standardize time measurement for both practical business, civil, and religious purposes. This section looks briefly at some of the approaches to standardization.

“Natural” Time Measures

The natural world offers us several possible standards for measurement of time.

For shorter time periods, the obvious choice is the daily cycle coinciding with earth's rotation with the marker being the movement of the sun through the sky. The actual amount of time represented by the sun's movement varies by season as you move away from the equator—being shorter in the winter than in the summer due to the earth's tilt with respect to the sun. It was still common to take the daylight time and divide it into an even number of increments, the length of which would vary by season.

For example, the Romans divided the daylight hours into 12 “horus” of equal length on any given day. The absolute amount of time represented by an increment would vary seasonally. Measurement could be made by sundial. They also divided the night into four “watches”, the length of which varied seasonally, also. Other civilizations had similar concepts for measuring time.

Finer increments of time have been defined using various natural phenomena, like the period of oscillation of a pendulum or the frequency of microwave radiation emitted by atoms. The ability to detect these measures is relatively recent, but they are none-the-less naturally occurring phenomena.

Longer time increments could be determined by the motions of the sun, moon, planets, and stars in the heavens. These gave rise to standardized calendars, discussed later. Astronomical and astrological observations are among the oldest efforts to standardize time measurements. The longer increments of time were used to guide determination of times for planting, harvesting, game migrations, celebrations, religious rituals, ages, and many other activities.

Some natural events that have been used to determine longer time standards are:

- Daily, solar or diurnal cycle—This is fairly universally used as one of the natural measures. The absolute length solar day is increasing slightly over time, but the change is small enough to be negligible for most purposes (1.7 milliseconds over the past 100 years). Still, the absolute length of a day was standardized in 1960 AD.
- Lunar cycle—The movement of the moon and the phases through which the moon passes in its 29.53 day cycle have been used as a standard in some systems. Unfortunately, the lunar cycle does not coincide evenly with an earth year. A lunar year (of 12 cycles) is 354.36 days long.
- Earth orbit around the sun (sidereal)—This 365.26 day period has been almost universally used as a long term measurement standard, although the exact time increment has varied based on the accuracy of measurement available at the time. Because the apparent star or constellation positions in the sky coincide with the sidereal cycle, the astrological year was essentially the same as the sidereal year. It should be noted that the length of a sidereal year actually is increasing slightly all the time, but the increase is small enough to normally be neglected.
- Sun's orbit around the Milky Way Galaxy (galactic year)—The entire solar system orbits the center of the Milky Way Galaxy roughly every 225–250 million years. For our purposes in measuring time, this is not a very useful standard, except as it relates to geologic time measurement. The entire history of human life on earth spans less than 0.01 galactic year.

Artificial Time Standards

Organized systems of units for time have been developed. These systems normally begin with the natural measures, but define the specific increments of time in a consistent and comprehensive manner. For example, in the SI system, we define that a second is 9,192,631,770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the Cs^{133} atom. This definition is artificial, but uses a natural phenomenon as a basis.

From seconds, we move up to minutes and hours. We also move to finer increments of time, such as milliseconds or nanoseconds. We artificially create some larger time measurement units for convenience, such as weeks, months, decades, centuries, and millennia. These units are specified by definition, starting with a natural phenomenon, but deviating somewhat. For instance, in the most common time system today:

- A second is defined by microwave radiation from Cs^{133} as the base unit for time.
- A minute is defined as 60 seconds.
- An hour is defined as 60 minutes.

- A day is 24 hours, but also coincides with one solar day.
- A week is defined as 7 days.
- There are different lengths for a month.
- A decade is 10 years.
- A century is 100 years.
- A millennium is 1000 years.

The use of 60 minutes in an hour and 60 seconds in a minute dates back to Mesopotamian times (before 4000 BC), where a Base 60 or Base 12 system was used in counting. This is not the only number base that has been used through history, but is the most persistent.

An interesting approach for forcing an artificial standard on time was developed for the French metric system in 1793 AD. It was in fact the first metric measure implemented. “Decimal time” divided a day into 10 metric hours of equal length. Each metric hour was, in turn divided into 100 equal metric minutes and each metric minute into 100 equal metric seconds. The day then equaled 100,000 metric seconds, compared to 86,400 seconds in our current system.

While decimal time worked fine for a single day, it offered no advantages beyond a single day, since solar years, lunar cycles, and other physical phenomena did not conveniently occur in multiples of ten. Decimal time was abandoned after a few years by “popular demand”, as they say. Other societies, notably the Chinese (as early as 1000 BC), have used a decimal time system in the past, but now use the same system employed elsewhere. There have been periodic attempts in France and Switzerland to implement such a system again in the past couple of centuries, but our old Mesopotamian system, awkward as it is, persists.

Calendars

The term calendar refers to an organized system for tracking longer time periods of more than one day. Calendars are used for commerce/business, agriculture, religious/ritual, administrative, and many other activities within societies. The smallest increment of time on a calendar is normally one day, with larger time increments created by grouping days or periods into some sort of system. The individual days and groupings are given specific designations, either numbers or names, to complete the calendar.

The current calendar used almost universally is, essentially, the Gregorian calendar introduced in 1582 AD. The lineage can be traced back to the Romans. Periodic calls for reform of this calendar have not met with much interest due to the difficulty in adopting such a revision on such a huge, worldwide scale.

There are several types of calendar considerations and systems:

- A full calendar uses a different designation for each day. The complete designation for a day in the Gregorian system, for example, includes a day number, a

month name, and a year number. In the Unix or Julian calendar, the days of the year are simply numbered along with a numbered year.

- The calendar can use different sub-cycles. The Gregorian calendar includes weeks and months. These may or may not be synchronized to natural events.
- An overall calendar is normally synchronized with a natural phenomenon, such as the sidereal (yearly) cycle or the lunar cycle. Some calendars used both.
- Most calendars use more than one type of cycle and many contain elements that are not based on natural cycles. For instance, a Gregorian month is roughly equal to a lunar cycle, but the lengths of the months varies between 28 days and 31 days so that when they all add together, you have a 365 day year, close to the actual 365.26 day sidereal year.
- Because calendars almost universally use one day and one year as bases for time measurement, systems include some sort of periodic intercalary adjustment to keep the calendar in sync with the desired natural phenomena. In the Gregorian calendar system, for example, there is one extra “leap” day inserted into the month of February every 4 years. There are also leap seconds inserted or subtracted as necessary. Other calendar systems, such as those based on the lunar and solar cycles, may insert complete leap months periodically to stay in sync with the sidereal cycle. For example, the Hebrew calendar inserts an extra month every 19 years, but the calendar slips a little relative to the seasons each year.

Table 8.2 provides a sampling of the many calendars that have been used over the centuries. You can see the wide range of calendar systems used throughout history, often overlapping or conflicting, even political. Many others have been proposed and not used. The “World” calendar proposed in 1930 AD would have changed our calendar from the Gregorian basis and was almost adopted by the United Nations. At this point, with worldwide applications of essentially the same calendar, the disruptions that would result from changing calendar systems would be huge.

One notable difference among most of the calendars listed is that, in numbering or naming the years on the calendar, the base year can change significantly. Our Gregorian calendar bases our counting of years on the traditional year of the birth (or conception depending on the reference) of Jesus Christ. There is no year zero. Years labeled “BC” are considered to be “Before Christ”, but are also labeled “BCE” for “Before Current Era” by non-Christians. For years following the traditional birth of Jesus Christ, the notation is “AD” for “Anno Domini”. Non-Christians may use “CE” to indicate “Current Era”. There is technically no year zero in this scheme; year 1 BC is succeeded by year 1 AD. Sometimes the AD, BC, BCE, or CE designation precedes the year, but the same connotations apply.

Not all cultures use the birth of Christ as the dividing line in history. Most recently, North Korea uses the birth of Kim Il-sung as the dividing line for the numbering of years.

The calendars do not always use the same event as the start of a year either. In the Gregorian calendar, we use January 1 to start the year, which is close to the

Table 8.2 Some examples of calendars throughout history [26]

Name	Basis	Society	Introduced	Notes
Egyptian	365 Days Fixed	Egypt	~ 2000 BC	Rising of Sirius begins year, 3 seasons
Umma (Babylon)	Lunisolar	Sumer, Mesopotamia	~ 2000 BC	Twelve lunar months plus intercalary month when decreed
Pentecontad	Solar	Amorites, Mesopotamia	~ 2000 BC	Seven periods per year plus annual addition of 15–16 days
Five Yin-Yang Phases	Solar	China	~ 2000 BC	Five phases per year, each with 1-day festival plus 2 months, 365 days
Four Seasons, Eight Nodes	Solar	China	~ 2000 BC	Four seasons, each season having a festival day & 3 months
Gezer	Lunar	Israel, Canaan	~ 1000 BC	Multiple divisions for year based on agricultural activities
Roman Republican	Solar	Roman Republic	713 BC	Divided original 10 lunar months plus unallocated days into 12 months, months had different lengths
Haab	365 Days Fixed	Maya	1st Millennium BC	Agricultural and ritual calendars, resp.; together formed 52 year cycle
Tzolk'in	260 Days Fixed	Maya	1st Millennium BC	
Attic	Lunisolar	Athens, Greece	6th Century BC	Several calendars; years had 10 or 12 mos, or multiple seasons
Old Persian	Lunisolar	Persian Empire	4th Century BC	Babylonian model
Seleucid	Lunisolar	Seleucid Empire	4th Century BC	Babylonian model
Qin	Lunisolar	China	3rd Century BC	Qin Dynasty
Genesis	Lunisolar	China	3rd Century BC	19 year cycle, Han Dynasty
Ptolemaic	Lunisolar	Egypt	238 BC	Similar to Julian, with leap day every 4th year
Julian	Solar	Roman Empire	45 BC	Revised Roman Republic calendar, still in use for rituals

(continued)

Table 8.2 (continued)

Name	Basis	Society	Introduced	Notes
Coptic	Solar	Egyptian	1st Century AD	Used by Coptic Church, combination of Julian and Ptolemaic
Ethiopian	Solar	Ethiopia	1st Century AD	Based on Coptic calendar
Qumran	364 Days Fixed	Judaism	1st Century AD	
Gaulish	Lunisolar	Gauls, Celts	2nd Century AD	Used before introduction of Julian calendar to Gauls and Celts
Zoroastrian	365 Days Fixed	Iran, Persia	226 AD	Combined Old Persian and Seleucid calendars
Chinese, Dàming	Lunisolar	China	510 AD	
Japanese	Lunisolar	Japan	6th Century AD	Multiple forms, derived from Chinese calendars
Chinese, Wùyín	Lunisolar	China	619 AD	
Islamic	Lunar	Islamic areas	632 AD	Continues in use for religious purposes
Pyu	Lunisolar	Southeast Asia	640 AD	In use until 19th century, Hindu/Buddhist
Nepal Sambat	Lunar	Nepal	9th Century AD	Buddhist origin
Byzantine	Solar	Constantinople	988 AD	Basically a Julian calendar derivative
Armenian	365 Days Fixed	Armenia, Iran	Medieval Times	Likely derived from Zoroastrian calendar
Florentine	Solar	Florence (Italy)	Medieval Times	Derived from Julian calendar
Pisan	Solar	Pisa (Italy)	Medieval Times	Derived from Julian calendar
Tamil	Solar	Tamil Nadu	Medieval Times	Hindu calendar
Nepali	Solar	Nepal	Medieval Times	Hindu calendar
Bengali	Solar	Bengal, Bangladesh	Medieval Times	Hindu calendar, revised as recently as 1987 AD
Thai Lunar	Lunisolar	Thailand	Medieval Times	Buddhist calendar
Pawukon	201 Days Fixed	Bali	10th Century AD?	Hindu basis, 10 concurrent weeks of 1 thru 10 days with intercalary days
Old Icelandic	Solar	Iceland	10th Century AD	Combined Julian & Germanic calendars, 364 days plus leap week

(continued)

Table 8.2 (continued)

Name	Basis	Society	Introduced	Notes
Jalali	Solar	Seljuk Sultanate, Iran	1078 AD	Influences by several calendars, including Julian, Hindu, Chinese-Uighur
Hebrew	Lunisolar	Judaism	11th/12th Cent. AD	Replaced Seleucid calendar, probably related
Tibetan	Lunisolar	Tibet	13th Century AD	Buddhist calendar
Seasonal Instruction	Solar	China	1281 AD	365.2425 day year
Runic	Solar	Sweden	13th Century AD	Coord. cycles in Sweden w/ Julian calendar, incompatible with Gregorian
Xiuhpohualli	365 Days Fixed	Aztec	~ 14th Century AD	Derived from Maya?, agricultural and ritual calendars, resp.; together formed 52 year cycle
Tonalpohualli	260 Days Fixed	Aztec	~ 14th Century AD	
Incan	Lunisolar	Inca Empire	15th Century AD	
Muisca	Lunisolar	Muisca (Colombia)	15th Century AD	Complex calendar with multiple types of years
Chula Sakarat	Lunisolar	Burma	16th Century AD	
Gregorian	Solar	Worldwide Standard	1582 AD	Modification of Julian calendar
Javanese	Lunar	Java	1633 AD	Combined Hindu and Islamic calendars
Seasonal Constitution	Solar	China	1645 AD	
Swedish	Solar	Sweden	1700 AD	Use in “political” opposition to Gregorian calendar until 1844 AD
Astronomical-year	Solar	Worldwide	1740 AD	Uses Julian years before 1582 AD; Gregorian after, 1 BC is year zero
French Republican	Solar	France	1793 AD	Gregorian calendar
Rumi	Solar	Ottoman Empire	1839 AD	Derived from Julian calendar
Badí’	Lunisolar	Bahá’í	1873 AD	19 month year with 19 days per month
Thai Solar	Solar	Thailand	1888 AD	Gregorian calendar with Buddhist year references
Minguo	Solar	Taiwan	1912 AD	Gregorian variant in Taiwan

(continued)

Table 8.2 (continued)

Name	Basis	Society	Introduced	Notes
Meletian	Solar	Some churches	1923 AD	AKA Revised Julian, synchronized to Gregorian with 900 year cycle
Solar Hijri	Solar	Iran, Afghanistan	1925 AD	Different year zero basis
Soviet	Solar	Soviet Union	1929–1940 AD	Gregorian basis, used 5 and 6 day weeks
Indian National	Solar	India	1957 AD	Gregorian-derived, used Indian months and different year zero
Juche Era	Solar	North Korea	1997 AD	Gregorian calendar with year zero of 1912 AD (birth of Kim Il-sung)
Nanakshahi	Solar	Sikhism	1998 AD	Gregorian calendar, Hindu months, different year numbering

winter solstice. Other calendars use other events as markers, such as the spring equinox.

The primary international standard for calendars today, however, is the Gregorian calendar with the first year of the calendar AD being the year following the traditional birth year of Jesus Christ and the year number changing on January 1 each year.

The current, primary calendar system in use in the western world is really a combination of overlapping types:

- The calendar is based on days. The number and designation for each day are incremented one unit every midnight. Midnight is shown as 12:00 AM in the 12 hour representation or 0 hour in a 24 hour representation. One hour after midnight is 1:00 AM or 0100 hour, and so on.
Since the planet is roughly spherical, midnight occurs at different times depending on where you are located. At one time, each location determined its own time locally, but this situation was changed in the 1800s when it became necessary to coordinate railroad schedules. At that time, 24 time zones were defined around the world, with the measured time incremented by 1 hour between each pair of time zones. Technically, a new day begins at the International Date Line (which runs through the Pacific Ocean at 180 degrees longitude where it would be midnight) when it is solar noon in the British Royal Observatory in Greenwich, England. The date change then follows the time zones at midnight in each zone.
- There is a weekly calendar consisting of 7 days which runs in a repeating cycle. Each day of the week has a name. In English: Monday, Tuesday, Wednesday, Thursday, Friday, Saturday, Sunday, and back to Monday to repeat. In some locations, the days may have numbers instead of names.

The origin of the 7 day cycle is ancient and probably religious. In one possible explanation, the Bible refers to God creating the earth in 6 days and then resting on the seventh. It was likely this was an early definition of the 7 day week cycle. There is no attempt to synchronize the 7-day cycle with any other natural or religious events. Hence, a solar year consists of 52 weeks plus 1 day and a few extra hours. The weekly calendar is primarily used to order commerce and everyday activities. Since this is just a repeating cycle of weeks (which may or may not be numbered), it is really an incomplete calendar.

- We use the Gregorian calendar system to organize our years. In this system, there are 12 months, either named or numbered. For various reasons, the months have different numbers of days. Each day is numbered within the month. In some cases, the day of the year may also be numbered, regardless of the month. The English names for the months in this calendar are:
 - January/1 (31 days)—January 1 is the start of the year and occurs in winter in the northern hemisphere.
 - February/2 (28 days or 29 days in Leap Years)
 - March/3 (31 days)
 - April/4 (30 days)
 - May/5 (31 days)
 - June/6 (30 days)
 - July/7 (31 days)
 - August/8 (31 days)
 - September/9 (30 days)
 - October/10 (31 days)
 - November/11 (30 days)
 - December/12 (31 days)

There are 365 days in the calendar, with one intercalary day added every 4 years (Leap Year) to the shortest month of the year (February) and other adjustments when necessary to keep the calendar within a day of being in sync with the solar cycle.

The years are also numbered from a key event, which is the traditional birth or conception of Jesus Christ in most of our culture. The names for the months were defined over 2000 years ago in ancient Rome.

- The year is also divided in other ways to form other incomplete calendars:
 - *Fiscal Calendar*: For commercial and business reasons, the year is normally divided into fiscal quarters consisting of 3 months each:

January, February, and March

April, May, and June

July, August, and September

October, November, and December

A business fiscal year may start at the beginning of any of these quarters, but most have a fiscal year that coincides with the calendar year, thus January

through March is the first quarter, April through June is the second quarter, and so on.

- *Seasonal Calendar*: With a nod to agriculture and ancient beliefs, the year is also divided into four seasons that change coincident with celestial events and do not coincide with the months, but may have been intended to at one time. The solstices, when the daylight hours are shortest (winter) or longest (summer) are used for one type of marker. The spring and fall/autumn equinoxes, when the lengths of day and night are equal, represent the other type of marker. Using the English terms:

Winter begins with the winter solstice and continues until the spring equinox. In recent years, this places the season of winter from about December 21–22 through March 20. Winter is not a growing season for agrarian economies in temperate climates.

Spring begins with the spring equinox and ends with the summer solstice. This means spring runs from about March 20 through June 20–21. For an agrarian society, spring would be planting time.

Summer begins with the summer solstice and ends with the fall or autumn equinox. Summer then runs from about June 20–21 to September 22–23. In agriculture, this is the primary growing season.

Fall or autumn begins with the fall equinox and ends with the winter solstice. The dates are about September 22–23 to December 21–22. This would be harvest season in an agrarian society.

- *Holiday/Special Events Calendar*: Societies have several holidays or special events sprinkled throughout each year (and sometimes over multiple years) that are defined to occur at specific times. The U.S. Federal calendar is an example, which includes defined holidays like Good Friday, Martin Luther King Day, President’s Day, Independence Day, Thanksgiving, Christmas, etc. Some of these are religious holidays and some are political holidays. Other cultures have similar calendars that run along with the primary annual calendars, like the Hebrew and Islamic religious calendars. School districts define academic calendars (using the main Gregorian calendar as a basis) and almost every one is different.

There are, in fact, multiple calendars running in parallel in all societies and for various purposes. Most are incomplete calendars that reference Gregorian dates for convenience.

Designations for Time and Date

We have used various forms to designate time and date in the above discussion without much definition of how these are designated. We will try to standardize the designations in this section.

For designation of time during a day, complete designation could take a couple of forms:

- 12 Hour Basis (e.g. Common in U.S.)
 - AA:BB:CC.CC DD
 - AA is the hour of the day. AA = 00 or 12. In English, the hour indicated would be called “AA o’clock”, an old term for “of the clock” that has persisted for centuries.
 - BB is the minute during that hour. From 00 to 59.
 - CC.CC is the decimal second during a specific minute from 00.000... to 59.9999... For many purposes, the decimal, or even the minute might be dropped from the designation.
 - DD is the designation of AM or PM. AM (*ante meridiem*) denotes times from midnight to midday or the point where the sun is highest in the sky. PM (*post meridiem*) denotes times between noon and midnight.
 - Some examples:
 - 10:01:34.24 AM indicates one minute and 34.24 seconds after 10 o’clock in the morning.
 - 1:36 PM indicates 36 minutes after 1 o’clock in the afternoon.
 - 12:00 AM is equivalent to 00:00 AM or midnight.
 - 12:00 PM is equivalent to 00:00 PM or noon.
- 24 hour Basis (e.g. Military, Airlines, and Europe)
 - EE:FF:GG.GG or EEFF
 - EE is the hour from 00 to 23
 - FF is the minute within the hour from 00 to 59
 - GG.GG is the second within the hour from 00.00... to 59.999... As above, for many purposes, the decimal is not needed or the seconds may not be used at all.
 - Some examples, equivalent to those above:
 - 10:01:34.24 indicates one minute and 34.24 seconds after 10 o’clock in the morning. 1002 would indicate essentially the same time, rounded to the nearest minute.
 - 13:36 or 1336 indicates 36 minutes after 1 o’clock in the afternoon.
 - 00:00 or 0000 indicate midnight.
 - 12:00 or 1200 indicate noon.

The forms designating a date also can vary:

- Month-Day-Year (e.g. common in the U.S.)
 - MMM... DD, YYYY ZZ
 - MMM... is the name or abbreviation for the month (e.g. January or Jan or J).
 - DD is the day of the month (e.g. 3 or 03)
 - YYYY is the year (e.g. 1956)

- ZZ indicates whether the year is AD or BC. Years are normally assumed to be AD and the designation is omitted. If the year is other than AD, then BC would be appended. CE and BCE could also be used in place of AD and BC, respectively.
- Examples:

February 23, 2001 would be the 23rd day of February in 2001 AD.
 Feb 23, 2001 would also be the 23rd day of February in 2001 AD.
 July 5, 34 BC would be the 5th of July in the year 34 BC.
- Day-Month-Year
 - DD MMM... YYYY ZZ
 - The definitions are the same as above.
 - Equivalent examples are:

23 February 2001
 23 Feb 2001
 5 July 34
- Shortened forms:

There are several short-hand forms for the dates used in various applications. Some examples are below:

 - MM-DD-[YY]YY or MM/DD/[YY]YY (Common in the U.S.A.)

MM is the number of the month from 1 (January) to 12 (December). You may or may not use leading zeros for month numbers less than 10.
 DD is the day of the month. You may or may not use leading zeros for day numbers less than 10.
 YY or YYYY is the year. If the first two digits of the year are omitted, it is assumed that the date is within the past 100 years. Hence 01 indicates 2001 and not 1901. When using older references, you need to be careful about this.

For examples:

 - 2-23-01 or 2/23/01 or 2/23/2001 could all indicate February 23, 2001 AD. In an older reference however, 2-23-01 or 2/23/01 could refer to 1901, 1801, etc.
 - DD-MM-[YY]YY (Common in Europe and elsewhere)

Definitions and traps in the terms are the same as above.
 One additional trap is created here: unless the day of the month is greater than 12, you can't tell this designation from the MM-DD-YYYY form and you can mix up days and months. Be sure to clarify the system being used. Usually you can tell from the context.

Using this system:

- 23-02-01 or 23/02/01 or 23/02/2001 could all indicate February 23, 2001 AD. In an older reference however, 2-23-01 or 2/23/01 could refer to 1901, 1801, etc.
- YYYY-MM-DD (Common for filing)

Definitions are the same as above.

This designation moves from the longest time period to the shortest, which make chronological filing easier. Very useful for computer files as a prefix. For example: 2001-02-23 would indicate February 23, 2001 AD.

- DDDDD.SSSSSSSSSS (Used in Computers)

This designation for a date is not based on a calendar, but uses the date December 31 (midnight), 1899 AD as zero date and time.

DDDDD is the number of days since December 31, 1899. It increments by one day every 24 hours.

SSSSS.... is a decimal fraction of the day.

Algorithms convert the decimal days to actual dates. Dates before 1900 are undefined in this system—or at the least are not always defined.

For example: 120.3567 indicates April 29, 1900 at 8:46 AM (120th day of 1900 AD plus 0.3567th of a day—8 hours and 46 minutes).

Note that this system works for a maximum of 99,999 days or about 274 years. We have to come up with something else after that, but we have about 150 years in which to do it.

In practice, the various ways date and time can be expressed are frequently mixed and matched, with time preceding the date or date preceding time, all in various formats and abbreviations. A quick look at Microsoft EXCEL formats, for instance, shows 16 options for the date (some of which include time) and 8 options for the time, as well as the option to define your own format. Fortunately, we are used to a wide variety of formats for date and time, so confusion is seldom generated.

Standard Time [11, 12, 16]

The common worldwide basis for standard time is Coordinated Universal Time (UTC or Universal Time, Coordinated). This was formerly Greenwich Mean Time (GMT) and was the time at the Prime Meridian at Greenwich, London, UK (0° longitude $\pm 7.5^\circ$ longitude). Since the planet is divided into 24 primary time zones (40 total zones if you include fractional hour adjustments), the time in any one of the zones can be determined by knowing the UTC and adding or subtracting one hour for each time zone the location is displaced from the Prime Meridian. One time

zone is equal to about 15 degrees of longitude, although the time zone boundaries have been adjusted somewhat for convenience and political purposes.

The time zones, and their displacements from UTC, are roughly indicated in Table 8.3 and in more detail in Fig. 8.9. Several locations have adjustments that are not even hours, several countries are split among zones, and daylight savings time impacts the differences seasonally.

Coordinated Universal Time (UTC, also called CUT or TUC) is synchronized with the earth's rotation and is just one of the international time standards used today. It is within one second of mean solar time at 0° longitude. UTC was initially developed in 1960 AD and has undergone changes since. The current UTC definition comes from the International Telecommunications Union standards and is based on International Atomic Time (TAI) and differs by a specific, controlled number of seconds from TAI. It was originally defined to be exactly 10 seconds faster than TAI in 1972. One second on UTC was defined to be exactly one second on TAI.

Leap seconds have been added as needed to compensate for the slowing of earth's rotation and to keep UTC within less than 1 second of mean solar time as noted above. The leap seconds are inserted roughly every 19 months on June 30 or December 31. Since 1960, a total of 16 positive leap seconds have been inserted, although a leap second could be negative also, if necessary. The need for leap seconds is affected by several natural phenomena, most notably major earth movements or earthquakes. UTC is used as the standard for worldwide internet, aviation, weather, global positioning, and other civil communications and digital applications.

UTC includes additional subdivisions of time starting with seconds. Longer times are defined using the Gregorian calendar, with Julian day numbering as an option. The day is divided into 24 hours of 60 minutes each. Each minute is technically 59–61 seconds, but normally 60 seconds. Seconds can be divided into smaller fractions. Seconds are defined to always be exactly the same length, so all smaller portions of a second are the same length. Longer time periods can vary in length, but only very slightly.

There are actually several “flavors” of universal time that lead to UTC [35]:

- UT—This is the generic term for time that is synchronized to the earth's rotation. It originally used astronomical readings, but now uses GPS satellites. It varies slightly and leads to the various other flavors of UT, of which UTC is one. Differences among the various flavors are less than 0.03 seconds.
- UT0—This is the base or “raw” universal time that is measured.
- UT1—This is UT0 corrected for polar shifts.
- UT2—In this case, UT1 is corrected by formula for seasonal changes in the earth's rotational speed. This form is really no longer used.
- UTC—As defined above, is basically UT1.

International Atomic Time (TAI = Temps Atomique International) is the weighted average time determined by about 400 atomic clocks that are maintained

Table 8.3 Worldwide time adjustments from Coordinated Universal Time (Neglecting daylight savings times) [14]

Central Ref. Longitude, °	Difference from UTC, Hours	Example Regions Included
0	0	United Kingdom (England, Scotland), Iceland, Ireland, Portugal, Western Africa, east central South Atlantic
15 East	+1	Norway, Sweden, central Europe, west central Africa
30 East	+2	Finland, eastern Europe, Libya, Egypt, South Africa
45 East	+3	Russia, Moscow, Saudi Arabia, eastern Africa, Iran (+3½ hrs)
60 East	+4	Oman, Afghanistan (+4½ hrs)
75 East	+5	West central Russia, Pakistan, India (+5½ hrs), Nepal (+5¾ hrs)
90 East	+6	Kazakhstan, Burma (+6½ hrs)
105 East	+7	Central Russia, southeast Asia, parts of Indonesia
120 East	+8	China, Taiwan, Philippines, Malaysia, parts of Indonesia, western Australia
135 East	+9	East central Russia, Korea, Japan, central Australia (+9½ hrs), parts of Micronesia
150 East	+10	Parts of eastern Russia, eastern Australia, several western Pacific islands, parts of Indonesia
165 East	+11	Parts of eastern Russia, several western Pacific islands
180 East/West	+12	International Date Line, far eastern Russia, Marshall Islands, New Zealand, several central Pacific Islands
195 East	+13	Tonga, Samoa, Phoenix Islands, central Pacific, Kiribati
165 West	−11	Midway Islands, American Samoa, central Pacific
150 West	−10	Hawaiian Islands, French Polynesia
135 West	−9	Alaska, Marquises (−9½ hrs)
120 West	−8	Western Canada, U.S. Pacific, part of Baja California
105 West	−7	West central Canada, U.S. Mountain, parts of Baja, central, and western Mexico
90 West	−6	Central Canada, central U.S., most of Mexico and Central America
75 West	−5	Eastern Canada, eastern U.S., Cuba, Panama, western South America
60 West	−4	Atlantic Canada, Dominican Republic, Puerto Rico, Venezuela (−4½ hrs), north central South America
45 West	−3	Most of Greenland, most of eastern Brazil, Argentina, west central North Atlantic
30 West	−2	East central North Atlantic/west central South Atlantic
15 West	−1	Eastern North Atlantic, Azores, Cape Verde Islands, central South Atlantic

by the national standards laboratories in several countries throughout the world. It was defined to be the same as UT1 on 1 January 1958. Since that time the UTC definition and leap seconds have resulted in UTC being 26 seconds ahead of TAI as noted above.

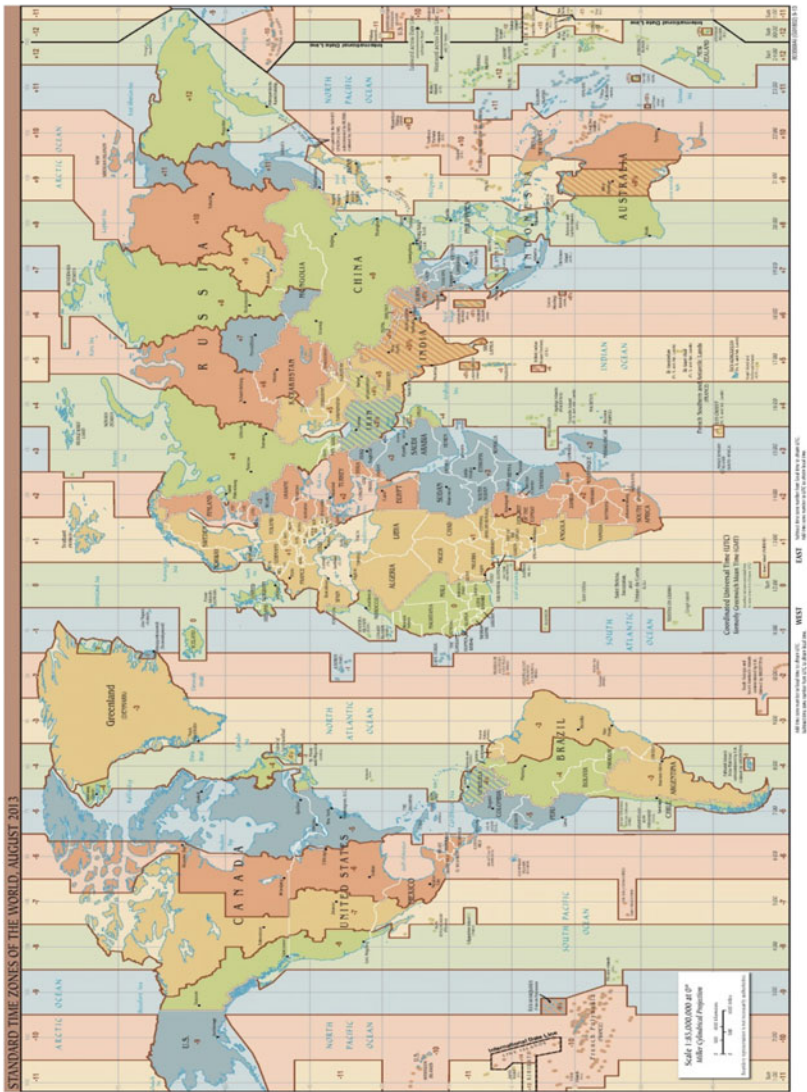


Fig. 8.9 Standard worldwide time zones, 2013 (Source CIA, Public Domain) [33]

Other time scales have been used in recent years for various purposes with their own definitions. Most notably, GPS time is TAI minus 19 seconds. GPS time was defined to be equal to UTC at midnight on 6 January 1980. GPS time does not use leap seconds for adjustment, so the difference from UTC has increased.

Integral with GPS time is the GPS week, defined as seven days in GPS time. GPS weeks are numbered with 0 set as midnight on 6 January 1980. The week numbers increase to 1023 and then roll back to 0 and start again, thus one cycle of GPS weeks is 19.62 years. The rollover can confuse GPS receivers that are not capable of handling it.

So you can see there have been a lot of different time scales and definitions. Fortunately, the time definitions in use today are all fairly consistent within a very small error.

Errors in Time Measurement

Through history, our ability to measure time has improved. The earliest time measurements, using simple observation or astronomical events, were rudimentary. Accuracies at best would have only been to $\pm$ several days on an annualized cycle. Daily time measurement accuracy and precision would have been, at best, $\pm$ a couple of hours.

The invention of sun dials, water clocks, hourglasses, and the like would have brought accuracy to within $\pm$ an hour or so. This level of accuracy persisted through the early eras after the invention of the mechanical clock.

Mechanical clocks enabled the improvement of accuracy and precision in time keeping to $\pm$ a few minutes per day and, with improvements, eventually $\pm$ a few seconds per day.

Electronic and electric clocks have enabled widespread accuracy and precision measurements to less than one second per day.

The measurements of time using atomic clocks today are commonly accurate to less than 1 second per 138 million years. This is being challenged by quantum clocks with accuracies of 1 second per 3.68 billion years.

So we can see that the accuracy of timekeeping has improve in fits and starts from a few days per year to fractions of a second over millions of years. In common use, we now measure time to fractions of a second per day with greater accuracy available when we need it.

Metric and U.S./English Time Units [8–10, 25]

For all practical purposes, the units used to measure time are the same between metric and U.S./English measurement systems today. The older English system, as well as the units throughout most of the world, descended from the Romans. As discussed previously, the day and night were both divided into periods of equal

length, but the actual duration of the periods would vary with the time of the year. Hours, minutes, and seconds were added as the technologies to measure time were improved and as society required. A day was 86,400 seconds long in this system.

There was an effort in 1793, when the metric system was first developed in France, to establish a decimal system for time keeping where one day was divided into 10 decimal hours, which had 100 decimal minutes, each containing 100 decimal seconds. In this system, a day was 100,000 decimal seconds long. So a decimal second was 0.864 English or traditional second. Beyond one day, the decimal form of this system broke down because a year is not any convenient multiple of 10. Within a few years, the attempt at decimalizing time was abandoned by the French and time measurement reverted to the old second, minute, hour, etc. system which continues to this day. Periodic attempts to revive decimal time have occurred, but it is no longer seriously considered.

The SI second is defined to be exactly 9,192,631,770 cycles of the radiation produced by the transition between two hyperfine levels of the Cs^{133} atom at 0°K . The buildup to larger units begins with this definition and uses the factors:

- 1 minute = 60 seconds
- 1 hour = 60 minutes
- 1 day = 24 hours

Weeks, years, and larger time periods follow the Gregorian calendar with periodic adjustments to maintain a 365.26 day year based on the earth's orbit of the sun.

Longer time units are decimalized to some extent, but these are not formal SI units, for example:

- Decade = 10 years
- Century = 100 years or 10 decades
- Millennium = 1000 years or 10 centuries

You can still find other long time periods that are used in reference, but these are not formal SI units either. For instance, we still see the terms:

- Fortnight = 2 weeks
- Olympiad = 4 years
- Bimillennium = 2000 years
- Epoch, Period, Era, and Eon refer to very long periods of time (millions of years), but the values vary

Comparisons of Historical Time Units

[1–4, 7–10, 15, 16, 27, 30–32, 35, 36]

Figure 8.10 provides a side-by-side comparison of some of the traditional or historical time units to the current, standard time units used for both U.S./English and Metric/SI systems. This table has some different historical references than other historical tables of this book because of the uniqueness of time measurement and its ritual, astronomical, astrological applications. Note the wide variety of time

measurement in India, for example. Only more common measures are included for India, as the units used in religious practices can run to billions of years.

Note that the comparison in Fig. 8.10 was developed from multiple sources listed in the “References” section of this chapter; hence, the individual references are not repeated here.

Historical Time Conversion Factor Values
[1–4, 7–10, 15, 16, 27, 30–32, 35, 36]

Because of the range and complexity of the numerous systems for measuring time, especially long time periods, Tables 8.4 and 8.5 are limited in scope. Table 8.4 provides conversion factors grouped by civilization and era, along with a little background for the specific systems to measure time in each civilization. Table 8.5 is an alphabetical listing of the conversion factors using the anglicized names. The conversions are, at best, approximate.

Table 8.4 Selected historical time measurement conversion factors by location and era. Multiple sources, see References

Region and unit	Seconds	Notes	Era
Biblical and Talmudic (Approx, used Babylonian system, no agreement on exact values, time values varied with the seasons)			Ancient to pre-modern
General: Hebrew calendar was based on moon with 12 months per year plus an extra month every few years. Length of months varied. Original descriptive names for months displaced by Babylonian names. In very ancient times, one lunar month was considered a year			
m’lo nimah or hairsbreadth		Smallest unit of time	
toch k’dai dibur		Time it takes to say “shalom aleichem rebi”	
rega or moment	0.47	1/76 part or 0.04386 seconds, varied with season, 1/24 et	
heleq, chelek, or part	3.23	1/1080 hour, 3–1/3 seconds, varied with season	
et or time	6.06	1/24 onah (taken as “hour”), 6.25 seconds	
kdei achilat p’ras	330	Time required to eat half a loaf of bread, varied from 2–9 minutes	
hiluch mil	1260	Time required to walk 2000 cubits, varied from 18–24 minutes	
sha’ah or hour	3642	~ 1/24 day, Babylonian, always exactly 12 hours between sunrise and sunset, so length of hour varied with season.	
sha’ah zemanit	3642	Proportional hour, with 12 hours of daylight & 12 hours of night, varied by season, average shown	
sha’ah regilah	3600	Regular hour, exactly 1/24 day	

(continued)

Table 8.4 (continued)

Region and unit	Seconds	Notes	Era
Biblical and Talmudic (Approx, used Babylonian system, no agreement on exact values, time values varied with the seasons)			Ancient to pre-modern
onah or period	43,200	Nominally refers to day or night—about 12 hours, but variable	
day or yom	86,400	24 hours, hour lengths varied by season, also referred only to daylight hours, me'et l'et refers to a 24 hours period	
shavua, shabbat, or week	604,793	Un-clear origin, months broken into weeks, but weeks ran independent of months. Names were day number of the week, Day 1 = “yom rishon”	
chodesh or month	2.47E+06	Average approx value, actual varied 29–30 days, in ancient times, a lunar month was considered one year	
tekufah or circuit	7.65E+06	Seasonal change	
shanah or year	3.06E+07	Varied from 353–355 days normally with leap year of 353–355 days with extra month in 7 years out of 19	
shmittah or sabbatical	2.14E+08	Every 7th year	
yovel or jubilee	1.53E+09	Nominal 50 years (after 7th Shmittah year in cycle)	
Chinese (pre-Modern, traditional values, modern values noted)			Traditional
hǎo (traditional)	0.000144	144 microseconds	
miǎo (modern)	1.00	1 second	
fēn (traditional)	14.4	100 hǎo	
fēn (modern)	60.0	60 miǎo = 1 minute	
kè (minor)	144	Traditional 10 fēn, re-defined multiple times	
kè (major)	864	Traditional 60 fēn, re-defined multiple times	
kè (modern)	900	Modern 15 minutes	
diǎn (traditional)	1440	24 minutes, 100 fēn	
diǎn (modern)	3600	1 hour, 60 fēn	
xiǎoshí or shí (modern)	3600	4 kè (modern), 1 hour	
shí (traditional)	7200	2 hours, 8–1/3 kè (major)	
shí (traditional, pre-Qin dynasty)	8640	2.4 hours, 10 kè (major)	
rì or tiān (traditional)	86,400	12 shí (traditional) or 1 day	
rì or tiān (modern)	86,400	24 shí (modern) or 1 day	
Hong Kong Measures (Mixed Origins, Cantonese terms)			
miu5	1	Second	
fan1 jung or fan1	60	Minute	

(continued)

Table 8.4 (continued)

Region and unit	Seconds	Notes	Era
Biblical and Talmudic (Approx, used Babylonian system, no agreement on exact values, time values varied with the seasons)			Ancient to pre-modern
ji6	300	5 minutes, commonly used	
gwat1	900	15 minutes, “quarter”	
jung1, jung1 tau4, or siu2 si4	3600	60 minutes, 4 quarters, “clock” or “bell” referring to chimes	
yat6	86,400	24 hours, day	
yut6 (Chinese)	2,550,000	29 or 30 days, roughly lunar cycle, used average, Chinese month	
yut6 (Gregorian)	2,628,029	Gregorian month, 30.417 days avg, implies 28, 29, 30, or 31 days	
nin4 (Chinese)	31,560,000	Chinese year, 12 or 13 Chinese months, used average same as Gregorian after adjustments	
nin4 (Gregorian)	31,560,000	365 or 366 days, solar cycle	
Egyptian—Ancient and 19th Century			Ancient
Years were named rather than numbered. Regnal years named after rulers. Year divided into 3 seasons. Calendar had 12 months of 30 days plus 5 epagomenal days. Seasons were shifted over time to account for actual 365.25 day annual cycle. Length of hours varied until 127 BC. Division of hour into minutes occurred in 2nd century AD. No information on finer units			
“minute”	60	1/60 hour after 2nd century AD	
wnwt	3600	Hour, approx. value, length varied until 127 BC	
hrw	86,400	Day	
abd	2,592,000	Month, 30 days, in very ancient times one abd was one lunar year	
Akhet or 3ht	10,368,000	Inundation season, 4 months of 30 days	
Peret or prt	10,368,000	Emergence season, 4 months of 30 days	
Shemu or shmu	10,368,000	Harvest season or summer, 4 months of 30 days, season of low water and included harvest time	
renpet	31,536,000	Year, 365 days	
French (Metric time, 1793–1806)			Metric
The French made an attempt to develop a decimal time system consistent with the metric system. It was introduced in 1793 and abandoned in 1806. Implementation proved to be far more difficult than expected. France reverted to traditional time of seconds, minutes, hours, days, etc. on Jan 1, 1806			
decimal second	0.864	1/10 decimal minute	
decimal minute	86.4	1/100 decimal hour	
decimal hour	8640	1/10 day	
day	86,400		
decimal week	864,000	10 days	

(continued)

Table 8.4 (continued)

Region and unit	Seconds	Notes	Era
Biblical and Talmudic (Approx, used Babylonian system, no agreement on exact values, time values varied with the seasons)			Ancient to pre-modern
Greek (Ancient)			Ancient
Time measured by sundials and water clocks (clepsydra). Day ran from sunset to sunset. Years named after Archon Eponymos for the year. Grouped by quadrennial epochs based on Olympiad. Months based on lunar cycles, one extra month added every 2nd year between 6th and 7th months. days had to be added periodically. Start of year was summer solstice. Months named after religious festivals			
day	86,400		
month	2,400,000	Estimated at 28 days, 29.53 days is a lunar cycle	
year	30,200,000	Est 350 days, with periodic adjustments	
Olympiad	121,000,000	~4 years	
Hindu (Ancient to modern, many variations, only sidereal measures listed)			Ancient to Modern
Sidereal Measures			
truti	3.1E-08		
renu	1.9E-06	60 truti	
lava	0.00011	60 renu	
likṣaka	0.00670	60 lava	
lipta or vipala	0.402	60 leekshaka	
pala, vighaṭi, or vinādī	24.1	60 lipta	
ghaṭi, nādī, or danda	1440	24 minutes, 60 vighaṭi	
muhūrta	2880	48 minutes, 2 ghaṭi	
nakṣatra ahorātram	86,400	Sidereal day, 60 ghaṭi, 30 muhūrta	
Alternate Sidereal Measures			
truti	3.6E-05		
tatpara	0.0036	100 truti	
nimesha	0.11	30 tatpara	
kāṣṭhā	3.2	30 nimesha	
kalā	96	30 kāṣṭhā	
muhūrta	2880	30 kalā	
nakṣatra ahorātram	86,400	Day, 24 hours, 30 muhūrta	
Veda Measures			
paramāṇu	2.6E-05		
aṇu	5.2E-05	2 paramāṇu	
trasareṇu	1.6E-04	3 aṇu	

(continued)

Table 8.4 (continued)

Region and unit	Seconds	Notes	Era
Biblical and Talmudic (Approx, used Babylonian system, no agreement on exact values, time values varied with the seasons)			Ancient to pre-modern
truṭi	0.00047	3 trasareṇu	
vedha	0.047	100 truṭi, 47.4 ms	
lava	0.14	3 vedha	
nimeṣa	0.43	3 lava	
kṣaṇa	1.3	3 nimeṣha	
kāṣṭhā	6.4	5 kṣaṇa	
laghu	96	15 kāṣṭhā, 1.6 minutes	
danda	1440	15 laghu, 24 minutes	
muhūrta	2880	2 danda, 48 minutes	
ahorātram	86,400	Day, 30 muhūrta	
masa	2,592,000	Month, 30 days, 30 ahorātram	
ritu	5,184,000	Season, 2 masa, 2 months	
ayana	15,552,000	3 ritu, 6 months	
samvatsara or ahorātram of Deva	31,104,000	Year, 360 days, 2 ayana	
Lunar Measures			
tithi	81,000	Lunar day, time required for long. angle between sun and moon to increase 12 degrees, varying unit from 19–26 hours, average shown	
pakṣa or pakṣa	1,215,000	Lunar fortnight, 15 tithis	
gaura or śukla pakṣa	1,215,000	New moon to full moon, waxing, half lunar cycle	
kṛṣṇa pakṣa	1,215,000	Full moon to new moon, waning, half lunar cycle	
māsa	2,430,000	Lunar month, 29.5 days approx, 2 pakṣas	
ṛtu	4,860,000	Season, 2 māsa	
ayana	14,580,000	3 ṛtus	
“year”	29,160,000	2 ayanas	
Tropical Measures (Averages)			
ghati	1440		
muhurta	2880		
hora	3600		
yāma	10,800	1/4 day or night, 3 hours, 7.5 ghatis, 3.75 muhurtas, 3 horas	
“Half-day”	43,200	4 yāmas, day or night	
sāvana ahorātram	86,400	Tropical day beginning & ending at sunset, average, 1 solar day, 8 yāmas	
There are other measures of time related to religious practices that range as high as 10^{22} seconds (~ 311 trillion years). These are not listed here			

(continued)

Table 8.4 (continued)

Region and unit	Seconds	Notes	Era
Biblical and Talmudic (Approx, used Babylonian system, no agreement on exact values, time values varied with the seasons)			Ancient to pre-modern
Incan (General comments)			Ancient
Incas maintained solar and lunar calendars for longer time measures. Adjustments to keep calendars in sync appear to have been made around winter solstice. Lunar months marked by festivals and rituals. Unknown if there were units similar to weeks. Months were not grouped into seasons. Shorter times during a day were based on how far the sun traveled and how long it took to perform a specific task			
Smallest calendar unit was 3 days. Combined with 10 days count to make a 30 day month, although other references show a 27.33 day month. Years were 12 months long (lunar) with 13 months every 3 years. Total calendar cycle was 37 months. 30 cycles made 60 years. The actual system was much more complex, but is not covered here			
Irish (General comments)			Medieval
The Irish reckoned their days as beginning at sunset. Night was called oídhche			
Mesopotamian (Sumerian/Akkadian, U₄ system U)			Ancient
General: Multiple solar and lunar calendars existed. The civil calendar was adopted in Babylon based on the calendar at Nippur. This calendar dates from 3500 BC and was based on older calendars of unknown origin. This system formed the basis for Elamite, Hebrew, Urartian, Hurrian, Hittite, Ugaritic, Phoenician, Babylonian, Assyrian, Persian, Arabic, and Islamic time measures			
“barleycorn”	3.3	3–1/3 seconds	
mu-eš (Sumerian) or geš (Akkadian)	240	Gesh, 1/360 day	
da-na (Sumerian) or bêru (Akkadian)	7200	Watch, 1/12 day	
ud (Sumerian) or immu (Akkadian)	86,400	Day	
itud (Sumerian) or arhu (Akkadian)	2,592,000	Month, 30 days	
mu (Sumerian) or šattu (Akkadian)	31,104,000	Year, 360 days	
Native American (Shoshone tribe, many other similar measures)			Pre-metric
General: Number of measurements used. Devices for measurement based on nature, more qualitative. Shorter times during day measured by lengths and directions of shadows or position of sun in the sky. Long durations defined by number of suns or moons. Long periods may be defined by time since a major event, like a big fire or storm. Record of time may be kept by notches on a stick or knots in a rope or rawhide. These served as physical calendars			
sun		“Day”, used for daily schedules, aligned only with actual duration of daylight, sun up to sun down	

(continued)

Table 8.4 (continued)

Region and unit	Seconds	Notes	Era
Biblical and Talmudic (Approx, used Babylonian system, no agreement on exact values, time values varied with the seasons)			Ancient to pre-modern
moons		Effectively a “month”,	
winter		Used to indicate years, e.g. age indicated by number of winters since person was born	
Ottoman (pre-1933, local variations and additional units not listed)			Medieval to pre-metric
General: Traditional calendar was the Hicri calendar. Counts from 622 AD. 12 lunar months per year. 11 days shorter than solar year. Second calendar started in 1839 (Rumi) which also counted from 622 AD, but year was defined as solar year 1840. Gregorian calendar adopted in Turkey in 1925 for official matters. Hicri calendar still used for Islamic purposes			
Roman (Ancient, many systems were used, local variations and additional units not shown)			Ancient to Medieval
General: Romans initially had a very complicated calendar that was replaced by the Julian calendar in 45 BC			
secunda (astrologers)	24	1/3600 day, 24 modern seconds	
minuta (astrologers)	1440	1/60 day, 24 modern minutes. Introduction of minutes and seconds occurred in middle ages	
horus (daylight only)	3715	“Hour”, daytime division into 12 hours, length varied by season. Average shown	
“hour” (astrologers)	3600	1/24 day, modern basis for clocks	
“watch” (night time only)	10,463	4 watches per night. Length varied by season. Average shown	
hebdomada	604,800	“Astrological week”, 7 days. Origin of names of the modern week (Saturn-day, Sun-day, Moon-day, Mars-day, Mercury-day, Jove-day, and Venus-day). Day began at sunrise. Seven-day week formalized in society by Constantine in 321 AD when he gave subjects every Sunday off in honor of the sun deity	
nundina	691,200	“Week”, 8 days, regular week	
year	31,536,000	365 days in normal year, 366 in leap year. From 45 BC to 1 AD, leap years occurred irregularly. Starting 4 AD, leap years defined as every 4 years. Years named after Consuls for the year. If numbered, used Greek Olympiads or number of years since founding of Rome in 753 BC (ab urbe condita). Numbering of years started in middle ages with BC and AD designations. Gregorian calendar is same as Julian, except skips 3 leap years every 4 centuries to approximate length of tropical year	

(continued)

Table 8.4 (continued)

Region and unit	Seconds	Notes	Era
Biblical and Talmudic (Approx, used Babylonian system, no agreement on exact values, time values varied with the seasons)			Ancient to pre-modern
Vietnamese (pre-metric, early 20th Century traditional values, additional units not shown)			Medieval to pre-metric
giờ, giờ đồng hồ, or tiếng đồng hồ	3600	1 hour	
canh or trống canh	7200	2 hours	
Welsh (pre-metric, local variations, additional units not shown)			Medieval to pre-metric
“week” (8 day)	691,200	8 or 9 days. Used long after conversion to Christianity	
“week” (9 day)	777,600		

Table 8.5 Selected historical time measurement conversion factors listed alphabetically. Multiple sources, see References

Unit (qualifiers)	Equivalent seconds	Region	Era	Application	Notes
3ht	1.037E+07	Egypt	Ancient to 1800s	Season	Inundation season, 4 months of 30 days
abd	2,592,000	Egypt	Ancient to 1800s	General	Month, 30 days, in very ancient times one abd was one lunar year
ahorātram	86,400	India, Hindu	Ancient to Modern	Religious	Day, 30 muhūrta, Veda measure
ahorātram of Deva	3.110E+07	India, Hindu	Ancient to Modern	Religious	Year, 360 days, 2 ayana, Veda measure
Akhet	1.037E+07	Egypt	Ancient to 1800s	Season	Inundation season, 4 months of 30 days
aṇu	5.185E−05	India, Hindu	Ancient to Modern	Religious	2 paramāṇu, Veda measure
arhu (Akkadian)	2,592,000	Mesopotamia, Sumer, Akkadia	Ancient	General	Month, 30 days
ayana	1.458E+07	India, Hindu	Ancient to Modern	Lunar	3 ṛtus
ayana	1.555E+07	India, Hindu	Ancient to Modern	Religious	3 rutu, 6 months, Veda measure

(continued)

Table 8.5 (continued)

Unit (qualifiers)	Equivalent seconds	Region	Era	Application	Notes
barleycorn	3.33	Mesopotamia, Sumer, Akkadia	Ancient	General	3–1/3 seconds
bêru (Akkadian)	7200	Mesopotamia, Sumer, Akkadia	Ancient	General	Watch, 1/12 day
canh	7200	Viet Nam	Medieval to pre-metric	General	2 hours
chelek	3.234	Biblical, Talmudic	Ancient to pre-metric	General	Part, 1/1080 hour, 3–1/3 seconds, varied with season
chodesh	2,472,962	Biblical, Talmudic	Ancient to pre-metric	General	Average approx value, actual varied 29–30 days; in ancient times, a lunar month was considered one year.
da-na (Sumerian)	7200	Mesopotamia, Sumer, Akkadia	Ancient	General	Watch, 1/12 day
danda	1440	India, Hindu	Ancient to Modern	General	24 minutes, 60 vighaṭi, sidereal
danda	1440	India, Hindu	Ancient to Modern	Religious	15 laghu, 24 minutes, Veda measure
day	86,400	France	Metric (1793–1806)	General	
day	86,400	Greece	Ancient	General	
decimal hour	8640	France	Metric (1793–1806)	General	1/10 day
decimal minute	86.40	France	Metric (1793–1806)	General	1/100 decimal hour
decimal second	0.8640	France	Metric (1793–1806)	General	1/10 decimal minute
decimal week	864,000	France	Metric (1793–1806)	General	10 days
diǎn	1440	China	Traditional	General	24 minutes, 100 fēn
diǎn	3600	China	Modern	General	1 hour, 60 fēn
et	6.064	Biblical, Talmudic	Ancient to pre-metric	General	Time, 1/24 onah (taken as “hour”), 6.25 seconds

(continued)

Table 8.5 (continued)

Unit (qualifiers)	Equivalent seconds	Region	Era	Application	Notes
fan1	60.00	Hong Kong, Canton	Traditional	General	Minute
fan1 jung	60.00	Hong Kong, Canton	Traditional	General	Minute
fēn	14.40	China	Traditional	General	100 hǎo
fēn	60.00	China	Modern	General	60 miǎo = 1 minute
gaura	1,215,000	India, Hindu	Ancient to Modern	Lunar	New moon to full moon, waxing, half lunar cycle
geš (Akkadian)	240	Mesopotamia, Sumer, Akkadia	Ancient	General	Gesh, 1/360 day
ghati	1440	India, Hindu	Ancient to Modern	General	Tropical measure
ghaṭi	1440	India, Hindu	Ancient to Modern	General	24 minutes, 60 vighaṭi, sidereal
giờ	3600	Viet Nam	Medieval to pre-metric	General	1 hour
giờ đồng hồ	3600	Viet Nam	Medieval to pre-metric	General	1 hour
gwat1	900.0	Hong Kong, Canton	Traditional	General	15 minutes, “quarter”
half-day	43,200	India, Hindu	Ancient to Modern	General	4 yāmas, day or night, tropical measure
hǎo	1.440E-04	China	Traditional	General	144 microseconds
hebdomada	604,800	Rome	Ancient to Medieval	General	“Astrological week”, 7 days. Origin of names of the modern week (Saturn-day, Sun-day, Moon-day, Mars-day, Mercury-day, Jove-day, and Venus-day). Day began at sunrise. Seven-day week formalized in society by Constantine in 321 AD when he gave subjects every Sunday off in honor of the sun deity

(continued)

Table 8.5 (continued)

Unit (qualifiers)	Equivalent seconds	Region	Era	Application	Notes
heleq	3.234	Biblical, Talmudic	Ancient to pre-metric	General	1/1080 hour, 3–1/3 seconds, varied with season
hiluch mil	1260	Biblical, Talmudic	Ancient to pre-metric	General	Time required to walk 2000 cubits, varied from 18– 24 minutes
hora	3600	India, Hindu	Ancient to Modern	General	Tropical measure
horus	3715	Rome	Ancient to Medieval	General	“Hour”, daytime division into 12 hours, length varied by season, daylight only. Average shown
hour (astrologers)	3600	Rome	Ancient to Medieval	General	1/24 day, modern basis for clocks
hrw	86,400	Egypt	Ancient to 1800s	General	Day
immu (Akkadian)	86,400	Mesopotamia, Sumer, Akkadia	Ancient	General	Day
itud (Sumerian)	2,592,000	Mesopotamia, Sumer, Akkadia	Ancient	General	Month, 30 days
ji6	300.0	Hong Kong, Canton	Traditional	General	5 minutes, commonly used
jung1	3600	Hong Kong, Canton	Traditional	General	60 minutes, 4 quarters, “clock” or “bell” referring to chimes
jung1 tau4	3600	Hong Kong, Canton	Traditional	General	60 minutes, 4 quarters, “clock” or “bell” referring to chimes
kalā	96.0	India, Hindu	Ancient to Modern	General	30 kāṣṭhā, alternate sidereal
kāṣṭhā	3.20	India, Hindu	Ancient to Modern	General	30 nimesha, alternate sidereal
kāṣṭhā	6.40	India, Hindu	Ancient to Modern	Religious	5 kṣaṇa, Veda measure
kdei achilat p’ras	330.0	Biblical, Talmudic	Ancient to pre-metric	General	Time required to eat half a loaf of bread, varied from 2– 9 minutes
kè	900.0	China	Modern	General	Modern 15 minutes

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Table 8.5 (continued)

Unit (qualifiers)	Equivalent seconds	Region	Era	Application	Notes
kè (major)	864.0	China	Traditional	General	Traditional 60 fēn, re-defined multiple times
kè (minor)	144.0	China	Traditional	General	Traditional 10 fēn, re-defined multiple times
kṛṣṇa pakṣa	1,215,000	India, Hindu	Ancient to Modern	Lunar	Full moon to new moon, waning, half lunar cycle
kṣaṇa	1.28	India, Hindu	Ancient to Modern	Religious	3 nimeṣha, Veda measure
laghu	96.0	India, Hindu	Ancient to Modern	Religious	15 kāṣṭhā, 1.6 minutes, Veda measure
lava	0.140	India, Hindu	Ancient to Modern	Religious	3 vedha, Veda measure
lava	1.116E-04	India, Hindu	Ancient to Modern	General	60 renu, sidereal
likṣaka	6.696E-03	India, Hindu	Ancient to Modern	General	60 lava, sidereal
lipta or vipala	0.402	India, Hindu	Ancient to Modern	General	60 leekshaka, sidereal
masa	2,592,000	India, Hindu	Ancient to Modern	Religious	Month, 30 days, 30 ahorātram, Veda measure
māsa	2,430,000	India, Hindu	Ancient to Modern	Lunar	Lunar month, 29.5 days approx, 2 pakṣas
me'et l'et	86,400	Biblical, Talmudic	Ancient to pre-metric	General	24-hour period, essentially a day
miǎo	1.000	China	Modern	General	1 second
minuta (astrologers)	1440	Rome	Ancient to Medieval	General	1/60 day, 24 modern minutes. Introduction of minutes and seconds occurred in middle ages
minute	0.02	Egypt	Ancient to 1800s	General	1/60 hour after 2nd century AD
miu5	1.000	Hong Kong, Canton	Traditional	General	Second
m'lo nimah		Biblical, Talmudic	Ancient to pre-metric	General	Hairsbreadth, smallest unit of time, no definitive value identified

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Table 8.5 (continued)

Unit (qualifiers)	Equivalent seconds	Region	Era	Application	Notes
month	2,400,000	Greece	Ancient	General	Estimated at 28 days, 29.53 days is a lunar cycle
moons	2,420,000	Shoshone (Native American)	Pre-metric	General	Effectively a “month”, approximate value
mu (Sumerian)	3.110E+07	Mesopotamia, Sumer, Akkadia	Ancient	General	Year, 360 days
mu-eš (Sumerian)	240	Mesopotamia, Sumer, Akkadia	Ancient	General	Gesh, 1/360 day
muhurta	2880	India, Hindu	Ancient to Modern	General	Tropical measure
muhūrta	2880	India, Hindu	Ancient to Modern	General	48 minutes, 2 ghaṭī, sidereal
muhūrta	2880	India, Hindu	Ancient to Modern	General	30 kalā, alternate sidereal
muhūrta	2880	India, Hindu	Ancient to Modern	Religious	2 danda, 48 minutes, Veda measure
nāḍī	1440	India, Hindu	Ancient to Modern	General	24 minutes, 60 vighaṭī, sidereal
nakṣatra ahorātram	86,400	India, Hindu	Ancient to Modern	General	Sidereal day, 60 ghaṭī, 30 muhūrta, sidereal
nakṣatra ahorātram	86,400	India, Hindu	Ancient to Modern	General	Day, 24 hours, 30 muhūrta, alternate sidereal
nimeṣa	0.427	India, Hindu	Ancient to Modern	Religious	3 lava, Veda measure
nimesha	0.107	India, Hindu	Ancient to Modern	General	30 tatpara, alternate sidereal
nin4 (Chinese)	3.156E+07	Hong Kong, Canton	Traditional	General	Chinese year, 12 or 13 Chinese months, used average same as Gregorian after adjustments
nin4 (Gregorian)	3.156E+07	Hong Kong, Canton	Traditional	General	365 or 366 days, solar cycle
nundina	691,200	Rome	Ancient to Medieval	General	“Week”, 8 days, regular week
Olympiad	1.210E+08	Greece	Ancient	General	4 years

(continued)

Table 8.5 (continued)

Unit (qualifiers)	Equivalent seconds	Region	Era	Application	Notes
onah	43,200	Biblical, Talmudic	Ancient to pre-metric	General	Period, nominally refers to day or night - about 12 hours, but variable by season
paksa	1,215,000	India, Hindu	Ancient to Modern	Lunar	Lunar fortnight, 15 tithis
pakṣa	1,215,000	India, Hindu	Ancient to Modern	Lunar	Lunar fortnight, 15 tithis
pala	24.1	India, Hindu	Ancient to Modern	General	60 lipta, sidereal
paramāṇu	2.593E-05	India, Hindu	Ancient to Modern	Religious	Veda measure
Peret	1.037E+07	Egypt	Ancient to 1800s	Season	Emergence season, 4 months of 30 days
prt	1.037E+07	Egypt	Ancient to 1800s	Season	Emergence season, 4 months of 30 days
rega	0.474	Biblical, Talmudic	Ancient to pre-metric	General	Moment, 1/76 part or 0.04386 seconds, varied with season, 1/24 et
renpet	3.154E+07	Egypt	Ancient to 1800s	General	Year, 365 days
renu	1.860E-06	India, Hindu	Ancient to Modern	General	60 truti, sidereal
rì	86,400	China	Modern	General	24 shi (modern) or 1 day
rì	86,400	China	Traditional	General	12 shi (traditional) or 1 day
ritu	5,184,000	India, Hindu	Ancient to Modern	Religious	Season, 2 masa, 2 months, Veda measure
ṛtu	4,860,000	India, Hindu	Ancient to Modern	Lunar	Season, 2 māsa
sabbatical	2.141E+08	Biblical, Talmudic	Ancient to pre-metric	General	Every 7th year
samvatsara	3.110E+07	India, Hindu	Ancient to Modern	Religious	Year, 360 days, 2 ayana, Veda measure
šattu (Akkadian)	3.110E+07	Mesopotamia, Sumer, Akkadia	Ancient	General	Year, 360 days

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Table 8.5 (continued)

Unit (qualifiers)	Equivalent seconds	Region	Era	Application	Notes
sāvana ahorātram	86,400	India, Hindu	Ancient to Modern	General	Tropical day beginning & ending at sunset, average, 1 solar day, 8 yāmas, tropical measure
secunda (astrologers)	24.0	Rome	Ancient to Medieval	General	1/3600 day, 24 modern seconds
sha'ah	3642	Biblical, Talmudic	Ancient to pre-metric	General	Hour, ~ 1/24 day, Babylonian, always exactly 12 hours between sunrise and sunset, so length of hour varied with season
sha'ah regilah	3600	Biblical, Talmudic	Ancient to pre-metric	General	Regular hour, exactly 1/24 day
sha'ah zemanit	3642	Biblical, Talmudic	Ancient to pre-metric	General	Proportional hour, with 12 hours of daylight & 12 hours of night, varied by season, average shown
shabbat	604,793	Biblical, Talmudic	Ancient to pre-metric	General	Week, un-clear origin, months broken into weeks, but weeks ran independent of months. Names were day number of the week, Day 1 = “yom rishon”
shanah	3.059E+07	Biblical, Talmudic	Ancient to pre-metric	General	Year, varied from 353–355 days normally with leap year of 353– 355 days with extra month in 7 years out of 19
shavua	604,793	Biblical, Talmudic	Ancient to pre-metric	General	Week, un-clear origin, months broken into weeks, but weeks ran independent of months. Names were day number of the week, Day 1 = “yom rishon”

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Table 8.5 (continued)

Unit (qualifiers)	Equivalent seconds	Region	Era	Application	Notes
Shemu	1.037E+07	Egypt	Ancient to 1800s	Season	Harvest season or summer, 4 months of 30 days, season of low water and included harvest time
shi	3600	China	Modern	General	4 kè (modern), 1 hour
shi	7200	China	Traditional	General	2 hours, 8–1/3 kè (major)
shi	8640	China	Ancient, Pre-221 BC	General	2.4 hours, 10 kè (major)
shmittah	2.141E+08	Biblical, Talmudic	Ancient to pre-metric	General	Every 7th year
shmu	1.037E+07	Egypt	Ancient to 1800s	Season	Harvest season or summer, 4 months of 30 days, season of low water and included harvest time
siu2 si4	3600	Hong Kong, Canton	Traditional	General	60 minutes, 4 quarters, “clock” or “bell” referring to chimes
śukla pakṣa	1,215,000	India, Hindu	Ancient to Modern	Lunar	New moon to full moon, waxing, half lunar cycle
sun	43,200	Shoshone (Native American)	Pre-metric	General	“Day”, used for daily schedules, aligned only with actual duration of daylight, sun up to sun down, average value
tatpara	3.556E–03	India, Hindu	Ancient to Modern	General	100 truti, alternate sidereal
tekufah	7,646,400	Biblical, Talmudic	Ancient to pre-metric	General	Circuit or seasonal change
tiān	86,400	China	Modern	General	24 shi (modern) or 1 day
tiān	86,400	China	Traditional	General	12 shi (traditional) or 1 day
tiếng đồng hồ	3600	Viet Nam	Medieval to pre-metric	General	1 hour

(continued)

Table 8.5 (continued)

Unit (qualifiers)	Equivalent seconds	Region	Era	Application	Notes
tithi	81,000	India, Hindu	Ancient to Modern	Lunar	Lunar day, time required for long. angle between sun and moon to increase 12 degrees, varying unit from 19–26 hours, average shown
toch k'dei dibur		Biblical, Talmudic	Ancient to pre-metric	General	Time it takes to say “shalom aleichem rebi”, no definitive value identified
trasareṇu	1.556E–04	India, Hindu	Ancient to Modern	Religious	3 aṇu, Veda measure
trống canh	7200	Viet Nam	Medieval to pre-metric	General	2 hours
truti	3.100E–08	India, Hindu	Ancient to Modern	General	Sidereal
truti	3.556E–05	India, Hindu	Ancient to Modern	General	Alternate sidereal measure
truṭi	4.667E–04	India, Hindu	Ancient to Modern	Religious	3 trasareṇu, Veda measure
ud (Sumerian)	86,400	Mesopotamia, Sumer, Akkadia	Ancient	General	Day
vedha	0.0467	India, Hindu	Ancient to Modern	Religious	100 truṭi, 47.4 ms, Veda measure
vighaṭi	24.1	India, Hindu	Ancient to Modern	General	60 lipta, sidereal
vinādī	24.1	India, Hindu	Ancient to Modern	General	60 lipta, sidereal
watch	10,463	Rome	Ancient to Medieval	General	4 watches per night. Length varied by season. Average shown. Night-time only
week (8 day)	691,200	Wales	Medieval to pre-metric	General	8 days. Used long after conversion to Christianity
week (9 day)	777,600	Wales	Medieval to pre-metric	General	9 days. Used long after conversion to Christianity

(continued)

Table 8.5 (continued)

Unit (qualifiers)	Equivalent seconds	Region	Era	Application	Notes
winter	3.110E+07	Shoshone (Native American)	Pre-metric	General	Used to indicate years, e.g. age indicated by number of winters since person was born, approximate value
wnwt	3600	Egypt	Ancient to 1800s	General	Hour, approx. value, length varied until 127 BC
xiǎoshí	3600	China	Modern	General	4 kè (modern), 1 hour
yāma	10,800	India, Hindu	Ancient to Modern	General	1/4 day or night, 3 hours, 7.5 ghatīs, 3.75 muhurtas, 3 horas, tropical measure
yat6	86,400	Hong Kong, Canton	Traditional	General	24 hours, day
year	2.903E+07	Ottoman Empire	Medieval to pre-metric	General	12 lunar months, 11 days shorter than solar year, Hicri calendar, still used for Islamic purposes
year	2.916E+07	India, Hindu	Ancient to Modern	Lunar	2 ayanas
year	3.020E+07	Greece	Ancient	General	Est 350 days, with periodic adjustments
year	3.154E+07	Rome	Ancient to Medieval	General	365 days in normal year, 366 in leap year. From 45 BC to 1 AD, leap years occurred irregularly. Starting 4 AD, leap years defined as every 4 years. Years named after Consuls for the year. If numbered, used Greek Olympiads or number of years since founding of Rome in 753 BC (ab urbe condita). Numbering of years started in middle

(continued)

Table 8.5 (continued)

Unit (qualifiers)	Equivalent seconds	Region	Era	Application	Notes
					ages with BC and AD designations. Gregorian calendar is same as Julian, except skips 3 leap years every 4 centuries to approximate length of tropical year
year	3.154E+07	Ottoman Empire	After 1840	General	12 solar months, Rumi calendar
yom	43,200	Biblical, Talmudic	Ancient to pre-metric	General	Alternate definition, daylight hours only, hour lengths varied by season
yom	86,400	Biblical, Talmudic	Ancient to pre-metric	General	Day, 24 hours, hour lengths varied by season, also referred only to daylight hours
yovel	1.529E+09	Biblical, Talmudic	Ancient to pre-metric	General	Jubilee, nominal 50 years (after 7th Shmittah year in cycle)
yut6 (Chinese)	2,550,000	Hong Kong, Canton	Traditional	General	29 or 30 days, roughly lunar cycle, used average, Chinese month
yut6 (Gregorian)	2,628,029	Hong Kong, Canton	Traditional	General	Gregorian month, 30.417 days avg, implies 28, 29, 30, or 31 days

The factors provided in the tables are averages for durations that would vary seasonally where necessary. For instance, since the Romans divided the daylight time into 12 horus, a horus would be anywhere from 4450 seconds in the summer to 2980 seconds in the winter with an average of 3715 SI seconds. A “watch” could be 8250 seconds in the summer or 10,460 seconds in the winter, averaging 10,463 SI seconds.

The data in Tables 8.4 and 8.5 were compiled from multiple sources listed in the “References” section of this chapter; hence, the individual references are not repeated here.

Conclusion

In many ways, the concept of time and the measurement of time are two of the more difficult problems in measurement, even neglecting relativity effects. Recognition of time philosophically as a “thing” that could be measured and the methods for performing that measurement required several millennia to develop. Measurement has moved from recognizing a consistent daily solar cycle to longer term measures that are synchronized with other celestial events. Shorter measures began as divisions of day and night into what amounted to hours. Smaller and smaller divisions of time have been made as the needs of technology and the technical capability of performing the fine time measurements grew together. We moved from recognition of the solar and lunar cycles to measurements of time in picoseconds (10^{-12} second). Relativity throws a bit of a monkey wrench into simple time measurement. Methods have been and are being developed to account for the effects of relativity on time measurement that will be needed in the future.

Interestingly, time is the one measurement that has become fairly standardized throughout the world and the standard in both the metric SI and English/U.S. systems is, oddly enough, based on the ancient Mesopotamian method of measurement starting with the second. Attempts to develop a decimal approach to time measurement have not met with success. The old 60 seconds = 1 minute, 60 minutes = 1 hour, 24 hours = 1 day, and so on, combined with the Gregorian and Julian calendars using 7 day weeks and 365/366 days per year continue to rule the measurement of time.

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Chapter 9

Historical Temperature



Abstract The concept of temperature was relatively slow to form among the base measurements. This chapter traces the history of temperature measurement from the earliest qualitative measures through the numerous attempts to develop a usable measurement scale, while the ability to actually determine temperature developed. The large number of alternative scales in use as late as the 19th century AD is reviewed. The number of scales has today been mostly reduced to the Kelvin/Celsius and Rankine/Fahrenheit scales. The development of the concept of absolute zero is explored. International standardization on the Kelvin and Celsius scales through the *Système international d'unités* (SI) or metric standards will continue progressing. This chapter also looks at the methods we use to measure temperatures in their historical contexts. It is hard to remember that temperature measurement was only qualitative until about 400 years ago. Precisely measuring and controlling temperatures has become a large part of our lives today.

Introduction

Compared to many of the other fundamental units, the measurement or quantification of temperature was a late development, occurring only in the past few hundred years. Prior to that, temperature was more of a qualitative property of something. The need to quantify temperature arose from the development of scientific needs and technology. Several measurement scales (at least 42) have been proposed over the centuries, but only four types of scales are in general use.

This chapter will explore temperature measurement and units in their historical context, which will necessarily include the modern scales. Comparative charts and formulae are provided for conversion among several of the more significant historical scales.

Historical Concepts of Temperature [9, 10, 13]

Mankind would have had a concept of temperature before recorded history. Objects and weather were recognized as hot, cold, warm, tepid, and so on in a qualitative way. Fire was recognized as hot and the size or intensity of the fire required to keep warm provided a relatively crude quantification. But it apparently did not occur to people that temperature could be quantified further, or that it might need to be, for several thousand years.

In the 16th century AD, as science and technology experienced their renaissance, the idea that temperature could and needed to be quantified for practical purposes took hold. A number of people proposed approaches to measure temperature combined with various scales. The devices and scales are discussed in the following section. This emphasis on quantifying temperature resulted in improving the ability to understand the physical world and to apply that knowledge, initially, in the development and design of the heat engines that powered the industrial revolution. We still rely heavily on this type of technology today.

Note that we measure the amount of heat relative to a reference point, as opposed to measuring the amount of cold by tradition. It could be done, and has been done, either way; but modern physics sets a lower limit on the amount of cold that is possible and no upper limit on the amount of heat, so the focus on heat makes physical sense.

In today's thinking, temperature, along with mass and other properties, provides a quantification of the amount of heat contained in an object or system. We are able to relate temperature to atomic and molecular movement. The ability to measure temperature is critical to our understanding of science and our ability to apply that understanding.

Historical Temperature Measurement [9–13, 16, 25]

Temperatures were measured from earliest human history using various types of indicators. In pottery, the color of the clay would provide a rough indication of the temperature and this could be correlated with achieving the correct end result in the pottery. People did not know what the temperature actually was, nor did they care. They were interested in the result. Table 9.1 provides a rough guideline for this type of indicator applied to steel. This color-temperature relationship will not match the Kelvin “color temperatures” used for lighting today that relates specifically to the spectrum emitted by an ideal black-body radiator. Color temperatures tend to be higher than the temperatures of most substances to produce similar visible light appearance. The emissions spectrum of iron, for instance, tends to be most intense at a few wavelengths compared to the continuous black body spectrum. We will not address lighting color temperatures in additional detail here, but will refer you to Chap. 13 on light measurement.

Table 9.1 Approximate color of steel at different temperatures [21, 26, 27]

Color	Approximate temperature range		
	°C	°F	K
Faint red 	480–510	900–950	750–780
Blood red 	560–590	1050–1100	830–860
Dark cherry 	620–650	1150–1200	890–920
Medium cherry 	670–700	1250–1300	940–970
Cherry red 	730–760	1360–1410	1000–1030
Bright cherry 	780–810	1450–1500	1050–1080
Salmon 	830–860	1520–1570	1100–1130
Dark orange 	870–900	1600–1650	1140–1170
Orange 	900–950	1650–1750	1170–1220
Lemon 	950–1050	1750–1920	1220–1320
Light yellow 	1050–1100	1920–2010	1320–1370
White 	1200–1530	2200–2800	1470–1800

Other types of early indicators that could be used in firing clay pottery or making glass, were mineral compositions that were known to melt or soften at desired conditions, probably determined by trial and error. These could be used to determine whether a kiln had reached the correct temperature, for instance. The use of small “pyrometric” cones that melt at specific temperatures can still be practiced today when making pottery.

The melting points of various naturally occurring metals, like copper, tin, silver, or gold, would also provide some practical temperature indications for early man, especially once humans began using metals more extensively in the Bronze Age (beginning about 3300 BC).

Controlling these temperatures was another matter. As man learned to make fire, he also developed the knowledge, through trial and error, of how to make fires for specific purposes. Fires, built by “formula” or “recipe”, would create certain desirable temperatures for use. Again, the emphasis was on obtaining the desired result; they did not need to quantify the temperature.

One of the first serious documented attempts to quantify temperature was undertaken by the Roman physician Claudius Galenus of Pergamum (AKA Galen, 129–200 AD) in 170 AD. He mixed equal parts (we would assume by weight) of ice and boiling water to create a standard temperature for reference. This would have provided a reference temperature of about 21 °C (70 °F) if he used actual ice and boiling water. If he used ice water and boiling water, the temperature could have been something like 38–49 °C (100–120 °F). He then defined four divisions

of “hot” between the reference and boiling water and four divisions of “cold” between the reference and ice. This was a rough, imprecise scale. It had a limited range that was within the realm of common experience.

From the time of Galen until the 16th century AD, there were few advances in temperature measurement. People understood that objects, especially gases, expanded when heated from ancient times and used that fact in practice, but they did not quantify the expansion. Application was, again, by trial and error.

In the 16th century AD, the development of scientific understanding led to the desire to measure temperature quantitatively. One of the earliest attempts was made by Galileo Galilei (1564–1642 AD). He wanted to measure relative temperature changes. To do this, he constructed a “thermoscope” which used a closed bulb filled with air that connected to a glass tube that was partially filled with liquid (water or alcohol/wine). The bottom of the tube was immersed in an open container of the liquid. This was similar to the inventions of others in the same era. If the air in the bulb was heated, the liquid was forced down the tube. If the air was cooled, the liquid was pulled upward in the tube. The relative change in level of the liquid in the tube, related to the relative change in temperature.

Sanctorius Sanctorius (1561–1636 AD) came up with the idea of adding a scale to the indicated level in the tube of the thermoscope to quantify the measurement in 1611 AD. He calibrated the scale by cooling the bulb with melting snow for the low temperature reference and used a candle to heat the bulb for the high temperature reference. A candle flame is about 1000 °C (1832 °F), but it is more likely his reference was in the 800 °C (1472 °F) range due to heat losses. Note that he understood that the temperature of melting snow/ice was a constant. He then divided the difference between the two indications into 110 equal segments. The reason he used 110 divisions is not clear, nor is it clear whether the top division indicated hot or cold. His approach to measuring temperature, i.e. calibrating his device using standard references and then dividing the difference in indications linearly to create a scale, was followed by most contributors since.

The thermoscope had two problems that are glaring sources of error today, but were probably not understood at the time: (1) Effect of atmospheric pressure and (2) evaporation of the liquid. The pressure problem was eventually recognized and one of the first solutions to it was invented by Jean Rey (1582–1645 AD) in France. He developed a liquid thermoscope where water was held in a flask with a long, thin neck. At room temperature, the water sat partially into the neck. As the flask was heated, the water rose in the neck. If the flask was cooled, the water shrank down in the neck. This expansion and contraction was basically linear and the thin neck amplified the change in water volume. Water limited the working range of this thermoscope and it did not solve the evaporation issue, but did reduce the impacts of evaporation and atmospheric pressure.

In 1641 AD, the Grand Duke of Tuscany, Ferdinand II (1610–1670 AD), constructed the first sealed “thermometer”. He was intensely interested in the new technology developments of his time, including hygrometers, barometers, thermometers, and telescopes. He sealed alcohol (likely distilled from wine or wine only) inside a glass bulb with a thin glass tube above the bulb. As with the others,

the alcohol came partially up into the tube. He then divided and marked the tube into 50 equal sections or degrees. This approach eliminated the influences of atmospheric pressure and evaporation losses. It was still subject to some error from expansion of the glass, but this was very small compared to the expansion of alcohol with temperature. The one fault we might find with the Grand Duke's approach is that he did not calibrate the device against any set standards.

The thermometer form was basically set by the Grand Duke's design. Over the next several decades, at least 35 different scales were proposed. Most of the scales followed the approach of Sanctorius Sanctorius in defining one or two reproducible reference temperatures and then dividing the indicated difference on the thermometer into a number of equal segments (linear scales). The types of fluids used in thermometers also expanded to include mercury and other liquids. The difficulty in reading the scale on an alcohol thermometer was alleviated by Robert Hook (1635–1703 AD), who added red ink to the alcohol in 1664, like we still do today.

Figure 9.1 illustrates the general forms of the early thermoscopes and thermometer. Figure 9.2 shows a modern application of the classic thermometer for monitoring candy-making temperatures.

Among the plethora of contributors, scales, and approaches promulgated during this time were:

- **Robert Hook:** In addition to using red ink in his alcohol thermometer, established a scale where each increment was equal to 1/500th of the total volume of liquid in the thermometer. He could then calibrate the scale using one fixed standard point, the Gresham College standard. This was used until 1709 AD.

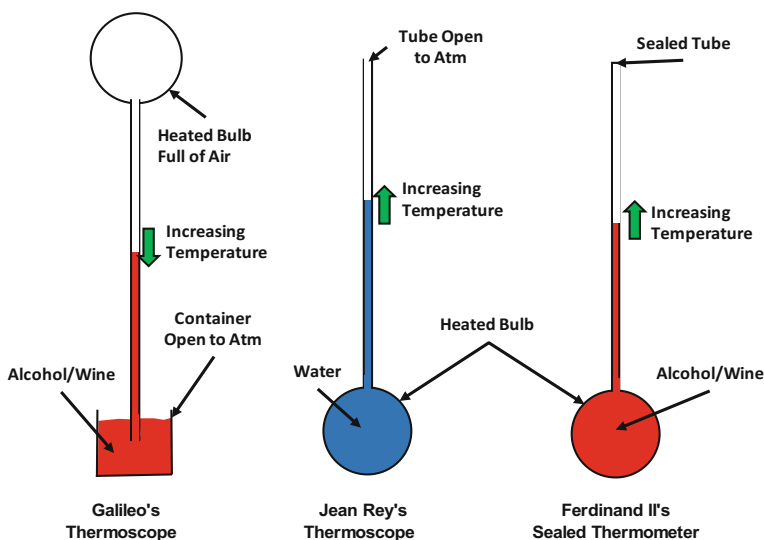


Fig. 9.1 Sketches of early thermoscopes and a thermometer

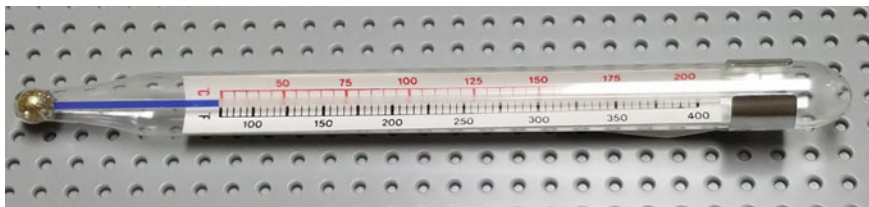


Fig. 9.2 Sealed candy thermometer of a standard type

- *Sir Isaac Newton* (1642–1727 AD): Newton used melting ice as zero and “human body temperature” as 12. He then had a 12° scale. Of course, measuring body temperature accurately is problematical.
- *Ole Rømer* (1644–1710 AD): This Danish astronomer used an ice-salt mixture for the low reference point and boiling water for an upper reference. His thermometer used red wine for the indicator fluid. The difference in indicated temperatures was divided into 60°. The ice-salt mixture of water-ice-ammonium chloride (in equal portions by weight) was a popular reference at the time and was subsequently used by others. Ice melted at 7.2 °Rø and the human body was believed to be 22.5 °Rø on this scale.
- *Daniel Gabriel Fahrenheit* [15] (1686–1736): Fahrenheit, a German, got many of his ideas on temperature measurement from Rømer during a visit in 1708. He wanted finer increments for measurement, so he took Rømer’s 60° and multiplied by 4 so that there were 240° between the water-ice-salt mixture and boiling water. He also defined a third reference point as human blood temperature. He did not use boiling water temperature as a reference. On his scale, then, the temperature of an equal-weight ice-water mixture was 30 °F and human blood temperature was initially set at 90 °F. He subsequently changed the melting point of ice to 32 °F and body temperature to 96 °F. Fahrenheit also adopted mercury as his indicating fluid, which eliminated several issues, while it created a new issue since the coefficient of expansion of mercury, while very linear, is not as large as alcohol’s. Still, it had a much wider range of operation. After Fahrenheit’s death, his scale and references were simplified to two reference points (melting ice = 32 °F and boiling water = 212 °F at standard pressure) and the elimination of human blood temperature and the “frigorific” water-ice-ammonium chloride mixture as references. Fahrenheit’s general system is still in common use today in the United States and a few other countries, alongside the SI system. Many references use Fahrenheit’s scale.
- *René Antoine Ferchault de Réaumur* (1683–1757 AD): Réaumur developed a temperature scale that used a brandy-water mixture for the working fluid in 1731 AD. He used a single calibration point (ice/water) and the linear expansion of the fluid mixture to define his scale. With the mixture chosen, the boiling point of water occurred at about 80°. Eventually, two calibration points were used: ice/water and boiling water with the temperatures defined as 0 and 80, respectively. Réaumur’s scale was adopted throughout much of Europe in the 1700s AD. It persisted until the early 20th century before being abandoned.

- *Joseph Nicolas Delisle* (1688–1768 AD) and *Josias Weitbrecht* (1702–1747): In 1732 AD, Delisle, a Frenchman living in Russia, developed a thermometer which used mercury as a working fluid and the boiling point of water as a single reference point. He then calibrated the thermometer scale using the contraction of mercury as temperature decreased in hundred-thousandths of the fluid volume. This gave a scale that might have 1400 gradations. The scale was inverted with zero at the top and the reading increasing with lower temperature. Delisle's scale was revised in 1738 AD by Weitbrecht with 0 °D as the boiling point of water and 150 °D as the freezing point of water. This temperature scale remained in use into the 19th century in Russia.
- *Anders Celsius* [14] (1701–1744): In 1742, Celsius proposed defining a difference of 100° between the temperature of melting snow (100°) and boiling point of water (0°), following the general approach of Delisle.
- *Carl Linnaeus* (1707–1778 AD): Linnaeus, a friend of Celsius, felt that a hotter temperature should have a higher numerical value to satisfy his sense of order. Hence, in 1744 AD, he inverted the Celsius scale so that 0° represented the melting point of snow and 100° was the boiling point of water. These are basically the scale divisions or increments adopted eventually for the SI standard. The 100 divisions between the two reference points were initially called “degrees centigrade”, but were changed to “degrees Celsius” in 1948 AD.
- *William Thomson* (AKA Lord Kelvin, 1824–1907 AD): In the 1800s AD there was a great increase in the understanding of thermodynamics and heat engines, especially relationships governing the volumes of gases. Lord Kelvin proposed the concept that there was a temperature at which the kinetic energy of the molecules in a gas would be zero. He defined this temperature as “absolute zero”. This represented the lowest possible temperature. It corresponded to about −273 °C. Lord Kelvin's absolute scale started at absolute zero and used the same scale increments as the centigrade scale, hence the freezing point of water was 273 K and the boiling point of water became 373 K. There are no negative temperatures on the Kelvin scale. The SI standards include this scale, with the scale divisions called “kelvins” rather than degrees. So the boiling point of water on the scale is 373 K, instead of 373 °K. Most of the time, the degree sign is erroneously used anyway, without really creating any confusion.
- *William John Macquorn Rankine* (1820–1872 AD): In 1859 AD, Rankine adopted the general concept of Lord Kelvin to use absolute zero as the bottom temperature on his scale, but he used the degree increments from the Fahrenheit system. On his scale, the freezing point of water was 492 °Ra and the boiling point of water was 672 °Ra. The designation was later changed to °R. This scale is still used today in thermodynamic applications when using English/U.S. Customary units for engineering, although it is giving way to SI units. Many references are available using these units. In this book, we will be providing data in both systems.

So far, we have been looking at temperature measurement using the expansion of a working fluid and the various scales that have been derived to quantify that

expansion. The measurement of temperature, however, can be accomplished through other methods. These methods may be correlated and calibrated against the traditional fluid expansion devices originally; but they are capable of measuring a much wider range of temperatures and capable of measuring to much finer accuracy and precision. The alternative measurements use the same magnitudes of scale divisions as physical thermometers ($^{\circ}\text{C}/\text{K}$ or $^{\circ}\text{F}/^{\circ}\text{R}$).

Among the additional methods that have been developed for temperature measurement beyond the simple thermometer, along with some of their key developers, are:

- *Thermocouple*: The most important temperature measuring device used in industry today is the thermocouple. Thomas Seebeck (1770–1831 AD), in 1821 AD, recognized that when two metals (or alloys) of dissimilar composition in intimate contact with each other were heated, they generated a tiny voltage that could be measured: a thermocouple. The voltage, or the resulting current in an electrical circuit, was a fairly linear function of the temperature applied and the two metals involved. The resulting voltage is compared electronically with a reference thermocouple junction that is maintained at a known temperature. Today we have tables for different types of thermocouples relating temperature to voltage. The temperature range over which thermocouples can be applied is very wide. Accuracy is normally about $\pm 2^{\circ}\text{C}$ ($\pm 4^{\circ}\text{F}$), but much higher accuracy is possible with calibration. Thermocouples are widely used and inexpensive. Table 9.2 lists the most common thermocouple types and their ranges of application. Figure 9.3 shows thermocouple millivolt temperature responses compared to a reference junction at 0°C . Note in Fig. 9.3 that responses are roughly linear, but not perfectly linear; hence the need for calibration in the desired operating range. This is also why the equations in Table 9.2 are not linear.
- *Resistance Temperature Device (RTD)*: Sir Humphrey Davy (1778–1829 AD) noted in 1821 AD that the resistivity of metals was a function of temperature. This concept was taken further by Sir William Siemens (1823–1883 AD) in 1861 AD when he proposed the platinum resistance thermometer using a fine platinum wire. Since that time, other types of resistance thermometers have also been developed.

In Siemens' device, the resistance of the platinum wire was essentially linear with temperature over a wide range. Platinum had the advantage of not oxidizing at high temperatures, so the resistance would not change due to oxidation. Today these devices, known as resistance temperature devices or RTDs, are common and capable of high accuracy, with errors less than $\pm 0.2^{\circ}\text{C}$ ($\pm 0.4^{\circ}\text{F}$) at 0°C (32°F) up to $\pm 2^{\circ}\text{C}$ ($\pm 4^{\circ}\text{F}$) at 650°C (1200°F). Much better accuracies are possible with calibration. Drift for RTDs is less than 0.1°C (0.2°F). Tables for RTD resistivities versus temperature are widely available today. Table 9.3 indicates ranges for common RTD types. Figure 9.4 illustrates the linearity of the resistance change with temperature.

Table 9.2 Comparison of common thermocouple types [28, 29]

Type	Junction	Operating range		Approx Equation for Temperature versus mv with 0 °C Reference, °C	Correlation R ²
		Metric, °C	English, °F		
J	Iron-Constantan	Continuous: 0 to +750 Short-term: -210 to +800	Continuous: +32 to +1382 Short-term: -350 to +1472	$^{\circ}\text{C} = 20.52(\text{mv}) - 0.341(\text{mv})^2 + 0.0167(\text{mv})^3 - (2.58\text{e-}04)(\text{mv})^4$	0.999954
K	Chromel-Alumel	Continuous: 0 to +1100 Short-term: -270 to +1372	Continuous: +32 to +2012 Short-term: -450 to +2500	$^{\circ}\text{C} = 28.2(\text{mv}) - 0.580(\text{mv})^2 + 0.0296(\text{mv})^3 - (6.53\text{e-}04)(\text{mv})^4 + (5.30\text{e-}06)(\text{mv})^5$	0.999942
R	Pt/Rh 87/13% - Pt	Continuous: 0 to +1600 Short-term: -50 to +1768	Continuous: +32 to +2912 Short-term: -58 to +3210	$^{\circ}\text{C} = 140(\text{mv}) - 7.40(\text{mv})^2 + 0.378(\text{mv})^3 - 0.00733(\text{mv})^4$	0.999926
S	Pt/Rh 90/10% - Pt	Continuous: 0 to +1600 Short-term: -50 to +1768	Continuous: +32 to +2912 Short-term: -58 to +3210	$^{\circ}\text{C} = 143(\text{mv}) - 7.00(\text{mv})^2 + 0.387(\text{mv})^3 - 0.00821(\text{mv})^4$	0.999951
T	Copper-Constantan	Continuous: -185 to +300 Short-term: -270 to +400	Continuous: -301 to +572 Short-term: -450 to +752	$^{\circ}\text{C} = 28.24(\text{mv}) - 0.965(\text{mv})^2 + 0.0254(\text{mv})^3$	0.999768
E	Chromel-Constantan	Continuous: 0 to +800 Short-term: -270 to +1000	Continuous: +32 to +1472 Short-term: -450 to +1830	$^{\circ}\text{C} = 18.16(\text{mv}) - 0.343(\text{mv})^2 + 0.00977(\text{mv})^3 - (1.29\text{e-}04)(\text{mv})^4 + (6.37\text{e-}07)(\text{mv})^5$	0.999967

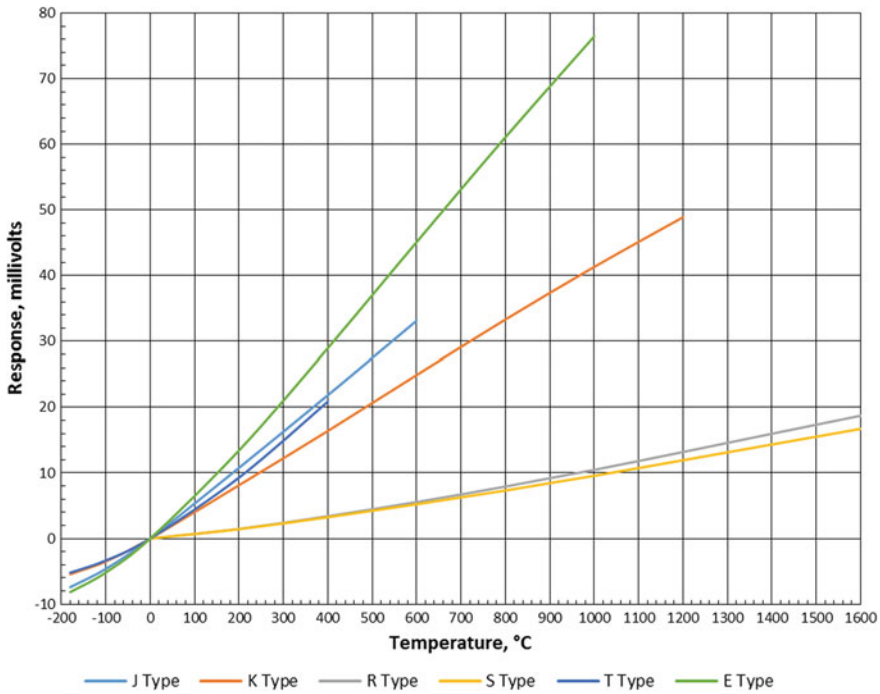


Fig. 9.3 Thermocouple responses over applicable temperature ranges using a 0 °C reference junction [29]

- Thermistor:** In 1833 AD, Michael Faraday (1791–1867 AD) noted that the electrical resistance of silver sulfide decreased with increasing temperature. This was the first observation of semi-conductor behavior as a function of temperature. It was discovered over the next decades that a number of materials, including ceramics and polymers, exhibited similar behavior. The effect was akin to RTDs, but the materials involved were not metals and the changes generally occurred over narrow temperature bands, but not in all cases. It was also noted that, depending on the material, the resistance could either increase or decrease with increasing temperature: Positive Temperature Coefficient (PTC) and Negative Temperature Coefficient (NTC) types, respectively. This effect gave rise to the thermistor.

Samuel Ruben (1900–1988 AD) developed the first practical commercial thermistor in 1930 AD. Thermistors are used for a number of applications today, including overload protection (switching PTCs), ultra-low temperature measurements, and medical applications. Operating temperature range for thermistors is -273.14 °C to $>1700\text{ °C}$ (-459.65 °F to $>\sim 3100\text{ °F}$), but most are designed to operate in a narrow temperature range. Some types still do operate over wide ranges with a linear coefficient, so that they can be used as temperature indicators. Table 9.4 shows a few thermistor types available. Figures 9.5, 9.6 and 9.7 illustrate resistance response to temperature for the thermistor types.

Table 9.3 Comparison of common RTD types [22, 30, 31]

RTD type	Material	Operating range			Approx equation for temperature versus 0 °C reference ohms	Correlation R ²
		Metric, °C	English, °F			
ITS-90, Pt100	Platinum, 100 Ω at 0 °C European Calib	Continuous: -250 to +650 Short-term: to ~+960	Continuous: -420 to +1200 Short-term: to ~+1760		°C = 0.001319 Ω ² + 2.276 Ω - 241.5	1.0000
Pt100, 404	Platinum, 100 Ω at 0 °C	Continuous: -250 to +650 Short-term: to ~+960	Continuous: -420 to +1200 Short-term: to ~+1760		°C = 0.001319 Ω ² + 2.276 Ω - 241.5	1.0000
Pt1000, 501	Platinum, 1000 Ω at 0 °C	Continuous: -250 to +650 Short-term: to ~+960	Continuous: -420 to +1200 Short-term: to ~+1760		°C = 0.00001045 Ω ² + 0.2349 Ω - 245.4	1.0000

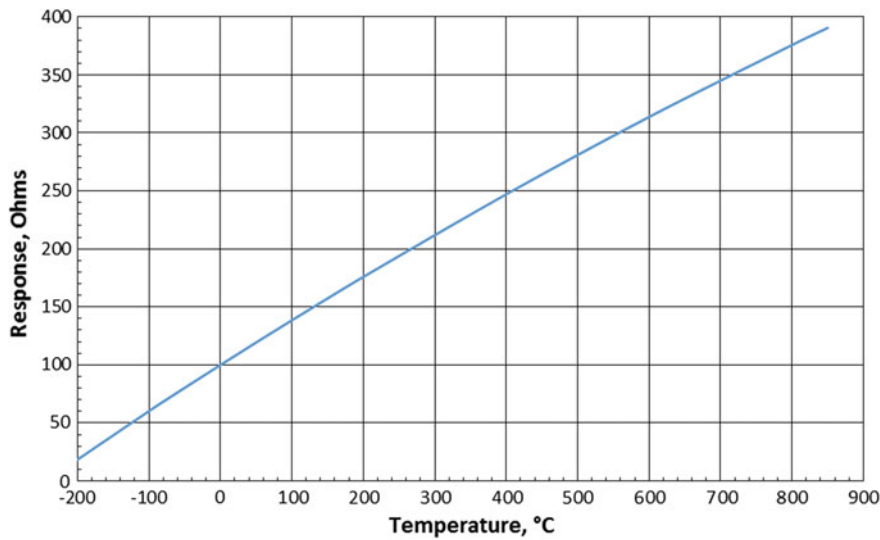


Fig. 9.4 Response of Type 404/ITS-90 RTD (Pt 100) to temperature [31]

Table 9.4 General types of thermistors [17–20, 32–34]

Thermistor type	Typical materials	Temperature response
Silistor	Silicon	Can be linear, similar to RTD, wide temperature range, see examples in figure
PTC switching type	Polymers, polycrystalline ceramics	Low resistance until reaches a specified temperature and then resistance increases rapidly to a high value over a narrow range, see figure
NTC, switching types	Metal oxides (Mn, Ni, Co, Cu, Fe)	High resistance until reaches a specified temperature and then resistance decreases rapidly to a low value over a narrow range, see figure

- *Pyrometer*: A pyrometer measures the temperature of an object using the intensity of the radiation emanating from the object over a specific band of wavelengths or color without the need to contact the object. Josiah Wedgewood (1730–1795 AD) was one of the first people to apply this principle formally in firing clay pottery, although the general principle was known from ancient times (see Table 9.1). In 1901 AD, the “disappearing filament pyrometer” was invented independently by Ludwig Holborn and Ferdinand Kurlbaum (1857–1927 AD) in Germany and by Harmon Northrup Morse (1848–1920 AD) in the United States. In this type of pyrometer, an appropriate filament is heated at known temperatures until it is the same color as the object being measured. The temperature of the filament can then be correlated to the object’s temperature. This was the first method for accurate measurement of temperatures over 1000 °C (>1832 °F).

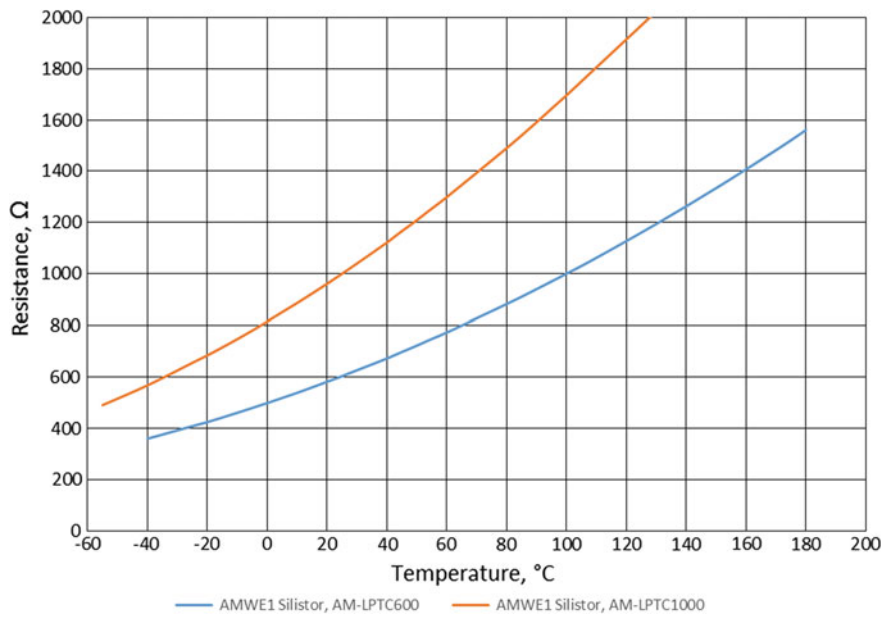


Fig. 9.5 Examples of response of typical PTC silistors to temperature [33]

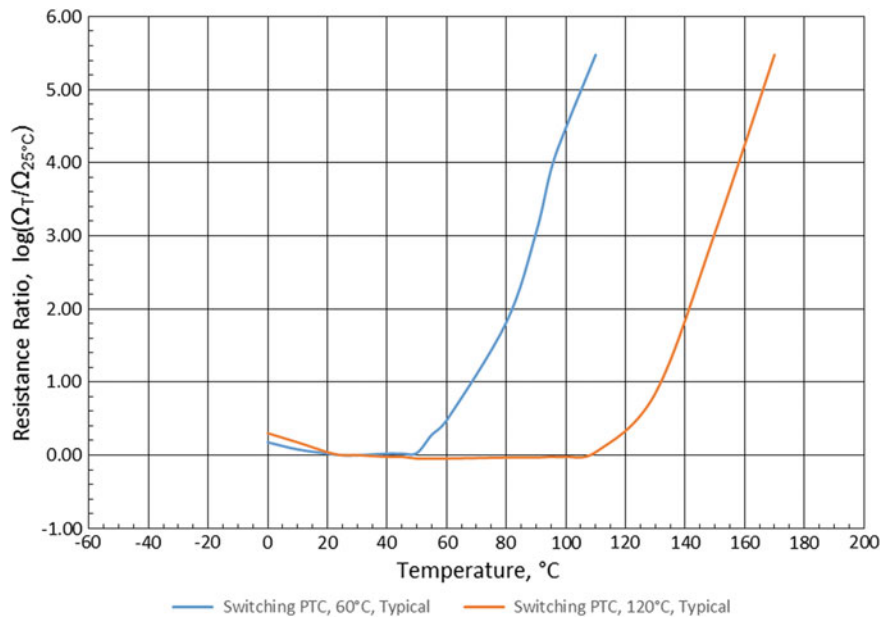


Fig. 9.6 Examples of response of typical PTC switching thermistor to temperature [17, 33]

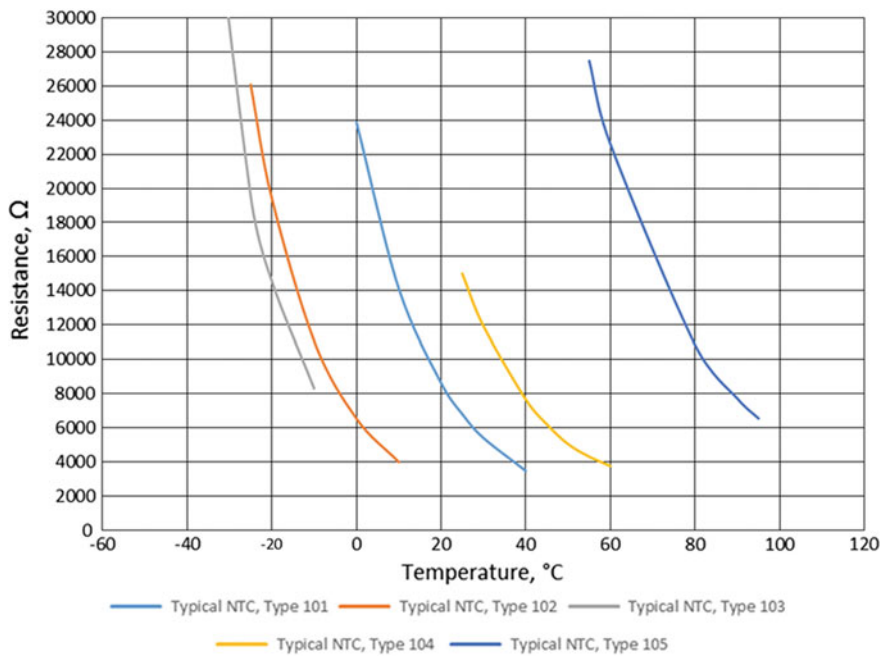


Fig. 9.7 Examples of response of typical NTC switching thermistors to temperature [19, 34]

- *Infrared Thermometer/Camera:* This is a specific type of optical pyrometer that uses the radiation emitted by an object in the infrared (IR) wavelengths range compared to a black body emitter to determine the object’s temperature without direct contact. These devices have become very common and inexpensive. You can buy simple IR thermometers at Walmart for less than \$20 US. IR devices are capable of measuring temperature at a single spot or can place a temperature map over an entire camera view, with compensation for an object’s equivalent black-body emissivity. Accuracies of inexpensive IR thermometers can be in the range $\pm 2\text{ }^{\circ}\text{C}$ ($\pm 4\text{ }^{\circ}\text{F}$) with accuracies of more sophisticated IR devices at less than $\pm 0.1\text{ }^{\circ}\text{C}$ ($<\pm 0.2\text{ }^{\circ}\text{F}$).

Sir William Herschel initially recognized infrared radiation and correlated this to temperature. Over the next several decades, various applications and devices for using infrared radiation for temperature measurement were developed. The bolometer, invented in 1878 by Samuel Pierpont Langley, was capable of detecting temperature differences as little as $\pm 0.00001\text{ }^{\circ}\text{C}$ ($0.00002\text{ }^{\circ}\text{F}$) at long distances. Notable applications of the early technology included iceberg detection (R. D. Parker, 1914 AD), forest fire detection (G. A. Barker, 1934 AD), and determining steel temperature (1935 AD). The IR camera was first developed in 1929 AD by Kálmán Tihanyi. Improvements progressed through the 1940s and 1950s AD from very slow devices to the instantaneous reading thermometers and cameras available today.

Table 9.5 IR temperature instrument operating ranges and applications [28]

IR type	Operating range		Accuracy	Comments
	SI units, °C	US/English, °F		
Spot thermometer	−60 to +3000	−76 to +5432	±0.5 to 1.0% of reading	High range, used in heaters, corrections required for heaters, need emissivity
IR Camera	0 to >1000	+32 to +1832		Portable and fixed models, bigger view for better analysis, false color images, calibration needed for accuracy

IR thermometers and cameras are commonly used for monitoring furnace tubes and electrical equipment to identify potential hot spots, overloads, and incipient failures.

Table 9.5 shows the typical operating ranges for IR instruments and their accuracy. Figure 9.8 shows an inexpensive, spot IR thermometer like those available at any hardware store. Figure 9.9 shows the false-color result of a typical IR camera shot of a heat exchanger for monitoring. The false color makes temperature differences easier to see and analyze.

- *Langmuir probe*: One of the more esoteric temperature devices is the Langmuir probe. This measurement approach is used for plasmas (ionized vapors, normally at very high temperatures). The method basically measures electrical properties of the plasma, which can be correlated to temperature.
- *Remote-sensing thermometer or metal bulb thermometer*: In industrial and home applications, the use of metal bulb or remote sensing thermometers is common. These devices are similar in concept to the classic thermometer, but the bulb or sensor is connected via a long capillary tube to a mechanical pressure indicating or actuating mechanism, like a bourdon tube. The bulb/sensor, capillary tube, and actuator are completely filled with a working fluid, such as an oil or gas. The sensor is immersed in the material or object whose temperature is to be measured. As the fluid expands or contracts, the changes in pressure are transmitted to the mechanism through the tube. Temperatures from −40 to 500 °C (−40 to 950 °F) are in the operating range for this type of thermometer. Accuracy is about ±3 °C (±~5 °F). You might find this type of sensor in a water heater tank connected to the heater control. Table 9.6 provides additional detail. Figure 9.10 illustrates an armored remote fluid filled sensor and gauge.
- *Bimetal strip*: John Harrison (1693–1776 AD) developed one of the earliest bimetal strip temperature mechanisms for temperature compensation of a marine chronometer in 1759 AD. It was known that different metals expanded at different rates when heated to the same temperatures. Harrison joined two metal strips of differing composition parallel to each other with rivets at each end. When the strips were heated, the device would bend away from the metal strip with the higher coefficient of thermal expansion. Eventually, Harrison developed a method for fusing the two strips together along their lengths. By fixing one end of the strips and coiling the strips around a rotating axis, when the coil



Fig. 9.8 An inexpensive spot infrared thermometer with laser aim

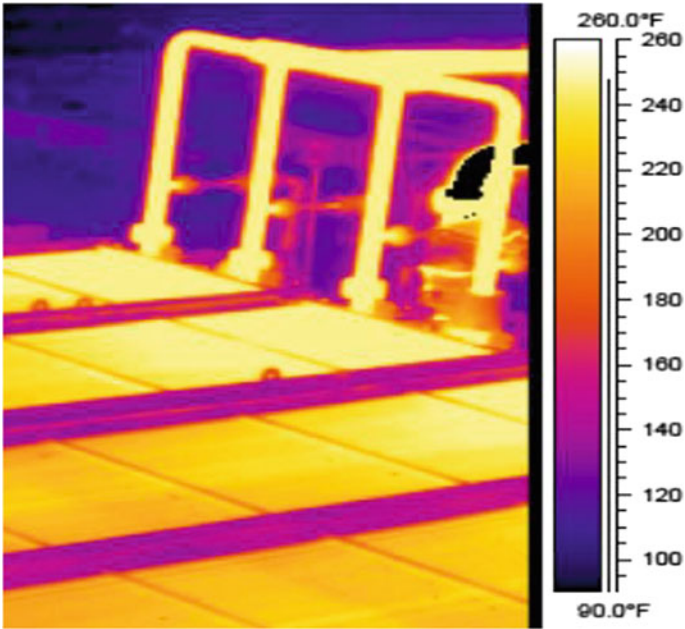


Fig. 9.9 False-color infrared camera image of an air cooler

Table 9.6 Remote-sensing/bulb temperature instrument operating ranges [28]

Operating range			
SI Units, °C	US/English, °F	Accuracy	Comments
Typical: -15 to +138; available to 500 °C	Typical: +5 to +248; available up to 930 °F	±3 °C (±5 °F)	Expansion or vaporization of a liquid in a sealed tube creates a force that drives a mechanical indicator or controller

was exposed to the desired temperature, the expansion rotated the axle. The rotation could be connected to a mechanical indicating or actuating mechanism, like a dial. Bimetal strip thermometers are common in heating, ventilation, and air conditioning systems for control and indication.

- *Temperature sensitive indicators:* During shipping, storage, and handling of temperature sensitive materials, often a temperature indicating strip is attached to the materials. These strips contain dots or strips of substances that change color at specific temperatures and then hold that color to indicate the maximum (or minimum) temperature to which they have been exposed. Accuracy of these indicators is probably not greater than about ±5–10 °C (±10–20 °F).

Higher accuracy thermometer strips are also available for measuring human body temperature using liquid crystals that change color with temperature. The strips used for body temperature may be accurate to less than ±0.1 °C (±0.2 °F).

In metal working or for monitoring hot, refractory-lined equipment, there are also temperature indicator paints and markers which change color when exposed to specific temperatures. Temperature indicating paints are only accurate to about ±10 °C (±20 °F).

A number of other applications of temperature changing paints and crystals have been commercialized. Figure 9.11 shows a temperature sensitive indicator for cooking meat. The indicator blade becomes red for rare beef (~60 °C, 140 °F), yellow for medium (~70 °C, 160 °F), and blue for well done (~80 °C, 175 °F).

In almost all the temperature measurement techniques available, it is necessary to ensure the measurement conditions are appropriate and the proper corrections are applied. For instance, in a glass thermometer containing mercury, the glass expands with temperature just as the mercury expands, but the extent of expansion of the glass is different from the mercury. This can introduce error in the measurement. The measured temperature must be adjusted for the glass expansion using defined methods to obtain the correct temperature. Most of the time, the correction is very small and is ignored, but sometimes it is significant.

Similar adjustments must often be applied to other measurement methods. For instance, measuring the tube wall temperature in a furnace using a spot infrared thermometer requires adjustment of the measured temperature for tube metal emissivity, radiant reflection from the walls, the viewing angle on the tube, and radiation from the furnace gases. It is also possible to select the specific IR radiation wavelength to minimize the interferences.



Fig. 9.10 Remote sensing temperature gauge with armored tube [35]



Fig. 9.11 Color-changing meat thermometer. When inserted into meat, color change on blade at left indicates the temperature and “doneness” of the meat. Reading shown is medium-well

Metric and U.S./English Temperature Units [1, 7, 10, 12]

The two primary temperature measurement scales used today are the SI standard or metric scale and the English/U.S. standard scale. These scales assume both common and absolute forms. The histories of these scales were discussed above.

The worldwide standard for temperature under the *Système international d'unités* (SI) or metric system is the kelvin. One kelvin is 1/273.16th of the thermodynamic temperature at the triple point of water. The SI scale starts at 0 K being absolute zero and increases so that the triple point of water would be 273.16 K and the boiling point of water would be 373 K. For everyday applications, we actually use the degree Celsius, which is equal to one kelvin unit. In Celsius, the freezing point of water is 0 °C, the triple point of water is 0.01 °C, and the boiling point of water at one standard atmosphere is 100 °C. While the formal definition of temperature units in SI is now in kelvins, the original definition (1743 AD) was in centigrade and later Celsius. For practical purposes, the kelvin and Celsius scales get used together depending on the context. For instance, in thermodynamics, kelvins are normally used.

In the United States and a few other countries, the corresponding standards for temperatures are the degree Rankin (°R) for the absolute thermodynamic scale and the degree Fahrenheit (°F) for the common scale. 0 °R is equal to 0 K. The increments between degrees in the U.S. system are equal to 5/9 (0.5555...) of a kelvin, i.e. 1 K = 1.8 Fahrenheit or Rankine degrees↓. Absolute zero on the Rankine scale is about −459.7 °F.

Both the SI/metric system and the U.S./English engineering systems are used in common engineering practice. It is routine to convert between them because data are not always available in the same set of units. Scientific work is generally done in SI temperature units. Engineering in the U.S. is often in English units, but may be in SI units, or some modified version of those units, in some industries and elsewhere in the world. There are different “flavors” and combinations of the temperature units that are applied.

Comparison of Historical Temperature Scales [9, 10]

Figures 9.12 and 9.13 compare several historical temperature scales with the modern scales. Figure 9.12 includes Kelvin, Modern Celsius, Rankine, Modern Fahrenheit, Original Celsius, and Original Fahrenheit scales. Figure 9.13 compares older temperatures scales (as well as can be determined) against the Kelvin scale. These figures show the scale reading temperatures at key indication points, so the values of the readings have a very wide range. Some scales are flatter than others. The reference points used to define the scales are highlighted by larger, square data point markers.

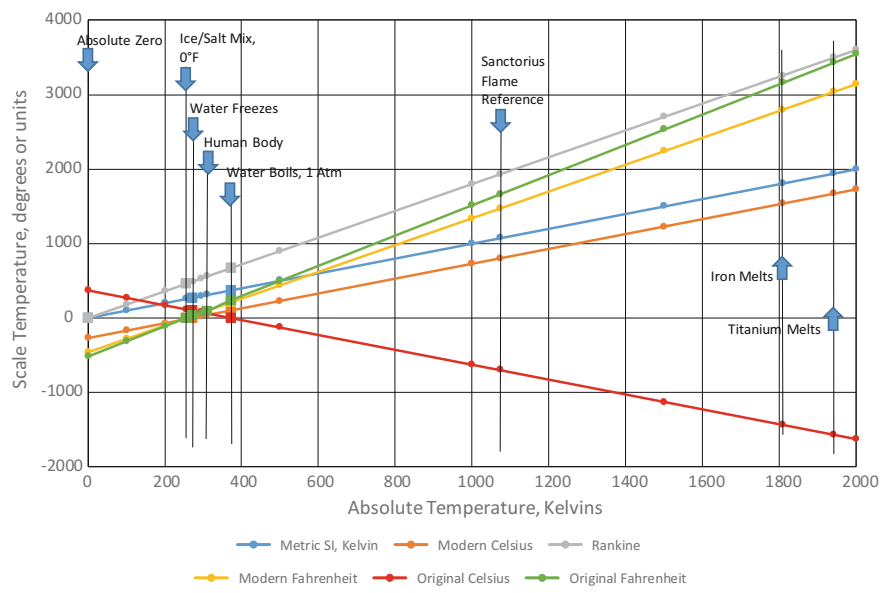


Fig. 9.12 Comparison of modern temperatures scales and some of their predecessors [9, 10]

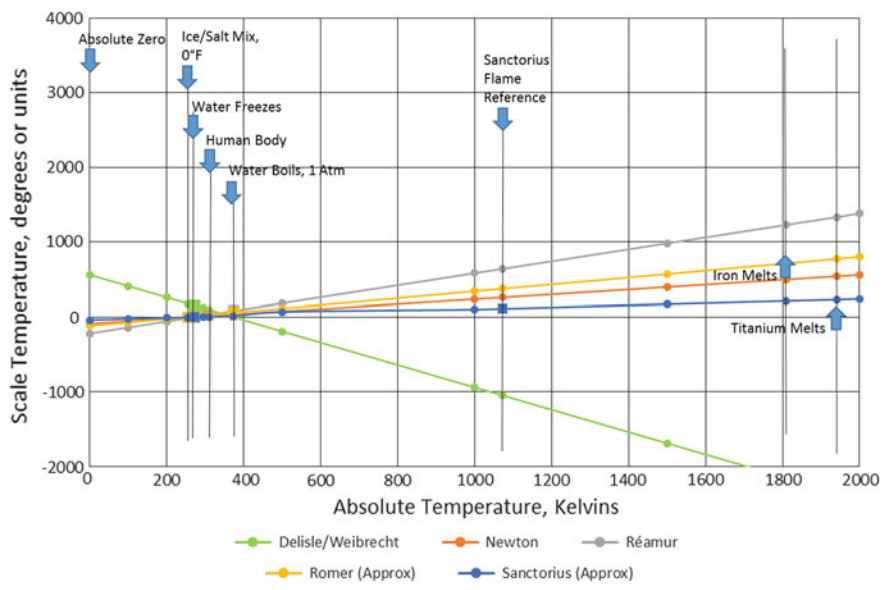


Fig. 9.13 Comparison of historical temperatures scales with current SI standard [9, 10]

In practice, most of the older scales were not conceived to span the range shown in the figures. The fluids used to define the scales would not be capable of being used under freezing conditions or at temperatures above boiling water or ethanol. The scale defined by Galen actually could only cover the temperature between ice and boiling water, so that scale was not included in the figures. Modern temperature measurement methods allow us to keep the same scale divisions and reference points and extend them upward and downward.

Note that some of the scales were not exactly linear and some used human blood temperature as a reference, but this value has changed with our medical understanding. Blood or body temperature has not been considered a good reference for about 200 years.

Historical Temperature Conversion Factor Values and Formulas [1–15, 23, 25]

Table 9.7 provides a series of correlations for estimating the conversions among different temperature scales. The most significant scales to us today are Kelvin, Rankine, Celsius, and Fahrenheit.

Table 9.8 is another way to view the historical scales comparing scale values that correspond to specific physical phenomena.

Note that the formulae in Table 9.7 only give estimates that are within about $\pm 1\text{--}2\text{ }^{\circ}\text{C}$ ($\pm 2\text{--}4\text{ }^{\circ}\text{F}$) except for conversions among Fahrenheit, Celsius, Kelvin, and Rankine scales. Some numerical reference points for the more significant scales are provided in Table 9.8 along with some additional history background.

The data used to develop Tables 9.7 and 9.8 were compiled from multiple sources in the “References” section; hence the reference numbers are not repeated here.

Table 9.7 Formulae for interconverting among historical temperature units, estimated. Multiple sources, see References

Starting units 	Equation for converting to  Accuracy about ±1–2 °C (±2–4 °F), correlation-based						
	Units/°C	Kelvin, K	Rankine, °R	Celsius/ Linnaeus, °C	Fahrenheit, °F	Original Celsius, °C ₀ (Appx)	Orig. Fahrenheit, °F ₀ (Appx)
Kelvin, K	1.000		1.8(K)	(K) – 273.15	1.8 (K) – 459.6	373 – (K)	2.037(K) – 524
Rankine, °R	1.800	0.5556(°R)		0.5556(°R) – 273	(°R) – 459.6	373 – 0.5556(°R)	1.132(°R) – 524
Celsius/Linnaeus, °C	1.000	(°C) + 273	1.8(°C) + 492		1.8(°C) + 32	100 – (°C)	2.037(°C) + 32
Fahrenheit, °F	1.800	0.5556(°F) + 255	(°F) + 459.6	0.5556(°F) – 17.6		118 – 0.5556 (°F)	1.13(°F) – 3.6
Original Celsius, °C ₀ (Appx)	1.000	373 – (°C ₀)	672 – 1.8(°C ₀)	100 – (°C ₀)	212 – 1.8 (°C ₀)		236 – 2.037(°C ₀)
Original Fahrenheit, °F ₀ (Appx)	2.034	0.491(°F ₀) + 257	0.884(°F ₀) + 463	0.491(°F ₀) – 15.8	0.884(°F ₀)	116 – 0.491 (°F ₀)	
Delisle/Weibrecht, °D (Appx)	1.500	373 – 0.6667 (°D)	672 – 1.20(°D)	100 – 0.6667 (°D)	212 – 1.20 (°D)	0.6667(°D) – 0.1	236 – 1.36(°D)
Newton, °N (Appx)	0.324	3.08(°N) + 273.3	5.558(°N) + 492	3.082(°N) + 0.3	5.548(°N) + 32.2	99.7 – 3.083 (°N)	6.278(°N) + 32.8
Réaumur, °Ré (Appx)	0.800	1.25(°Ré) + 273	2.25(°Ré) + 491	1.25(°Ré) – 0.4	2.25(°Ré) + 31	100.4 – 1.25 (°Ré)	2.546(°Ré) + 31.5
Rømer, °Rø (Appx)	0.459	2.18(°Rø) + 255	3.922(°Rø) + 459.4	2.18(°Rø) – 17.9	3.922(°Rø) – 0.6	117.9 – 2.179 (°Rø)	4.438(°Rø) – 4.3
Sanctorius Uts, SU (Appx)	0.138	7.28(SU) + 254	13.1(SU) + 458	7.28(SU) – 18.8	13.1 (SU) – 2.2	118.8 – 7.28 (SU)	14.83(SU) – 6.2

Table 9.7 (continued)

Equation for converting to  Accuracy about ±1–2 °C (±2–4 °F), correlation-based						
Starting units 	Units/°C	Delisle/Weibrecht, °D (Appx)	Newton, °N (Appx)	Réaumur, °Ré (Appx)	Rømer, °R0 (Appx)	Sanctorius Uts, SU (Appx)
Kelvin, K	1	576 – 1.5(K)	0.324(K) – 88.6	0.8 K – 218	0.459(K) – 117	0.136(K) – 33.9
Rankine, °R	1.8	577 – 0.84(°R)	0.180(°R) – 88.7	0.444(°R) – 218	0.255(°R)–117	0.0755(°R) – 33.9
Celsius/Linnaeus, °C	1	164 – 1.51(°C)	0.324(°C)	0.8(°C)	0.459(°C) + 8.2	0.136(°C) + 3.3
Fahrenheit, °F	1.8	190 – 0.840(°F)	0.180(°F) – 5.8	0.444(°F) – 13.8	0.255(°F) + 0.2	0.0755(°F) + 0.9
Original Celsius, °Co (Appx)	1	1.51(°Co) + 12.4	32.3 – 0.324 (°Co)	80.3 – 0.8(°Co)	54.1 – 0.459 (°Co)	16.9 – 0.136(°Co)
Original Fahrenheit, °Fo (Appx)	2.034	174 – 0.737(°Fo)	0.159(°Fo)–5.2	0.392(°Fo) – 12.4	0.225(°Fo) + 1.0	0.0668(°Fo) + 1.1
Delisle/Weibrecht, °D (Appx)	1.5		32.4 – 0.216 (°D)	80.4 – 0.533(°D)	54.2 – 0.306 (°D)	16.9 – 0.0906(°D)
Newton, °N (Appx)	0.324	49.8 – 4.625(°N)		2.465(°N) + 0.5	1.415(°N) + 8.4	0.419(°N) + 3.3
Réaumur, °Ré (Appx)	0.8	151 – 1.876(°Ré)	0.406(°Ré) – 0.2		0.574(°Ré) + 8.1	0.170(°Ré) + 3.2
Rømer, °Rø (Appx)	0.459	177.1 + 3.27(°Rø)	0.707(°Rø) – 5.9	1.743(°Rø) – 14		0.296(°Rø) + 0.8
Sanctorius Uts, SU (Appx)	0.138	178 – 10.9(SU)	2.363(SU) – 6.2	5.83(SU) – 14.8	3.342(SU) – 0.4	

Table 9.8 Comparison of historical temperature scales at specific points (Bold numbers are the scale definition points). Multiple sources, see References

Scale name	Scale notes	Initial date defined	°C per scale unit	Approximate Scale Values For:						
				Freezing point of water	Boiling point of water (1 Atm)	Thermo-dynamic absolute zero	Ice/salt/ water mixture	Body/ blood temper-ature	Melting point of iron	Melting point of titanium
Celsius or centigrade (original)	Defined 100° between freezing point and boiling points of water, with boiling point = 0° and freezing point = 100°	1744	1.000	100 °C₀	0 °C₀	373 °C ₀	118 °C ₀	63 °C ₀	−1435 °C ₀	−1568 °C ₀
Celsius or centigrade (modern scale)	Reused by Linneaus so hotter temperatures correspond to higher values. Same reference points and unit magnitudes		1.000	0 °C	100 °C	−273°C	−18 °C	37 °C	1535 °C	1668 °C
Kelvin and SI	Defined theoretical thermodynamic absolute zero as zero and used centigrade scale units	1848	1.000	273.15 K (triple point)	373 K	0 K	255 K	310 K	1808 K	1941 K
Fahrenheit (original scale)	Originally defined with freezing point of ice/salt mixture of 0°, freezing point of water as 30°, and human “blood” temperature as 90°. Blood temperature not accurate. Subsequent revisions to current scale	1724	0.492	30 °F₀	240 °F₀	−519 °F ₀	0 °F₀	90 °F₀	3159 °F ₀	3549 °F ₀
Fahrenheit (modern scale)	Corrected for errors and changed to freezing and boiling points of water as basis		5/9 or 0.5556	32 °F	212 °F	−460 °F	0 °F	98.6 °F±	2795 °F	3034 °F
Rankine	Similar to Kelvin. Defined thermodynamic absolute zero as	1859	5/9 or 0.5556	0 °F	672 °R	0 °R	460 °R	559 °R	3255 °R	3494 °R

(continued)

Table 9.8 (continued)

Scale name	Scale notes	Initial date defined	°C per scale unit	Approximate Scale Values For:						
				Freezing point of water	Boiling point of water (1 Atm)	Thermo-dynamic absolute zero	Ice/salt/water mixture	Body/blood temperature	Melting point of iron	Melting point of titanium
	zero and used Fahrenheit magnitude units for the scale									
Delisle	No longer used. Defined boiling point of water as zero and freezing point of water as 150. Based on contraction of mercury. Used in Russia for about 100 years. Modified by Weibrecht	1732/1738	1.500	150 °D	0 °D	560 °D	177 °D	95 °D	−2153 °D	−2352 °D
Newton	No longer used. Defined melting point of water as zero. Original proposal was to have 12° between melting point of water and human blood temp., but blood temp. eventually determined to vary too much	1701	3.1	0 °N	32 °N	−89 °N	−6 °N	12 °N	498 °N	541 °N
Réaumur	No longer used. Defined freezing point of water as zero and boiling point of water as 80. Used for many years in Europe	1730	1.25	0 °Ré	80 °Ré	−218 °Ré	−14 °Ré	30 °Ré	1228 °Ré	1334 °Ré
Rømer	No longer used. Defined freezing point of brine solution as zero and boiling point of water as 60	1701	1.97	7.2 °RØ	60 °RØ	−117 °RØ	0 °RØ	22.5 °RØ	712 °RØ	774 °RØ

Conclusion

The concept of temperature was relatively slow to form among fundamental or base measurements. Mankind developed methods for practical creation and application of temperatures before the ability to quantify these temperatures. The development of serious, accurate methods for measurement of temperature began in the 16th century AD.

The number of measurement scales increased to over 42 types during the 17th through 19th centuries AD. Eventually, in the 19th century AD, the primary scales in use today became dominant: Centigrade (eventually called Celsius) and Fahrenheit. These scales have displaced other approaches, with Celsius preferred for scientific use.

The development of the concept of absolute zero in the 19th century resulted in the Kelvin and Rankine scales, which used the Centigrade and Fahrenheit-sized units, respectively, but started with zero as absolute zero. The modern scales in use today are: Kelvin/Celsius and Fahrenheit/Rankine. Other scales have pretty much disappeared. The Fahrenheit/Rankine scale is expected to eventually fall into disuse, but this will take time.

The *Système international d'unités* (SI) or metric standard unit for temperature is the kelvin, which has unit increments equal in magnitude to the Celsius degree.

As quantification of temperature has progressed over the past 200 years, the number of techniques to measure temperature has greatly expanded beyond the simple thermometer. Today, these techniques include:

- Thermocouples
- Resistance temperature devices (RTDs)
- Thermistors
- Pyrometers
- Infrared thermometers and cameras
- Langmuir probes
- Remote-sensing fluid-filled thermometers
- Bimetal strips
- Temperature sensitive/color-changing coatings and liquid crystals

Temperature measurement is commonly practiced in many areas today including science and research, industrial manufacturing, electrical overload protection, home cooking and heating, and many other areas. It is hard to remember that temperature measurement was only qualitative until about 400 years ago. Precisely measuring and controlling temperatures has become a large part of our lives today.

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Chapter 10

Historical Angular Measurement



Abstract The quantification and measurement of angles is important in scientific, as well as every day, applications. Several systems have been developed to quantify angles beginning in ancient times. Most systems begin with a circle and divide the circle into equal segments of arc. Measurement of the angles thus defined has been accomplished by using a number of devices and/or the functions defined by trigonometry. There are two common angle systems in use today: English/U.S. standard of degree-minute-seconds and the SI standard of radians. For solid angles, the SI standard is the steradian. From a practical standpoint, the use of degrees is far more common. This chapter reviews the history of the approaches to defining angles and provides methods for converting between angular measurements.

Introduction

We've looked at quantification of a number of factors, but have not really explored the relationships among factors. In angular measurement, we have a fundamental quantity that can describe the geometric or spacial relationship between two intersecting rays (linear measurements) or planes (area measurements). See Fig. 10.1.

We define the various angles at which rays or planes intersect qualitatively by terms such as acute, right, or obtuse as illustrated in Fig. 10.2.

In this chapter, we will examine some of the historical concepts of quantitative angular measurement, along with the units commonly applied today.

Historical Angular Measurement [1–5]

Early mankind likely measured angles at a distance using various parts of the hand with the arm extended. This method is still used by amateur astronomers to describe star and constellation locations. Evidence of this type of informal and rough

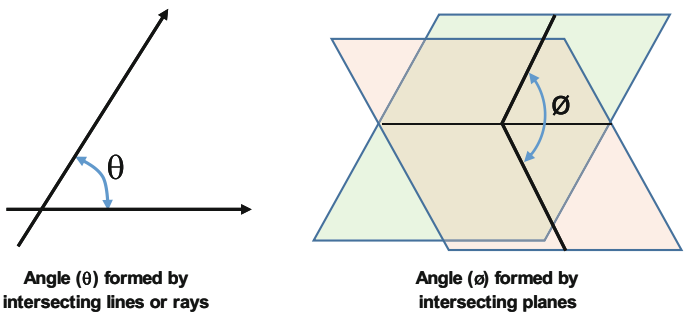
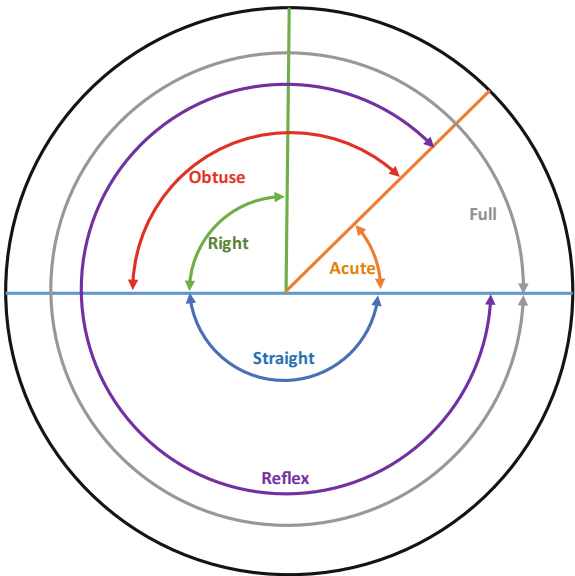


Fig. 10.1 Angles formed by intersecting ray/lines and intersecting planes

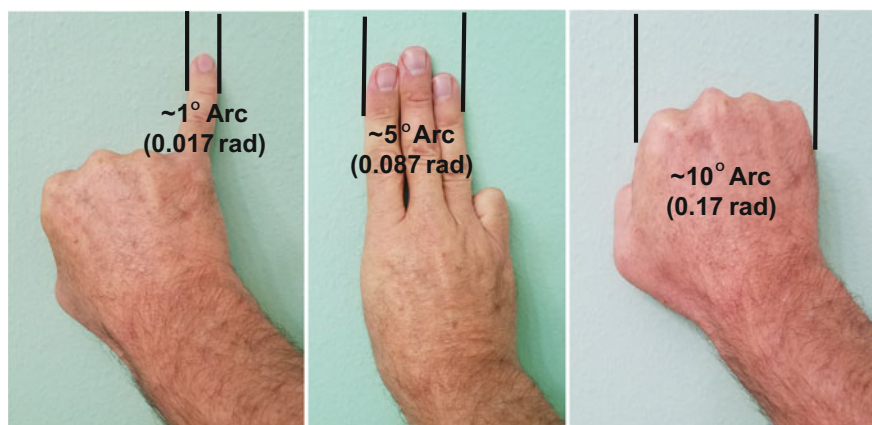
Fig. 10.2 Types or terms for various angles



Other terms for angles:
Right angle: normal, orthogonal, perpendicular
Full angle: complete, perigon, turn
Angles other than right: oblique

measurement was also present in Native American cultures. Using a body part for rough angular measurement is consistent with other early rough measurements using units like hands, palms, and spans. Figure 10.3 illustrates some angular measurements that can be made using body parts.

Attempts to better quantify angles date back to the earliest applications of geometry and astronomy. We know that the Mesopotamian civilizations had an approach to angular measurement as early as 4000–3000 BC. Their ideas about planar geometry were propagated to the Greeks and Persians over the centuries.



Values are approximate angle measurements when sighting distant objects with hand at arm's length.

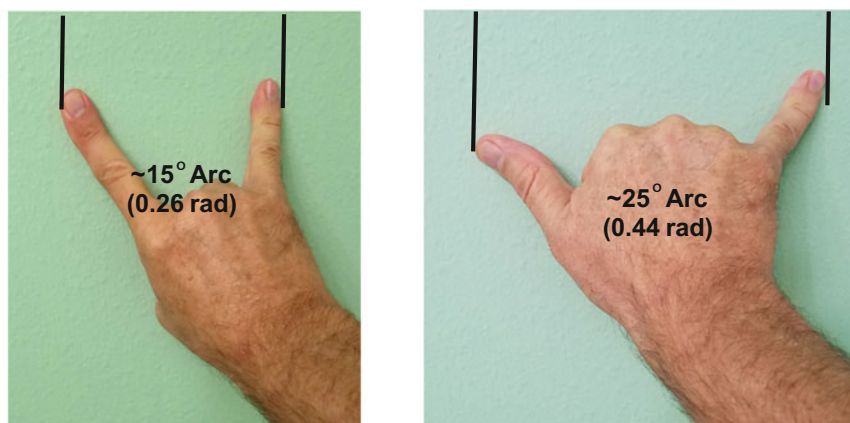


Fig. 10.3 Approximate angle measurements using your hand at arm's length [5]

Angular measures were closely associated with astronomy, e.g. how high a particular star or constellation was above the horizon or how far apart two stars were in the sky. It was not possible to actually define some of these distances in the sky except by some sort of angular relationship with respect to a given reference point or points.

Some early efforts often attempted to describe angles in terms of chords of a circle, Fig. 10.4. The length of various chords was related to the radius or diameter of the circle. The chords were, in turn, subdivided in smaller and smaller units to quantify angles. This also led to the definition of pi (π) as the ratio of the circumference of half of a circle to the radius of the circle (essentially an infinite number of subdivisions of half the chord across the center of the circle).

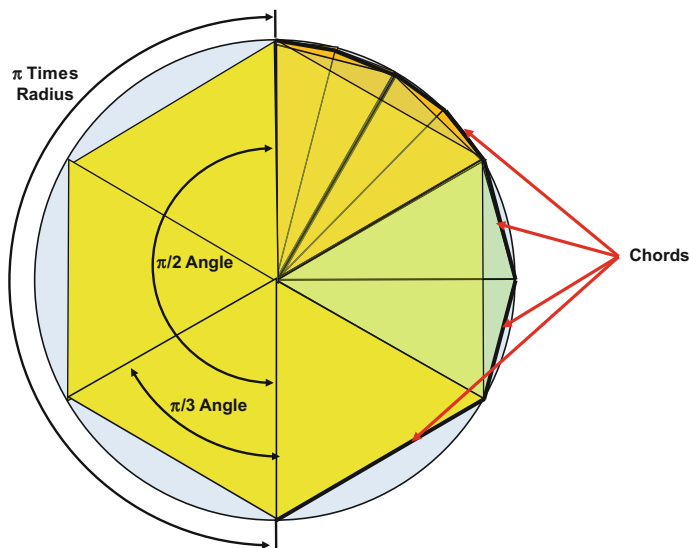


Fig. 10.4 Using chords to divide a circle into angles or arcs

One of the earliest and most persistent angular measures is the degree [6]. This is $1/360$ th of a complete circle. The basis for using 360° is the subject of some debate. The most likely explanation is that a year is about 360 days long, which is about how long it takes the constellations and stars to appear to make a complete circuit of the sky. The ancients knew that the year was actually about 365 days long, but for practical reasons, 360 was used, since it is a nicely divisible number. Whole number divisibility was important to civilizations like the Babylonians that used whole number fractions to subdivide quantities in their sexagesimal (base 60) system. The number 60 has 24 possible divisors that can be used. Other civilizations, like that in India, also described a circle as 360 units. Whether this was developed through contact during trade or independently is not clear. It is known that there was significant contact among the ancient civilizations that could have led to transfer of this type of knowledge or concept. The degree was subsequently divided into 60 arcminutes and 3600 arcseconds in more recent times, with minutes being introduced about 300–200 BC.

The Greek mathematician Euclid of Alexandria (mid-4th to mid-3rd centuries BC) formalized much of the foundation for plane geometry as we know it today. He was not as concerned with the measurement units as he was interested in the mathematical relationships among angles and planes.

The angular unit of the “turn” or “revolution” represents a complete circle [7]. The first use of this unit is not clear. It was known in the 17th and 18th centuries AD, but had conceptually been used much earlier. Protractors based on percentages of a turn were available in the 1920s AD. Formal division of the turn into smaller fractions or decimals was proposed in the early 20th century AD by Sir Fred Hoyle (1915–2001 AD).

He proposed dividing a circle into decimal portions such as centiturns and milliturns. Previous divisions of a turn followed whole number fractions like half-turn or quarter-turn. Mechanically, the use of turns is common when applied to large angles. For example, a wire may be wound 200 turns (or 200 complete times) around a core. The late 20th and early 21st centuries AD have seen some calls for the wider use of turns as a standard angular measurement unit in a decimal system. See Fig. 10.5 for examples of various angles using the system of turns.

Around 1800 AD, in a continuing attempt at metrication or decimalization of measurements, the French originated the grad or gradian [8]. This has also been called the metric degree. The unit was meant to designate an arc equal to 100 km of circumference at the equator. Since the earth’s circumference at the equator was taken as 40,000 km, this meant that a right angle, was divided into 100 grads. The grad was further subdivided decimally into decigrads, centigrads, and so on. Hence, a complete turn or circle consisted of 400 grads. The unit was eventually renamed the “gon” to avoid confusion with other units and terms, but we find a wide range of terms still in use today. We will use the term “grad” here in most cases. Gradians never really saw general use. They were only adopted by a few countries and only in specific applications like surveying, mining, geology, and artillery. French artillery used grads as a standard for several decades. Grads have been annotated in several ways: “grad”, “gon”, “gr”, “grd”, “g”, and “g^o”. Surveying applications of

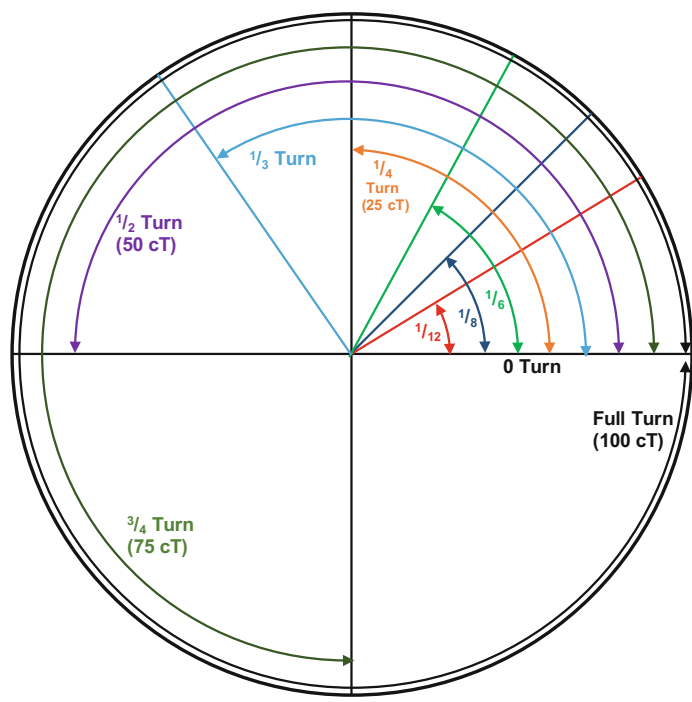


Fig. 10.5 Definitions of angles by turns using fractions and decimals 10

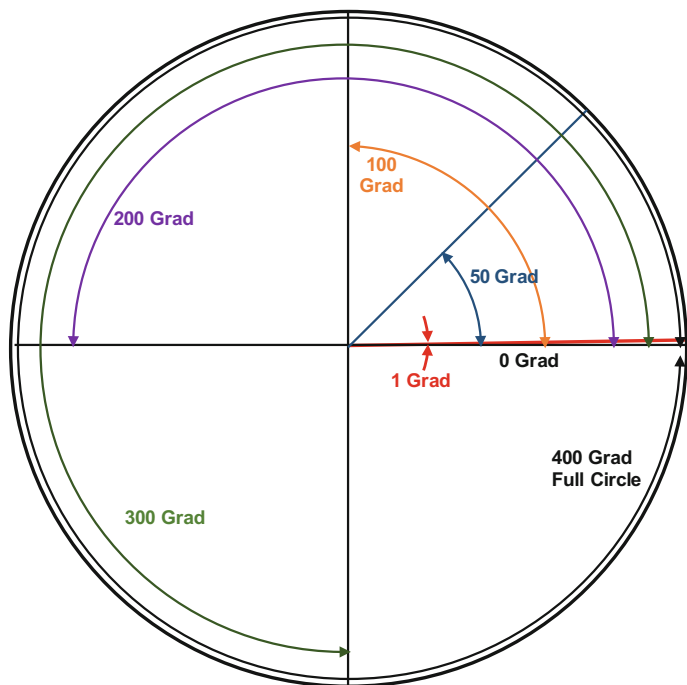


Fig. 10.6 Definitions of angles by gradians [8]

gradians also include the notations “c” ($=0.01$ grad) and “cc” ($=0.0001$ grad). Figure 10.6 illustrates angles using the gradian system.

In the 19th century AD, the angular mil was introduced as a measure of angle for military applications, such as artillery [9]. The definition of an angular mil was not generally standardized, however. The Russians defined an angular mil as $1/6000$ th of a circle or turn. The French and United States used $1/6400$ th of a circle. The equivalent Swedish unit, the “streck”, was $1/6300$ th of a circle. The size of the unit was based on one mil being about 1 m in size at a distance of 1 km. Soldiers were taught to estimate the number of mils using body parts, similar to earlier angular measures. The annotation for angular mils is normally “ang mil”. Figure 10.7 provides a comparison of angles using the various angular mil systems.

Another method for measuring angles is based on the “radian” [10]. One radian is equal to the angle created by a circular arc with a length equal to one radius of a circle. This concept is illustrated in Fig. 10.8. The system derives from geometry practice. A complete circle consists of 2π (6.2831...) radians. This is the angular measurement approach adopted for the *Système international d’unités* (SI), although I will admit that I have never seen a practical protractor or other angle measurement device with radians actually being used in practice. The fact that the radius does not evenly (or even decimally) divide a circle is awkward when trying to apply this approach. It does provide a base quantity (the radius) that enables one

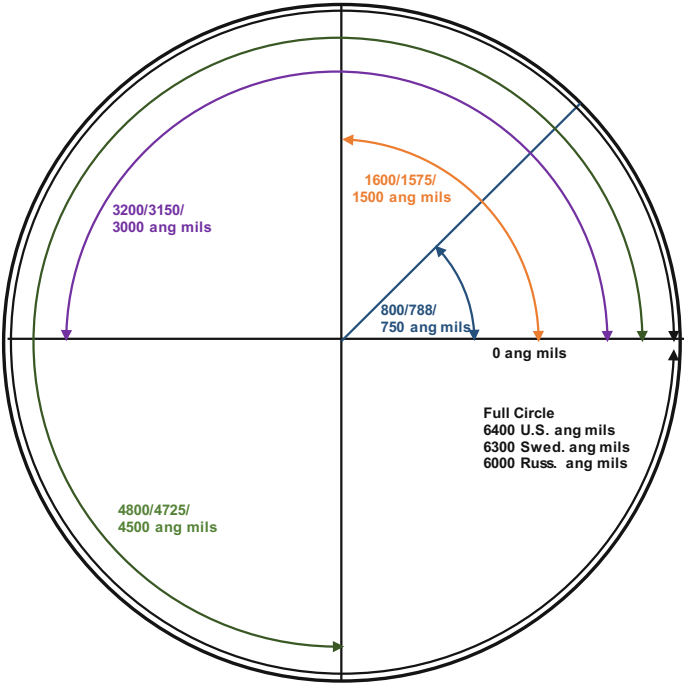


Fig. 10.7 Comparison of angular mil systems [9]

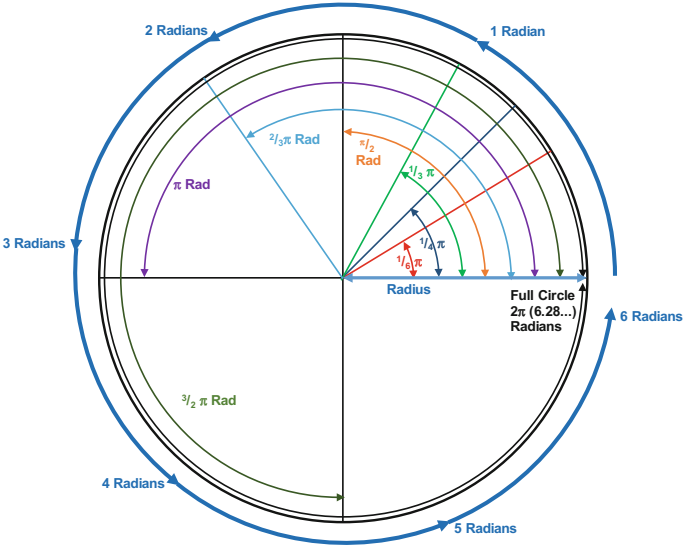


Fig. 10.8 Angular measurement using radians [10]

to divide up any circular arc as desired, making the definition appealing from an order standpoint, but practical application is limited. Mathematically things are nice and elegant, however.

There are traditionally two additional methods used to designate angles which should be mentioned here: the compass and the clock face. The compass has been used for navigation for centuries. Long before compasses contained degree markings, they used simple directions like North (N), South (S), East (E), and West (W), as well as intermediate directions like Northwest (NW) and North-Northwest (NNW). A total of 16 directions were usually defined on a compass, which covered a complete circle. Each compass direction or “point” was 22.5° from the next point. The compass has been used to designate angular location in applications beyond just maritime use, e.g. in the card game, Bridge.

Similar to the compass, a clock face has been used as a guide to describe directions and angles. The circular clock face is normally divided into 12 segments of 30° each. (A 24 h clock is normally not used for this.) The top of the face is normally labeled 12, with the numbers 1 through 11 each labeling a dividing line between segments and proceeding around the face “clockwise”. In fact clockwise defines a specific standard direction of movement around the face. In practice, directions from a point are often given as though a person is at the center of the clock facing 12. If you direct the person to the “2 o’clock” position, it is understood that the direction will be 60° to the person’s right. Similarly, the “6 o’clock” position is behind the person. This is easier than trying to communicate in degrees (or especially radians!). A clock face is also used sometimes for describing angular elevation in the same manner.

Figure 10.9 illustrates angles that are described by both compasses and clock faces.

Calculators and other devices today fortunately include trigonometric functions that can use degrees, gradians, or radians. The use of degrees is the most common in

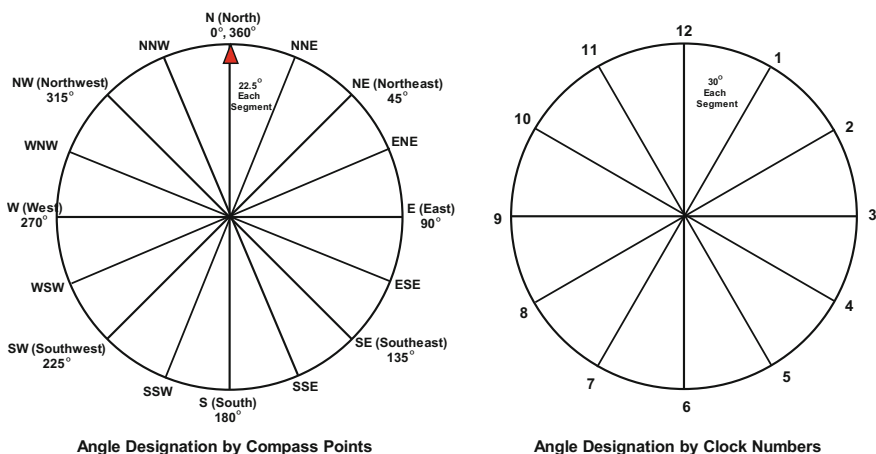


Fig. 10.9 Angle designations by compass and clock face

industry throughout the world. In mathematics, radian measures are also common, but these are not used much outside of mathematics. Turns, of course, have common use, but it is doubtful the general public thinks of a “turn” as an actual unit of measurement.

As you can see, a number of approaches have been used for angular measurement scales over the centuries. The measures were often derived for specific purposes and used in limited applications.

Angle Measurement Devices [2, 3, 11]

For measurement of angles, several devices and approaches have been developed over the centuries. Not all of these measurement devices depend on having a quantitative value for an angle. Many depend on relationships among the angles and sides of triangles, which follow strict rules.

Some examples of the primary angle measurement devices include:

- Fixed Devices (Fig. 10.10)
 - Triangle templates or “squares”
 - Distance sighting using body parts
 - Center-finder
- Variable/Flexible Devices (Fig. 10.11)
 - Compass
 - Angle finders
 - Combination square
 - Transit and Sextant

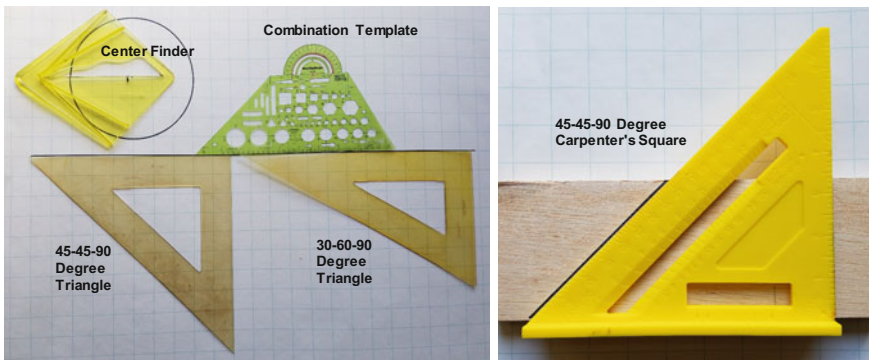


Fig. 10.10 Various types of fixed angle measurement devices



Fig. 10.11 Various types of flexible angle measurement devices

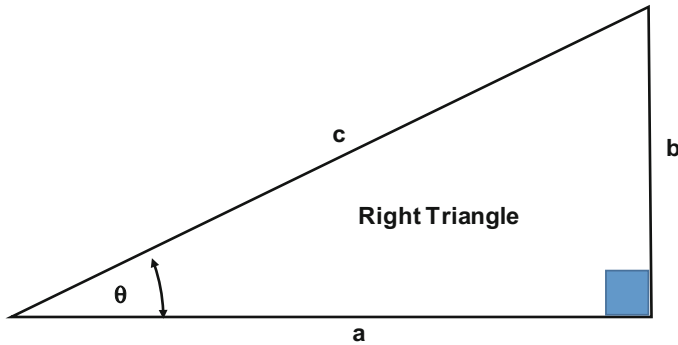


Fig. 10.12 Relationships for determining angles using trigonometric functions

- Mathematical relationships (Fig. 10.12)
 - Trigonometry

Various templates and squares are available which are designed to create specific angles. Figure 10.10 provides several examples of this type of device. These are used for designing, drafting, and construction of structures and machinery, among other uses. Most of these devices rely on aligning one side of an angle with one side of the device and projecting the desired angle along another side of the device. Squares are particularly useful when you want to create a cut that goes “straight” or at 90° across a board or metal bar with respect to one side, for instance.

Approximating angles using body parts was discussed earlier. This is essentially a system that uses more or less fixed references to determine angle. This approach is useful for estimating heights or lengths of distant objects by applying the symmetric properties of triangles. You need to have some idea of how far away the object being measured is located to complete a length or height measurement, but the angle can be estimated directly.

A center finder is a fixed device used to determine the approximate location of the center of a cylindrical object that is used in wood working and machinery. Essentially, it is an angle that has been bisected exactly so that when you place the edges of the two outer sides of the center finder on either side of the cylindrical shape, the center indicator edge will cross the center of the cylinder. By using this device from a couple of different angles around the cylinder, you can locate the center fairly closely.

A compass is the most common, flexible device used to measure angles. A typical compass consists of a straight edge for reference and a semi-circular or circular arc with its center located on the straight edge. The circular arc is marked in degrees or other desired units. The compass is normally clear so you can see the angles for alignment. By placing the center of the compass at the vertex of an angle and aligning one side of the angle along the straight edge, the angle for the other side is indicated on the compass scale. See Fig. 10.11 for an example.

An “angle finder” is an articulated set of straight edges that can be aligned along the sides of an angle with the vertex of the angle at a defined point on the angle finder. The angle can be read off a scale on the device. This is useful for approximations of angles.

A combination square is often used in shops to set angles for fabrication. The “combo” square has a long straight edge to be used as a reference and a second straight edge that is attached to a compass (or may be at a fixed angle, also) which allows this edge to be adjusted to a desired angle. Operation is similar to a compass in that a center point on the straight edge is placed at the vertex of the angle with one side of the angle along the straight edge. The compass is adjusted to the desired angle and the straight edge that is attached to the compass then indicates the desired angle for marking. Much more sophisticated versions of this type of device are sometimes built into machines with much higher accuracy to permit precise milling.

For high accuracy of larger angle measurements, surveyors use a transit and mariners use a sextant. The devices are located at the vertex of the angle to be determined and two index lines are sighted along the sides of the desired angle. The angle is then indicated on a scale.

The application of the mathematical relationships for angles from trigonometry provides another technique for measuring angles with great accuracy, guiding construction of devices, or measuring large distances or areas. The trigonometric functions are based on the relationships among the sides and angles of a right triangle as illustrated in Fig. 10.12. By measuring the lengths of two appropriate sides of a right triangle, angles can be determined. The key relationships are:

$$\text{sine } (\theta) = b/c \quad (10.1)$$

$$\text{cosine } (\theta) = a/c \quad (10.2)$$

$$\text{tangent } (\theta) = b/a \quad (10.3)$$

$$\text{arcsine}(b/a) = \text{arccosine}(a/c) = \text{arctangent}(b/a) = \theta \quad (10.4)$$

So, suppose we have $a = 43$ ft, $b = 26$ ft. Using the properties of a right triangle, then:

$$\begin{aligned} c^2 &= a^2 + b^2 \\ c^2 &= 43^2 + 26^2 = 1849 + 676 = 2525 \\ c &= \sqrt{2525} = 50.25 \text{ ft} \end{aligned} \quad (10.5)$$

From this, we can derive:

$$\begin{aligned} \sin (\theta) &= 26/50.25 = 0.5174 \rightarrow \arcsin(0.5174) = 31.16^\circ = \theta \\ \cos (\theta) &= 43/50.25 = 0.8557 \rightarrow \arccos(0.8557) = 31.16^\circ = \theta \\ \tan (\theta) &= 26/43 = 0.6047 \rightarrow \arctan(0.6047) = 31.16^\circ = \theta \end{aligned}$$

This discussion provides a sampling of methods for measurement of angles in practice. There are many other approaches possible to determining these important relationships.

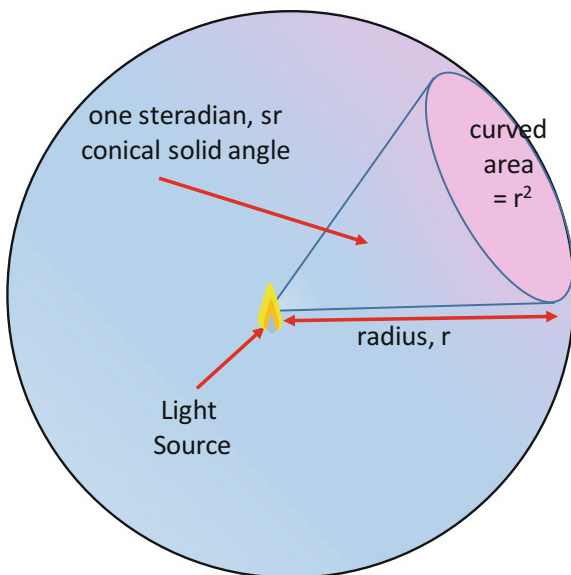
Three-Dimensional Angles [12]

The measurement of angles in three dimensions is somewhat more complex than measurement of angles in a plane. In 3-D, angles are measured by projected area. In SI units, these angles (also called solid angles) are measured by steradians.

The steradian, is a dimensionless quantity for a solid angle in 3-dimensional space. See Fig. 10.13. The area of a sphere around a point in space that represents one steradian of solid angle $= r^2$ where r is the distance from the center of the sphere to the projected area radially. Essentially, a steradian around a point subtends the same fraction of a spherical surface around the source ($1/4\pi \rightarrow \sim 7.96\%$), regardless of the distance from the source. This eliminates dependence of the angular measurement on distance.

This measurement is used for defining the intensity of light sources radiating spherically outward. The actual intensity per unit area will change with the inverse square of the distance from a light source, but the total amount of light radiated over one unit of solid angle around a source will still be the same regardless of the distance—it's kind of a slick trick. Of course, we know that light sources are not actually point sources, but are three dimensional objects. There are mathematical

Fig. 10.13 Graphical definition of a steradian solid angle relative to a sphere [12]



relationships available to account for the differences introduced by real object shapes. We will revisit the application of steradians when we talk about light in Chap. 13.

Metric and English/U.S. Angular Units [10, 13]

The metric unit for plane angular measure defined by *Système international d’unités* (SI) is the radian, where it is considered to be a secondary unit, since it is a length of circular arc divided by the circle’s radius. From a dimensional analysis view, the radian is dimensionless. Solid angles in metric units are measured in steradians.

The U.S. or English system generally uses the degree-minute-second system for angular measure, with some specific exceptions, such as surveying or military applications. For the U.S./English system of units, there is really no measure for solid angle. Projected area and distance from a point source are used instead.

Comparison of Historical Angle Measurement Scales

Figures 10.14 and 10.15 provide a comparison of the various angular measurement systems that has been linearized along a common axis to make it easier to visualize the magnitudes of the units in the different systems. Multiple sources listed in the

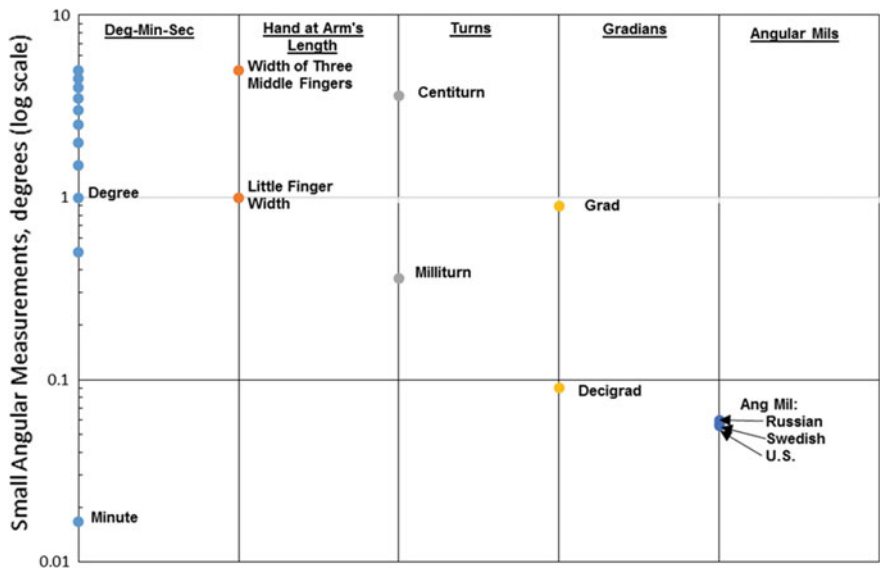


Fig. 10.14 Relative magnitudes of angular measures of less than 5°

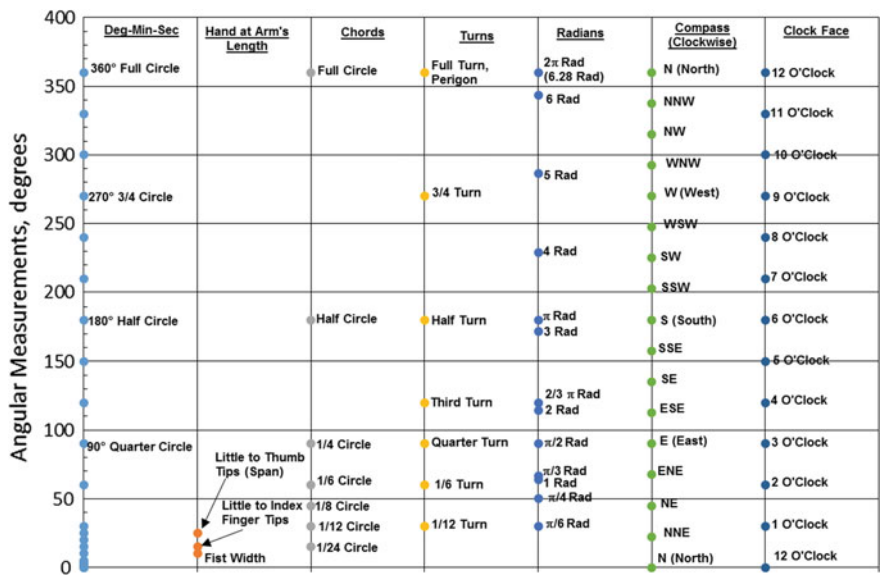


Fig. 10.15 Relative magnitudes of angular measures of greater than 5°

“References” section were used in developing this comparison; hence, they are not listed separately here.

Figure 10.14 covers angles less than 5° or 0.0873 radians. Note that Fig. 10.14 uses a logarithmic distribution for the y-axis. Figure 10.15 illustrates relative magnitudes of the units up to one full circle of 360° or 2π radians.

Historical Angle Conversion Factor Values [1, 5–16]

Table 10.1 provides a summary of many of the historical measures for angles, while Table 10.2 provides conversion factors for the various historical measures to radians and fractional degrees.

Table 10.1 Summary of historical angular measurement units

Scale	Units in circle	Degrees per unit	Radians per unit	Notes	Initial date defined
<i>Radians</i>					
General: This measurement is most common in mathematics. It is based on the observation that 2π times the diameter of a circle equals the circumference of the circle. It is the standard for metric measurement for angles, but commonly the public uses degrees, minutes, and seconds					19th Century Metric

(continued)

Table 10.1 (continued)

Scale	Units in circle	Degrees per unit	Radians per unit	Notes	Initial date defined
Radian	6.283	57.300	1.000	2 π radians make one complete circle	

Degrees-Minutes-Seconds

General: Ancient origin. Earliest records back to Mesopotamia. One theory is that 360 degrees (°) was based on approximate number of days in a year rounded to a convenient number for calculation. 1° is the approximate distance the position of the constellations move in the sky each day. Minutes (or arcminutes) came from the Greeks who divided each degree into 60 arcminutes using the sexagesimal (Base 60) mathematical system from the Babylonians. Division into seconds (or arcseconds) occurred later on the same basis. Other civilizations also used 360 divisions for a circle, e.g. India. Fit nicely with a clock. Relatively easy math—divisible by 24 different numbers. Still the most common system in general use today

Degree	360	1.000000	0.01745	Unclear origin. Ancient division. π /180 radians	~ 3000–4000 BC
Minutes	21,600	0.016667	0.000291	Greek origin. 60 minutes per degree	~ 200–300 BC
Seconds	1,296,000	0.000278	4.85E–06	60 seconds per minute.	

Turns

General: This measure is simply a fractional count of a portion of a circle. Still used to describe rotation. Normally broken into fractions based on 1/2ⁿ units (1/2, 1/4, 1/8, etc.). May also have divisions of 1/12 or 1/24

Turn	1	360	6.283	2 π radians	Unknown
Half-turn	2	180	3.142		
Quarter-turn	4	90	1.571		

Grads

General: The metric system doggedly tried to redefine all units in multiples of 10. The metric version of angular measure divided a right angle into 100 parts called “grads” or “gons”. These were then further divided using a base 10 system. A complete circle was 400 grads. French military used the system in World War I artillery. Calculators still have provisions for these units. Not in general use, abandoned generally in early 1800s

Grad or gon	400	0.900	0.0157		
Decigrad	4000	0.0900	0.00157		

Angular mil

General: This was primarily a military unit of measure varying 6000–6400 units for a circle. Russians divided a circle into 600 units and these were further divided into 6000 units or angular mils by the Russian Army for artillery use. Commonly used in military. One mil subtends about one meter at a distance of 1000 meter. Angular mils can be approximated using the hand with outstretched arm (values below are based on 6400 ang mils per circle

(continued)

Table 10.1 (continued)

Scale	Units in circle	Degrees per unit	Radians per unit	Notes	Initial date defined
Angular mil (Russian)	6000	0.0600	0.00105	Variant of the unit	
Angular mil (French, U.S.)	6400	0.0563	0.000982	Variant of the unit	
Streck (Swedish)	6300	0.0571	0.000982	Variant of the unit	
Index finger width	212	1.7	0.029	30 ang mils	
Index + middle finger width	92	3.9	0.069	70 ang mils	
Three finger width	64	5.6	0.098	100 ang mils	
Four finger width	51	7.0	0.12	125 ang mils	
Fist width	36	10.0	0.18	180 ang mils	
Span width	21	17.0	0.29	300 ang mils, hand spread wide	
<i>Hand estimates</i>					
General: While not a formal system of measurement, amateur astronomers frequently estimate angles using a technique similar to that described above for the angular mil viewing the back of the hand at the end of the outstretched arm. The values below are approximate for different hand positions					19th Century
Little finger width	360	1	0.017		
Width of three middle fingers	72	5	0.087	disagrees a little with ang mil	
Width of fist	36	10	0.17		
Tip of little finger to tip of index finger outstretched, closed hand	24	15	0.26		
Span width, tip of little finger to tip of thumb outstretched, closed hand	14	25	0.44	disagrees a little with ang mil, different references	
<i>Compass points</i>					
General: This system has been used for navigation for centuries. The compass points define 16 equal segments of a circle, starting with north at the top. North, of course, is oriented magnetically. The designations for compass points or directions proceed around the compass, with a point defined every 22.5°					Medieval
Compass point	16	22.5	0.393		
<i>Clock face</i>					
General: This system has been used designate directions for centuries, also. The 12-hour clock face number positions define 12 equal segments of a circle, starting with 12 at the top and proceeding clockwise from 1 through 11. The separation between the adjacent hour markings is 30°. A 24 h clock face has also been used					Medieval

(continued)

Table 10.1 (continued)

Scale	Units in circle	Degrees per unit	Radians per unit	Notes	Initial date defined
Clock face hour separations	12	30.0	0.524	12 h clock basis	
Clock face hour separations	24	15.0	0.262	24 h clock basis	

Table 10.2 Alphabetical historical angle conversion factor values

Unit	Units in circle	Degrees per unit	Radians per unit	Notes
Angular mil (French, U.S.)	6400	0.0563	0.000982	
Angular mil (Russian)	6000	0.0600	0.00105	
Centiturn	100	3.60	0.0628	
Clock face hour separations	12	30.0	0.524	
Clock face hour separations	24	15.0	0.262	
Compass point separation	16	22.5	0.393	
Decigrad	4000	0.0900	0.00157	
Deciturn	10	36.0	0.628	
Degree	360	1.000000	0.01745	Unclear origin. Ancient division
Fist width	36	10.0	0.18	180 ang mils
Four finger width	51	7.0	0.12	125 ang mils
Grad or gon	400	0.900	0.0157	
Half-turn	2	180	3.142	
Index + middle finger width	92	3.9	0.069	70 ang mils
Index finger width	212	1.7	0.029	30 ang mils
Little finger width	360	1	0.017	
Milliturn	1000	0.360	0.00628	
Minutes	21,600	0.016667	0.000291	Greek origin. 60 minutes per degree
Quarter-turn	4	90	1.571	
Radian	6.283	57.300	1.000	2π radians make one complete circle
Seconds	1,296,000	0.000278	4.85E-06	60 seconds per minute
Span width	21	17.0	0.29	300 ang mils, hand spread wide
Span width, tip of little finger to tip of thumb outstretched, closed hand	14	25	0.44	disagrees a little with ang mil, different references

(continued)

Table 10.2 (continued)

Unit	Units in circle	Degrees per unit	Radians per unit	Notes
Streck (Swedish)	6300	0.0571	0.000982	
Three finger width	64	5.6	0.098	100 ang mils
Tip of little finger to tip of index finger outstretched, closed hand	24	15	0.26	
Turn	1	360	6.283	2π radians
Width of fist	36	10	0.17	
Width of three middle fingers	72	5	0.087	disagrees a little with ang mil

Conclusion

The quantification and measurement of angles is important in scientific, as well as everyday, applications. Several systems have been developed to quantify angles beginning in ancient times. Most systems begin with a circle and divide the circle into equal segments of arc. Measurement of the angles thus defined has been accomplished by using a number of devices and/or the functions defined by trigonometry. There are two common angle systems in use today: English/US standard of degree-minute-seconds and the SI standard of radians. For solid angles, the SI standard is steradians. From a practical standpoint, the use of degrees is far more common.

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Chapter 11

Historical Electrical Charge and Current



Abstract The history of electrical units of measurement is only about 200 years long, but certainly convoluted. It is a story of numerous international conferences, congresses, committees, actions (and inactions), and changes in what has eventually become the international standard for electrical measurement: electric current. Electrical measurement is intricately linked to magnetic measurements, forming a cohesive system. This chapter describes the journey from tiny laboratory-based measurements to practical-sized units. The standard units have been, at various times, EMF, resistance, conductance, and magnetic units. The result so far is that the standard electrical unit of measurement is the SI ampere measuring the flow rate of electrical charge, with many the other units derived from combinations of the ampere and other base units. We can expect this saga to continue, as re-definition of the ampere is currently being considered by the SI community.

Introduction

The quantification of electrical and magnetic parameters is a very recent development in the overall landscape of measurement units, having taken place primarily over the past, roughly, 200 years. Quantification of electrical, and related magnetic, phenomena has followed a complex and convoluted route to the “current” definition (pun intended). We may expect that the evolution of electrical measurement has not yet reached a long-term stage as you will see later.

The primary SI unit for electrical measurement is the ampere which quantifies electrical current or flow of electric charge. This unit is based indirectly on the passage of a defined number of free electrons by a specified point in one second. Because of the way it has been developed, it could almost be considered a derived unit of measure since it initially depended on other fundamental units like length, mass, and time. Still, because it is based on the charge of an electron, which is considered a property of matter, electric current can be said to be a base unit.

Early investigators into electrical and magnetic phenomena struggled with practical, reproducible methods to measure something that was not directly

observable. You couldn't just simply count electrons passing a point, for instance, since you could not see them individually (nor could you probably count that high in your lifetime). The researchers understood the relationships among electrical charge, potential, and movement of charge, as well as factors such as resistance, inductance, magnetism, capacitance, and electric fields. But development of a measurement system that could be applied to these relationships has taken many years.

Prior to the late 1700s AD, there were really no scientific concepts of electricity or magnetism. Electricity was just something that was represented by lightning. Magnetism is what made a compass maintain a specific orientation. Interest in electrostatic and electromagnetic phenomena, new research methods, and the availability new mathematical tools around the start of the 19th century AD resulted in rapid progress in understanding and applying these phenomena for practical purposes.

This chapter will explore some of the steps along the way to the present day fundamental electrical property, current, and provide a glimpse at possible future direction.

Historical Electrical Measurements [1–11, 29, 34]

Georg Simon Ohm (1789–1854 AD), proposed a relationship among electrostatic potential, electrical resistance, and electrical flow in 1827 AD. This relationship became “Ohm’s Law” [31] and is expressed, in somewhat simplified terms, as:

$$I = V/R' \quad (11.1)$$

where:

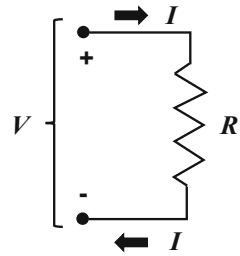
- I Current through a conductor
- V Electrical potential
- R' Electrical resistance or load

This relationship was developed by Ohm to explain the experimental results he derived from a simple, direct-current circuit similar to that depicted in Fig. 11.1. Various forms of Ohm’s Law have been subsequently applied with the use of different, but consistent units of measurement. From a practical standpoint, this relationship still holds true.

Efforts to standardize on electrical property measurements since Ohm’s time have focused on establishing measures that fit into Ohm’s Law. The law only requires you to define two factors and the third is then determined. For instance, if the electrical potential and the load are known, then the current is also defined.

The genesis of electrical measurements was furthered in 1832 AD when Karl Friedrich Gauss (1777–1855 AD) proposed a set of electrostatic and electromagnetic units [12]. These were based on the “new” metric system. In keeping with the

Fig. 11.1 Simple direct-current circuit applicable to Ohm's Law



desire to base the measurement system on universal constants, Gauss proposed magnetic units based on the strength of Earth's magnetic field measured in millimeters, milligrams, and seconds. Eventually, the unit basis was changed to centimeters, grams, and seconds (CGS [29]) to create more practical sized units. Gauss' approach was considered to provide "absolute" units and gave rise to the so-called "absolute" system of electrical measurement.

Wilhelm Eduard Weber (1804–1891 AD) became a collaborator of Gauss in developing absolute units. He published an approach to defining these units in 1848 AD: "On the Measurement of Electro-dynamic Forces." Weber linked the strength of electrical phenomena to the dimensions of length, mass, and time, similar to Gauss' approach. Depending on how strictly we follow base units, these could be considered derived units, but the introduction of electric charge gives a new dimension. In 1851 AD, Weber succeeded in inducing and measuring an electric current that was correlated to length, mass, and time. In his work, Weber used a Grove Cell battery to create the desired voltage. There is more discussion of these cells later.

The Move Toward Standardization [9, 11]

Now what became known as the CGS system had both electrostatic and electromagnetic units that could only be described as a "mishmash" of units [13]. They were dimensionally consistent, but had huge differences in orders of magnitude that could not be easily resolved. The sizes of the units might have been fine for the laboratory scale; but for industrial applications, the units were either too small or too large. There were also variations of the CGS system used in the 1800s AD, including the "Heaviside" system which combined the electrostatic and electromagnetic systems.

Efforts to standardize on a common electrical system of measurement focused on adapting the CGS electromagnetic units to practical scales. The standardized measurement units were defined as multiples of the corresponding CGS electromagnetic units.

Prior to 1848 AD, there was little standardization of electrical units. Moritz Hermann von Jacobi (1801–1874 AD), at that time, noted that it would be relatively

easy to establish a reproducible standard for electrical resistance using a defined length and diameter of wire having a standard composition. Jacobi created such a standard and sent copies to the notable electricity researchers of his time. The standards each consisted of 1 m of circular wire that was 1 mm in diameter and made of a particular copper alloy. The measured resistance of these samples was about 0.6367 modern ohms. He was unable to gain any traction on this concept, however.

Werner von Siemens (1816–1892 AD) proposed an alternative to the Jacobi resistance unit in 1860. Siemens' definition was based on the electrical resistance at 0 °C of a column of mercury that was 1 mm² in cross-section and 1 m high. This became known as a Siemens or Siemens-Einheit Unit (SU). This mercury standard has persisted for several decades. It was adopted by many countries as the resistance standard.

In 1861 AD, the British Association for the Advancement of Science (BA) established a committee to define a standard for resistance. They set the standard unit of resistance as 10⁷ CGS absolute units of resistance, but used the meter for length. This actually made the unit of resistance 10⁹ absolute CGS electromagnetic units of resistance. The BA used a Daniell Cell for the standard electromotive force in this direct current arrangement.

The British Association also attempted to standardize the resistance units using wire that was 2 parts silver to 1 part platinum between 1863 and 1864 AD. They distributed copies of the proposed resistance standard to other countries, but the standard was only adopted by some English-speaking countries. Others continued using the Siemens standard.

The various standards continued in use around the world until 1881, when the French proposed an International Congress in Paris to standardize electrical units that could then be used for legal definitions (and incidentally international trade purposes). Some of the key results from this meeting included:

- Adoption of the CGS absolute electromagnetic system of units as the base.
- The resistance unit was defined as the ohm with a value of 10⁹ CGS units (similar to the BA definition).
- The ohm was to be defined using an approach similar to Siemens' mercury standard (0 °C, 1 mm² cross-section, but length to be defined by a committee).
- The unit of electromagnetic force or potential was defined as the volt [33] which was equal to 10⁸ CGS units.
- The ampere was defined as the unit of electric current produced through a 1 Ω resistance by 1 V of electromotive force.
- An ampere was to represent one coulomb of electricity flowing per second.
- The unit of electrical capacitance was defined as the farad, in which 1 C of electric charge would raise the potential of a capacitor by 1 V.

Following the International Congress of 1881, the committee on the resistance standard actually did work toward fulfilling their charge and many measurements of the height of the mercury column were made. These varied from 106.0 to 106.3 cm

to obtain the targeted $1\ \Omega$ resistance. It proved to be very difficult to construct a glass column for the mercury that was exactly the same diameter throughout its approximately 1 m length. The variations in the required heights were likely from tiny differences in column diameter.

The International Conference of 1884 (AD) in Paris built on the work of the 1881 Congress. The conference settled on several points, including:

- The height of the mercury column would be defined as 106 cm for the resistance standard ohm (in spite of the observed variations).
- The ampere would be defined as 0.1 CGS electromagnetic current unit.
- The definition of the volt was changed to equal the electromotive force required to maintain 1 A of current through a resistance of 1 legal ohm.

Work still continued toward improving the CGS system of measurement, while other standards were progressing. In 1884, Heinrich Rudolf Hertz (1857–1894 AD) combined the CGS electrostatic and electromagnetic systems of measurement into a common system. He determined that the speed of light ($c = 2.998 \times 10^{10}$ cm/s) acted as a constant that related the two systems together. His resulting units were called the “Gaussian System” [35].

In 1889, the Second International Congress of Electrician in Paris continued the standardization work of the prior conferences. Among decisions at this meeting were:

- The joule was defined as the unit for electrical energy and it was set equal to 10^7 CGS electromagnetic units or the energy produced in 1 s by a 1 A current from a $1\ \Omega$ resistance.
- The watt was defined as the practical unit of power and was set equal to 10^7 CGS electromagnetic units of power or 1 J/s.
- Several other unit definitions were put forth, including quadrant for induction, period for oscillation and frequency, mean intensity, effective intensity, effective electromotive force, and apparent resistance.
- This was the conference that established a convention for wiring with the “+” pole of a battery or cell was to be connected to the “+” pole of a DC generator or dynamo during charging and was to be connected to the “+” pole of the load during discharging.

Representatives of the English Board of Trade, with participation by other British technical associations and some other countries met in Edinburgh between 1890 and 1892 AD to work further toward defining electrical standards. Building on the previous efforts and lessons, some key proposals from this effort included:

- Definition of the standard ohm using a column of mercury 106.3 cm tall of uniform, circular cross-section containing 14.4521 g of mercury. This got away from the inability to precisely control the $1\ \text{mm}^2$ cross-section tube that was used in prior definitions and matched the experimental results for height more accurately.

- The new definition of an ampere was proposed based on electrodeposition. An ampere would be the current required to deposit exactly 0.001118 g of silver per second onto an electrode from a saturated solution of silver nitrate in water in a voltameter.
- The Clark cell was proposed as a standard for the volt, with the electromotive force (EMF) provided by a Clark cell defined as 1.434 V at 15 °C. This was later determined to deviate slightly from the intended definition of a volt, so the actual EMF was subsequently determined to be 1.4328 V. The Clark cell is discussed later.

The Fourth Electrical Congress was held in Chicago in 1893. The results of this meeting provided the basis for most legal definitions and standards. The key proposals put forth included:

- Each participating country should adopt the standards proposed as their legal standards.
- The ohm is the unit of resistance and was called the International Ohm. It was defined as 10^9 CGS electromagnetic resistance units and was represented by the mercury standard ohm—106.3 cm high column of uniform cross-section containing 14.4521 g pure mercury.
- The ampere is the unit of current (International Ampere) and is equal to 1/10th of a CGS electromagnetic current unit. It was based on electrodeposition of 0.001118 g/s of silver from a saturated aqueous silver nitrate solution onto an electrode. The form of this silver voltameter was specified in precise detail.
- The volt would be the standard unit of EMF (International Volt) and was defined as the EMF required to cause 1 International Ampere of direct current in a circuit with 1 International Ohm of resistance. An alternative definition allowed the volt to be 1000/1434th of the voltage produced by a Clark cell at 15 °C. A committee was appointed to develop a detailed specification for the standard Clark cell subsequent to the meeting, but the committee never issued any reports (in typical committee fashion).
- The International Coulomb was defined as the unit of charge and was specified as the amount of electricity transferred in 1 second by a current of 1 International Ampere.
- The International Farad was defined as the standard unit of electrical capacitance and was equal to the amount of electricity required to change the potential of a condenser by 1 International Volt using 1 International Coulomb of charge.
- The International Joule was the standard unit of work, defined as 10^7 CGS electromagnetic work units. This was to be the amount of energy expended in a 1 International Ohm circuit in 1 second.
- The International Watt was the standard unit of power, defined as 10^7 CGS units of power or 1 International Joule per second.
- The Henry was the international unit of induction. It was defined to be the electromagnetic field induced by 1 International Volt producing a current that varied by 1 International Ampere per second.

- The magnetic units used in the CGS electromagnetic system were adopted without any special names.

The legal definitions proposed at the 1893 international congress were adopted by several nations in the subsequent years, but some inconsistencies among the definitions began to crop up as more precise and accurate measurements were made. So, at the International Electrical Congress in Paris in 1900, there was discussion of the issues and improvements to the definitions. The desire to include definitions for magnetic units was also evident. This meeting only acted on the magnetic definitions.

The 1904 International Electrical Congress was held in St. Louis. A commission was proposed to resolve any discrepancies among the definitions and to ensure consistent international standards. Unfortunately, the commission was never appointed and the proposal died without action.

The Congress meeting in Berlin in 1905 made some progress. It was decided that there would be two fundamental units chosen for electrical measurement: the International Ohm (defined using the mercury column standard) and the International Ampere (defined by electrodeposition of silver in a voltameter). In addition:

- The International Volt (DC) was defined as the EMF required to produce 1 A current in 1 Ω resistance. The American delegation had actually proposed that the volt be the other fundamental electrical unit, but they lost this battle.
- Details were added to the International Ohm standard.
- The Weston cell, producing 1.018638 V, was detailed as a secondary voltage standard because of its relative stability over a wide temperature range.

Electrical standards remained pretty much as defined in the 1905 congress until 1933. At the 8th international General Conference of Weights and Measures (AKA *Conférence générale des poids et mesures*, CGPM) there was a proposal to replace the international electrical units (that had taken decades to define) with absolute units again, but this was not done at the time.

The 9th CGPM began the move toward a return to absolute unit definitions by adopting the ampere as the unit of current and adopted a definition from the International Committee for Weights and Measures (*Comité international des poids et mesures*, CIPM):

...constant current which, if maintained in two straight parallel conductors of infinite length, of negligible circular cross-section, and placed 1 m apart in vacuum, would produce between these conductors a force equal to 2×10^{-7} MKS unit of force per meter length.

The term “MKS unit of force” was named the “Newton” in the same meeting and the magnetic constant of a vacuum was defined to be $4\pi \times 10^{-7}$ H per meter. The definition for the ampere is probably scientifically elegant, but sort of impractical since few people have infinitely long straight wires that have no cross-sectional area and an infinitely long vacuum chamber. Of course there are ways around that, but the definition is still awkward.

In 2005, the CIPM began studying improvements to the definition of the ampere. They were considering redefining the ampere as equal to 1 C of elementary electric charges passing a point in one second, with 1 C equal to 6.242×10^{18} electrical charges. In some ways, this is as difficult to use as the force between two infinite wires, but it does move further toward defining current in terms of a fundamental property of matter. The CPGM considered this change in 2014, but has not adopted it to date.

Today, the definitions of electrical units stand pretty much as they were left in 1948, but we would have to consider the unit definitions still somewhat in flux (an unintentional pun):

- The ampere (A) is the fundamental unit of electric current using the infinite wire definition from 1948.
- The ohm is a derived unit from volts divided by amps (units are $\text{m}^2\text{kg}/(\text{s}^3\text{A}^2)$).
- The volt is a derived unit from watts divided by amps (units are $\text{m}^2\text{kg}/(\text{s}^3\text{A})$).
- The watt is a derived unit from joules divided by seconds (units are $\text{m}^2\text{kg}/\text{s}^3$).

Comparisons of Electrical Units

Now, from a practical standpoint, just how much difference do all these gyrations in the definitions of electrical units make? Not really very much. The differences, expressed as percentages, are usually somewhere out in the second or third decimal place. Our ability to see these differences or be affected by them in most practical electrical devices is pretty much non-existent, so for practical purposes the international, absolute, and SI ampere definitions have effectively the same values.

Alternating and Direct Current

The definitions of electrical units have mostly been derived on a direct current (DC) basis. However, common electrical generation, transmission, distribution, and uses today are based on alternating current (AC), explored by Nikola Tesla (1856–1943 AD). We apply the DC-derived definitions to the AC case by converting the AC measurements to equivalent DC values.

In an AC circuit, we think of the electrical charges flowing first one direction and then the other on a certain frequency. In North America, the power system is based on an alternating current at 60 cycles per second (Hertz). In Europe, 50 Hz distribution is common. In practice, the resistance or load on a circuit doesn't care which way the current flows, so the factor that drives the current is an alternating voltage. In most large systems the voltage varies from positive to negative in a more or less sinusoidal pattern as illustrated in Fig. 11.2. This variation in voltage causes a variation in current and can mathematically involve a lot of complex numbers.

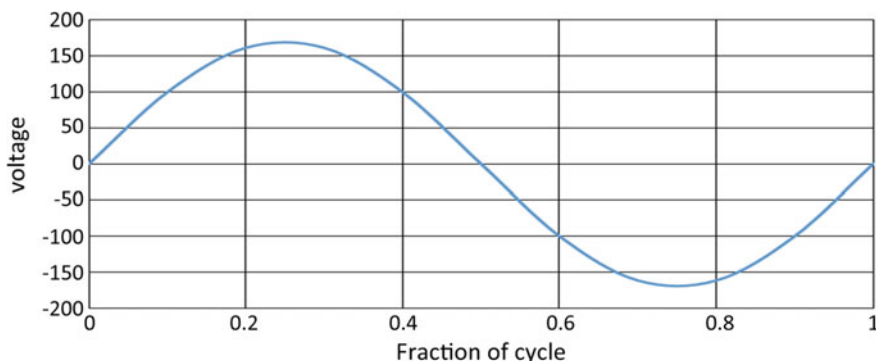


Fig. 11.2 Sine wave of alternating voltage found in 120 V AC circuits

To allow the definitions of the electrical units to still be useful, the variations in voltage are converted to the root mean square (RMS) voltage. This is the amount of AC power that produces the same heating effect as an equivalent amount of DC power. The definition tries to define equivalent AC and DC effects for the same load. From a power standpoint, it doesn't matter which direction the current is flowing.

For a typical AC cycle that is sinusoidal:

$$V_{\text{RMS}} = V_{\text{max}} / \sqrt{2} \quad (11.2)$$

where:

V_{max} Peak voltage during a cycle.

Graphically, determination of RMS is shown in Fig. 11.3. The alternating sine wave of the voltage is effectively converted to all positive voltage by integrating the squares of the instantaneous voltages over one complete cycle and taking the square root of the integral to obtain an effective average over the cycle. This general procedure works for other AC wave forms found in some electronic devices, such as square waves in AC motor speed controls.

Historical Standard Cells [14, 15]

A bit of an interesting sidebar in the development of electrical standard definitions has been the application of different “standard” cells at different points in time. Of course, now the definitions do not depend on precisely constructed standard reference electrical cells, but for over a century they did.

Electrochemical batteries themselves may have been known over 2000 years ago as evidenced by the discovery of what became known as the “Baghdad battery” in

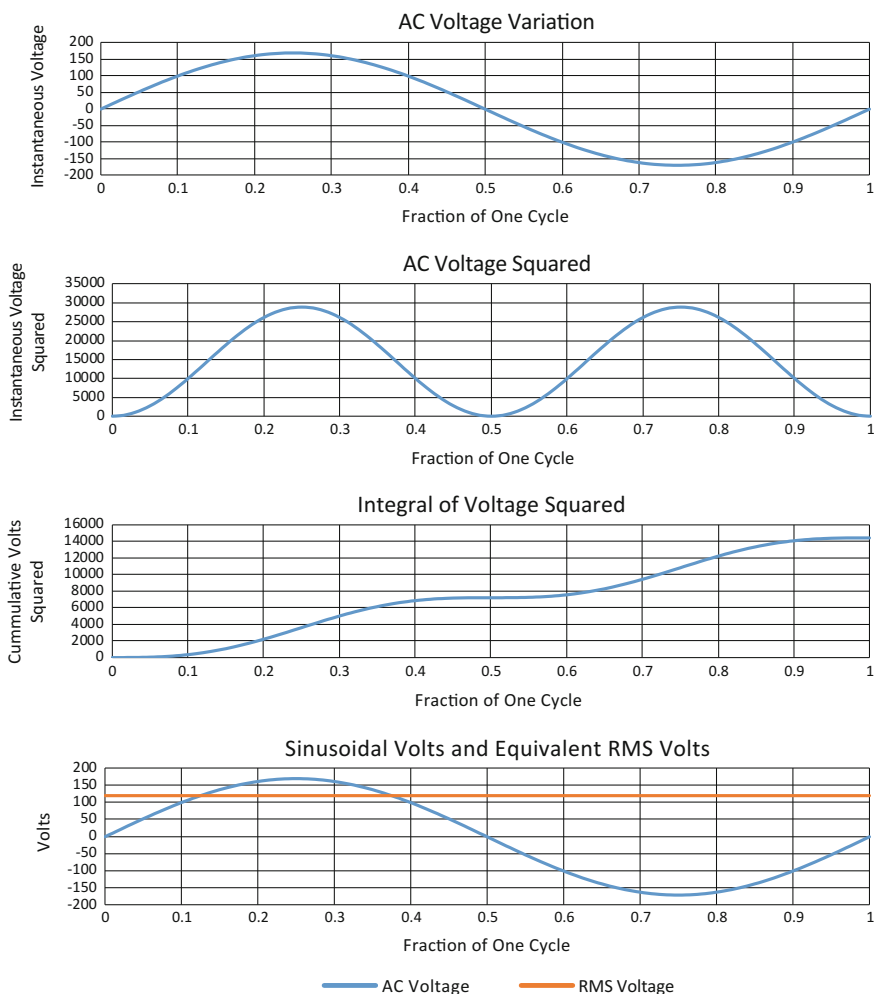


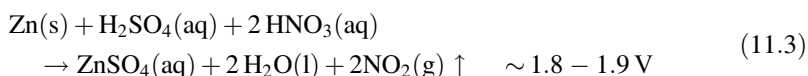
Fig. 11.3 Development of RMS voltage for a sine wave form

1936 AD; although this concept has been largely discredited by further archeological work. The earliest “Modern” electrochemical batteries were made by Alessandro Volta (1745–1827 AD) in 1800 AD. He stacked copper and zinc discs separated by cloth or cardboard soaked in brine solution as an electrolyte. These “Voltaic Piles” could supply a stable voltage and current for experiments, but the EMF supplied was low. The stacked arrangement gave way to a side-by-side arrangement eventually before better battery configurations were developed.

The standard cells that followed Volta’s efforts were not necessarily in keeping with what we would consider safe practice today. They frequently involved liquid mercury or gave off poisonous and corrosive NO_2 vapors. Even the lithium hydride

cells we use today, that have been known to generate enough heat to catch fire, are safer than some of these early cells.

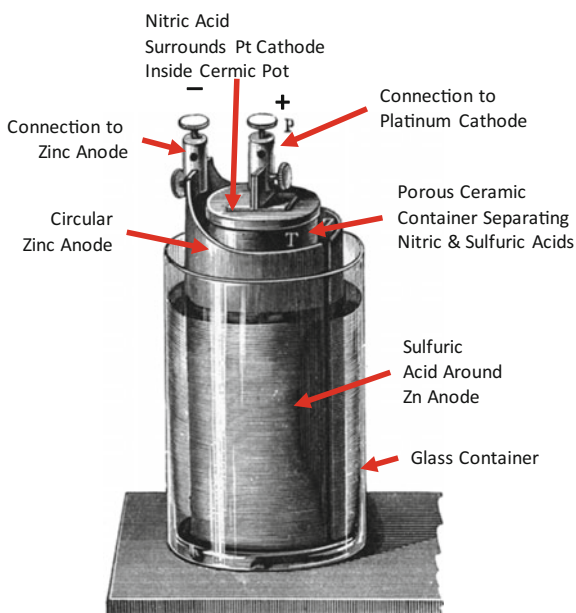
We'll do a quick review of the old standard cells and their evolution, starting with the Grove cell. In Weber's work published in 1848 AD, he used the Grove cell as a standard. This primary (i.e. non-rechargeable) cell was a wet chemical cell invented by Sir William Robert Grove (1811–1896 AD) in 1839 AD. The general cell arrangement is shown in Fig. 11.4. In this, essentially, concentric, circular cell design within a glass container, a zinc anode was immersed in dilute sulfuric acid around a central platinum cathode that was, in turn, immersed in concentrated nitric acid. Separating the two acids was a porous ceramic pot. The overall reaction occurring in the cell was:



The poisonous NO_2 gas that was evolved was said to corrode everything in a room where Grove cells were used. This type of cell was used extensively for telegraph power until the 1860s, when safer cells became available. The cell could deliver 1.8 V at about 13 A until it was exhausted.

The Bunsen cell replaced the Grove cell. This primary cell was developed by Robert Wilhelm Bunsen (1811–1899 AD) in 1841 AD. In the Bunsen cell, the expensive platinum cathode was replaced by carbon, but otherwise the cell was similar. Surrounding the center cathode, Bunsen used either concentrated nitric or

Fig. 11.4 Typical grove standard cell of the mid-1800s AD



chromic acids or a mixture. Short circuit current for Bunsen cells was 12–13 A with voltage still about 1.8–1.9 since the chemistry was otherwise the same as a Grove cell. When using nitric acid, this design suffered from the same NO_2 emission problem that the Grove cell had. Interestingly, a group of 90 Bunsen cells was stacked together by Henri Moissan (1852–1907 AD) to electrolyze hydrofluoric acid to produce elemental fluorine for the first time. Frankly, this sounds like an extraordinarily hazardous operation from both the batteries and the chemicals, but it is typical of the sorts of activities that run through the history of electrochemistry.

In 1836 AD, John Frederic Daniell (1790–1845 AD) invented a primary cell that used zinc and copper for the anode and cathode, respectively. See Fig. 11.5. This type of cell was used as the standard by the British Association for the Advancement of Science beginning with their work to establish a standard for resistance in 1861 AD. Use of the cell as a standard continued until around 1890 when the Clark cell replaced the Daniell cell.

In a Daniell cell, the zinc anode was immersed in sulfuric acid or zinc sulfate solution. The copper was immersed in a saturated copper (II) sulfate solution or the cell vessel was simply built from copper. The electrodes were separated by either a ceramic pot or an ox-gullet tube (of all things). The initial design of the cell was fairly complicated and actually had a reservoir that held copper sulfate crystals around the copper cathode to ensure a saturated CuSO_4 solution was present, but the battery arrangement became simplified over the years. The original forms that evolved were somewhat akin to the Grove and Bunsen cell arrangements. Daniell's important innovation was to couple two half-reactions together to eliminate the evolution of gases from the cell. He was trying to prevent hydrogen evolution that occurs if you use a zinc-sulfuric acid half-reaction to generate voltage. Within the Daniell cell, the reactions occurring were:

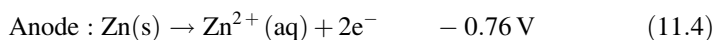
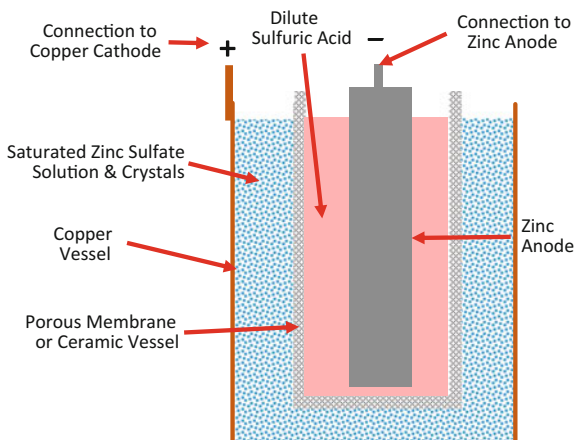
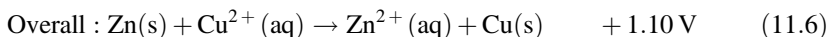
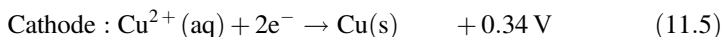


Fig. 11.5 Schematic of a Daniell cell [24]





A variant of the Daniell cell was invented in the 1860s by a Frenchman named Callaud was the “gravity cell”. Unfortunately, little is available about Callaud, considering his contribution to battery development. In Callaud’s arrangement, he took advantage of the specific gravity differences between the dilute sulfuric acid and saturated copper sulfate solutions in a Daniell cell by laying a copper cathode at the bottom of a glass vessel and piling copper sulfate crystals on it. Then, he hung a zinc anode from the top of the vessel and filled the apparatus with dilute sulfuric acid. See Fig. 11.6. As the battery was used, a layer of dense, saturated copper (II) sulfate solution formed in the bottom of the vessel and slowly expanded toward the top. This layer would be bright blue and could indicate the extent of discharge of the battery. There were two key drawbacks to this arrangement:

1. The cell could not be moved or the gravity separation would be upset.
2. The cell had to be used continuously so the gravity difference was maintained; otherwise, the solution mixed with the acid and the cell would not work.

If a gravity cell was exhausted, it could easily be emptied and replenished by the user with commonly available materials. This type of cell was used extensively for telegraph services into the 1950s AD, especially at remote locations.

When the English Board of Trade met with representatives of other British associations and other countries in Edinburgh in 1890–1892 AD they chose a new type of cell for a voltage standard, the Clark cell. The Clark cell was invented by Josiah Latimer Clark in 1873 AD and was known to produce a highly stable voltage.

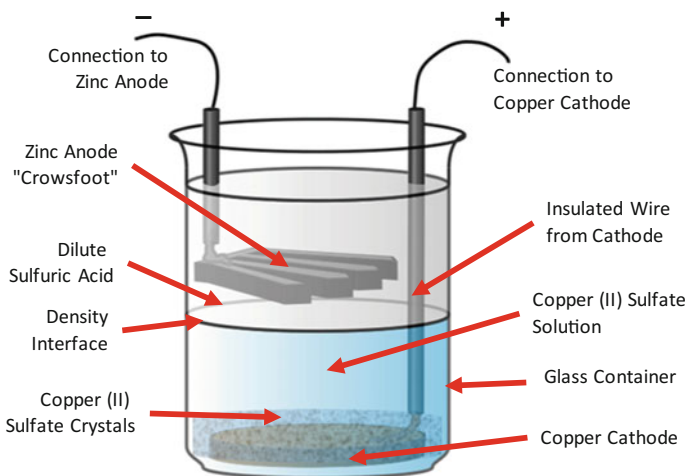
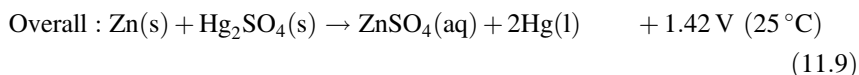
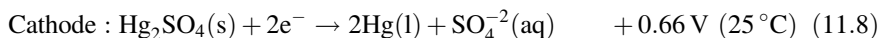


Fig. 11.6 Gravity cell schematic

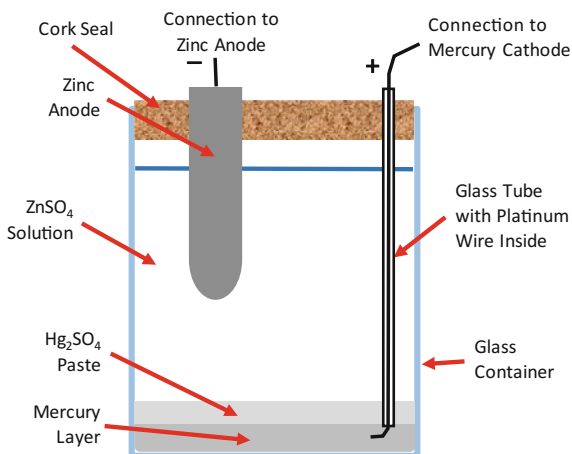
This primary mercury/zinc wet cell was configured as sketched in Fig. 11.7. It consisted of a glass vessel with a layer of mercury on the bottom. A paste of mercurous sulfate covered the mercury layer. Above the paste was a solution of zinc sulfate. A zinc or zinc (Hg) amalgam anode was hung down into the ZnSO_4 solution, suspended from a cork closure. A platinum wire sealed inside an insulating glass tube connected the mercury layer on the bottom through the cork closure to provide the cathode connection. The apparatus was then sealed with marine glue.

In service, the Clark cell yields a reference EMF of 1.4328 V at a temperature of 15 °C with no current draw. The Clark cell electrochemical reactions are below. The cathode reaction EMF varies widely among references and appears to be a function of the concentration of the media. The EMF of the cell, as constructed, and the EMF of zinc are well known, so the EMF of the mercury reaction has been back-calculated and may vary slightly from available tables, but it is consistent with the standard mercurous sulfate reference electrodes available:



The Clark cell voltage is, unfortunately, a strong function of temperature, with the voltage decreasing 0.00115 V per °C. This shortcoming did not prevent it from being adopted as a standard reference for EMF at the Fourth International Electrical Congress in 1893; where 1 V was defined as 1000/1434ths of the EMF of a Clark cell at 15 °C. This definition lasted until 1905 when a change to the Weston cell was proposed at the meeting of the Congress in Berlin and adopted at the International Conference on Electric Units in London in 1908 AD.

Fig. 11.7 General configuration of a Clark cell



The Weston primary cell, invented by Edward Weston (1850–1936 AD) in 1893 AD, was much less sensitive to temperature changes than the Clark cell [16, 17]. Weston replaced the zinc electrode with a cadmium-mercury amalgam electrode and arranged the cell in an “H” form as illustrated by Fig. 11.8. In one arm of the H, the cadmium-mercury amalgam was placed and topped with $\text{CdSO}_4 \cdot \frac{8}{3}\text{H}_2\text{O}$ crystals. This formed the anode. In the other arm of the H, a layer of mercury was topped with mercurous sulfate paste and a layer of $\text{CdSO}_4 \cdot \frac{8}{3}\text{H}_2\text{O}$ crystals. The H was filled with a saturated solution of cadmium sulfate. The EMF produced by the Weston cell (with no current draw) is 1.0183 V at 20 °C and changes by only -0.0015 V from 0 to 40 °C.

Reactions occurring in the Weston cell are:

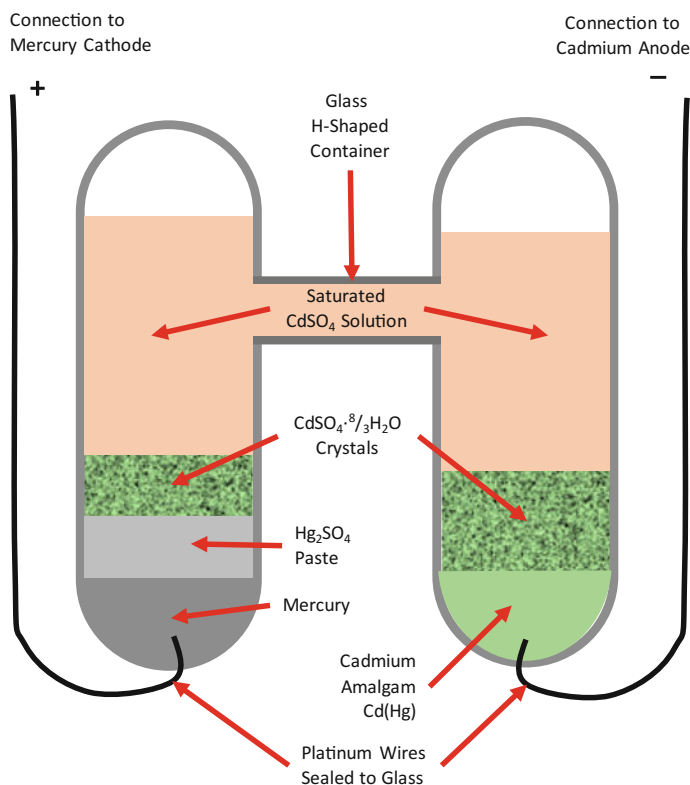
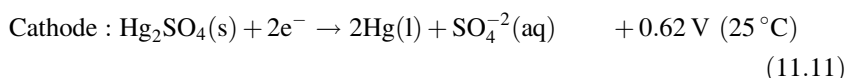
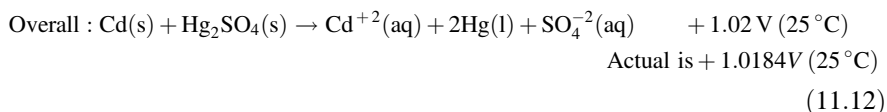


Fig. 11.8 Schematic of Weston standard cell [14, 16, 17]



The cadmium and sulfate ions end up forming a precipitate of $\text{CdSO}_4 \cdot \frac{8}{3}\text{H}_2\text{O}$ crystals.

The Weston cell was used as a primary reference cell into the 1970s AD. The volt was effectively eliminated as a fundamental unit of measurement at the 9th Conférence générale des poids et mesures (CGPM) in 1948 AD. In the SI system, the volt is a derived unit with units of $\text{kg m}^2/(\text{A s}^3)$. The standard cells are still useful as general references, however.

Current Measurement [1, 2, 10, 18]

The measurement of electric current has assumed a number of forms over the short history of electrical units. Frankly, electric current is probably one of the more difficult factors to measure. Almost all the methods available to measure current do so by converting the current to a magnetic field whose strength is then read either mechanically, electrically, or electronically. There are several options, among which are:

- *Electromechanical* [19, 20]: The electromechanical ammeter (ampere meter) measures electrical current indirectly by converting the current to a magnetic or other force that is a function of the current and comparing that force to a known force, like a spring. The origins of this type of meter are rooted in the basic relationship that was originally noted between a compass needle and the strength of the magnetic field that could be produced by a specific DC current in a nearby wire in 1820 AD by Hans Christian Ørsted (1777–1851 AD). This “tangent galvanometer” could be used to measure current by how much the compass needle was deflected. The earth’s magnetic field acted as the force against which the field generated by the current worked (the restoring force). The more wire or turns of wire near the compass needle, the more effect was seen to increase sensitivity. This effect has been applied in several types of ammeters, where an electromagnetic field induced around a wire interacts with a magnet to move a needle on a gauge. The difficulty with Ørsted’s device was that it needed to be oriented with the earth’s magnetic field to work. Although used for many years, subsequent meters eliminated this need by using springs to provide the restoring force against which the magnetic field worked and to return the meter indication to zero. The concept really is applied in all kinds of dial electrical meters. Among the types of ammeters that have been and continue to be used are:

- **Moving coil:** In the astatic D’Arsonval galvanometer, a coil of wire was linked to a needle and the coil was then placed between fixed north and south permanent magnet poles. The needle was also connected to hair-springs to provide the counteracting force and restore the coil to a zero position. The current to the tiny coil often flows through the hairsprings. See Fig. 11.9a for a schematic of the concept. This meter was invented by Jacques-Arsène d’Arsonval (1851–1940 AD) and Marcel Deprez (1843–1918 AD) in 1882. As current is applied to the coil, the electromagnetic force produced causes the coil to rotate in the permanent magnetic field, working against the hairsprings. The extent of rotation is a function of the current. This type of mechanism is limited in practical current carrying capacity to the milliamp range by the hairsprings that must carry the full current.
- **Moving magnet:** This is sort of a reverse of the D’Arsonval meter in that a rotating, permanent magnet is attached to the indicator needle. The electric coil to deflect the needle is fixed around the permanent magnet. Because larger wire can be used for the fixed coil, this ammeter could measure higher currents. See Fig. 11.9b for a conceptual sketch.
- **Electrodynamic:** This is similar to the moving magnet meter, but also uses an electromagnetic coil attached to the needle instead of a permanent magnet. These meters can measure both AC and DC amps.
- **Moving-iron:** This meter, invented by Friedrich Drexler (1858–1945 AD) in 1884, features a moving iron vane, attached to an indicator that is subjected to the magnetic field generated by a coil of wire. The movement of the iron vane is proportional to the square of the current in the coil. An example of the arrangement of this type of meter is in Fig. 11.9c, although the actual forms in practical use vary significantly. This meter is usable for both AC and DC readings.
- **Hot-wire meter** [19, 20]: This type of ammeter does not depend on electro-magnetism; but, instead, depends on the current flowing through a wire which

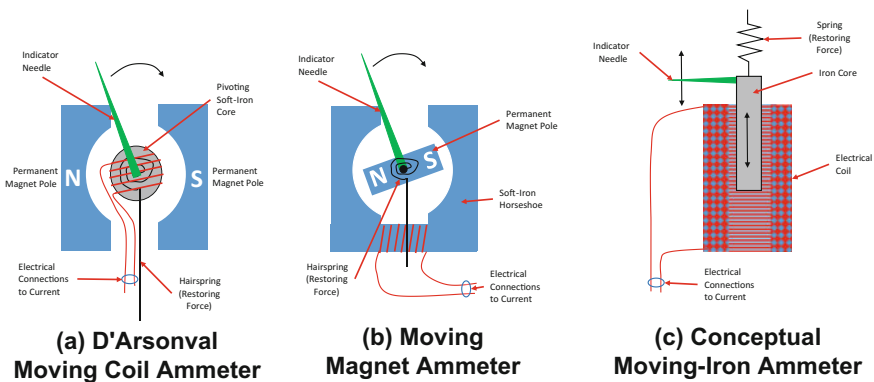


Fig. 11.9 Concepts behind various types of electromechanical ammeters [20]

heats up and expands. The resulting expansion is a function of the current applied and can be used to mechanically move an indicator dial or be sensed electronically. The principle works for both AC and DC measurements. In the case of AC, the wire effectively reflects the RMS current.

- Shunt metering [18, 19]: For metering very large currents which are beyond the normal range of an ammeter, a large shunt resistor of known, very low resistance, can be placed in series with the load in an electrical circuit. The voltage across this resistor can then be measured and converted to current using Ohm's Law. The shunt resistor must also be capable of handling the voltage and current required in the circuit. The resistor will generate heat, which must be managed to maintain accuracy. This approach works for both AC and DC currents.
- Hall Effect [18, 21]: In a Hall Effect electronic sensor for current, an applied fixed voltage and current are passed through a conductor "plate", usually made of semiconductor material—let's say this current is flowing along the X-axis. The current to be measured passes through a toroid of soft iron to create a magnetic field. The strength of the magnetic field is a function of the current being measured. The poles of the magnetic field are arranged so that they are perpendicular to the current flowing through the plate—let's say this is along the Z-axis. The result is that there is a second, induced voltage along the Y-axis perpendicular to both the current flow of the applied voltage and the magnetic field on the Z-axis. The induced voltage is a function of the magnetic field. See Fig. 11.10 for an illustration of the concept. This effect was first described in 1879 AD by Edwin Herbert Hall (1855–1938 AD); hence, it is called the Hall Effect. The measured, induced voltage can be related to the current being measured. This type of meter is seen either permanently installed or with split ring, clamp on meters [32] which are extensively available today. Normally, these are digital, electronic meters.
- Current transformer [7, 22]: A current transformer (CT) can be used on AC circuits to measure currents which would otherwise be far too large or for current measurements in very high voltage circuits which would be outside the safe range of other measurement methods. In some ways, a current transformer approach is similar to Hall Effect. In a CT arrangement, the AC current in a main circuit is passed through a toroidal ring which has a secondary coil of wire wrapped around it. See Fig. 11.11 for the conceptual arrangement. The magnetic field induced in the ring, generates a current in the secondary coil which can then be measured electronically or mechanically and is related to the current in the main circuit. This is another type of meter that can be installed permanently in a system or can be used in a clamp-on configuration [32]. This meter only works for AC circuits (where transformers will work).
- Magnetoresistance [23]: Sir William Thompson (Lord Kelvin, 1824–1907 AD), discovered that the resistance of some materials changed when subjected to a magnetic field in 1856 AD. He also noted that the magnitude of the resistance change depended on the direction of current through the material with respect to the magnetic field (anisotropic magnetoresistance, AMR). That is, if a current flows along an X-axis in a material, like a semiconductor and you apply the

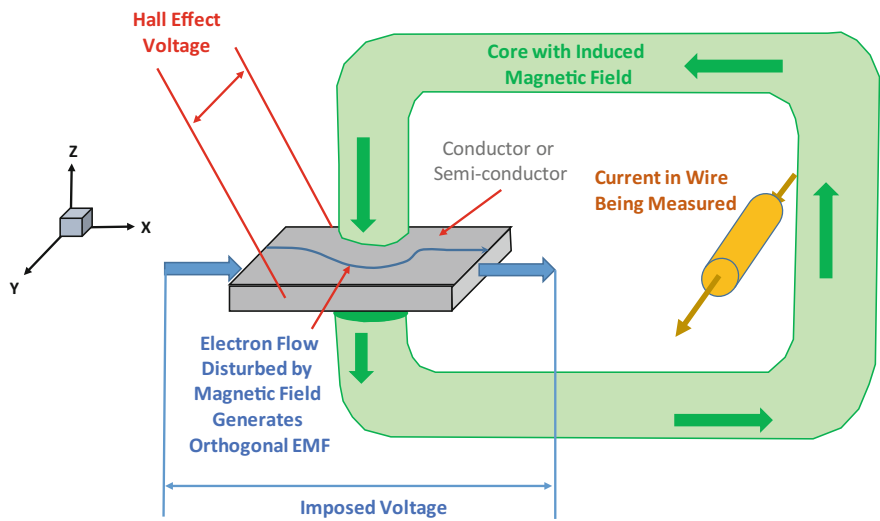


Fig. 11.10 Conceptual illustration of Hall Effect [21]

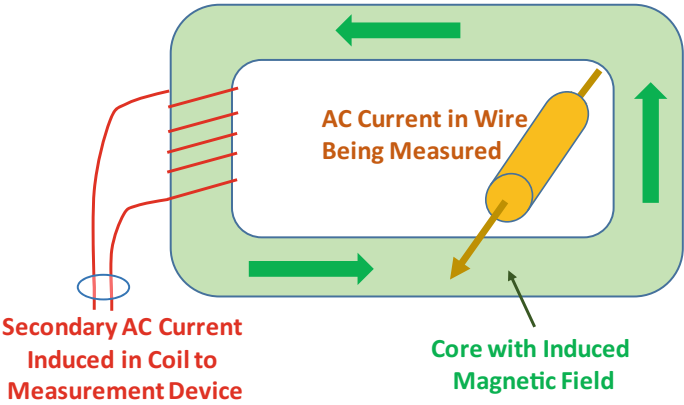


Fig. 11.11 Current transformer measurement concept [22]

magnetic field along the Z-Axis, the resistance increases along the X-axis. This effect is actually related to the Hall Effect. The magnitude of the effect was very low for the materials Lord Kelvin had available to him; but, since his time, materials have been developed that have significant resistance changes with magnetic field intensity. The Corbino disc is an example of a form which can be useful for metering current using magnetoresistance. A Corbino disc is a flat conductor or semiconductor disc with a hole in the middle. A known voltage is applied between the middle and the outer edges of the disc. A magnetic field, created by the current to be measured, is superimposed on the disc and

Table 11.1 Historical electric conversion factors (Multiple sources, see References)

System	Unit	SI equivalent value	SI unit
CGS system (stat → electrostatic system, ab → electromagnetic system); Gaussian Units (mid-1800s)			
Current	statampere, stata, A-esu	3.335641×10^{-10}	Ampere (A)
Current	abampere or biot	10.0	Amperes (A)
EMF/Potential	statvolt, statv, V-esu	299.792458	Volts (V)
EMF/Potential	abvolt	1×10^{-8}	Volt (V)
Resistance	statohm	$8.987551787 \times 10^{11}$	Ohms (Ω)
Resistance	abohm	1×10^{-9}	Ohm (Ω)
Conductance	statmho (stat $\mathfrak{U}$)	1.112650×10^{-12}	Siemens (S)
Conductance	abmho (ab $\mathfrak{U}$)	1×10^9	Siemens (S)
Capacitance	statfarad	1.11265×10^{-12}	Farad (F)
Capacitance	abfarad	1×10^9	Farads (F)
Charge	statcoulomb	3.335641×10^{-10}	Coulombs
Charge	abcoulomb	10.0	Coulombs
Inductance	stathenry	8.987552×10^{11}	Henrys (H)
Inductance	abhenry	1×10^{-9}	Henry (H)
Gaussian or CGS units electromagnetic and electrostatic units are related to each other using the speed of light, c ($= 2.998 \times 10^{10}$ cm/s), as a constant. For resistance, the statohm $= c^2$ abohms; so an SI ohm $= c^2/10^9$ abohms. A statampere $= 1/c$ abamperes; so an SI ampere $= 10/c$ abamperes. Similarly, an SI volt $= c/10^8$ abvolts using Ohm's Law ($V = IR$)			
Practical electrical units or absolute practical electrical units (1891)			
EMF/potential	Practical volt	1.00	Volt (V)
Resistance	Practical ohm	1.00	Ohm (Ω)
Other units were derived, including current. Technical and theoretical problems with these definitions followed adoption			
International electrical units (1908)			
Current	International ampere	1.000022	Amperes (A)
EMF/potential	International volt (derived)	1.00034	Volts (V)
Resistance	International ohm	1.00049	Ohms (Ω)
Conductance	International mho ($\mathfrak{U}$)	0.99951	Siemens (S)

- orthogonal to the plane of the disc. This causes the disc resistance to increase as a function of the magnetic field intensity and the change in current can be measured electronically.
- **Electrodeposition or electroplating:** This was one of the earliest methods for measuring current and provided the basis for the ampere definition for several decades. The current was a function of how much metal deposited on an electrode in a given amount of time. The metal accumulated could be measured gravimetrically. From a practical standpoint, it is not at all useful for instantaneous current measurement; since the other devices cited are able to provide instantaneous measurement. There are really no electric current measurement devices that use electrodeposition as a basis.

There are, then, several options for measurement of electric current. Most use a combination of magnetic effects and mechanical or electronic measurements of those effects to infer the magnitude of the current. A wide range of ammeters is easily available today to accommodate almost all situations.

Historical Electrical Conversion Factors [25–30, 33–35]

Unlike most of the other fundamental units described so far, the electrical units do not have many variations or conversions required. Their development history is much shorter than that of the other units. Essentially, we have:

- CGS and/or MKS units derived from Gauss/Weber units
- Practical Electrical Units
- International Electrical Units
- SI units

Since our focus here is on electrical current, we don't have too many conversion factors for just one ampere. For completeness, however, we will include the other, related units of measurement in this complex system. Table 11.1 provides the conversions among the different systems.

The information in Table 11.1 has been compiled from multiple sources listed in the “References” section; hence, the reference numbers are not repeated here.

Conclusion

The history of electrical units of measurement is only about 200 years long, but certainly convoluted. It is a story of numerous international conferences, congresses, committees, actions (and inactions), and changes in what would eventually become the international standard for electrical measurement: electric current. Electrical measurement is intricately linked to magnetic measurements, forming a cohesive system. The standard has journeyed from tiny laboratory-based measurements to practical sized units. The standard units have been, at various times, EMF, resistance, conductance, and magnetic units. The result so far is that the standard electrical unit of measurement is the SI ampere, with many the other units derived from combinations of the ampere and other fundamental units. We can expect this saga to continue, as re-definition of the ampere is currently being considered by the SI community.

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Chapter 12

Historical Amounts of Substances



Abstract The base unit for measuring the amount of a substance, the mole, developed over the past couple of centuries as our understanding of chemistry and chemical reactions grew. The mole [or its larger embodiments: the kilomole (kmol) and pound mole (lbmol or lb-mol)] is used extensively in laboratory chemistry as well as industrial chemical and petroleum facility design and operation. The development of the concept of a mole from the earliest chemical work defining combining weights to modern understanding is explored. The SI definition of a mole and its implications are discussed. This SI base unit is being considered for revision, but remains with the current definition at the present time.

Introduction

The measurement unit for the amount of a substance, the mole, is a relatively recent development that has its roots and applications in chemistry. It is a unit that measures the quantity or size of a group of elementary chemical entities. It is a standard unit in the SI/metric system of measurement, but the concept has also been used in English engineering work. It is especially extensively used by chemical engineers in design of chemical processing facilities.

One mole is defined as $6.02214... \times 10^{23}$ elementary entities (termed Avogadro's number). An elementary entity can be thought of as the smallest part of a substance that possesses the specific properties of interest in that substance. For a chemical element, this would be the smallest quantity of that element that acts like the element in a chemical reaction (one atom). For a molecular reaction, the smallest entity would be a molecule. We also talk about moles of electrons, protons, and other particles depending on the context being considered.

If we consider the number of atoms of, say, carbon, we can determine the number of moles of carbon atoms we have using the atomic weight of carbon, which is 12 atomic mass units taken in grams. So 12 grams of carbon is comprised of exactly $6.02214... \times 10^{23}$ atoms or entities of carbon. Generically for any chemical substance:

$$\text{Moles} = \text{grams}/\text{amu} \quad (12.1)$$

where:

Moles amount of substance in mols

grams the quantity of the substance in grams

amu the atomic or molecular weight of the substance in atomic mass units

The number of elementary entities (#Entities) in the quantity of substance (measured in grams) is, then:

$$\# \text{ Entities} = \text{Moles} \times 6.02214 \dots \times 10^{23} \quad (12.2)$$

Now this amount of substance or number of entities in chemistry has some interesting properties. For example, if we consider an ideal gas, one mole of an ideal gas occupies 22.4 litres of volume at standard conditions (1 atm, 0 °C), regardless of the specific gas involved. This number of entities has the same mass as the atomic or molecular weight of the substance. As we shall see, this simplifies practical application of chemical reaction equations.

The evolution of this concept took over 200 years to reach its current stage of understanding. The mole as a unit of measurement is still undergoing evolution.

In the following discussion, we will first look at how the concept of the mole got to its present state, review the practical applications, and consider what changes may be in store in this developing story.

Historical Development of Amount of Substance Measures [1, 5, 6, 9, 12, 14, 15]

Evolving Concepts of “Entities”

The understanding that certain quantities of materials combined together to make a new substance in specific proportions was vaguely understood for many centuries. It was understood, for instance, that to produce iron required that ore and charcoal be mixed in specific proportions and heated to make the best iron. These types of “recipes” for chemical or alchemical reactions were similar to cooking, without any clear understanding of why the proportions had to be what they were. They were determined by trial and error over centuries and the information was closely guarded. Some early scientists, like Mikhail Lomonosov (1711–1765 AD), wondered if there wasn’t something more fundamental involved.

Our story of the evolution of modern concepts for the amount of substance begins in 1777 AD when Carl Friedrich Wenzel (~1740–1793 AD) demonstrated that the anion and cation proportions among two reacting, neutral salts remained constant.

The concept that substances were composed of chemical elements was introduced by Antoine-Laurent de Lavoisier (1743–1794 AD) in 1789 AD. Lavoisier unfortunately got himself executed in the French Revolution or he might have contributed much more.

The concept of stoichiometry, that elements or substances chemically reacted in “definite proportions” by weight (combining or equivalent weight), was introduced in 1792 AD by Jeremias Benjamin Richter (1762–1807 AD). He developed tables of equivalent weights for reacting substances. The understanding of equivalent weights was furthered by Joseph Louis Proust (1754–1826 AD) in 1794 AD with the publication of Proust’s Law, which generalized the concept of definite proportions to all types of chemical reactions.

In 1805 AD, John Dalton (1766–1844 AD) published the first of his papers proposing that substances are made of “ultimate particles” which had specific relative weights. This was the first step in the recognition of atoms as the fundamental entities of which elements were composed. His concept of atoms was not readily accepted at the time, but the relative weights of different substances or elements was found to be useful. Dalton followed his early publications with “A New System of Chemical Philosophy” in 1808 where he provided specific relative weights for the elements using the relative weight of hydrogen as 1. See Fig. 12.1.

The key points in Dalton’s thinking were:

1. Elements are made of ultimate particles called atoms; although Dalton also called compounds “atoms”.
2. All atoms of a specific element have the same size, mass, and other properties.
3. Atoms of each element have a specific size, mass, and other properties that differ from other elements. He did not know about isotopes at the time.
4. Atoms cannot be split, created, or destroyed. Of course, today we know this only applies to normal chemical reactions.
5. Atoms of different elements can chemically combine in simple whole-number ratios to form chemical compounds.
6. In chemical reactions, atoms are combined, separated, or rearranged. This applies to normal chemical reactions.

Dalton’s theories thus provided the foundations for much of modern chemistry. Now the exact values and combinations shown by Dalton in his table of atomic weights were eventually shown to be wrong or misconceived, but his fundamental concepts helped develop further understanding of chemistry.

In 1809 AD, Joseph Louis Gay-Lussac (1778–1850 AD), postulated his Law of Combining Volumes. He stated that there is an integer relationship between the total volume of reactants and the total volume of products in a gas-phase chemical reaction. Effectively, a specific amount of one gas will react with a specific amount of another gas to form a specific amount of product and the coefficients for the volume relationships are integers. This concept led to the hypothesis advanced by Lorenzo Romano Amedeo Carlo Avogadro di Quaregna e di Cerreto (1776–1856 AD) in 1811 AD that, regardless of the gas involved, a given volume of any gas contained the same number of particles as the same volume of any other gas. This idea will help us later.

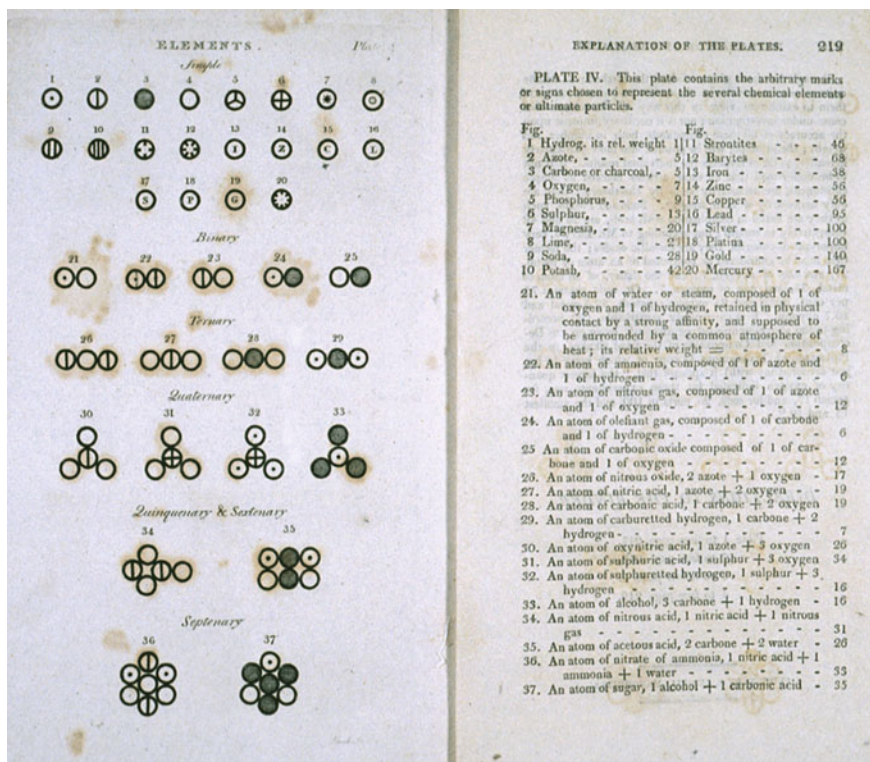


Fig. 12.1 Dalton's symbols and relative atomic weights (From *A New System of Chemical Philosophy*, 1808 AD) [13]

Not everyone accepted Dalton's use of the relative mass of hydrogen being equal to 1. In particular, Baron Jöns Jacob Berzelius (1779–1848 AD), in 1813/1814 AD, proposed a table of relative atomic or combining weights for elements based on oxygen equal to 100. This concept did not gain much traction. Agreeing generally with Dalton, William Prout (1785–1850 AD), in 1815 AD, proposed the theory that all atomic weights were integer multiples of hydrogen and published a table to that effect. Of course, this theory fell apart with an understanding of heavier elements, like chlorine.

The Ideal Gas Law, proposed by Benoît Paul Émile Clapeyron (1799–1864 AD) in 1834 AD, developed a relationship among the quantity of a substance in a system and physical parameters of the system. We might see this as an extension and refinement of Avogadro's idea. The Ideal Gas Law for a given system, as formulated today, states that:

$$PV = nRT \quad (12.3)$$

where:

P the pressure in absolute units of measurement

V the volume of the system

n the amount of substance contained in the system

R gas constant that is independent of the system or substance

T absolute temperature of the system

To make the Ideal Gas Law work, the value of n was needed. This is the amount of substance which eventually led to the concept of the “mole”.

The mid-1800s AD saw a continuing development of chemistry that focused on an understanding of reacting species. The Karlsruhe Congress held in Germany in 1860 AD was the first international meeting of chemists. It had been called to enable a widespread discussion aimed at developing a common basis and standards for chemical symbols, nomenclature, the nature of atoms, and other matters. Some of the discussions were centered on how molecules compared to atoms and the atomic weights to be assigned to various chemical entities. A reprint of an 1858 AD paper by Stanislao Cannizzaro (1826–1910 AD) on atomic weights helped crystallize one area of chemistry where a consensus was reached on relative atomic weights for the common elements. Cannizzaro’s work had been based on earlier work by Avogadro. It recognized that some gaseous elements were actually diatomic (like H_2 , N_2 , and O_2). Cannizzaro also demonstrated that molecular weights could be derived by adding atomic weights of the appropriate elements. Relative atomic weights for the actual elements were then assigned integer values like:

- Hydrogen = 1
- Carbon = 12
- Oxygen = 16

Johann Josef Loschmidt (1821–1895 AD) first estimated the volume occupied by the individual gas molecules that make up air in 1865. His estimate could then be used to determine the number of molecules in a given volume of gas. At standard conditions (0 °C, 1 bara), he calculated that 1 cm³ of air contained 2.69×10^{19} molecules, eventually called the Loschmidt constant. This would give a value of 6.0256×10^{23} molecules per mole as compared to the modern value of the Avogadro number: 6.02214×10^{23} entities per mole. Pretty good agreement for this early time.

Further evidence of the “particle” nature of atoms and molecules came from the development of mass spectrometry in the late 1800s AD. It was observed in 1886 AD by Eugen Goldstein (1850–1930 AD) that ionized particles of a gas followed discrete paths between two electrodes under the influence of a magnetic field. The paths were a function of the particle charge divided by its mass (charge-to-mass ratio, Q/m). The mass spectrometer enabled the determination of atomic and molecular masses for many elements and compounds.

The term “mole” or “mol” was first published in 1893 AD to describe an amount of substance by Friedrich Wilhelm Ostwald (1853–1932 AD). It was translated and shortened from the word “Molekül” in German. This term made its way to the English language in 1897 AD.

We have referred to the “Avogadro number” above, but the term was actually not used until 1909 AD when Jean Baptiste Perrin (1870–1942 AD) coined the term and estimated the value of the “Avogadro number” using several different methods. The Avogadro number was defined as the number of hydrogen atoms in 1 gram-mole. The Avogadro constant is the number of discrete entities, usually atoms or molecules, contained in 1 gram-mole of any substance. For practical purposes, the Avogadro number and constant are essentially the same value. Perrin won the Nobel Prize in Physics for this work in 1926 AD.

Of course, there was a bit of a “fly in the ointment” for understanding atomic weights. In 1913 AD, Frederick Soddy (1877–1956 AD) and Sir Joseph John Thomson (1856–1940 AD) discovered that even non-radioactive elements have isotopes—so that the atomic weights of all atoms in an element were not exactly the same. Instead the weights varied by specific values. We know today that the variation is primarily due to differing numbers of neutrons present in the nuclei of the atoms, but the widespread presence of isotopes in the elements was news.

In 1920, Francis William Aston (1877–1945 AD) proposed an update of Proust’s hypothesis: the “whole number rule”. Aston worked extensively in mass spectrometry and observed that “the mass of the oxygen isotope being defined [as 16], all the other isotopes have masses that are very nearly whole numbers”. Note that he has shifted the atomic weights away from hydrogen as a basis and used oxygen for his work. He received the 1922 AD Nobel Prize in Chemistry for his work.

Thus the landscape for determining the amount of substance was formed. A gram-mole was defined as the atomic or molecular weight taken in grams and one gram-mole of a material contained a specific number of discrete chemical entities (atoms, molecules, etc.) equal to one Avogadro number.

Standardizing Units for Amount of Substance [7, 12, 15]

In 1959 AD, one standard for atomic weights defined oxygen as 16.000 and other atomic weights were calculated relative to oxygen. The use of oxygen as the standard reference value came from mass spectrometry practice. With oxygen’s atomic weight defined as 16, carbon was 12.011 atomic mass units (amu) and hydrogen was 1.0080 amu.

In 1959–1960 AD, the International Union of Pure and Applied Physics (IUPAP) and the International Union of Pure and Applied Chemistry (IUPAC) agreed to a unified, standard scale for relative atomic weights. They agreed to define the atomic weight of carbon-12 as exactly 12 units. Other atomic weights were calculated relative to this standard. Including isotopes, the normally observed (average) atomic weight of carbon was 12.01115 amu. Oxygen’s atomic weight then became 15.9994 amu and hydrogen’s atomic weight became 1.00794 amu. This is essentially the standard used today.

The International Committee for Weights and Measures (CIPM) recommended in 1968 AD that the mole be included in the international standards of the *Système*

international d'unités, (SI). This recommendation was adopted for the SI/metric system in 1972 AD; hence, the mole became the fundamental SI unit for amount of a substance and the abbreviation for the unit was assigned to be “mol.”

The actual wording of the SI definition of a mole from the 14th General Conference on Weights and Measures (CGPM) in 1971 is:

1. “The mole is the amount of substance of a system which contains as many elementary entities as there are atoms in 0.012 kg of carbon 12; its symbol is ‘mol.’
2. “When the mole is used, the elementary entities must be specified and may be atoms, molecules, ions, electrons, other particles, or specified groups of such particles.”

This definition was further clarified by the CIPM in 1980:

“In this definition, it is understood that unbound atoms of carbon 12, at rest and in their ground state, are referred to.”

In common terms, this is the gram-mole, determined by the atomic, molecular, or entity weight taken in grams. In technical terms, a mole is the entity (atomic, molecular, etc.) weight divided by the molar weight constant of 1 gram per mole.

There has been some controversy over the adoption of mole as a base unit by the SI. The objections generally have fallen into the following categories:

1. A base unit is not needed since the mole simply represents a specific number of entities (Avogadro’s number).
2. The definition of a mole imposes large, avoidable economic costs on advanced economies (hard to see how since it is already used extensively in industry for economical designs).
3. It is not a true base measurement unit, but is a parametric unit, i.e. a unit that is derived from other factors.
4. The definition is based on entities with a single dimension and thus excludes continuous quantities.

To date, the mole continues as an SI base unit, although there discussion began in 2011 AD at the 24th CGPM conference to make the mole equal to an amount of substance that would fix the Avogadro constant at exactly $6.02214X \times 10^{23} \text{ mol}^{-1}$ (X represents additional digits to be defined). The definition for a mole would then fall out of the value for the constant. This is consistent with other SI units which are defined relative to various natural phenomena that are believed to be universally constant. Adoption of this change has not yet occurred.

“Standard” Conditions [3, 4, 8]

At various places, we’ve referred to “standard conditions” as a basis for translation of molar amounts to volumes of gases. In each reference, the standard conditions of

pressure and temperature have been specified. Why? Because there is no single “standard” condition that has been used by scientists over the years. There are, instead, at least 18 sets of temperatures and pressures (and sometimes other conditions) that have been used by some organization or the other. No doubt there are many more such standards in use today and in the past. Several standard conditions are summarized in Table 12.1.

Abbreviations (as referenced above) that you will often see for conditions are:

- STP for Standard Temperature and Pressure, from IUPAC at 0 °C, 1 bara.
- ISA for International Standard Atmosphere used by various agencies and associations at 15 °C, 1 atm.
- NTP for Normal Temperature and Pressure from the U.S. EPA and National Institute of Standards and Technology at 20 °C, 1 atm.
- SATP for Standard Ambient Temperature and Pressure from IUPAC at 25 °C, 1 bara.
- In petroleum for gases:
 - SCF or scf refers to Standard Cubic Feet at 60 °F and 1 atm.
 - NCM refers to Normal Cubic Meters at 15 °C and 1 atm (same as ISA).

Metric/SI and English/U.S. Engineering Applications [7]

In practice, there are a few flavors of the “mole” in use.

The mole SI base unit is understood to be the atomic or molecular weight of a substance divided by 1 g/mol. Hence the basis for the unit is grams in the SI system.

In normal use, however, a gram is an inconveniently small quantity. Industry and engineering activities commonly use kilograms (or even metric tonnes) for practical-sized quantities of materials. Hence, engineering (esp. chemical) practice uses the kilogram-mole (kg-mol) for design and operation of facilities. One kg-mol is equal to 1000 gram-moles (or simply 1000 mol). Following a pseudo SI convention for the units, the kilogram-mol is abbreviated as kmol. A kmol contains 2.022×10^{26} elementary entities.

The English/U.S. Customary system of units uses a similar approach in chemical engineering of commercial facilities. The pound-mole (lb-mol or lbmol) is the atomic or molecular weight of a substance taken in pounds mass. 1 lbmol equals the atomic or molecular weight divided by 1 lb/lbmol. One lbmol is equal to 453.59237 mol of the SI system, so a lbmol actually contains 9.17×10^{25} elementary entities .

Typically, engineers working in English units will refer to the lbmol as simply a mole or mol, which can create confusion when working problems involving both metric and English units. Care needs to be exercised in the use of the term “mole” to be sure you are using the correct basis and avoid confusing units from the different systems.

Table 12.1 Range of common “standard” temperatures and pressures [2, 8]

Source of standard	Abb.	Temperature		Pressure		Pressure			Rel. humid.	Molar volume	
		°C	°F	kPa	mm Hg	Atm	psia	in Hg		dm ³ /mol	ft ³ /lbmol
International Union of Pure & Applied Chemistry (IUPAC)	STP	0	32	100.000 (1 bara)	750.06	0.9869	14.5038	29.530		22.711	363.75
U.S. National Institute of Standards and Technology (NIST), ISO 10780 (Emissions Meas.), Formerly IUPAC		0	32	101.325	760.00	1.0000	14.6959	29.921		22.414	358.99
International Civil Aviation Organization's (ICAO) International Std. Atm (ISA), ISO 13443 (Nat. Gas Metering), European Environment Agency (EEA), Canadian Energy & Gas Inspection Act (EGIA)	ISA	15	59	101.325	760.00	1.0000	14.6959	29.921	0% (dry)	23.645	378.70
U.S. Environmental Protection Agency (EPA), NIST	NTP	20	68	101.325	760.00	1.0000	14.6959	29.921		24.055	385.28
Amer. Assn. of Physicists in Medicine		22	72	101.325	760.00	1.0000	14.6959	29.921	20–80%	24.219	387.90
IUPAC	SATP	25	77	100.000	750.06	0.9869	14.5038	29.530		24.790	397.04
EPA		25	77	101.325	760.00	1.0000	14.6959	29.921		24.466	391.85
Compressed Air & Gas Institute (CAGI)		20	68	100.000	750.06	0.9869	14.5038	29.530	0% (dry)	24.374	390.38
Society of Petroleum Engineers (SPE)		15	59	100.000	750.06	0.9869	14.5038	29.530		23.958	383.72
ISO 5011 (Air Intake Filters)		20	68	101.3	760	1.00	14.69	29.9	50%	24.06	385.4

(continued)

Table 12.1 (continued)

Source of standard	Abb.	Temperature		Pressure						Rel. humid.	Molar volume	
		°C	°F	kPa		mm Hg	Atm	psia	in Hg		dm ³ /mol	ft ³ /lbmol
Euro-Asian Council for Standardization, Metrology and Certification (Russian GOST) 2939-63		20	68	101.33		760.0	1.000	14.696	29.92	0% (dry)	24.05	385.3
SPE, U.S. Occupational & Health Administration (OSHA), U.S. Southern California Air Quality Management District (SCAQMD)		16	60	101.33		760.0	1.000	14.696	29.92		23.72	379.48
EGIA, Organization of Petroleum Exporting Countries (OPEC), U.S. Energy Information Agency (EIA)		16	60	101.6		762	1.003	14.73	30.0		23.66	378.61
US Army Std. Metro		15	59	99.99		750.0	0.9868	14.503	29.63	78%	23.96	383.8
ISO 2314 (Gas Turbine Tests), ISO 3977-2 (Gas Turbine Rating)		15	59	101.33		760.0	1.000	14.696	29.92	60%	23.644	378.69
Air Movement & Control Association (AMCA), Air at 0.075 lb _m /ft ³		21	70	101.3		760	1.00	14.70	29.92	0% (dry)	24.14	386.7
U.S. Federal Aviation Administration (FAA)		15	59	101.3		760	1.00	14.70	29.92		23.65	378.8
Common U.S. Refinery Std Conditions		15.6	60	101.325		760.00	1.0000	14.6959	29.921		23.691	379.44

Historical Amount of Substance Conversion Factors

Since the development of the concept of “amount of substance” is relatively recent, there are not all that many historical conversion factors to consider. Table 12.2 provides conversions among the more common measurement units. It also provides conversion factors to move from standard reference conditions for gases to molar quantities, which are often useful to chemical engineers.

Table 12.2 Selected amount of substance interconversion factors. Multiple sources, see References

From unit	Sym	To unit	Sym	Multiply by	Notes, reference
<i>General molar conversions</i>					
gram-mole	gmol	kilogram-mole	kmol	0.001	
gram-mole	gmol	kilomole	kmol	0.001	
gram-mole	gmol	mole (SI)	mol	1.00000	
gram-mole	gmol	pound-mole (English)	lbmol	0.00220462	
kilogram-mole	kgmol	gram-mole	gmol	1000	
kilogram-mole	kgmol	kilomole	kmol	1.00000	
kilogram-mole	kgmol	mole (SI)	mol	1000	
kilogram-mole	kgmol	pound-mole (English)	lbmol	2.2046	
kilomole	kmol	gram-mole	gmol	1000	
kilomole	kmol	kilogram-mole	kgmol	1.00000	
kilomole	kmol	mole (SI)	mol	1000	
kilomole	kmol	pound-mole (English)	lbmol	2.2046	
mole (SI)	mol	gram-mole	gmol	1.00000	
mole (SI)	mol	kilogram-mole	kgmol	0.001	
mole (SI)	mol	kilomole	kmol	0.001	
mole (SI)	mol	pound-mole (English)	lbmol	0.00220462	
pound-mole (English)	lbmol	gram-mole	gmol	453.59	
pound-mole (English)	lbmol	kilogram-mole	kgmol	0.45359	
pound-mole (English)	lbmol	kilomole	kmol	0.45359	
pound-mole (English)	lbmol	mole (SI)	mol	453.59	
<i>Ideal gas volume interconversions—metric</i>					
cubic meter	NCM	kilomole	kmol	0.042210	US Refy std cond. (60 °F, 1 Atm)
cubic meter	NCM	mole (SI)	mol	42.210	US Refy std cond. (60 °F, 1 Atm)

(continued)

Table 12.2 (continued)

From unit	Sym	To unit	Sym	Multiply by	Notes, reference
cubic meter (NIST)	NCM	kilomole	kmol	0.044615	NIST Std cond. (0 °C, 1 Atm)
cubic meter (NIST)	NCM	mole (SI)	mol	44.615	NIST Std cond. (0 °C, 1 Atm)
cubic meter (NTP)	SCM	kilomole	kmol	0.041571	U.S. EPA, NIST (20 °C, 1 Atm) NTP
cubic meter (NTP)	SCM	mole (SI)	mol	41.571	U.S. EPA, NIST (20 °C, 1 Atm) NTP
cubic meter (SATP)	SCM	kilomole	kmol	0.040339	IUPAC SATP (25 °C, 1 bara)
cubic meter (SATP)	SCM	mole (SI)	mol	40.339	IUPAC SATP (25 °C, 1 bara)
cubic meter (STP)	SCM	kilomole	kmol	0.044032	IUPAC STP (0 °C, 1 bara)
cubic meter (STP)	SCM	mole (SI)	mol	44.032	IUPAC STP (0 °C, 1 bara)
kilomole	kmol	cubic meter	NCM	23.69	US Refy std cond. (60 °F, 1 Atm)
kilomole	kmol	cubic meter (NIST)	NCM	22.41	NIST Std cond. (0 °C, 1 Atm)
kilomole	kmol	cubic meter (NTP)	SCM	24.06	U.S. EPA, NIST (20 °C, 1 Atm) NTP
kilomole	kmol	cubic meter (SATP)	SCM	24.79	IUPAC SATP (25 °C, 1 bara)
kilomole	kmol	cubic meter (STP)	SCM	22.71	IUPAC STP (0 °C, 1 bara)
kilomole	kmol	std. cu. feet	scf	836.52	US Refy std cond. (60 °F, 1 Atm)
kilomole	kmol	std. cu. feet (NIST)	scf	791.44	NIST Std cond. (0 °C, 1 Atm)
kilomole	kmol	std. cu. feet (NTP)	scf	849.40	U.S. EPA, NIST (20 °C, 1 Atm) NTP
kilomole	kmol	std. cu. feet (SATP)	scf	875.32	IUPAC SATP (25 °C, 1 bara)
kilomole	kmol	std. cu. feet (STP)	scf	801.93	IUPAC STP (0 °C, 1 bara)
liter	l, dm ³	kilomole	kmol	0.000042210	US Refy std cond. (60 °F, 1 Atm)
liter	l, dm ³	mole (SI)	mol	0.042210	US Refy std cond. (60 °F, 1 Atm)
liter (NIST)	l, dm ³	kilomole	kmol	0.000044615	NIST Std cond. (0 °C, 1 Atm)
liter (NIST)	l, dm ³	mole (SI)	mol	0.044615	NIST Std cond. (0 °C, 1 Atm)

(continued)

Table 12.2 (continued)

From unit	Sym	To unit	Sym	Multiply by	Notes, reference
liter (NTP)	l, dm ³	kilomole	kmol	0.000041571	U.S. EPA, NIST (20 °C, 1 Atm) NTP
liter (NTP)	l, dm ³	mole (SI)	mol	0.041571	U.S. EPA, NIST (20 °C, 1 Atm) NTP
liter (SATP)	l, dm ³	kilomole	kmol	0.000040339	IUPAC SATP (25 °C, 1 bara)
liter (SATP)	l, dm ³	mole (SI)	mol	0.040339	IUPAC SATP (25 °C, 1 bara)
liter (STP)	l, dm ³	kilomole	kmol	0.000044032	IUPAC STP (0 °C, 1 bara)
liter (STP)	l, dm ³	mole (SI)	mol	0.044032	IUPAC STP (0 °C, 1 bara)
mole (SI)	mol	cubic meter	NCM	0.02369	US Refy std cond. (60 °F, 1 Atm)
mole (SI)	mol	cubic meter (NIST)	NCM	0.02241	NIST Std cond. (0 °C, 1 Atm)
mole (SI)	mol	cubic meter (NTP)	SCM	0.02406	U.S. EPA, NIST (20 °C, 1 Atm) NTP
mole (SI)	mol	cubic meter (SATP)	SCM	0.02479	IUPAC SATP (25 °C, 1 bara)
mole (SI)	mol	cubic meter (STP)	SCM	0.02271	IUPAC STP (0 °C, 1 bara)
mole (SI)	mol	liter	l, dm ³	24.22	AAPM (72 °F, 1 Atm)
mole (SI)	mol	liter	l, dm ³	24.14	AMCA (70 °F, 1 Atm)
mole (SI)	mol	liter	l, dm ³	24.37	CAGI (20 °C, 1 bara)
mole (SI)	mol	liter	l, dm ³	24.05	GOST (20 °C, 1 Atm)
mole (SI)	mol	liter	l, dm ³	23.65	ISA, ICAO, EEA (15 °C, 1 Atm)
mole (SI)	mol	liter	l, dm ³	24.06	ISO 5011 (20 °C, 1 Atm)
mole (SI)	mol	liter	l, dm ³	23.64	ISO for Gas Turbines (15 °C, 1 Atm)
mole (SI)	mol	liter	l, dm ³	23.66	OPEC, EGIA, US EIA (60 °F, 1 + Atm)
mole (SI)	mol	liter	l, dm ³	23.96	SPE (15 °C, 1 bara)
mole (SI)	mol	liter	l, dm ³	23.72	SPE, OSHA, SCAQMD (60 °F, ~1 Atm)
mole (SI)	mol	liter	l, dm ³	23.96	U.S. Army Std (15 °C, ~1 bara)
mole (SI)	mol	liter	l, dm ³	24.47	U.S. EPA (25 °C, 1 Atm)
mole (SI)	mol	liter	l, dm ³	23.65	U.S. FAA (15 °C, 1 Atm)
mole (SI)	mol	liter	l, dm ³	23.69	US Refy std cond. (60 °F, 1 Atm)
mole (SI)	mol	liter (NIST)	l, dm ³	22.41	NIST Std cond. (0 °C, 1 Atm)
mole (SI)	mol	liter (NTP)	l, dm ³	24.06	

(continued)

Table 12.2 (continued)

From unit	Sym	To unit	Sym	Multiply by	Notes, reference
					U.S. EPA, NIST (20 °C, 1 Atm) NTP
mole (SI)	mol	liter (SATP)	l, dm ³	24.79	IUPAC SATP (25 °C, 1 bara)
mole (SI)	mol	liter (STP)	l, dm ³	22.71	IUPAC STP (0 °C, 1 bara)
mole (SI)	mol	std. cu. feet	scf	0.83652	US Refy std cond. (60 °F, 1 Atm)
mole (SI)	mol	std. cu. feet (NIST)	scf	0.79144	NIST Std cond. (0 °C, 1 Atm)
mole (SI)	mol	std. cu. feet (NTP)	scf	0.84940	U.S. EPA, NIST (20 °C, 1 Atm) NTP
mole (SI)	mol	std. cu. feet (SATP)	scf	0.87532	IUPAC SATP (25 °C, 1 bara)
mole (SI)	mol	std. cu. feet (STP)	scf	0.80193	IUPAC STP (0 °C, 1 bara)
<i>Ideal gas volume interconversions—English</i>					
pound-mole	lbmol	cu. meter	SCM	10.746	US Refy std cond. (60 °F, 1 Atm)
pound-mole	lbmol	cu. meter (NIST)	SCM	10.911	NIST Std cond. (0 °C, 1 Atm)
pound-mole	lbmol	cu. meter (NTS)	NCM	10.167	U.S. EPA, NIST (20 °C, 1 Atm) NTP
pound-mole	lbmol	cu. meter (SATP)	SCM	10.725	IUPAC SATP (25 °C, 1 bara)
pound-mole	lbmol	cu. meter (STP)	SCM	10.301	IUPAC STP (0 °C, 1 bara)
pound-mole	lbmol	liter	l, dm ⁵	10,725	IUPAC SATP (25 °C, 1 bara)
pound-mole	lbmol	liter	l, dm ³	10,301	IUPAC STP (0 °C, 1 bara)
pound-mole	lbmol	liter	l, dm ⁶	10,911	NIST Std cond. (0 °C, 1 Atm)
pound-mole	lbmol	liter	l, dm ⁴	10,167	U.S. EPA, NIST (20 °C, 1 Atm) NTP
pound-mole	lbmol	liter	l, dm ⁷	10,746	US Refy std cond. (60 °F, 1 Atm)
pound-mole	lbmol	std. cu. feet (NIST)	scf	358.99	NIST Std cond. (0 °C, 1 Atm)
pound-mole	lbmol	std. cu. feet (NTP)	scf	385.28	U.S. EPA, NIST (20 °C, 1 Atm) NTP
pound-mole	lbmol	std. cu. feet (SATP)	scf	397.04	IUPAC SATP (25 °C, 1 bara)
pound-mole	lbmol	std. cu. feet (STP)	scf	363.75	IUPAC STP (0 °C, 1 bara)
pound-mole	lbmol	std. cubic feet	scf	387.90	AAPM (72 °F, 1 Atm)

(continued)

Table 12.2 (continued)

From unit	Sym	To unit	Sym	Multiply by	Notes, reference
pound-mole	lbmol	std. cubic feet	scf	386.70	AMCA (70 °F, 1 Atm)
pound-mole	lbmol	std. cubic feet	scf	390.38	CAGI (20 °C, 1 bara)
pound-mole	lbmol	std. cubic feet	scf	385.30	GOST (20 °C, 1 Atm)
pound-mole	lbmol	std. cubic feet	scf	378.70	ISA, ICAO, EEA (15 °C, 1 Atm)
pound-mole	lbmol	std. cubic feet	scf	385.40	ISO 5011 (20 °C, 1 Atm)
pound-mole	lbmol	std. cubic feet	scf	378.69	ISO for Gas Turbines (15 °C, 1 Atm)
pound-mole	lbmol	std. cubic feet	scf	378.61	OPEC, EGIA, US EIA (60 °F, 1+ Atm)
pound-mole	lbmol	std. cubic feet	scf	383.72	SPE (15 °C, 1 bara)
pound-mole	lbmol	std. cubic feet	scf	379.48	SPE, OSHA, SCAQMD (60 °F, ~1 Atm)
pound-mole	lbmol	std. cubic feet	scf	383.80	U.S. Army Std (15 °C, ~1 bara)
pound-mole	lbmol	std. cubic feet	scf	391.85	U.S. EPA (25 °C, 1 Atm)
pound-mole	lbmol	std. cubic feet	scf	378.80	U.S. FAA (15 °C, 1 Atm)
pound-mole	lbmol	std. cubic feet	scf	379.44	US Refy std cond. (60 °F, 1 Atm)
std. cu. feet (NIST)	scf	kilomole	kmol	0.0012635	U.S. EPA, NIST (20 °C, 1 Atm) NTP
std. cu. feet (NIST)	scf	mole (SI)	mol	1.26352	U.S. EPA, NIST (20 °C, 1 Atm) NTP
std. cu. feet (NIST)	scf	pound-mole	lbmol	0.0027856	U.S. EPA, NIST (20 °C, 1 Atm) NTP
std. cu. feet (NTP)	scf	kilomole	kmol	0.0011773	IUPAC SATP (25 °C, 1 bara)
std. cu. feet (NTP)	scf	mole (SI)	mol	1.17731	IUPAC SATP (25 °C, 1 bara)
std. cu. feet (NTP)	scf	pound-mole	lbmol	0.0025955	IUPAC SATP (25 °C, 1 bara)
std. cu. feet (SATP)	scf	kilomole	kmol	0.0011424	NIST Std cond. (0 °C, 1 Atm)
std. cu. feet (SATP)	scf	mole (SI)	mol	1.14243	NIST Std cond. (0 °C, 1 Atm)
std. cu. feet (SATP)	scf	pound-mole	lbmol	0.0025186	NIST Std cond. (0 °C, 1 Atm)
std. cu. feet (STP)	scf	kilomole	kmol	0.0012470	IUPAC STP (0 °C, 1 bara)
std. cu. feet (STP)	scf	mole (SI)	mol	1.24699	IUPAC STP (0 °C, 1 bara)
std. cu. feet (STP)	scf	pound-mole	lbmol	0.0027491	IUPAC STP (0 °C, 1 bara)

(continued)

Table 12.2 (continued)

From unit	Sym	To unit	Sym	Multiply by	Notes, reference
std. cubic feet	scf	kilomole	kmol	0.0011954	US Refy std cond. (60 °F, 1 Atm)
std. cubic feet	scf	mole (SI)	mol	1.19542	US Refy std cond. (60 °F, 1 Atm)
std. cubic feet	scf	pound-mole	lbmol	0.0026355	US Refy std cond. (60 °F, 1 Atm)

These factors were compiled from multiple sources listed in the “References” section. The reference numbers are not repeated here.

Conclusion

The unit for measuring the amount of a substance, the mole, developed over the past couple of centuries as our understanding of chemistry and chemical reactions grew. The mole [or its larger embodiments: the kilomole (kmol) and pound mole (lbmol)] is used extensively in industrial chemical and petroleum facility design and operation.

An SI standard mole is equal to the atomic or molecular weight of a substance taken in grams with the atomic weight of carbon-12 assigned as exactly 12. Each gram-mole contains exactly $6.02214... \times 10^{23}$ discrete chemical entities: normally either atoms or molecules.

If the entities are present as a gas, that gas will occupy the same volume (about 22.4 L at 0 °C and 1 atmosphere pressure) regardless of the substance. A mole of hydrogen (H₂), for instance, occupies the same volume as a mole of carbon dioxide (CO₂) under the same conditions of vapor. The volume occupied by one mole of both hydrogen and oxygen would be exactly the same, although the density of the two gases would be vastly different (2 grams for hydrogen and 44 grams for CO₂).

This SI base unit is being considered for revision, but remains with the current definition at the present time.

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Chapter 13

Historical Luminous Intensity



Abstract Efforts to quantify and standardize light intensity measurement have only really spanned the past couple hundred years, since the mid-19th century AD. This chapter sheds light on the many approaches that have been taken. The basis for the standard used to establish light intensity has moved from a candle to standard lamps to a carbon filament electric light to molten platinum at its freezing point to a theoretical Planckian blackbody emitter. This evolution will likely continue, but the standard SI unit for light intensity, the candela, still remains close to one old candle (within about 10%). Conversion factors between different light intensity measurement units are provided.

Introduction

Efforts to quantify the intensity of light have been relatively recent in the overall history of measurement units. This history is continuing to unfold.

The internationally used base unit in the SI/metric system is the candela, which is defined as the intensity of light of a specific frequency distributed over a defined solid, spherical angle. Getting to the candela has taken many turns, however.

Our discussion here will begin with the basic oil lamp and candle and progress to our modern efforts to measure the intensity of light emitting diodes. We will discuss how both directional and non-directional light sources are handled. We'll also take a side trip to a discussion of "color temperature" and its meaning in the light intensity landscape.

We will start our discussion of the development of the candela unit with how light measurement got to its present state in the next section.

Historical Development of Light Intensity Measures [1–10]

Early Measurement Methods

For much of human history, the candle or the oil lamp have provided de facto standards for light intensity. If you wanted more light, you just used more lamps or more candles. People did understand that some types of oils and waxes emitted more light than other types, but aside from specifying the source for the material being burned, there was no general standardization of the light intensity.

In the mid-19th century AD, efforts were made to define the intensity of light by several researchers and authorities. In England, “candlepower” was formally defined by the Metropolitan Gas Act of 1860 as the light produced in a specific direction by a pure spermaceti candle weighing 1/6 lb and burning at a rate of 120 grains per hour. See Fig. 13.1. In metric terms, this was a 76 g candle burning 7.8 grams per hour. Spermaceti wax was derived from the material found in a sperm whale’s head. It was an expensive commodity in the 1800s AD and was one of the key drivers in the profitability of the whaling industry at the time. The candle is a nearly omni-directional light source, so intensity was essentially spread in all directions, but the intensity was measured in only one direction.

To determine candlepower of a light source, a standard candle was burned next to the light source of interest, separated by an opaque divider. See Fig. 13.2. The standard candle was placed a specific distance from a screen on one side of the divider. The light source of interest was placed in front of a similar screen on the other side of the divider. The unknown light source was then moved back and forth on the other side of the divider, changing the distance to the screen until the intensity of light striking the screen on both sides of the divider was judged to be

Fig. 13.1 One candlepower was the intensity of light from a standard 1/6 lb spermaceti candle burning at a rate of 120 grains/hr



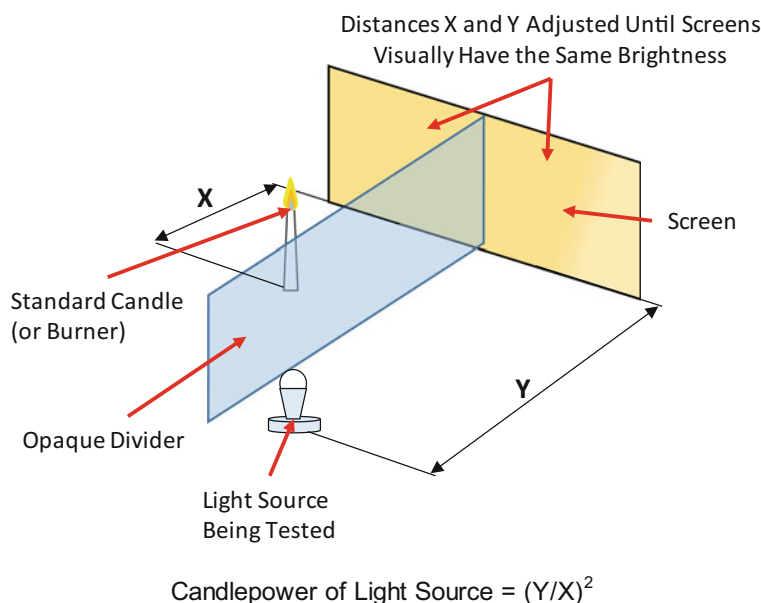


Fig. 13.2 Determining the candlepower of a light source the old fashioned way—visually

Fig. 13.3 Carcel lamp clockwork pump mechanism



the same. The candlepower of the unknown light source was then calculated from the distances of the candle and the light source from their respective screens using the inverse square relationship.

The candlepower standard survived into the 20th century AD. One candlepower (or *bougie de l'étoile* in French) is about 0.981 modern candelas.

In mid-19th century France, light intensity was defined in terms of a Carcel burner of a standard design using colza or rapeseed oil at a rate of 42 grams per hour with a flame 40 mm high. The Carcel burner had been patented in 1800 AD by Bernard Guillaume Carcel (1750–1818 AD). See Fig. 13.3. It consisted of an oil

reservoir in the bottom of the lamp with a clockwork pump that moved oil to the burner. Like a candle, the Carcel burner emitted light in all directions. The lamp could deliver light of relatively constant intensity for up to 16 h and use all its available oil. This type of lamp was used in many lighthouses. The actual burner was a version of the Argand-type burner, that used a cylindrical (hollow) wick which allowed good air distribution to the wick. Carcel's objective in his design was to eliminate the large reservoir that was located on the side of an Argand lamp that fed the burner by gravity, but also created a large shadow in the direction of the oil reservoir. See Fig. 13.4. The light measured by the Carcel burner was in units called carcels, which were equal to about 9.74 modern candelas or about 10 candlepower.

Germany established a light intensity standard called the "Hefner unit" in the late 1800s AD. This standard was based on the use of the Hefner lamp, developed by Friedrich Heinrich Philipp Franz von Hefner-Alteneck (1845–1904 AD) in 1884 AD. See Fig. 13.5. This lamp used an 8 mm diameter, round wick burning amyl acetate with a flame 40 mm high. Hefner specifically developed this lamp for a luminous intensity standard. He modestly proposed that the unit of measurement be the Hefnerkerze (HK). This unit was adopted in Germany and used into the 1940s AD. One HK was equal to about 0.920 modern candelas.

Another standard lamp, invented in 1883 and improved on in the following years was the pentane-air lamp. It was first developed by A. Vernon Harcourt (1834–1919). In Harcourt lamps, which came in 1 and 10 candlepower versions, air and pentane

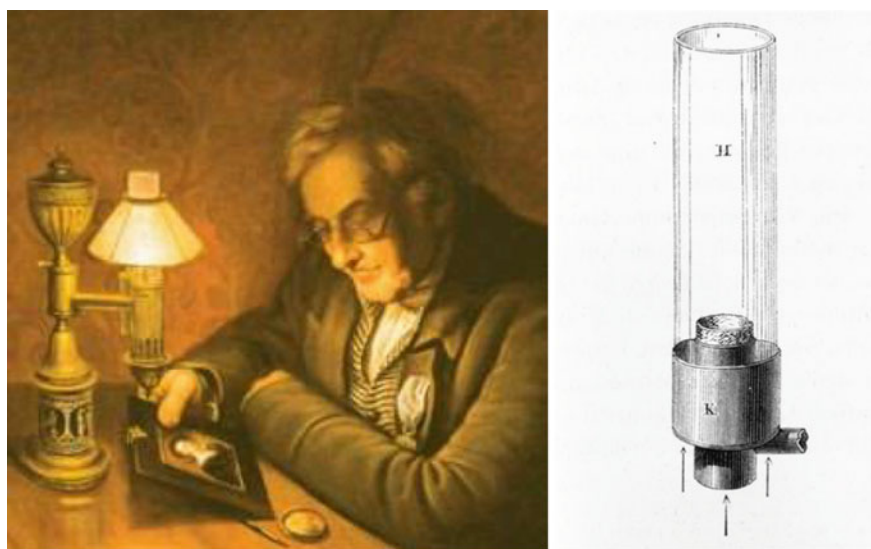
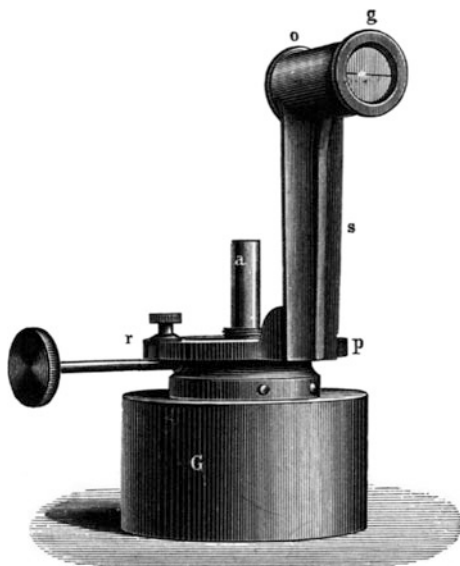


Fig. 13.4 Argand lamp in use and detail of the Argand burner (patent drawing). The burner featured a hollow, cylindrical wick with air flow around the outside and through the middle of the wick. Oil enters through the tube on the side

Fig. 13.5 Hefner standard lamp (patent drawing)



were premixed and fed to a burner with air entering through an annular space around the burner. Immediately above the burner was a viewing port where the standard light intensity was provided. The flame continued into a short chimney to the atmosphere. The concept of this design was that the portion of the flame available for viewing was consistent and the light emitted was not affected by other parts of the flame because they were hidden in the chimney. References are still available for candle units as measured by the pentane lamp, but this design never gained wide acceptance.

All these early “standards” suffered from numerous inconsistencies in their output due to factors like the exact composition of the fuel, the ambient temperature, ambient humidity, differences in construction, and air currents. The results were not very reproducible among researchers. Light was also radiated in all directions, so intensity was not clearly defined. Intensity varied roughly by the inverse square of the distance from the flame.

Each country also applied its own standard for light measurement. The move toward a common, international standard had to wait until 1909 AD.

Standardizing Units for Light Intensity

There was a strong desire among scientists to establish a unit for light intensity that did not depend on as many uncontrolled variables as the combustion-based measures in the mid-1800s. One of the most notable efforts along these lines was made by Jules Louis Gabriel Violle (1841–1923 AD). Violle proposed a standard based on the light from the surface of molten platinum. The standard unit (modestly called a

violle) was equal to the light emitted from a one square centimeter flat surface of pure molten platinum at its melting/freezing point of ~ 2042 K (1768 °C, 3215 °F).

Violle's proposed standard was embraced at the 1889 AD Second International Electrical Congress where those at the Congress defined a "new" standard candle equal to 1/20th of a violle. The magnitude of the candle was thus close to the candlepower definition of the British.

This definition lasted until the International Electrotechnical Congress meeting in Geneva in 1896 AD, reverted to a definition of a "new candle" equal to one Hefner unit. This was partly due to the difficulties in working with platinum at such high temperatures. The French Laboratoire Central de l'Electricité (Paris) in 1906 AD also reverted to a combustion definition for the decimal candle. Their standard equated the light output of a Carcel burner consuming 42 g/h of rapeseed oil to 9.6 decimal candles. Basically, we were back where we started.

In 1909 AD, the national laboratories of the United States, Britain, France, and Germany met to establish a more common standard, the international candle. The standard was to be based on a standard electric lamp with a carbon filament. Not all the participants adopted the standard however, with Germany notably sticking with the Hefner standard and defining the international candle as 9/10 of the light from a Hefner lamp.

Thus things remained until 1921 AD, when the *Commission Internationale de l'Eclairage* (International Commission for Illumination, CIE) reiterated the more common definition of the international candle in terms of a standard carbon filament electric lamp. Unfortunately, a carbon filament lamp is notoriously delicate and unreliable.

The electric lamp standard was proposed for replacement again in 1937 AD by a measure based on the light intensity from a Planckian blackbody radiator at the temperature of molten platinum at its freezing point (2042 K). This luminance level was defined to be 58.9 international candles per cm^2 (originally 60). This proposal originated with the CIE and the *Comité international des poids et mesures* (CIPM). The standard was formally proposed by CIPM in 1946 AD and adopted in 1948 AD at the 9th International General Conference of Weights and Measures (*Conférence générale des poids et mesures*, CGPM). The name for this new unit was the "candela" (cd). The definition was amended in 1967 AD. The candela was more precisely defined as:

"...the luminous intensity, in a perpendicular direction, of a surface of $1/600,000^{\text{th}}$ square meter of a black-body at the temperature of freezing platinum under a pressure of 101,325 newtons per square meter."

The candela works out to be equal to a little over one candlepower by these definitions.

In 1977 AD, the CIPM attempted to define the candela a different way. They defined it as the luminous efficacy of monochromatic light (approximately chartreuse green, ) emitted at 540×10^{12} Hz corresponding to 683 lumens per watt. The CGPM adopted a version of this definition that states:

“The candela is the luminous intensity, in a given direction, of a source that emits monochromatic radiation of frequency 540×10^{12} Hz and that has a radiant intensity in that direction of 1/683 W per steradian.”

This definition corresponds more closely to the real nature of most light: that it originates largely from a point source and moves radially away from the source. The steradian, referred to above, is a dimensionless quantity for a solid angle in 3-dimensional space. The definition and detailed discussion of solid angle measurement by steradians is in Chap. 10.

If we back-calculate what this would mean for one “candle”, normally taken as 0.981 candelas, we would find that the total light radiation from a candle (in all directions) would be about 4π times 0.981 candelas or about 12.3 candelas. This would also correspond to about 18 milliwatts total radiation ($4\pi \times 1/683$ W/steradian).

This is where things stand at the present. The candela is the standard unit for luminous intensity in the SI/metric system and it is slightly larger (by about 2%) than one old candlepower. The standard is based on a specific frequency of blackbody (platinum) radiation at 2045 K. Attempts to measure the magnitude of a candela exactly have proven to be difficult. Different researchers get different results. So, we might expect that this is not yet the end of the development of the definition for a candela.

Relationships Among Light Units [7, 8, 10, 11]

Now the candela is not the only unit you will see for lighting intensity, it is just the official SI/metric standard unit. The more common measurement units applied in commercial and residential lighting practices are different, but are related to the candela and to each other. The terms candela, lumen, and lux are generally applied in the case of something that is being lit. Luminance is applied to a surface that is light emitting, like a flat screen monitor or cellular phone.

- *Candela, cd* [6, 11–14]: This was discussed in some detail above. It is the official standard for luminous intensity and the definition in terms of a solid, 3-dimensional angle means that the distance from the light source is irrelevant in its measurement. If we view light as a flow of photons, this is the effectively like the concentration of photons in a given direction.
- *Lumen, lm* [11]: Whereas the candela expresses light intensity over a defined angle, the lumen accounts for the actual angle and shape of the light source. It is the total amount of light leaving the source. Using a photon flow analogy, this is like the total flow of photons from the light source. Lumens and watts do not directly correlate. Mathematically, lumens relate to candelas:

$$\Phi_v = I_v \cdot \Omega \quad (13.1)$$

where:

Φ_v Lumens, total light, lm

I_v Luminous intensity in candelas, cd

Ω Three dimensional angular span over which light is emitted in steradians, sr.

If light is emitted equally in all directions (spherically), then $\Omega = 4\pi$. For a half sphere, $\Omega = 2\pi$.

Now for light sources which have narrower beams, the determination of Ω can be a little more complex. Referring to Fig. 13.6, you determine the Ω by identifying the angle at which a light source is brightest. Then determine the angle between the brightest direction and the direction in which the light is about 50% as bright (somewhat a judgement call). This angle is “ θ .” The total “apex angle” is 2θ . These angles are measured in radians. The 3-dimensional apex angle, Ω , is then:

$$\Omega = 2\pi[1-\cos(2\theta/2)] \tag{13.2}$$

- *Lux, lx* [11]: Lux is a measure of actual surface illumination, effectively the flux of photons hitting a surface. Light meters measure lux directly. Light meters may also measure in footcandles (1 footcandle = 10.764 lx). Figure 13.7 shows an old photographic light meter that determines the lighting level using a selenium photovoltaic cell’s milliamp output. This Weston Universal Meter measured candles/ft² (although it is not marked) and was intended to measure reflected light from a photographic subject. The meter included an circular exposure calculator.

Technically, lux is derived from lumens, but it comes indirectly from candelas. Basically, lux is the amount of light hitting a given surface area and it will vary as the inverse square of the distance from the light source. The units of lux are lumens per square meter. The equation for lux is:

$$L_v = \Phi_v/A \tag{13.3}$$

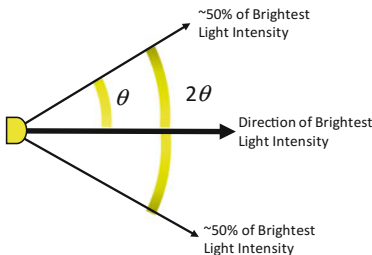
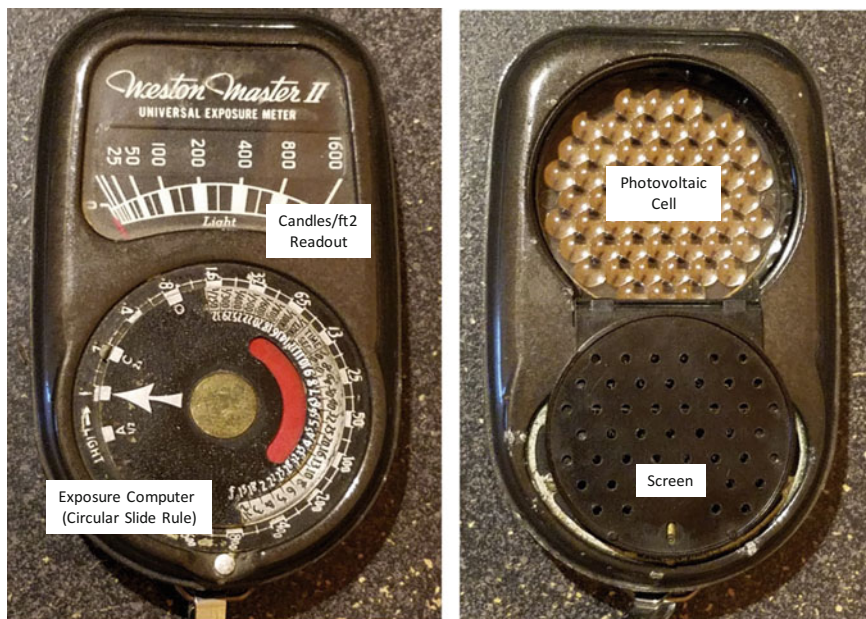


Fig. 13.6 Graphical concept for apex angle of a narrow-beam light source



Meter Reading and Exposure Computer
(Photocell was pointed toward subject and light level was read from the scale.)

Photoelectric Cell to Measure Light Level
(Black screen with holes shown open for low light levels, screen was closed for high light levels.)

Fig. 13.7 A 1950s era Weston exposure meter for measuring surface illumination for photography

where:

L_v Illumination in lux or lx

Φ_v Lumens, total light emitted, in lm

A Area illuminated (factoring in distance) in m^2 .

Suppose we have a circular screen that is $1 m^2$ in area placed 1 m from a light source. By definition, then, the screen subtends about one steradian. If we have a one candela light source, then:

$$1 \text{ candela} \times 1 \text{ steradian} = 1 \text{ lumen} \quad (13.4)$$

$$1 \text{ lumen}/1 m^2 = 1 \text{ lm}/m^2 = 1 \text{ lux} \quad (13.5)$$

Now suppose we have a 5 cd source that puts out light evenly in a half-spherical pattern and we want to know the illumination 2 m from the light source. In this case, we have to adjust for distance from the light source and the emission angle:

5 candelas $\times 2\pi$ steradians (half sphere) = 10π lumens total output

Half – spherical area 2 m from source = $1/2(4\pi r^2) = 1/2(4\pi(2)^2) = 8\pi \text{ m}^2$

So, lux = $10\pi \text{ lm}/8\pi \text{ m}^2 = 1.25 \text{ lm}/\text{m}^2 = 1.25 \text{ lx}$

It is noted that the apparent point source location should be used for these distances. For instance, a light-emitting diode (LED) has an apparent location that may be a few millimeters below the actual LED location. This would only be significant for short distances, however.

- *Luminance, cd/m^2 or nits* [11]: Sometimes, the light source cannot be reduced to a single point. This is the case of a glowing computer flat screen or laptop computer screen. In these cases, the light level emitted is measured in the derived units for luminance: candelas per square meter, sometimes called “nits.” Older units for luminance include the foot-lambert (1 foot-lambert = $3.425 \text{ cd}/\text{m}^2$), which is similar to a foot candle.

The relationship between luminance and lux is:

$$E_v = \pi L_v \quad (13.6)$$

where:

E_v Illumination in lux, lx

L_v luminance of a surface in cd/m^2 (or nits).

You will also hear the term lighting efficiency or lighting efficacy. This is the efficiency of a specific light source in terms of lumens per watt of power input. It is often expressed as a percentage of the maximum theoretical light produced by the standard black body (used for the definition of a candela) of 683.002 lumens per watt at 555 nm wavelength. Some typical lighting efficacies are in Table 13.1. Note that the efficiency ranges are quite large for most types of lights and that none of the light types, even the most efficient, is very good at producing light.

Luminous efficacy has a precise mathematical definition also:

$$K = \Phi_v / \Phi_e = \frac{\int_0^\infty K(\lambda) (\Phi_{e,\lambda}) d\lambda}{\int_0^\infty (\Phi_{e,\lambda}) d\lambda} \quad (13.7)$$

where:

K Luminous efficacy

Φ_v Luminous flux

Φ_e Radiant flux

$\Phi_{e,\lambda}$ Spectral radiant flux (accounts for range of frequencies emitted)

(λ) $K_m V(\lambda)$, Spectral luminous efficacy (function of wavelength).

Table 13.1 Selected, typical lighting element efficacies and ranges [21–24]

Light source	Power (watts)	Lumens (lm)	Lumens/watt	% Efficacy
<i>Ideal sources</i>				
Green light, 555 nm, maximum theoretical efficacy			683.002	100.000
5800 K Blackbody, visible light (400–700 nm)			251	37
Ideal 4000 K blackbody			54.7	8
Class G star, 5800 K			93	13.6
Ideal 7000 K blackbody			95	14
Class M star, 3000 K			30	4
<i>Combustion</i>				
Candle			0.3	0.04
Gas mantle lamp			1–2	0.15–0.3
<i>Incandescent</i>				
Typical range			10–17	1.5–2.5
40 W, 2500 K, candelabra	40	340	8.5	1.2
40 W, standard base	40	450	11.3	1.7
60 W, soft white, candelabra	60	625	10.4	1.5
60 W, standard base	60	300–900	5.0–15.0	0.7–2.2
75 W, GE reveal	75	830	11.1	1.6
100 W, standard base	100	1600–1800	16.0–18.0	2.3–2.6
150 W standard base	150	2600–2800	17.3–18.7	2.5–2.7
High wattage projection lamp			35	5.1
<i>Light emitting diode (LED)</i>				
White LED typical range, 5000 K			20–130	2.9–19.0
Maximum theoretical limit, color mixing			260–300	38.1–43.9
Spotlight, 2700 K	10.5	650	61.9	9.1
40 W replacement, standard base	4–5	450	90–113	13.2–16.5
60 W replacement, standard base	6–8	300–900	38–150	5.6–22.0
100 W replacement, standard base	16–20	1600–1800	80–113	11.7–16.5
150 W replacement, standard base	25–28	2600–2800	93–112	13.6–16.4
200 W, 5000 K	200	8000	40	5.9
4.1 W lamp	4.1	240–340	58.5–82.9	8.6–12
5.4 W lamp	5.4	550	102	14.9
6.9 W lamp	6.9	380–570	55.1–81.9	8.1–12
7 W lamp, PAR 20	7	200	28.6	4.2
7 W lamp, PAR 30	7	420	60	8.8
8.7 W lamp	8.7	600–800	69–93.1	10.1–13.6
<i>Fluorescent</i>				
Typical range–Compact (CFL)			40–70	5.9–10.2
Typical range–Linear bulbs, 4100 K			30–110	4.4–16.1
CFL, 60 W replacement	13	800	61.5	9.0

(continued)

Table 13.1 (continued)

Light source	Power (watts)	Lumens (lm)	Lumens/ watt	% Efficacy
CFL, 100 W replacement	23	1600	69.6	10.2
40 W replacement, standard base	8-12	450	37.5–56.3	5.5–8.2
60 W replacement, standard base	13-18	300–900	16.7–69.2	2.4–10.1
100 W replacement, standard base	25-30	1600–1800	53.3–72.0	7.8–10.5
150 W replacement, standard base	30-55	2600–2800	47.3–93.3	6.9–13.7
Inductively coupled lamp, 200 W, 5000 K	200	16,400	82	12.0
<i>Halogen</i>				
Typical range			12–22	1.8–3.2
Spotlight, 3000 K	38	530	13.9	2.0
Tungsten Glass Halogen	2.6	50	19.2	2.8
Tungsten Quartz Halogen			24	3.5
<i>Sodium gas discharge</i>				
High pressure sodium, typical range, 2100 K			50–150	12–21
Low Pressure Sodium, typical range			100–200	15–29
<i>Metal halide</i>				
Typical range, 3700 K			65–115	9.5–16.8
<i>Arc lamp</i>				
Carbon			2–7	0.3–1.0
Xenon			30–50	4.4–7.3
Mercury-Xenon			50–55	7.3–8.0
Mercury vapor, typical range			25–60	3.7–8.8
Ultrahigh-pressure mercury vapor			58–78	8.5–11.4
Ultrahigh-pressure mercury vapor projector bulb			30–50	4.4–7.3
<i>Sulfur lamp</i>				
Typical	1400	140,000	100	15
<i>Cathodoluminescence (e.g. television screen)</i>				
Typical			30	5
<i>Plasma display panel</i>				
Typical range			2–10	0.3–1.5

We won’t worry too much about this formal definition here. Our primary concern really is the definition of the candela, which is the base, fundamental unit for light measurement in the SI system.

So, if we pull together the various measurements and equations for light, we come up with Table 13.2 to define the relationships:

Table 13.2 Summary of equations for light measurements

Measurement	Unit	Abbv.	Definition
Light intensity	Candela	cd	Base SI unit = luminous intensity in a given direction of light from a 540×10^{12} Hz (chartreuse) light source with intensity of 1/683 W per steradian.
Total light from a given source	Lumen	lm	$\Phi_v = I_v \cdots \Omega = 2\pi I_v \cdots (1 - \cos(\alpha/2))$
Light level or flux over a given area	Lux	lx	$L_v = \Phi_v/A$
Luminance of glowing surface	Candelas per square meter or nits	cd/m ² , nit	$E_v = \pi L_v$
Luminous efficacy	Candelas per square meter	cd/m ²	$K = \Phi_v/\Phi_e = \frac{\int_0^\infty K(\lambda)(\Phi_{e,\lambda})d\lambda}{\int_0^\infty (\Phi_{e,\lambda})d\lambda}$

Symbols in the equations are:

- Φ_v Lumens, total light, lm
- I_v Luminous intensity in candelas, cd
- Ω Three dimensional angular span over which light is emitted in steradians, sr ($\Omega = 2\pi [1 - \cos(2\theta/2)]$)
- L_v Illumination in lux or lx or cd/m²
- A Area illuminated (factoring in distance) in m²
- E_v Luminance of glowing surface in lux, lx, cd/m², or nits
- α Total apex angle in radians = 2θ
- θ Half planar angle for a narrow light beam where light intensity is 50% less than brightest direction.
- K Luminous efficacy
- Φ_e Radiant flux (all wavelengths)
- $\Phi_{e,\lambda}$ Spectral radiant flux (accounts for range of frequencies emitted)
- $K(\lambda)$ $K_m V(\lambda)$, Spectral luminous efficacy (function of wavelength).

***Coordinated Color Temperature (CCT)
and Human Perception [15–17]***

The light intensity measures give little information about the “quality” of the light provided. The candela defines the intensity at a specific light wavelength in the chartreuse color range, but not all lights are the same color. The color temperature for light is an additional dimension unique to illumination. While referred to as a “temperature”, this measurement has little to do with actual temperatures, but instead refers to a theoretical basis. This is, in turn, correlated in an odd way to human reactions to shades of light, which we will discuss later.

Color temperature is a number that represents the appearance of the color. It is relative to the emissions from an ideal black body radiator. As temperature increases, a blackbody radiator will change color as the composite, blended radiation from the blackbody changes frequency.

In the discussion of temperature, we alluded to how color of an object changes with temperature for steel, refractories, ceramics, and other materials. The appearance of specific colors in a material changes as the material is heated. Our perception of an object's color moves from longer wavelengths to shorter wavelengths as the material is heated. To us, the color appears to change from deep red, through orange and yellow, to very bright white as the total light from the object fills in the full color spectrum in our eye's perception. In reality, the blend of colors emitted continues to move toward ultraviolet, but we are unable to see light in that range very well.

For the definition of color temperature, we use a theoretical blackbody radiator as a basis. There are no true blackbodies in nature, but the stars are very close. Also, a tungsten incandescent light bulb is close to a black body, so the temperature of the tungsten filament is actually close to the color temperature displayed by the bulb (about 2500–3350 K, soft yellow-white). The tungsten filament temperature won't exceed 3600 K because the filament will melt at that temperature. A candle is about 1850 K, sort of orange-yellow. The color temperature approximates the light source temperature for light sources that use thermal radiation as a method for producing light. Sources like fluorescent bulbs and LEDs produce light by other methods and their spectra then appear to be equivalent to a blackbody at higher temperatures, greater than about 4000 K.

For the blackbody, the intensity of light at various visible light wavelengths will change with temperature as depicted in Fig. 13.8. The blend of these colors is what we perceive. Note that the intensities actually go through peaks in wavelength as the blackbody heats up (i.e. the lines in the chart cross as temperature increases)—the maximum emission moves toward shorter wavelengths with temperature.

The theoretical blackbody radiator temperature is correlated to perceived color using the “Coordinated Color Temperature” or CCT. This temperature is not related to the actual light source temperature except by appearance. A cool white fluorescent bulb, for instance, produces a bluish-white light with a CCT of about 5000 K, but the bulb only heats slightly because the mechanism for generating the light is electrical excitation of mercury atom electrons with subsequent emission of photons as the electrons drop from higher energy orbitals—which requires little or no heat.

Figure 13.9 shows how the CCT for the theoretical blackbody radiator looks on a special form of the color chart called the International Commission on Illumination (CIE) 1931 X,Y Color Space. This was an attempt to correlate our perceptions of color with the ideal black body radiator temperature.

Now we've mentioned that color temperature has nothing to do with actual temperature. Instead, the color temperature is more of a psychological temperature and, in this our actual perceptions are reversed. We think of colors as “warmer” or “colder” based on our perception. This probably goes back to our natural

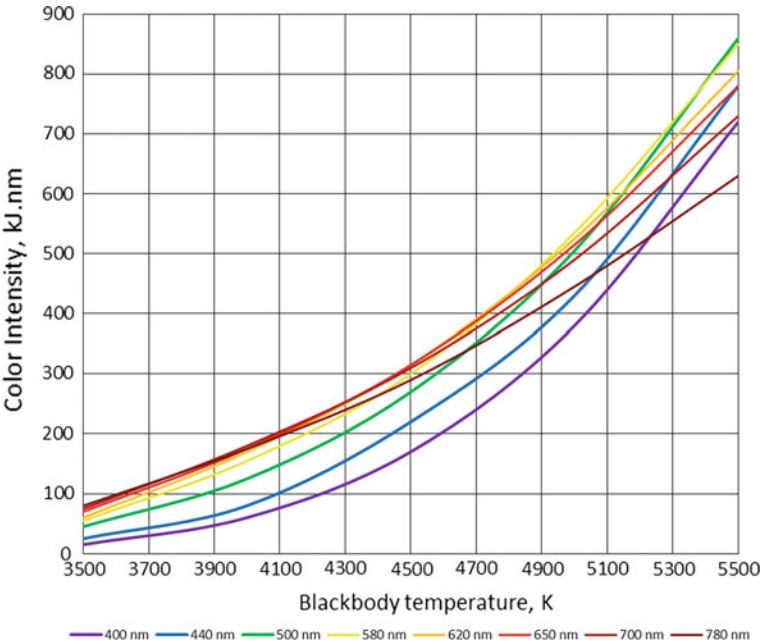


Fig. 13.8 Light intensity from a black body as a function of temperature [18–20]

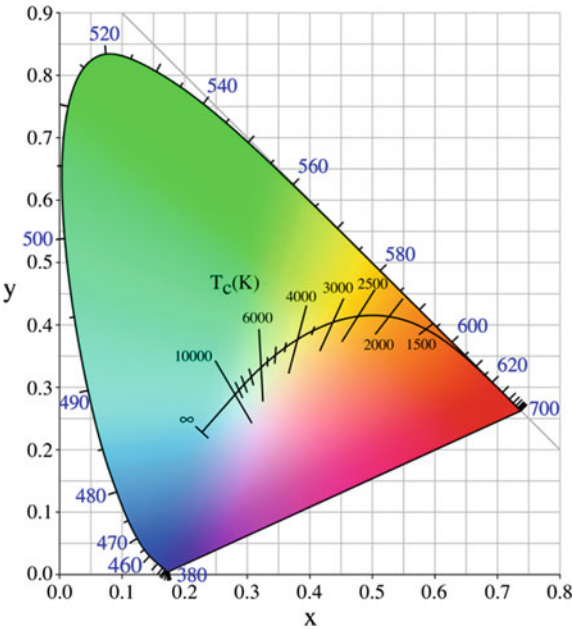


Fig. 13.9 CIE 1931 Color Space map. Blue numbers are wavelengths. X is the human eye normalized cone response to a specific color. Y is the luminance. The labeled black line is the CCT scale for a black body, showing equivalent color temperatures

experiences. We know that we feel warm when the yellowish sun is out or we are near a blazing fire, so we perceive yellowish and reddish colors to be warm. Looking at the CCT for those types of colors we see the colors are actually in the lower CCT range (1500–4100 K).

Similarly, we associate the bluish-white colors of winter days with cold weather. The reality is that the CCT or the blackbody temperatures necessary to produce that color of light are actually very high: 5000–6500 K.

Because different light sources emit different light spectra, we see different colors of light that do not necessarily correspond with the actual light intensity. Our eye sort of averages the colors along the lines used to create the CCT chart. Natural daylight appears fairly “white” because the intensity of light is relatively evenly distributed across the visible light spectrum. Incandescent bulbs look orange to yellow-white because the spectrum for that type of bulb is toward the yellow/red end with little light in the green/blue range of wavelengths. A high pressure sodium light is very orange because it puts out most of its light in a narrow frequency range close to 580–590 nm (the so-called sodium D-lines). A fluorescent light looks bluish-white because there are specific, high peaks in the light spectrum that correspond to violet, blue, green, and yellow (400–580 nm)—there are only minor peaks in the red and orange ranges (greater than 580 nm).

Table 13.3 provides a reference for the typical colors produced by various types of light sources. This information is drawn from a number of references.

So, in general we correlate the color of a particular light source against the color of a black body radiator at a specific temperature. As the blackbody temperature increases, the color of the black body moves from red through yellow, blue, and ultraviolet. Human perception of the color is reversed, with reds and yellows considered “warm” colors and whites and blues considered “cold” colors.

Historical Light Measurement Conversion Factors

Table 13.4 provides a summary of the common conversion factors for light intensity measurement units. Keep in mind that the candela is the base unit of measurement in the SI/metric system. There is a wide range of conversion factors purporting to convert between the same two measurement units, so some of these factors show ranges. This multiplicity of factors reflects the difficulty in obtaining consistent, good light intensity measurements from the standards. Some old measures continue to survive because of tradition or some specific area in which they are useful. Other measures of illumination cited above will be covered later in another chapter under derived units. Refer to “References” for data sources.

Table 13.3 Color temperatures for typical, common light sources [16, 20]

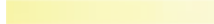
Light source	Color temperature, K	Light appearance
Glowing fire embers	800	
Candle	1800–1830	
High pressure sodium	2100	
Incandescent (tungsten) lamp	2500–2900	
Class M star	3000	
Tungsten-halogen lamp	3000–3200	
Metal halide	3700	
Ballast fluorescent (mercury)	4100–4700	
Inductively-coupled fluorescent (mercury)	5000	
Noontime sunlight	5600	
Class G star	5800	
Computer monitor screen	6500	
Outdoor shade	8000	
Skylight	10,000	

Table 13.4 Historical light intensity measurement conversion factors (Multiple sources, see References)

Historical unit	Abbrev.	Equivalent SI candelas, cd	Time frame (AD)	Notes
Bougie decimal	b	1.0085	1896	French decimal candle
Candle	cd	0.981	1860	England, standard spermaceti candle, old candlepower (cp)
Candle (German)	cd (Ger)	1.042–1.10	~ 1900	Nominal 1.062 cd
Candle (new)	cd	1	1948	Candela is a “new” candle
Candle (pentane)	cd	1.0085	1883	Standard lamp, invented by A. Vernon Harcourt (1834–1919)
Candle (pentane, 10 cp)		10.1	1897	10 candlepower standard, invented by A. Vernon Harcourt (1834–1919)
Candle (UK)	cd (UK)	1.051–1.062	~ 1900	
Carcel		9.74	~ 1850	France, standard clockwork Carcel burner
Carcel (redefined)		9.60–9.80	1906	France
Decimal candle	cd	1.019–1.02	~ 1900	
Hefner unit	HK	0.92	1884	Germany, Hefner standard lamp

(continued)

Table 13.4 (continued)

Historical unit	Abbrev.	Equivalent SI candelas, cd	Time frame (AD)	Notes
Hefner unit (redefined)	HK	0.9	1909	Germany, Hefner standard lamp
International candle	cd (Int'l)	1.019	1909	Carbon filament electric lamp
International candle (redefined)	cd (Int'l)	1.00–1.02	1937	1/58.9th or 1/60th of Planckian black body (Pt) freezing at ~ 2042 K
International candle (redefined)	cd (Int'l)	1	1948	
Lumen/steradian	lm/sr	1	1948, 1977	
Violle		20.17	1889	~ 1900 AD, France, light from one cm^2 surface of molten platinum at about 2042 K

Conclusion

Efforts to quantify and standardize light intensity measurement have only really spanned the past couple hundred years, since the mid-19th century AD. Many approaches have been taken. The basis for the standard used to establish light intensity has moved from a candle to standard lamps to a carbon filament electric light to molten platinum at its freezing point to a theoretical Planckian blackbody emitter. This evolution will likely continue, but the standard SI unit for light intensity, the candela, still remains very close to one candle ($\pm$ about 10%).

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Chapter 14

From Base Units to Derived Units



Abstract Base units in a measurement system are a handful of defined quantities from which all other measurements in the system can be derived. SI base units are mass (kg), length (m), time (s), thermodynamic temperature (K), luminous intensity (cd), electric current (A), and the chemical amount of a substance (mol). A similar set of base units is used in the English/US system. These base units are defined in terms of universal constants or properties which, for all practical purposes, remain the same in our common frames of reference. The base units give rise to what we will call here secondary units which are used to develop all the other derived units. The secondary units include measurements like area, volume, velocity, acceleration, and plane angle. There is only a handful of the secondary units. Combining the base and secondary units in various ways provides the wide array of derived units which find use in science and technology today. The primary derived units are identified along with interconversion factors between metric and English/US units.

Introduction

So far, we have looked at the general landscape of measurement units and have gone into some depth on the seven SI/metric base units as well as some other units that have historically been used as base units. This chapter will examine the structure and application of the historical units to the huge variety of units used in various fields today. The units allow us to quantify measurements that have specific applications when we research and design both fundamental and practical devices and systems.

Figure 14.1 is a simplification of the structure we will use for the discussion in this chapter in deriving other useful units of measurement. In simple terms, we start with fundamental properties of matter and define “base” units of measurement using these properties. The base units should then be consistent.

We will define a number of common measures derived from the base units. These we will call “secondary” units. The secondary units can really be considered to be derived units that mostly describe physical relationships. They are used in so many other derivations or are used in defining the “base” units that they are singled out as acting like de facto base units in this discussion.

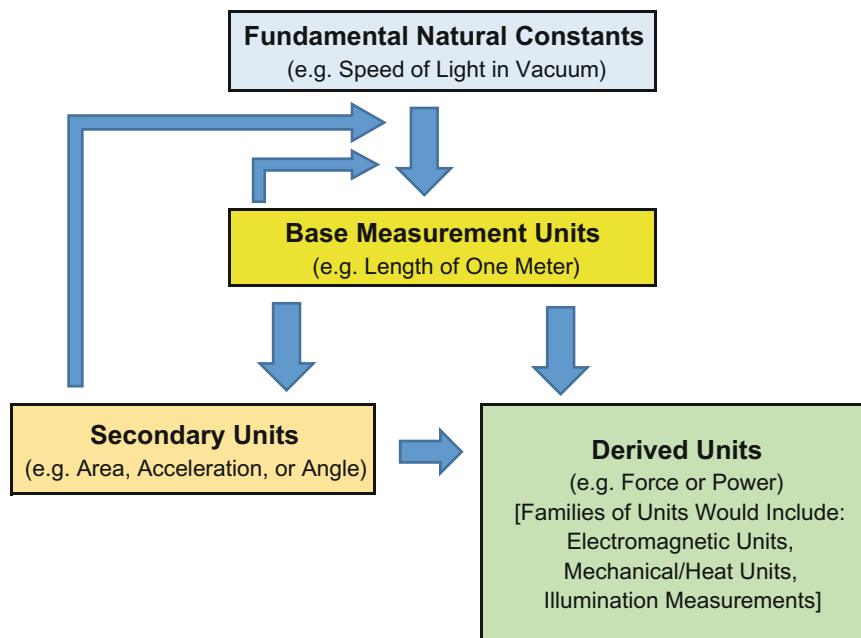


Fig. 14.1 Relationships of different types of measurement units

Then we find a plethora of “derived” units in all fields of study that apply the base and secondary units, and sometimes other derived units, in specific situations to make practical use of various measurements. Some derived units have their own names that often disguise the true origins of the units. For our discussion, we will divide the derived units into families that share some common roots and are used in specific contexts, such as the units used to measure mechanical work or heat—essentially thermodynamic measurements. Another family would involve electrical or electromagnetic measurements. Some of the families share common units and some derived units are unique to the family.

If some of the units in this system seem arbitrary, that is because they are. To make a measurement that can be used consistently, somebody (or somebodies) had to “put a stake in the ground” and say “this quantity shall be defined as one unit” of a certain type of measurement. The “somebodies” in this case are today the International Committee for Weights and Measures (CIPM) and/or the General Conference of Weights and Measures (CPGM) which establish and agree on the SI standards. For the English system today, the standards are normally set by the U.S. National Institute of Standards and Technology (NIST), but the standards are actually defined in terms of SI base units, so there is consistency between the two systems. In previous centuries, a ruler or a local administrator would have been the “somebody” defining a unit quantity; but influence of these local definitions was limited. The definitions today apply worldwide.

Now if some of the units in this system seem to have circular definitions; that is also true. This is unavoidable if we want the systems to be consistent and if we want to use the physical constants, which are not dimensionless. Consider the meter, defined in terms of the speed of light, which is effectively in meters per second. We need to apply the definition of the second to the speed of light to get at the length of the meter.

This system is simpler to use in practice than to describe; but the current chapter will follow the development of the units from the fundamental physical constants to the wide world of derived units for both metric and English measurement systems. The journey will help provide perspective on how these systems all fit together.

Genesis of Base and Secondary Units

SI/Metric Units [1, 11, 16, 22, 27–29, 30]

In general concept, the International System of Units or *Système international d'unités*, abbreviated SI, is based on fundamental constants or properties in nature. These are measures that are believed to be exactly the same throughout the universe. Sometimes we find this belief is not exactly right (as in relativistic mechanics); but it is good enough for our purposes in establishing units of measurement.

The seven fundamental constants or properties used for the most basic units in SI are:

1. Decay rate of Cesium 133 → Seconds (Time)
2. Speed of Light in a Vacuum → Meter (Length)
3. Planck Constant → Kilogram (Mass, although the current definition still uses a standard kilogram artifact or weight)
4. Boltzmann Constant → Kelvin (Thermodynamic temperature)
5. Blackbody Light Emission Intensity → Candela (Luminous Intensity)
6. Electron Charge (coulombs, C) → Ampere (Electric Current, C/s)
7. Avogadro Constant → Mole (Amount of Substance).

The historical contributions by several individuals are recognized by some of the names of the base units and constants:

- Max Karl Ernst Ludwig Planck (1858–1947 AD) was the originator of quantum theory and made other major contributions to the understanding of matter and energy. The Planck Constant relates energy to frequency of emission. This can then be related back to mass.
- Ludwig Eduard Boltzmann (1844–1906 AD) related macroscopic and atomic level phenomena. The Boltzmann Constant relates energy (J) to absolute thermodynamic temperature (K).

- André-Marie Ampère (1775–1836 AD) was able to relate electrical current to electromagnetic force, classically in two parallel wires. The name for the base SI unit of electric current is named in his honor.
- Charles-Augustin de Coulomb (1736–1806 AD) made many contributions to the understanding of electrical theory, especially the relationships of phenomena to electric charge. The unit of electrical charge in the SI system is named the “coulomb” in his honor.
- Lorenzo Romano Amedeo Carlo Avogadro (1776–1856 AD) postulated that equal volumes of gases contain equal numbers of individual chemical entities. This gave rise, some years after his death, to the definition of the Avogadro Constant ($6.022... \times 10^{23}$ entities), representing the number of atoms or molecules in one gram-molecular weight of a substance (grams times the relative atomic or molecular weight). The concept is critical to understanding chemical reactions.

The base units derived from the fundamental constants are then used to derive a second set of units we are calling secondary units here. These units are used extensively in further derivations, so they are set aside as a separate category for this discussion (although this would make a hard-core metrologist sick). Three of these units (area, volume, and plane angle) were actually used as base units for much of human history; hence, previous chapters of this book have been devoted to these units. Included in the secondary units are:

- Velocity → Combination of Length and Time
- Acceleration → Combination of Velocity and Time
- Area → Combination of Lengths
- Volume → Combination of Areas and Lengths
- Plane Angle → Relationship between Lengths
- Solid Angle → Relationship between Length and Area.

The derivation and relationships of the base and secondary SI units are depicted in Fig. 14.2. The fundamental constants or properties are in the blue circles. The SI base units with their dimensions are shown in yellow. The secondary units with dimensions are in green. Arrows connecting the circles and boxes indicate relationships among the constants, properties, and units.

Note that the constants and properties have units based on other SI units in many cases. For this reason, the system needs to be considered as a whole to make it internally consistent.

English/US Customary Units [31]

Similar to the SI units, you can develop a map for the base and secondary units in the English/US Customary system. One version of the map is Fig. 14.3. This system has some base units that are similar to and others that differ from SI base units.

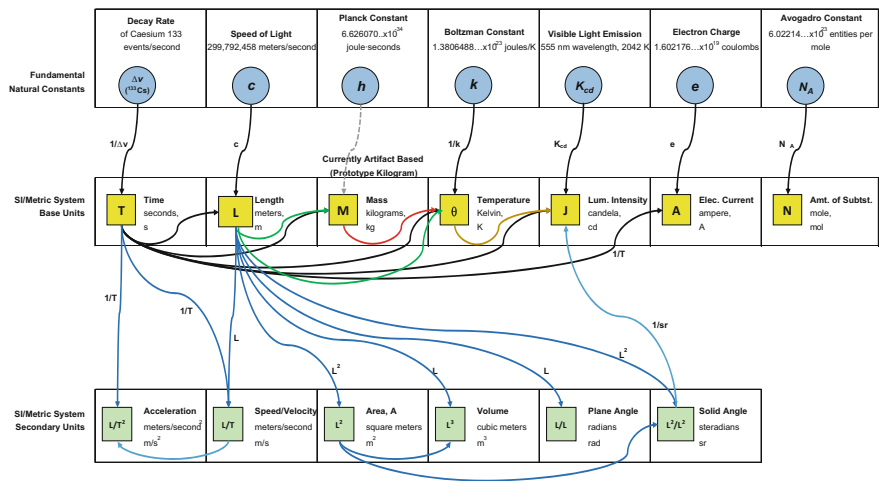


Fig. 14.2 SI base and secondary units are derived from fundamental constants and properties

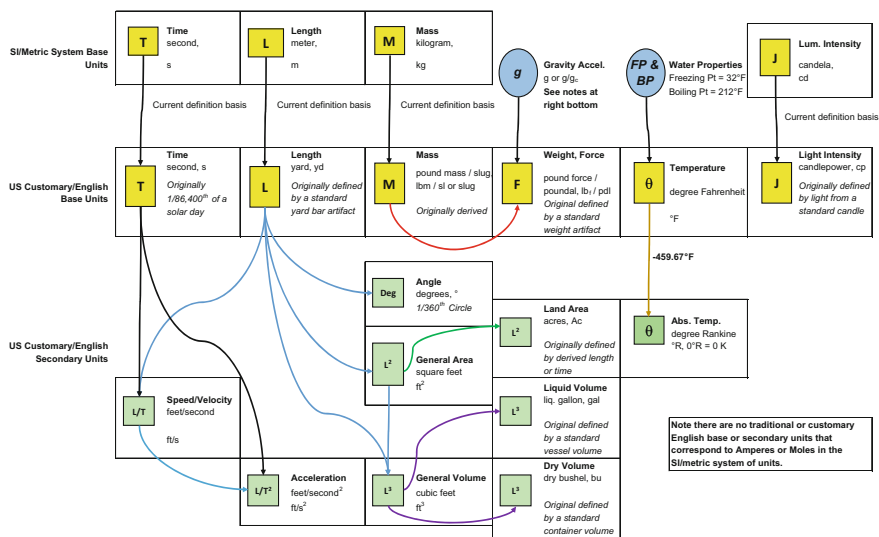


Fig. 14.3 The English/US customary base and secondary units landscape

- The similar base units are:
- Time:** Originally defined one second as 1/86,400th of a mean solar day, the time standard is now defined such that it is the same as the SI standard second.
 - Length:** Initially length was defined in terms of a standard yard bar maintained in England and then, later, by a bar at the U.S. National Bureau of Standards.

The current definition is a defined fraction of the standard SI meter, which is, in turn, based on the speed of light in a vacuum. In spite of the yard being the actual standard, the foot is the most common length measurement standard unit in the English system and is defined as exactly 1/3rd of a yard.

- *Mass*: In the English system, mass was not an original base unit. It was derived from a standard weight artifact using gravitational acceleration. Today, the mass standard is based on a defined fraction of the kilogram SI standard; however, there are two units of mass in the English system, depending on definition and application: pound mass (lb_m) and slug (sl). The pound mass is the most common unit and the one we will use here. After applying gravitational acceleration and the appropriate conversion factor ($g_c = 32.17 \text{ ft lb}_f/\text{lb}_m \text{ s}^2$), one lb_m is numerically (and conveniently) equal to one lb_f weight at the earth's surface—effectively it is 1 lb_m under the influence of 1 standard earth gravity.
- *Temperature*: The common temperature base units in the English system are degrees Fahrenheit ($^{\circ}\text{F}$). The difference between the freezing and boiling points of water at atmospheric pressure on the Fahrenheit scale is defined to be 180° . The absolute Rankine temperatures are simply the Fahrenheit temperatures plus 459.17° . In the English system, Rankine temperatures can be considered to be derived units.

Some effectively base units in the English/US Customary system of measurement that are not base units in the SI system are:

- *Force/Weight*: The pound force (lb_f) is essentially a base unit in the English system. It was initially based on a standard weight artifact under the acceleration of 1 gravity. The definition of lb_f today relates to SI units for convenience and consistency. The poundal (pdl) is also a force unit in one of the English systems equal to 1 pound mass accelerated at 1 ft/s. Refer to Fig. 14.3 for the interrelations among mass and force units between the English and SI systems. From a practical standpoint, in everyday activities and in this reference, $1 \text{ lb}_f = 1 \text{ lb}_m$.
- *Light Intensity*: Candlepower (cp) is defined in terms of a specific type and size of candle in English units. This unit is close to the SI unit of the candela (cd), which was originally defined so that it was close to the candlepower unit.

The English secondary units correspond pretty much with the SI secondary units with a few exceptions and changes to the English basis:

- *Angle*: In the English system, especially in engineering, angles are measured in degrees, with one degree defined as subtending 1/360th of a circle. Angle describes the spacial relationship between two lines in the same plane. This is essentially an independent definition of relationships. There is no unit for solid angle that corresponds with the steradian of the SI system.
- *Speed or Velocity*: The base units are feet per second (ft/s) derived like the m/s SI unit.
- *Acceleration*: Based on speed and length as measured in English units, acceleration in the English system is analogously expressed in feet per second squared (ft/s^2).

- *Area*: There are really two types of area base units used in the English system:
 - General Area: For general use, the base unit of area is the square foot (ft^2 or sq ft) derived in a manner similar to the square meter SI secondary unit.
 - Land Area: This unit of measurement is called the acre (Ac) and is used in surveying and agriculture. The acre today is defined as a specific number of square feet—so it is derived from length measures. It historically was a base unit of its own that was loosely defined in terms of an area that could be plowed by a team of oxen in a specific time and later by a number of square survey rods.
- *Volume*: Similar to area, there are three types of volumes that are standardized in the English/US Customary system. Distinctions are drawn between liquids and solids.
 - General Volume: This is defined in terms of cubic feet (ft^3 or cu ft) and is used for a wide variety of purposes. It is analogous to measurements in cubic meters in SI units. General volume is also often expressed in cubic inches (cu in or in^3), but it is still derived from basic length units.
 - Liquid Volume: The English liquid volume unit is the gallon (gal). Originally, liquid volume was a base unit in the English system that was established by a specific vessel defined to have a volume of exactly 1 gallon (or another measure that could be related to a gallon). The actual volume represented by a gallon depended on the commodity in some cases, with wine being different from water which was different from beer, and so on. Today, a liquid gallon is defined to be equal to an exact number of cubic inches regardless of the commodity.
 - Dry Volume: The English dry volume unit is the bushel (bu). Originally, dry volume was a base unit in the English system and the physical volume represented depended on the commodity (sort of density-based), but it could be related to a specific vessel volume of exactly 1 bushel of a specific commodity. As with liquid volumes today, a dry bushel is defined to be equal to an exact number of cubic inches regardless of the commodity.
- *Absolute Temperature*: This temperature corresponds to the Thermodynamic Temperature in SI units. In English units, absolute temperature is measured in degrees Rankine ($^{\circ}\text{R}$) with one K SI unit = 1.8°R . In the English system, however, absolute temperature is essentially derived from a common temperature basis.

Whereas the magnitude of an SI unit is designated by a prefix corresponding to a power of 10 (e.g. millimeter, decimeter, centimeter), the English units are divided and composited in different multiples and each of the smaller and larger units has a unique name. This was discussed extensively in the previous chapters on historical and SI/English units. For instance, the yard standard for length, following the path toward smaller units, gives rise to:

- foot: 1/3rd yard
- inch: 1/12th ft or 1/36th yard
- line: 1/12th inch or 1/432nd yard
- point: 1/6th line or 1/2592nd yard
- mil: 1/1000th inch or 1/36,000th yard
- twip: 1/20th point or 1/51,840th yard.

Following the path toward larger units, we get:

- fathom: 2 yards
- survey rod: 5.5 yards
- cable: 100 fathoms or 200 yards
- mile: 1760 yards
- nautical mile: 10 cables or 2000 yards
- league: 3 nautical miles or 6000 yards.

The practice of using a different name for each of the units and using a different factor between each layer of units certainly complicates the English/US Customary system of units. Fortunately, most of the time, only a handful of the units are commonly used and we end up looking up the conversion factors if we want another unit in the English system. The most common units you will encounter are:

- *Length*: mil, fractional ($1/2^n$ divisions) inches, inch, foot, yard, mile, nautical mile
- *Weight*: pound (force), ton
- *Volume*: cubic inch, small kitchen measures (teaspoons and tablespoons), cup, pint, quart, gallon, cubic foot, barrel
- *Time*: Same as SI system—fractional (decimal) second, second, minute, hour, day, etc.
- *Temperature*: °F, °R
- *Angle*: second, minute, fractional (decimal) degree, degree, revolution or turn
- *Area*: square inch, square foot, square yard, acre, square mile
- *Speed/velocity*: feet per second, miles per hour
- *Acceleration*: feet per square second.

In the current context, we are not considering all these multiples of the base or secondary units as derived units. Technically, they could be considered to be derived. Derived units, in our context here, will be units that are composites of two or more of the base and secondary units.

Families of Derived Units

In an effort to provide an orderly discussion of derived units, this section of the chapter looks at units that are built from two or more base (or, in some cases, secondary) units. The common, derived units have been broken into groups that are closely related. We will call these “families” for the purposes of discussion. The families are:

- Mechanical/thermal
- Electromagnetic
- Physical Flow Rates and Fluxes
- Miscellaneous.

We will look at the applicable families of derived units for both the SI and English/US systems.

SI/Metric Families [27, 28]

Mechanical/Thermal Derived Units

This family includes the units used for force, energy, work, power, and related measurements. Figure 14.4 illustrates the relationships of the mechanical/thermal units to the base and secondary SI units. These units have unique names in the system assigned by the General Conference on Weights and Measures (CGPM) in 1948 AD which honor historical scientific figures related to the units. (The names were actually in use somewhat earlier, but not officially adopted.) This is a nice gesture; but, unfortunately, assigning unique names also disguises the genesis of the units. Derivation of the units is much simpler than the unique names would imply.

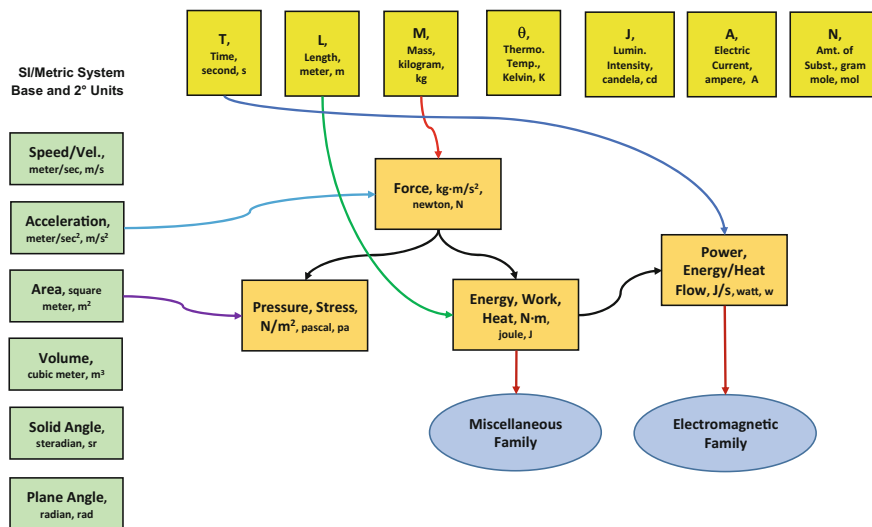


Fig. 14.4 Relationships within the SI mechanical/thermal family of derived units

The units in this family are

- *Force*: Derived from mass (kg) times acceleration (m/s^2), so the resulting unit is kg m/s^2 . This unit is called a “newton” (N) in the SI system in honor of Sir Isaac Newton (1642–1727 AD), who was key in recognizing and quantifying the relationship of gravity/acceleration and mass.
- *Pressure or Stress*: Derived from force (N) divided by the area (m^2) over which the force is applied. The result is a unit that is in kg/s^2 . This unit is called a “pascal” (Pa) after Blaise Pascal (1623–1662 AD). Pascal made significant contributions to the understanding of pressure.
- *Energy, Work, and Heat*: Derived from force (N) applied through a distance (m), the dimensional units are then $\text{kg m}^2/\text{s}^2$ or N m (not to be confused with torque which has the same units). In the SI system, this is called a “joule” (J) after James Prescott Joule (1818–1889 AD). The unit name recognizes Joule’s contributions in understanding the equivalence among work, heat, and energy. He correlated energy produced by various sources (heat, electrical, etc.). Ironically, Joule did much of his work in the English system of units.
- *Power, Energy/Heat Flow*: This unit is simply the rate at which work is done or energy is transferred. The dimensional units are then $\text{kg m}^2/\text{s}^3$ or J/s. The unit of power and energy flow was designated as the “watt” in 1882 AD, named after James Watt (1736–1819 AD) in recognition of his development of the steam engine—also working, ironically, in the English system of units.

These units are linked to other units in the Electromagnetic and Miscellaneous families in our subsequent discussion.

Electromagnetic Derived Units

The next SI family of units we will consider covers electromagnetic measurement units. These units are somewhat more recent in development than the mechanical/thermal units. The family “tree” is represented in Fig. 14.5.

The base unit that is most common to the members of the electromagnetic family is the ampere (or coulombs per second) of electrical current. Since electrical current and electromagnetism are so closely related, both electrical and magnetic measures fit into this common family. Most of the names in this category were adopted in or before 1948 AD, many in the late 1800s AD.

The primary, named, members of the electromagnetic family are:

- *Electromotive Force (EMF)*: This unit divides the power measured in watts from the mechanical/thermal family of units by the current in amperes used to produce that power. The dimensional units would then be $\text{kg m}^2/\text{C s}^2$ or $\text{kg m}^2/\text{A s}^3$ or W/A. This unit is named the “volt” in recognition of the contributions to knowledge of electricity and electrochemistry by Alessandro Giuseppe Antonio Anastasio Volta (1745–1827 AD). The term “volt” was in use prior to its general adoption in 1881 AD. While “electromotive force” is technically the correct term,

- *Conductance*: This unit is merely the reciprocal of the resistance. Dimensionally, the unit is $A^2 s^3/kg m^2$ or $1/\Omega$. The unit has been called the “mho” ($\oslash$), which is just the reverse spelling of ohm, as suggested by Lord Kelvin; but the official SI unit since 1971 AD is the “siemen” (S). Ernst Werner Siemens (1816–1892 AD) is honored by the unit name to recognize his contributions to practical applications of electrical technology. He was the founder of what is now Siemens AG, one of the largest electrical equipment companies in the world.
- *Capacitance*: Capacitance is measured in “farads”, so coined in 1861 to honor Michael Faraday (1791–1867 AD). The name was officially adopted in 1881 AD. Dimensionally the farad is in units of C/V or $A^2 s/W$ or $A s^4/kg m^2$. Faraday contributed extensively to understanding of electromagnetism. Capacitance describes the ability of a device to accumulate static electrical charge.
- *Inductance*: The unit of inductance is a “henry” (H). Dimensionally, a henry is wb/A or $kg m^2/A^2 s^2$ or $V s/A$. The unit name recognizes Joseph Henry (1797–1878 AD). Henry discovered electromagnetic self-inductance.
- *Magnetic Flux Density*: The magnetic flux impacting a given area is the magnetic flux density. Dimensionally, the flux has units of $kg/A s^2$ or wb/m^2 or $V s/m^2$. The unit for magnetic flux density is the “tesla” (T), honoring Nikola Tesla (1856–1943 AD) for his extensive contributions to electrical and electromagnetic applications, especially alternating current.

Because the development of electromagnetic technology is recent compared to mechanical/thermal understanding, the electromagnetic units defined for the SI system are also used in the English/US Customary system for the same purposes. There are no separate English unit definitions for these measurements.

Physical Flow Rates and Fluxes

There are different types of flow rates and fluxes which quantify the movement of physical materials and are derived from the base or secondary SI units. We are treating these measurement units together as a family for discussion. They do not have special names, like some of the other SI derived units; but instead retain the simple SI dimensional names.

There are similar units defined for other types of rates and fluxes. Some of these have already been described, for example: speed/velocity (m/s), magnetic flux (webers) and flux density (teslas), and energy flow (watts). We will describe a few others later. For now we are sticking with physical quantity movements. Figure 14.6 depicts the most common of these physical flow and flux units.

Generically, a flow is considered here as a physical quantity transported from point A to point B divided by the time required to move it. This is essentially the first derivative a changing physical quantity with respect to time. The flux is the flow rate divided by the area over which that flow occurs. These fluxes and flows are often used in further derivations, but this is for later description.

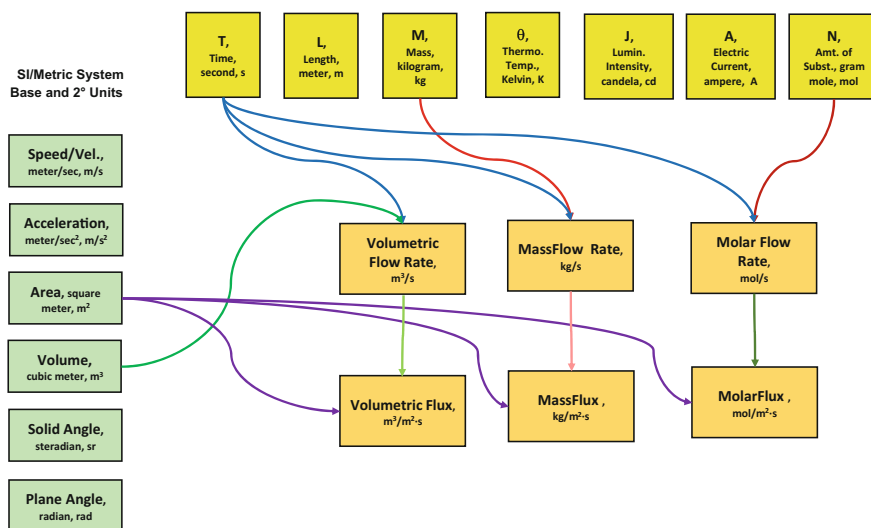


Fig. 14.6 Relationships within the SI physical flow and flux derived units

The three physical quantities we define here are mass, volume, and molar-based.

- **Mass:** Mass flow is the mass transported per unit time, expressed in base units of kg/s. The mass flux is the mass flow per unit area or kg/m² s.
- **Volume:** Similar to mass, volumetric flow rate in SI base units is m³/s derived from the volume moving divided by the time required to move the volume. Volumetric flux is the volumetric flow rate divided by the flowing area giving m³/m² s, which reduces dimensionally to m/s. The conditions for determining the flowing volume must be specified, especially for gases. There are several standard conditions defined by various entities. Often we will use “normal” cubic meters (NCM) for instance, giving units for flow of NCM/s or NCM/m² s.
- **Molar:** The same general approach is used to define the molar flow rate in SI units of mol/s and the molar flux in units of mol/m² s. In commercial applications, a mol is normally too small for practical use, so engineers use the kilogram-mole (kg mol or kmol) for design, so we have units like kmol/s.

Miscellaneous Derived Units

There are several other derived units that round out the units we will consider here. Each of the miscellaneous units we will list has its own unique name. Some names honor a specific contributor to the relevant science, while others have names that are otherwise derived. The miscellaneous units and relationships are shown in Fig. 14.7.

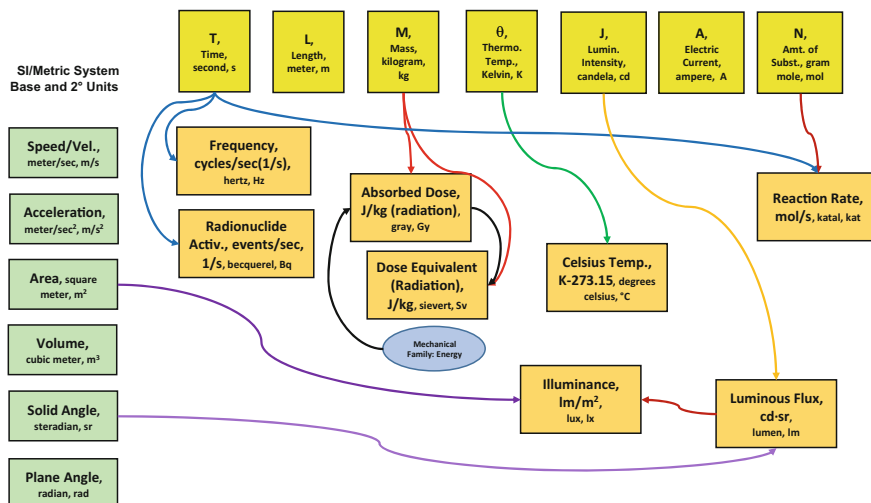


Fig. 14.7 Relationships defining the SI miscellaneous derived units

We'll look at each of the units along with the origins of the names in turn:

- **Frequency:** Frequency is defined as the number of cycles of a phenomenon per unit time. In SI base units, this would be in 1/s. The SI unit of frequency is the “hertz” (Hz) named after Heinrich Rudolf Hertz (1857–1894 AD). Hertz’s contributions included improving the scientific understanding of electromagnetism and wave phenomena, hence the relationship to frequency.
- **Radionuclide Activity:** This is a measure of the rate decay of a radioactive substance in terms of the number of nuclei decays per second, giving the measurement SI base units of 1/s. The SI unit name adopted for this measure is the becquerel (Bq) in recognition of the contributions of Antoine Henri Becquerel (1852–1908 AD) to the understanding of spontaneous radioactive decay. One becquerel is equal to one nucleus decaying per second.
- **Absorbed Dose (D):** This unit is based on the absorption of one joule of ionizing radiation energy per kilogram of matter; thus, dimensionally, an absorbed dose is in joules per kilogram (J/kg) or m²/s² in base units. The SI unit name for absorbed dose is the “gray” (Gy). The unit is named after Louis Harold Gray (1905–1965 AD) to recognize his work on the effects of radiation on living organisms. The name was adopted in 1975 AD.
- **Dose Equivalent (H):** The dose equivalent has the same SI base units as the absorbed dose: J/kg or m²/s²; but it applies to biological effects of an absorbed dose of ionizing radiation. In terms of definition, $H = D Q$; where Q is a constant related to the biological effect. The SI derived unit for dose equivalent is the “sievert” (Sv). Rolf Maximilian Sievert (1896–1966 AD) contributed to the quantification of radiation effects on health.

- *Celsius Temperature*: We have previously discussed temperature from an historical standpoint. The Celsius temperature, in the present SI system, is numerically equal to the Kelvin temperature (K) minus 273.15. The unit is expressed as degrees Celsius ($^{\circ}\text{C}$). This is the most common unit used for temperatures in the SI system, even though the official base unit is the Kelvin. Of course, the unit name here recognizes the contributions of Anders Celsius (1701–1744 AD) to temperature measurement and scales. He initially proposed the scale which divided the difference in temperature between freezing and boiling water into 100 units.
- *Reaction Rate*: The rate of a catalytic chemical reaction can be expressed in mols of one reactant or product per unit time; hence the derived unit for reaction rate is mol/s in terms of SI base units. The name adopted for this unit is the “katal” (kat). This unit is primarily applied in biochemistry, especially for enzyme-catalyzed reactions. You will rarely hear the term outside this environment. The name “katal” is derived from the Greek word “katalysis”, which relates to dissolution or breaking down something.
- *Luminous Flux*: This measurement is derived from the weighted luminous intensity of light visible to the human eye in candelas (cd) times the total solid angle over which the light is emitted measured in steradians (sr). A point source of light, emits the light in all directions, or 4π steradians. A light with an internal reflector may only emit light over half a sphere, or 2π steradians. Luminous flux is essentially the total amount of visible light emitted by a light source, regardless of direction. The SI dimensional units for luminous flux are then cd sr. The SI unit name for this unit is the “lumen” (lm). The lumen term does not recognize any particular individual or root. Generically, this is not actually a “flux” by the usual definition of something flowing over an area; but lighting definitions seem to follow their own rules.
- *Illuminance*: This is actually a “flux” by the usual definition, but is labeled otherwise when describing lighting. Illuminance is equal to the luminous flux in lumens (lm) divided by the area over which that light is actually distributed or received. Dimensionally, the unit is cd sr/m^2 and this quantity is designated as “lux” (lx). Note that the area of interest here is the area actually illuminated by the light source at whatever distance it is from the source. Hence, the lux number will drop off as the inverse square of the distance from a point source, for example.

A few other named units persist from prior forms of the metric system. Among the most common of these are:

- *calorie (cal or g-cal)*: This unit was defined originally in 1824 AD by Nicolas Clément (1779–1841 AD) as the heat energy required to raise the temperature of 1 gram of water by 1 degree Celsius. It is analogous to the British thermal unit (Btu) discussed later. Essentially this is a unit of energy in the centimeter-gram-second (cgs) system of units that was commonly used in the 1800s AD. It’s general use persisted until the 1950s AD for all kinds of scientific and engineering work in the metric system. It was obsoleted with

adoption of the SI system and the definition of watt in that system. However, there is so much history that you will still find the unit used today. It is most commonly used today for defining the energy value of foods or other combustibles; but the food calorie is actually a kilogram calorie (kcal or Cal with a capital “C”) equal to 1000 base calories, even though it is labeled as a calorie. In other common uses today, many references to heat content of fuels or heats of chemical reactions are still defined in terms of kcals per mol or kcals per kg, for instance.

- *dyne (dyn)*: A dyne is the unit of force in the cgs system of units. It is numerically equal to 1 g cm/s² or 10⁻⁵ N or 10⁻⁵ kg m/s².
- *erg*: The erg is the unit of work in the cgs system of units. It is numerically equal to 1 dyne cm or 1 g cm²/s² or 10⁻⁷ joules.
- *sthène (su)*: This is the unit of force in the meter-tonne-second (MTS) system of metric units. It was called a “funal” when first originated by the British in 1876 AD. The term sthène came from a French proposal in 1919 AD. Numerically, 1 su = 1000 N or 224.8 lb_f. This unit is generally no longer used.
- *curie (Ci)*: Named after Pierre Curie (1859–1906 AD) this non-SI unit of radioactivity was originally defined as the mass of radiation emitted in equilibrium with 1 gram of radium; but this definition was not very clear. It is now defined as 3.7×10^{10} decays per second of radium 226. In modern metric units, it is equal to 3.66×10^{10} Bq/g.
- *rad*: This is a unit of radiation dosage equal to 0.01 Gy or 0.01 J/kg. It originated in the cgs system of units in 1953 as the dosage that would cause 100 ergs of energy to be absorbed by 1 gram of organic matter.
- *roentgen (R)*: This is a measure of X-ray or gamma ray ionizing radiation. It is named for Wilhelm Röntgen (1845–1923 AD) in 1908 AD in recognition of his discovery of X-rays. The 1998 definition for this unit, in SI terms is 2.58×10^{-4} C/kg.

There are many other derived SI units that grow from the base and secondary units described here. We will get into these units a little later, but first we will review the English/US Customary units which parallel the SI system unit families.

English/US Customary Families [\[31\]](#)

Mechanical/Thermal/Energy Derived Units

This family corresponds to a similar family discussed under the SI/metric system. In the English system, the mechanical units are treated somewhat differently than the thermal or energy units. The commonly used units may be stated in terms of the root units or may use unique names, like some SI units.

The landscape for the English mechanical and thermal/energy derived units is illustrated in Fig. 14.8. Note that the units that can be considered base and

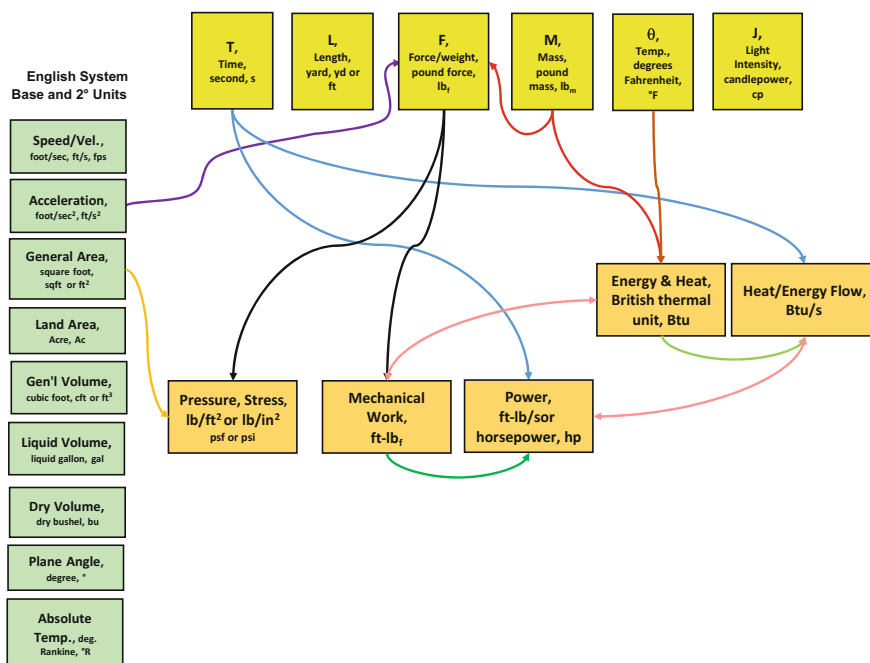


Fig. 14.8 Relationships within the English mechanical/thermal/energy family of derived units

secondary are a little different in nature from the SI base and secondary units. For example, force is really used as a base unit in this system.

Looking closer at each of the types of derived units:

- **Pressure/Stress:** In the English system, these measures are derived in the same way as in the SI system using force per unit area. Stress or pressure units using English base units would be expressed in terms of pounds force per square foot (lb_f/ft^2 or psf); but more often the units are pounds force per square inch (lb_f/in^2 or psi). It is customary to omit the subscript “f” from pounds force. You almost never see these measures expressed as pounds per square yard, even though the yard is technically the base unit of length.
- **Mechanical Work:** Mechanical work units are derived from the definition of work: force times distance moved (or the integral of force with respect to distance). The units are foot-pounds in this system. There are no special names used. The subscripted “f” in pounds force is generally omitted. As for the SI system, the units here are not to be confused with ft lbs used for mechanical torque.
- **Power:** Mechanical power is calculated in ft lb_f per second; but is normally expressed in terms of “horsepower”, hp. The term “horsepower” was originated by James Watt (1736–1819 AD) in the late 1700s AD. It was intended for use in comparing the rates at which work was done by different types of “drivers”, such

as comparison of work by horses with steam engines. Watt used the horsepower unit as a basis for marketing his steam engines. It was based on an estimate of the rate at which a horse could turn a mill wheel of 24 feet diameter pulling with a force of 180 lb in an hour. He estimated the horse could turn the mill wheel 144 times in one hour. From this he could calculate the power as 32,572 ft lb_f/min, which was rounded to our current definition of 33,000 ft lb_f/min or 550.0 ft lb_f/s. In fact, a horse cannot maintain this rate of power output very long, so Watt actually over-estimated the work a horse could do. Estimates of this value by others varied widely. There are several other types of horsepower defined. The normal horsepower definition applies to mechanical horsepower, but a few of the other definitions are:

- Metric horsepower: Equal to 0.986 mechanical horsepower, with a definition from the late 1800s AD that was similar to Watt's definition, but used metric units instead of English units.
 - Boiler horsepower: Thermally-based unit equal to the heat required to evaporate 34.5 lb water per hour at 212 °F. This belongs more to the thermal power category and is equal to 33,479 Btu/hr or about 9.3 Btu per second.
 - Electric motor horsepower: Equal to 745.7 watts (US) normally; but may also be based on 735 watts (old European Continental). The 745.7 watt conversion is equivalent to mechanical horsepower.
 - RAC or taxable horsepower: There were several measures of horsepower developed for the purposes of taxation in the early 20th century AD. These systems had a range of values based on a vehicle engine's cylinder bore and number of cylinders, which had no real relationship to the actual horsepower produced, because it neglected displacement. This application is no longer used.
 - Hydraulic horsepower: This is the same as the mechanical energy imparted to a moving fluid by a pump at 100% efficiency.
 - Air horsepower: Similar to hydraulic horsepower, this is the energy added to air as it is compressed, assuming 100% efficiency.
 - Drawbar horsepower: This measure is used for power provided by a locomotive, tractor, or aircraft in moving a load at a specified speed in miles/hour (mph). It is roughly equivalent to mechanical horsepower and is determined by dynamometer normally. The constant used is 1 hp = 375 lb_f mph.
- *Energy and Heat:* In the English system, energy and heat are expressed in terms of British thermal units (Btu), with different roots than mechanical work. One Btu is the amount of energy or heat required to raise the temperature of one pound of water by one degree Fahrenheit. It is equal to 1055 joules (from the SI system) by definition since 1956 AD. An early recorded definition of what would eventually become the Btu appeared in a book by Thomas Tredgold (1788–1829 AD) on heating and ventilation of buildings published in 1824 AD. Tredgold was actually a railroad design engineer, who was interested in heating and ventilation on the side. He proposed measuring the heat required to raise the temperature of 1 cubic foot of water one degree Fahrenheit as a way of

comparing different fuels. Eventually the basis was changed to one pound to improve consistency, since the energy/heat required actually varies based on starting temperatures and densities otherwise. The term “Btu” itself appears to have originated in engineering before 1897 AD. It was used in a thermodynamics text by DeVolson Wood (1832–1897 AD) in 1893 AD, for instance.

For a magnitude reference, one Btu is roughly equal to the total energy output of one wooden kitchen match burning. The Btu (and multiples, separated into factors of 1000) is still used extensively in the United States and a few other locations to measure and design thermal and energy transfer equipment. The units you will often find in practice may include:

- Thousand Btus (MBtu or kBtu; “M” originates with Roman numeral designation for thousand, whereas “k” comes from metric prefixes)
- Million Btus (MMBtu or $\text{Btu} \times 10^6$; called a “therm”, th, in some industries, like oil; “MM” has Roman numeral roots)
- 100,000 Btus (called a “therm”, th, in other industries, like natural gas)
- [Obviously the term therm can be a little vague].

Btu is a unit of work. Most often, in practice, it is used in specifying power or heating/cooling rates, so it is expressed in units like Btu/hr or MMBtu/s.

- *Heat and Energy Flow*: This is effectively “power” by the usual definition, work per unit time, with work measured in British thermal units per unit time, Btu/s (or Btu/hr or MMBtu/hr and so on). From a base unit standpoint, the units for work in the English system would be Btu/s, although a longer time base is normally used in practice (minute or hour). There is no special name for heat/energy flow in the English engineering system. One Btu/s is equal to 0.29283 watts in SI units.

Electromagnetic Derived Units

The electromagnetic units used in the English or English engineering system are the same as for the SI/metric system. They are linked to the mechanical/thermal/energy derived units through conversion to watts or kilowatts. This owes largely to the later and more complete development of electromagnetic units in the SI system. The English system had relatively little historical precedent for these measurements.

Physical Flow Rates and Fluxes

Analogous to the flows and fluxes developed for the SI/metric system, the English system employs similar units as depicted in Fig. 14.9. These flows and fluxes do not have specific names, but instead retain the units of their roots, just as they did in SI units. These units apply to physical transport of quantities of matter. Other units apply to movement of electricity, waves, etc., which are covered elsewhere.

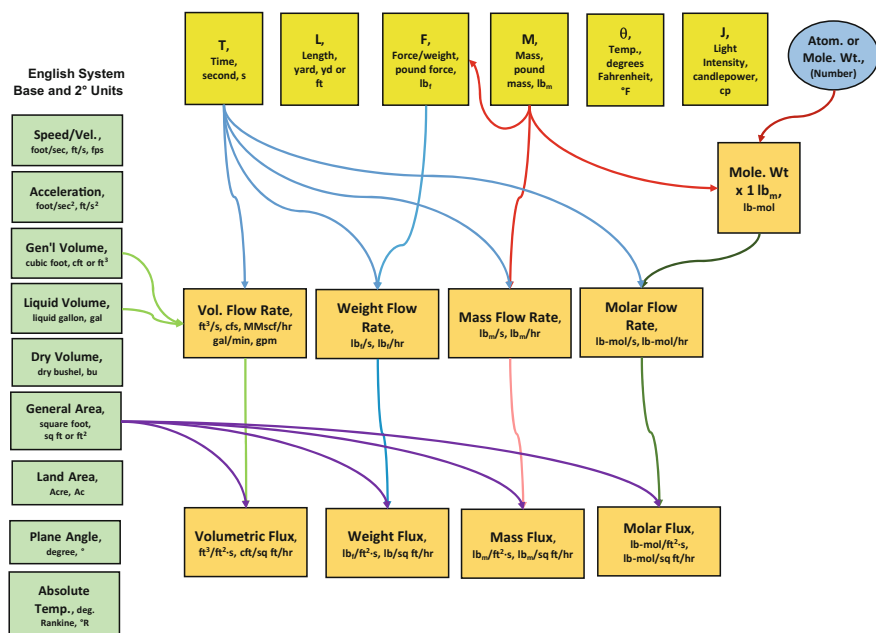


Fig. 14.9 Relationships within the English/US customary physical flow and flux derived units

As with the SI units, flow rate is considered here as a physical quantity transported from point A to point B divided by the time required to move it (i.e. the first derivative of a changing physical quantity with respect to time). Flux is the flow rate divided by the area over which that flow occurs. These fluxes and flows are used in further applications.

The four physical quantities we define here are weight, mass, volume, and molar-based.

- **Weight:** Weight flow rate is the weight of a material moved per unit time. This flow, of course, would be based on one standard earth gravity—so it only works in a terrestrial reference. Units for weight flow are lb_f/s or lb/s or lb/min and so on. The abbreviation for pound (lb) normally omits the subscript “f”. The reference period is normally more than one second when using weight flow. The weight flux is simply the weight flow divided by the area over which flow is occurring in lb/ft² s (or another time base).
- **Mass:** Mass flow is the mass (lb_m) transported per unit time (s, min, hr, etc.), expressed in base units of lb_m/s or some other time base. The mass flux is the mass flow per unit area or lb/ft² s. Because 1 lb_m is basically numerically equal to 1 lb_f within the normal range of accuracies, mass and weight flows and fluxes are essentially the same; hence, the common practice of dropping the “m” or “f” subscripts.

- **Volume:** Similar to mass, volumetric flow rate in English base units is ft^3/s derived from the volume moving divided by the time required to move the volume. As with other English units, the time frame is usually longer than the second in common practice. The volumetric flow used frequently also assumes the units in which the volume is measured. We commonly have volumetric flows in gallons of liquid per minute (gpm), for example. Volumetric flux is the volumetric flow rate divided by the flowing area giving $\text{ft}^3/\text{ft}^2 \text{ s}$ using English base units, which reduces dimensionally to ft/s . Again, the flux is often provided in other units, such as $\text{gal}/\text{ft}^2 \text{ hr}$ flux in a distillation column. As for SI units, the conditions under which the volume is measured must be defined for the units to make sense. For gases in the petroleum industry, for instance, it is common to use standard conditions of 60°F and $14.696 \text{ lb}_f/\text{in}^2$ absolute pressure (14.696 psia) as a basis for “standard cubic feet” (scf), so a flow might be in scf/hr .
- **Molar:** Moles in the English engineering system are defined by multiplying the relative atomic or molecular weight of a substance (carbon = 12.0000) by 1 lb mass to obtain the mass of one pound-mole of a substance. The pound-moles thus obtained are then converted to molar flows and fluxes. Molar flow rates are then lbmol/s (or another convenient time base, such as an hour) and molar fluxes are then $\text{lbmol}/\text{ft}^2 \text{ s}$ (or another convenient time and area basis). To avoid confusion with SI units, we normally keep the lb-mol designation. A lbmole is equal to 453.6 SI system gram-moles or mols, so is significantly larger than an SI mole. A lbmole is 0.4536 kg-moles or kmols, so is of comparable magnitude to this “de facto” SI unit that is used for design work.

Miscellaneous Derived Units

There are only a handful other derived units that round out the base and secondary units for the English system that correspond to similar measures in SI units. These are highlighted in Fig. 14.10.

Derived English units that correspond to metric units previously discussed are:

- **Frequency:** Essentially the definition of frequency for a cyclic phenomenon, like radio waves, is the same in English units as in SI units. The unit is cycles per second ($1/\text{s}$), which is sometimes called just “cycles”. In recent years, the term Hertz (Hz), as defined for the SI system, has pretty much replaced this unit.
- **Illumination:** The traditional English unit of illumination is the foot candle (fc), which is equal to illumination of the inside of a 1 foot radius sphere by one standard candle. One foot-candle is approximately 1 lm per square foot, if we mix the SI and English systems. This unit is still used for lighting and in cinematography. For reference, the full sun on a clear day with the sun directly overhead provides about 10,000 fc.

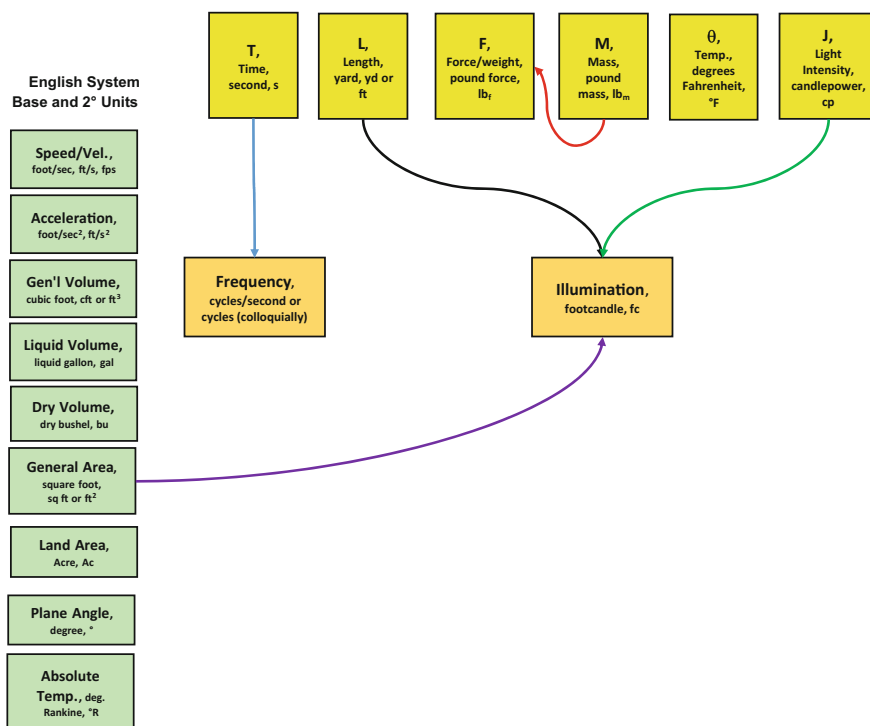


Fig. 14.10 Relationships defining the english miscellaneous derived units

As mentioned above, other multiples and fractions of the English derived units also exist. Many of these have unique names. For now, we will close this section and pick up discussion of the wide range of units which grow from the units we have already defined.

A Plethora of Other Derived Units

[2–5, 15, 16, 21, 26, 29–31]

From the basic “families” of units we’ve discussed, many other units are created for application in specific subject areas. Table 14.1 summarizes some of the more common combinations of these other units and provides a comparison of the magnitudes in both the SI and English/US Customary systems. This is by no means an exhaustive listing. The table is grouped alphabetically by the application: mass, length, area, mass flux, etc.

The information in Table 14.1 is compiled from multiple sources listed in the “References” section. The individual sources are not repeated here.

Table 14.1 The wide range of derived units in the metric and English/US systems. Multiple sources, refer to References

Application/field	Unit name	Notation	SI dimension	SI/metric system		English/US system	
				Conversion factor	Unit	Conversion factor	Unit
Absorbed Radiation Dose	erg per gram	erg/g	L^2T^{-2}	0.0001	Gy	0.01	rad
Absorbed Radiation Dose	gram-rad	g-rad	L^2T^{-2}	0.01	Gy	1	rad
Absorbed Radiation Dose	gray	Gy	L^2T^{-2}	1	Gy	100	rad
Absorbed Radiation Dose	rad	rad	L^2T^{-2}	0.01	Gy	1	rad
Acceleration	foot per second squared	ft/s^2 or ft/sec^2	LT^{-2}	0.3048	m/s^2	1	ft/s^2
Acceleration	meter per second squared	m/s^2	LT^{-2}	1	m/s^2	3.28084	ft/s^2
Activation Energy	Btu per pound mole	Btu/lb-mol	$L^2N^{-1}T^{-2}$	2326	J/mol	1	Btu/lb-mol
Activation Energy	calorie (mean) per gram mole	cal/mol	$L^2N^{-1}T^{-2}$	4.18675	J/mol	0.0018000	Btu/lb-mol
Activation Energy	joule per gram mole	J/mol	$L^2N^{-1}T^{-2}$	1	J/mol	0.00042992	Btu/lb-mol
Activation Energy	joule per kilogram mole	J/kmol	$L^2N^{-1}T^{-2}$	1000	J/mol	0.42992	Btu/lb-mol
Activation Energy	kilocalorie per kilogram mole	kcal/kmol	$L^2N^{-1}T^{-2}$	4.18675	J/mol	0.0018000	Btu/lb-mol
Amount of Substance	kilogram mol or kmol	kmol	N	1000	mol	2.2046	lb-mol
Amount of Substance	mole (gram)	mol	N	1	mol	0.0022046	lb-mol
Amount of Substance	pound-mole	lb-mol or mole	N	453.6	mol	1	lb-mol
Angle, Plane	degree	°	Dmils	0.0174533	rad	1.0000	deg (°)
Angle, Plane	gon	g or gon	Dmils	0.015708	rad	0.90000	deg (°)
Angle, Plane	grade	g or grad	Dmils	0.015708	rad	0.90000	deg (°)
Angle, Plane	minute (new)	¢	Dmils	0.00015708	rad	0.0090000	deg (°)

(continued)

Table 14.1 (continued)

Application/field	Unit name	Notation	SI dimension	SI/metric system		English/US system	
				Conversion factor	Unit	Conversion factor	Unit
Angle, Plane	minute of angle	'	Dmils	0.000290888	rad	0.016667	deg (°)
Angle, Plane	percent	%	Dmils	0.062832	rad	3.6000	deg (°)
Angle, Plane	plane angle	—	Dmils	3.141593	rad	180.00	deg (°)
Angle, Plane	quadrant	quadr	Dmils	1.570796	rad	90.000	deg (°)
Angle, Plane	radian	rad	Dmils	1	rad	57.296	deg (°)
Angle, Plane	right angle	⊥	Dmils	1.570796	rad	90.000	deg (°)
Angle, Plane	round	tr or r	Dmils	6.283185	rad	360.00	deg (°)
Angle, Plane	second (new)	cc	Dmils	1.5708E-06	rad	9.0000E-05	deg (°)
Angle, Plane	second of angle	“	Dmils	4.8481E-06	rad	2.7778E-04	deg (°)
Angle, Plane	thousandth (US)	‰ (US)	Dmils	0.0015708	rad	0.090000	deg (°)
Angle, Plane	turn	turn or rev	Dmils	6.283185	rad	360.00	deg (°)
Angle, Solid	spat	spat	Dmils	12.5663	sr	41.253	(°) ²
Angle, Solid	square degree	(°) ²	Dmils	0.000304617	sr	1.0000	(°) ²
Angle, Solid	square gon	(g) ²	Dmils	0.00024674	sr	0.81000	(°) ²
Angle, Solid	steradian	sr	Dmils	1	sr	3282.8	(°) ²
Angular Acceleration	radian per second squared	rad/s ²	T ⁻²	1	rad/s ²	0.1592	rev/sec ²
Angular Acceleration	revolution per second squared	rev/sec ²	T ⁻²	6.2832	rad/s ²	1	rev/sec ²
Angular Acceleration	rpm (or revolution per minute) per minute	rev/min ² or rpm/min	T ⁻²	0.001745	rad/s ²	0.0002778	rev/sec ²
Angular Momentum	gram centimeter squared per second	g cm ² /s	ML ² T ⁻¹	1.00E-07	kg m ² /s	2.373E-06	lb ft ² /sec

(continued)

Table 14.1 (continued)

Application/field	Unit name	Notation	SI dimension	SI/metric system		English/US system	
				Conversion factor	Unit	Conversion factor	Unit
Angular Momentum	kilogram meter squared per second	kg m ² /s	ML ² T ⁻¹	1	kg m ² /s	23.73	lb ft ² /sec
Angular Momentum	pound force square foot per second	lb ft ² /sec	ML ² T ⁻¹	0.04214	kg m ² /s	1	lb ft ² /sec
Area	acre (general)	ac	L ²	4046.856	m ²	43560.0	ft ²
Area	are	a	L ²	100	m ²	1076.39	ft ²
Area	arpent (Quebec)	arp	L ²	3418.89	m ²	36800.6	ft ²
Area	barn	b	L ²	1.00E-28	m ²	1.0764E-27	ft ²
Area	circular inch	cin	L ²	0.000506707	m ²	0.0054542	ft ²
Area	circular mil	cmil	L ²	5.07E-10	m ²	5.4542E-09	ft ²
Area	hectare	ha	L ²	10,000	m ²	107639.2	ft ²
Area	shed	shed	L ²	1.00E-52	m ²	1.0764E-51	ft ²
Area	square centimeter	cm ²	L ²	0.0001	m ²	0.00107639	ft ²
Area	square chain (Ramsden)	sq ch (Rams)	L ²	929.03	m ²	10,000	ft ²
Area	square chain (Survey, Gunter's)	sq ch (surv)	L ²	404.6856	m ²	4356.0	ft ²
Area	square decimeter	dm ²	L ²	0.01	m ²	0.10764	ft ²
Area	square fermi	F ²	L ²	1.00E-30	m ²	1.0764E-29	ft ²
Area	square foot	sq ft or ft ²	L ²	0.092903	m ²	1.0000	ft ²
Area	square hectometer	hm ²	L ²	10,000	m ²	107639.2	ft ²
Area	square inch	sq in or in ²	L ²	0.00064516	m ²	0.0069444	ft ²
Area	square kilometer	km ²	L ²	1,000,000	m ²	1.0764E+07	ft ²
Area	square league (statute)	sq lg (stat)	L ²	2.3310E+07	m ²	2.5091E+08	ft ²

(continued)

Table 14.1 (continued)

Application/field	Unit name	Notation	SI dimension	SI/metric system		English/US system	
				Conversion factor	Unit	Conversion factor	Unit
Area	square meter	m ²	L ²	1	m ²	10.7639	ft ²
Area	square micron	μm ² or μ ²	L ²	1.00E-12	m ²	1.0764E-11	ft ²
Area	square mile (statute)	sq mi (stat)	L ²	2.5900E+06	m ²	2.7879E+07	ft ²
Area	square mile (US survey)	sq mi (US Surv)	L ²	2.5900E+06	m ²	2.7879E+07	ft ²
Area	square millimeter	mm ²	L ²	0.000001	m ²	1.0764E-05	ft ²
Area	square nanometer	nm ²	L ²	1.00E-18	m ²	1.0764E-17	ft ²
Area	square yard	sq yd	L ²	0.836131	m ²	9.0000	ft ²
Area	township (US)	twship	L ²	9.3240E+07	m ²	1.0036E+09	ft ²
Area per Unit Volume	square centimeter per cubic centimeter	cm ² /cc	L ⁻¹	100	m ² /m ³	30.48	sqft/cft
Area per Unit Volume	square foot per cubic foot	ft ² /ft ³ or sqft/cft	L ⁻¹	3.2808	m ² /m ³	1	sqft/cft
Area per Unit Volume	square inch per cubic inch	in ² /in ³ or sq.in./cu. in.	L ⁻¹		m ² /m ³	12	sqft/cft
Area per Unit Volume	square meter per cubic meter	m ² /m ³ or 1/m ³	L ⁻¹	1	m ² /m ³	0.3048	sqft/cft
Atomic Weight	atomic mass unit (12C)	amu	MN ⁻¹	1	g/mol	1	lb/lb-mol
Atomic Weight	grams per mole	g/mol	MN ⁻¹	1	g/mol	1	lb/lb-mol
Atomic Weight	kilograms per kilomole	kg/kmol	MN ⁻¹	1	g/mol	1	lb/lb-mol
Atomic Weight	pounds per pound mole	lb/lb-mol or lb/mole	MN ⁻¹	1	g/mol	1	lb/lb-mol
Concentration	grains of “i” per cubic foot	gr/ft ³ or gr/cft	ML ⁻³	0.002288	kg/m ³	0.00014284	lb/ft ³
Concentration	grains of “i” per gallon (US)	gr/gal	ML ⁻³	0.017115	kg/m ³	0.0010685	lb/ft ³
Dynamic Fluidity	meter-seconds per kilogram	m s/kg	TLM ⁻¹				
Dynamic Fluidity	rhe	rhe	TLM ⁻¹	1	m ² /(N s)	47.881	ft ² /(lb sec)

(continued)

Table 14.1 (continued)

Application/field	Unit name	Notation	SI dimension	SI/metric system		English/US system	
				Conversion factor	Unit	Conversion factor	Unit
Dynamic Fluidity	square foot per pound second	ft ² /(lb sec)	TLM ⁻¹	0.002086	m ² /(N s)	1	ft ² /(lb sec)
Dynamic Fluidity	square meters per newton per second	m ² /(N s)	TLM ⁻¹	1	m ² /(N s)	47.881	ft ² /(lb sec)
Electric Capacitance	“cm”	“cm”	T ⁴ A ² L ⁻² M ⁻¹	1.1111E-12	F	1.1111E-12	F
Electric Capacitance	abfarad	emu cgs	T ⁴ A ² L ⁻² M ⁻¹	1.00E+09	F	1.00E+09	F
Electric Capacitance	farad	F	T ⁴ A ² L ⁻² M ⁻¹	1	F	1	F
Electric Capacitance	farad (intl)	F (intl)	T ⁴ A ² L ⁻² M ⁻¹	0.99951	F	0.99951	F
Electric Capacitance	jar	jar	T ⁴ A ² L ⁻² M ⁻¹	1.1111E-09	F	1.1111E-09	F
Electric Capacitance	puff	puff	T ⁴ A ² L ⁻² M ⁻¹	1.00E-12	F	1.00E-12	F
Electric Capacitance	statfarad	esu cgs	T ⁴ A ² L ⁻² M ⁻¹	1.1130E-12	F	1.1130E-12	F
Electric Charge	abcoulomb	emu cgs	TAN ⁻¹	0.000103643	F	0.0027778	Ah
Electric Charge	ampere-hour	Ah	TAN ⁻¹	0.03731138	F	1	Ah
Electric Charge	coulomb	C	TAN ⁻¹	1.0364E-05	F	0.00027778	Ah
Electric Charge	faraday (C12)	F	TAN ⁻¹	1	F	26.80147	Ah
Electric Charge	franklin	Fr	TAN ⁻¹	3.45715E-15	F	9.26570E-14	Ah
Electric Charge	statcoulomb	esu cgs	TAN ⁻¹	3.45715E-15	F	9.26570E-14	Ah
Electric Charge	u.a. charge	u.a.	TAN ⁻¹	1.66054E-24	F	4.45049E-23	Ah
Electric Current Intensity	abampere	emu cgs	A	10	A	10	A

(continued)

Table 14.1 (continued)

Application/field	Unit name	Notation	SI dimension	SI/metric system		English/US system	
				Conversion factor	Unit	Conversion factor	Unit
Electric Current Intensity	ampere (intl mean)	A (int mean)	A	0.99985	A	0.99985	A
Electric Current Intensity	ampere (intl US)	A (int US)	A	0.999835	A	0.999835	A
Electric Current Intensity	ampere or amp	A	A	1	A	1	A
Electric Current Intensity	biot	biot	A	10	A	10	A
Electric Current Intensity	statampere	esu cgs	A	3.33564E-10	A	3.33564E-10	A
Electric Current Intensity	u.a. or current	u.a.	A	0.00662362	A	0.00662362	A
Electric Dipole Moment	ampere meter second	A m s	ALT	1	A m s		
Electric Dipole Moment	coulomb meter	C m	ALT	1	A m s		
Electric Dipole Moment	debye	D	ALT	3.3356E-30	A m s		
Electric Dipole Moment	electron meter	e m	ALT	1.6022E-19	A m s		
Electric Field Strength	volt per centimeter	V/cm	$MLT^{-3}A^{-1}$	100	V/m		
Electric Field Strength	volt per meter	V/m	$MLT^{-3}A^{-1}$	1	V/m		
Electric Inductance	abhenry	emu cgs	$ML^2T^{-2}A^{-2}$	1.00E-09	H	9.99505E-10	H (int US)

(continued)

Table 14.1 (continued)

Application/field	Unit name	Notation	SI dimension	SI/metric system		English/US system	
				Conversion factor	Unit	Conversion factor	Unit
Electric Inductance	cm	cm	$ML^2T^{-2}A^{-2}$	1.00E-09	H	9.99505E-10	H (int US)
Electric Inductance	henry	H	$ML^2T^{-2}A^{-2}$	1	H	0.99951	H (int US)
Electric Inductance	henry (intl mean)	H (int mean)	$ML^2T^{-2}A^{-2}$	1.00049	H	1.00000	H (int US)
Electric Inductance	henry (intl US)	H (int US)	$ML^2T^{-2}A^{-2}$	1.000495	H	1	H (int US)
Electric Inductance	mic	mic	$ML^2T^{-2}A^{-2}$	1.00E-06	H	9.99505E-07	H (int US)
Electric Inductance	stathenry	esu cgs	$ML^2T^{-2}A^{-2}$	8.9876E+11	H	8.9831E+11	H (int US)
Electric Potential	abvolt	emu cgs	$ML^2T^{-3}A^{-1}$	1.00E-08	V	1.00E-08	V
Electric Potential	statvolt	esu cgs	$ML^2T^{-3}A^{-1}$	299.792	V	299.792	V
Electric Potential	u.a. potential	u.a.	$ML^2T^{-3}A^{-1}$	27.2114	V	27.2114	V
Electric Potential	volt	V	$ML^2T^{-3}A^{-1}$	1	V	1	V
Electric Potential	volt (intl mean)	V (int mean)	$ML^2T^{-3}A^{-1}$	1.00034	V	1.00034	V
Electric Potential	volt (US)	V (int US)	$ML^2T^{-3}A^{-1}$	1.00033	V	1.00033	V
Electric Resistance	abohm	emu cgs	$ML^2T^{-3}A^{-2}$	1.00E-09	Ω	1.00E-09	Ω
Electric Resistance	jacobi	–	$ML^2T^{-3}A^{-2}$	0.64	Ω	0.64	Ω
Electric Resistance	lenz	Metric	$ML^2T^{-3}A^{-2}$	8.00E+04	Ω	8.00E+04	Ω
Electric Resistance	ohm	Ω	$ML^2T^{-3}A^{-2}$	1	Ω	1	Ω
Electric Resistance	ohm (intl mean)	Ω (int mean)	$ML^2T^{-3}A^{-2}$	1.00049	Ω	1.00049	Ω
Electric Resistance	ohm (intl US)	Ω (int US)	$ML^2T^{-3}A^{-2}$	1.000495	Ω	1.000495	Ω
Electric Resistance	ohm (legal)	Ω (legal)	$ML^2T^{-3}A^{-2}$	0.9972	Ω	0.9972	Ω
Electric Resistance	precece	precece	$ML^2T^{-3}A^{-2}$	1.00E+06	Ω	1.00E+06	Ω

(continued)

Table 14.1 (continued)

Application/field	Unit name	Notation	SI dimension	SI/metric system		English/US system	
				Conversion factor	Unit	Conversion factor	Unit
Electric Resistance	statohm	esu cgs	$ML^2T^{-3}A^{-2}$	8.987552	Ω	8.987552	Ω
Electric Resistance	wheatstone	—	$ML^2T^{-3}A^{-2}$	0.0025	Ω	0.0025	Ω
Electrical Conductance	emu cgs	abmho	$T^3A^2M^{-1}L^{-2}$	1.00E+09	S		
Electrical Conductance	esu cgs	statmho	$T^3A^2M^{-1}L^{-2}$	1.1127E-12	S		
Electrical Conductance	mho	mho	$T^3A^2M^{-1}L^{-2}$	1	S		
Electrical Conductance	microsiemens	μS	$T^3A^2M^{-1}L^{-2}$	1.00E-06	S		
Electrical Conductance	siemens	S	$T^3A^2M^{-1}L^{-2}$	1	S		
Electrical Permittivity	farad per meter	F/m	$A^2T^4M^{-1}L^{-3}$	1	F/m		
Electrical Resistivity	circular mil-ohm per foot	circmil Ω /ft	$ML^3T^{-3}A^{-2}$	1.6624E-09	Ω m	0.06545	$\mu\Omega$ in
Electrical Resistivity	emu cgs	abohm cm	$ML^3T^{-3}A^{-2}$	1.00E-11	Ω m	3.94E-04	$\mu\Omega$ in
Electrical Resistivity	microhm-inch	$\mu\Omega$ in	$ML^3T^{-3}A^{-2}$	2.5400E-08	Ω m	1	$\mu\Omega$ in
Electrical Resistivity	ohm-centimeter	Ω cm	$ML^3T^{-3}A^{-2}$	0.01	Ω m	3.9370E+05	$\mu\Omega$ in
Electrical Resistivity	ohm-meter	Ω m	$ML^3T^{-3}A^{-2}$	1	Ω m	3.9370E+07	$\mu\Omega$ in
Energy Flux	Btu per square foot per hour	Btu/ft ² /hr	MT^{-3}	3.1546	W/m ²	1	Btu/ft ² /hr
Energy Flux	calorie per square centimeter per second	cal/cm ² /s or cal/(cm ² s)	MT^{-3}	41,868	W/m ²	13,272	Btu/ft ² /hr
Energy Flux	Celsius heat units (Chu) per square foot per hour	Chu/ft ² /hr	MT^{-3}	5.6784	W/m ²	1.8000	Btu/ft ² /hr

(continued)

Table 14.1 (continued)

Application/field	Unit name	Notation	SI dimension	SI/metric system		English/US system	
				Conversion factor	Unit	Conversion factor	Unit
Energy Flux	kilocalorie per square foot per hour	kcal/(ft ² hr)	MT ⁻³	12.518	W/m ²	3.9682	Btu/ft ² /hr
Energy Flux	kilocalorie per square meter per hour	kcal/(m ² hr)	MT ⁻³	1.163	W/m ²	0.36867	Btu/ft ² /hr
Energy Flux	watt per square meter	W/m ²	MT ⁻³	1	W/m ²	0.31700	Btu/ft ² /hr
Energy per Unit Area	British thermal unit per square foot	Btu/ft ² or Btu/sq ft	MT ⁻²	11,354	J/m ²	1	Btu/ft ²
Energy per Unit Area	joule per square meter	J/m ²	MT ⁻²	1	J/m ²	8.8072E-05	Btu/ft ²
Energy per Unit Area	Langley	Ly	MT ⁻²	41,840	J/m ²	3.6849	Btu/ft ²
Energy, Heat, Work	barrel oil equivalent or equivalent barrel	bboe or boe	ML ² T ⁻²	6.12E+09	J	5.8006E+06	Btu
Energy, Heat, Work	billion electronvolt	BeV	ML ² T ⁻²	1.6022E-10	J	1.5186E-13	Btu
Energy, Heat, Work	British thermal unit (4 °C)	Btu (39.2 °F)	ML ² T ⁻²	1059.67	J	1.0044	Btu
Energy, Heat, Work	British thermal unit (60 °F)	Btu (60 °F)	ML ² T ⁻²	1054.678	J	0.99964	Btu
Energy, Heat, Work	British thermal unit (international steam tables)	Btu (IT)	ML ² T ⁻²	1055.055853	J	1.0000	Btu
Energy, Heat, Work	British thermal unit (ISO/TC 12)	Btu (ISO)	ML ² T ⁻²	1055.06	J	1.0000	Btu
Energy, Heat, Work	British thermal unit (mean)	Btu (mean) or Btu	ML ² T ⁻²	1055.87	J	1.0008	Btu
Energy, Heat, Work	British thermal unit (thermochemical)	Btu (therm)	ML ² T ⁻²	1054.35	J	0.99933	Btu
Energy, Heat, Work	calorie (20 °C)	cal (20 °C)	ML ² T ⁻²	4.1819	J	0.0039637	Btu
Energy, Heat, Work	calorie (4 °C)	cal (4 °C)	ML ² T ⁻²	4.2045	J	0.0039851	Btu

(continued)

Table 14.1 (continued)

Application/field	Unit name	Notation	SI dimension	SI/metric system		English/US system	
				Conversion factor	Unit	Conversion factor	Unit
Energy, Heat, Work	calorie (international steam tables)	cal (IT)	ML^2T^{-2}	4.18674	J	0.0039682	Btu
Energy, Heat, Work	calorie (mean)	cal (mean)	ML^2T^{-2}	4.19002	J	0.0039714	Btu
Energy, Heat, Work	Calorie (nutritional)	Cal (nutr)	ML^2T^{-2}	4184	J	3.9657	Btu
Energy, Heat, Work	calorie (thermochemical)	cal (therm)	ML^2T^{-2}	4.184	J	0.0039657	Btu
Energy, Heat, Work	Celsius heat unit	Chu	ML^2T^{-2}	1899.18	J	1.8001	Btu
Energy, Heat, Work	Celsius heat unit (15 °C)	Chu (15 °C)	ML^2T^{-2}	1899.1	J	1.8000	Btu
Energy, Heat, Work	electron volt	eV	ML^2T^{-2}	1.6022E-19	J	1.5186E-22	Btu
Energy, Heat, Work	erg	erg	ML^2T^{-2}	1.00E-07	J	9.4781E-11	Btu
Energy, Heat, Work	foot pound force (duty)	ft lb _f	ML^2T^{-2}	1.355818	J	0.0012851	Btu
Energy, Heat, Work	foot-poundal	ft pdl	ML^2T^{-2}	0.04214	J	3.9941E-05	Btu
Energy, Heat, Work	frigorie	fg	ML^2T^{-2}	-4.19E+03	J	-3.9671	Btu
Energy, Heat, Work	hartree (atomic unit of energy)	E _H a.u.	ML^2T^{-2}	4.3597E-18	J	4.1322E-21	Btu
Energy, Heat, Work	joule	J	ML^2T^{-2}	1	J	0.00094781	Btu
Energy, Heat, Work	joule (international)	J (intl)	ML^2T^{-2}	1.000165	J	0.00094797	Btu
Energy, Heat, Work	kilocalorie (thermal)	kcal (therm)	ML^2T^{-2}	4184	J	3.9657	Btu
Energy, Heat, Work	kilogram force meter	kg _f m	ML^2T^{-2}	9.80665	J	0.0092949	Btu
Energy, Heat, Work	kiloton (TNT)	kt (TNT)	ML^2T^{-2}	4.18E+18	J	3.9619E+15	Btu
Energy, Heat, Work	kilowatt hour	kWh	ML^2T^{-2}	3.60E+06	J	3412.1	Btu
Energy, Heat, Work	liter atmosphere	L atm	ML^2T^{-2}	101.325	J	0.096037	Btu
Energy, Heat, Work	megaton (TNT)	Mt (TNT)	ML^2T^{-2}	4.18E+21	J	3.9619E+18	Btu
Energy, Heat, Work	pound centigrade unit (15 °C)	pcu (15 °C)	ML^2T^{-2}	1899.1	J	1.8000	Btu

(continued)

Table 14.1 (continued)

Application/field	Unit name	Notation	SI dimension	SI/metric system		English/US system	
				Conversion factor	Unit	Conversion factor	Unit
Energy, Heat, Work	prout	prout	ML^2T^{-2}	2.9638E-14	J	2.8091E-17	Btu
Energy, Heat, Work	Q unit	Q	ML^2T^{-2}	1.055E+21	J	9.9994E+17	Btu
Energy, Heat, Work	quad (quadrillion Btu)	quad	ML^2T^{-2}	1.0551E+18	J	1.0000E+15	Btu
Energy, Heat, Work	rydberg	Ry	ML^2T^{-2}	2.1799E-18	J	2.0661E-21	Btu
Energy, Heat, Work	therm (EEG)	therm (EEG)	ML^2T^{-2}	1.0551E+08	J	1.0000E+05	Btu
Energy, Heat, Work	therm (refineries)	therm (refy) or therm	ML^2T^{-2}	1.0559E+09	J	1.0008E+06	Btu
Energy, Heat, Work	therm (US)	therm (US) or therm	ML^2T^{-2}	1.0548E+08	J	9.9976E+04	Btu
Energy, Heat, Work	ton coal equivalent	tce (tec)	ML^2T^{-2}	2.929E+08	J	2.7761E+05	Btu
Energy, Heat, Work	ton oil equivalent	toe (tep)	ML^2T^{-2}	4.187E+08	J	3.9685E+05	Btu
Force	crinal	crinal	MLT^{-2}	0.1	N	0.022481	lb _f
Force	dyne	dyn	MLT^{-2}	0.00001	N	2.2481E-06	lb _f
Force	funal	funal	MLT^{-2}	1000	N	224.81	lb _f
Force	kilogram force	kg _f	MLT^{-2}	9.80665	N	2.2046	lb _f
Force	kip force	kip _f	MLT^{-2}	4448.22	N	1000.0	lb _f
Force	newton	N	MLT^{-2}	1	N	0.22481	lb _f
Force	ounce force	oz _f or oz	MLT^{-2}	0.27801385	N	0.062500	lb _f
Force	pond	p	MLT^{-2}	0.0098066	N	0.0022046	lb _f
Force	pound force	lb _f or lb	MLT^{-2}	4.4482216	N	1.0000	lb _f
Force	poundal	pdl	MLT^{-2}	0.13825495	N	0.031081	lb _f
Force	slug force	slug _f	MLT^{-2}	143.117	N	32.174	lb _f
Force	sthène	sn	MLT^{-2}	1000	N	224.81	lb _f

(continued)

Table 14.1 (continued)

Application/field	Unit name	Notation	SI dimension	SI/metric system		English/US system	
				Conversion factor	Unit	Conversion factor	Unit
Force	ton (force, long)	LT	MLT^{-2}	9964.016	N	2240.0	lb _f
Force	ton (force, metric)	MT	MLT^{-2}	9806.65	N	2204.6	lb _f
Force	ton (force, short)	T	MLT^{-2}	8896.44	N	2000.0	lb _f
Force (Body)	dyne per cubic centimeter	dyn/cc or dyn/cm ³	$MLT^{-2}L^{-3}$	10	N/m ³	0.063659	lb _f /cft
Force (Body)	kilogram force per cubic centimeter	kg/cm ³	$MLT^{-2}L^{-3}$	9.8067E+06	N/m ³	62428.0	lb _f /cft
Force (Body)	kilogram force per cubic meter	kg/m ³	$MLT^{-2}L^{-3}$	9.80665	N/m ³	0.062428	lb _f /cft
Force (Body)	newton per cubic meter	N/m ³	$MLT^{-2}L^{-3}$	1	N/m ³	0.0063659	lb _f /cft
Force (Body)	pound force per cubic foot	lb _f /cft	$MLT^{-2}L^{-3}$	157.087	N/m ³	1	lb _f /cft
Force (Body)	pound force per cubic inch	lb _f /cu.in.	$MLT^{-2}L^{-3}$	2.7145E+05	N/m ³	1728	lb _f /cft
Force (Body)	ton force per cubic foot	ton _f /cft	$MLT^{-2}L^{-3}$	3.5188E+05	N/m ³	2240	lb _f /cft
Force per Unit Mass	dyne per gram	dyn/g	LT^{-2}	0.01	N/kg	0.0010197	lb _f /lb _m
Force per Unit Mass	kilogram force per kilogram	kg/kg	LT^{-2}	9.80665	N/kg	1	lb _f /lb _m
Force per Unit Mass	newton per kilogram	N/kg	LT^{-2}	1	N/kg	0.10197	lb _f /lb _m
Force per Unit Mass	pound force per pound mass	lb _f /lb or lb _f /lb _m	LT^{-2}	9.80665	N/kg	1	lb _f /lb _m
Force per Unit Mass	pound force per slug	lb _f /slug	LT^{-2}	0.3048	N/kg	0.031081	lb _f /lb _m
Frequency Voltage Ratio	cycles per second per volt	cycle/(sec V)	$T^3AM^{-1}L^{-2}$	1	Hz/V	1	cycle/(sec V)
Frequency Voltage Ratio	hertz per volt	Hz/V	$T^3AM^{-1}L^{-2}$	1	Hz/V	1	cycle/(sec V)
Frequency Voltage Ratio	terahertz per volt	THz/V	$T^3AM^{-1}L^{-2}$	1.00E+12	Hz/V	1.00E+12	cycle/(sec V)
Fuel Consumption	100 km per liter	100 km/l	L^{-2}	100	km/l	235.21	mpg (US)

(continued)

Table 14.1 (continued)

Application/field	Unit name	Notation	SI dimension	SI/metric system		English/US system	
				Conversion factor	Unit	Conversion factor	Unit
Fuel Consumption	gallons (UK) per 100 miles	gal (UK)/100 mi	L ²	35.4	km/l	83.267	mpg (US)
Fuel Consumption	gallons (US) per 100 miles	gal (US)/100 mi	L ²	42.51	km/l	100	mpg (US)
Fuel Consumption	kilometers per gallon (UK)	km/gal (UK)	L ⁻²	0.21997	km/l	0.51740	mpg (US)
Fuel Consumption	kilometers per gallon (US)	km/gal(US)	L ⁻²	0.26417	km/l	0.62137	mpg (US)
Fuel Consumption	kilometers per liter	km/l	L ⁻²	1	km/l	2.3521	mpg (US)
Fuel Consumption	liters per 100 km	l/100 km	L ²	100	km/l	235.21	mpg (US)
Fuel Consumption	liters per kilometer	l/km	L ²	1	km/l	2.3521	mpg (US)
Fuel Consumption	meters per gallon (UK)	m/gal (UK)	L ⁻²	2.1997E-04	km/l	0.00051740	mpg (US)
Fuel Consumption	meters per gallon (US)	l/gal (US)	L ⁻²	2.2642E-04	km/l	0.00062137	mpg (US)
Fuel Consumption	miles per gallon (UK)	mi/gal (UK) or mpg (UK)	L ⁻²	0.35401	km/l	0.83267	mpg (US)
Fuel Consumption	miles per gallon (US)	mi/gal (US) or mpg (US)	L ⁻²	0.42514	km/l	1	mpg (US)
Fuel Consumption	miles per liter	mi/l	L ⁻²	1.6093	km/l	3.7854	mpg (US)
Heat of Combustion	British thermal unit per pound	Btu/lb	L ² T ⁻²	2326	J/kg	1	Btu/lb
Heat of Combustion	calorie per gram	cal/g	L ² T ⁻²	4186	J/kg	1.7997	Btu/lb
Heat of Combustion	Chu per pound	Chu/lb	L ² T ⁻²	4186.8	J/kg	1.8	Btu/lb
Heat of Combustion	joule per kilogram	J/kg	L ² T ⁻²	1	J/kg	0.00042992	Btu/lb
Heat of Fusion	British thermal unit (mean) per pound	Btu (mean)/lb	L ² T ⁻²	2327.79	J/kg	1.0008	Btu/lb
Heat of Fusion	British thermal unit per pound	Btu/lb	L ² T ⁻²	2326	J/kg	1	Btu/lb
Heat of Fusion	calorie per gram	cal/g	L ² T ⁻²	4186	J/kg	1.7997	Btu/lb

(continued)

Table 14.1 (continued)

Application/field	Unit name	Notation	SI dimension	SI/metric system		English/US system	
				Conversion factor	Unit	Conversion factor	Unit
Heat of Fusion	Chu per pound	Chu/lb	$L^2 T^{-2}$	4186.8	J/kg	1.8	Btu/lb
Heat of Fusion	joule per kilogram	J/kg	$L^2 T^{-2}$	1	J/kg	0.00042992	Btu/lb
Heat of Vaporization	British thermal unit per pound	Btu/lb	$L^2 T^{-2}$	2326	J/kg	1	Btu/lb
Heat of Vaporization	calorie per gram	cal/g	$L^2 T^{-2}$	4186	J/kg	1.7997	Btu/lb
Heat of Vaporization	Chu per pound	Chu/lb	$L^2 T^{-2}$	4186.8	J/kg	1.8	Btu/lb
Heat of Vaporization	joule per kilogram	J/kg	$L^2 T^{-2}$	1	J/kg	0.00042992	Btu/lb
Heat Transfer Coefficient	Btu per square foot per hour per degree Fahrenheit (or Rankine)	Btu/(ft ² h °F)	$MT^{-3}\theta^{-1}$	5.679	W/(m ² °C)	1	Btu/(ft ² h °F)
Heat Transfer Coefficient	watt per square meter per degree Celsius (or kelvin)	W/(m ² °C)	$MT^{-3}\theta^{-1}$	1	W/(m ² °C)	0.1762	Btu/(ft ² h °F)
Illuminance	foot-candle	ft-C or ft-Cd	JL^{-2}	10.76391	lx	1	ft-Cd
Illuminance	lux	lx	JL^{-2}	1	lx	0.0929030	ft-Cd
Illuminance	nox	nox	JL^{-2}	1.00E-03	lx	9.2903E-05	ft-Cd
Illuminance	phot	ph	JL^{-2}	1.00E+04	lx	929.03	ft-Cd
Illuminance	skot	skot	JL^{-2}	1.00E-03	lx	9.2903E-05	ft-Cd
Kinetic Energy of Turbulence	square foot per second squared	ft ² /s ² or sqft/sec ²	$L^2 T^{-2}$	0.0929	m ² /s ²	1	ft ² /s ²
Kinetic Energy of Turbulence	square meters per second squared	m ² /s ²	$L^2 T^{-2}$	1	m ² /s ²	10.764	ft ² /s ²
Length	ångström	Å	L	1.00E-10	m	3.2808E-10	ft
Length	arpent (Quebec)	arp	L	58.47	m	191.83	ft
Length	astronomic unit	AU	L	1.4960E+11	m	4.9081E+11	ft
Length	attometer	am	L	1.00E-18	m	3.2808E-18	ft

(continued)

Table 14.1 (continued)

Application/field	Unit name	Notation	SI dimension	SI/metric system		English/US system	
				Conversion factor	Unit	Conversion factor	Unit
Length	calibre (centinch)	cin	L	0.000254	m	0.00083333	ft
Length	centimeter	cm	L	0.01	m	0.032808	ft
Length	chain (Engr's or Ramsden)	ch (eng or Rams)	L	30.48	m	100	ft
Length	chain (Gunter's)	ch (Gunt)	L	20.1168	m	66	ft
Length	chain (surveyors)	ch (surv)	L	20.1168	m	66	ft
Length	cubit (UK)	cu (UK)	L	0.4572	m	1.5000	ft
Length	ell	ell	L	1.143	m	3.75	ft
Length	fathom	fath	L	1.8288	m	6.0000	ft
Length	femtometre	fm	L	1.00E-15	m	3.2808E-15	ft
Length	fermi	F	L	1.00E-15	m	3.2808E-15	ft
Length	foot	ft	L	0.3048	m	1.0000	ft
Length	furlong (UK and US)	fur	L	201.168	m	660	ft
Length	inch	in	L	0.0254	m	0.0833	ft
Length	kilometer	km	L	1000	m	3280.84	ft
Length	league (US, statute)	lg (US, stat)	L	4828	m	15839.9	ft
Length	lieue (metric)	lieue (metric)	L	4000	m	13123.4	ft
Length	ligne (metric)	ligne (metric)	L	0.0023	m	0.007546	ft
Length	line (US)	li (US)	L	0.000635	m	0.0020833	ft
Length	link (surveyors)	li (surv)	L	0.201168	m	0.6600	ft
Length	meter	m	L	1	m	3.2808	ft
Length	micrometer	µm	L	0.000001	m	3.2808E-06	ft
Length	micron	µ	L	0.000001	m	3.2808E-06	ft

(continued)

Table 14.1 (continued)

Application/field	Unit name	Notation	SI dimension	SI/metric system		English/US system	
				Conversion factor	Unit	Conversion factor	Unit
Length	mil	mil	L	0.0000254	m	0.000083333	ft
Length	mile (geographical)	mi	L	7421.59	m	24349.0	ft
Length	mile (US, nautical)	mi (US, naut)	L	1853.2	m	6080.1	ft
Length	mile (US, statute)	mi	L	1609.344	m	5280.0	ft
Length	mile (US, survey)	mi (US, surv)	L	1609.3	m	5279.9	ft
Length	millimeter	mm	L	0.001	m	0.0032808	ft
Length	millimicron	mμ	L	1.00E-09	m	3.2808E-09	ft
Length	nanometer or nanon	nm	L	0.000000001	m	3.2808E-09	ft
Length	parsec	pc	L	3.0860E+16	m	1.0125E+17	ft
Length	perche	rod	L	5.0292	m	16.5	ft
Length	pica	pica	L	0.0042175	m	0.013837	ft
Length	picometer	pm	L	1.00E-12	m	3.2808E-12	ft
Length	point (Didot)	pt (Didot)	L	0.00037597	m	0.0012335	ft
Length	point (US)	pt (US)	L	0.00035146	m	0.0011531	ft
Length	rod or pole	rod	L	5.0292	m	16.5	ft
Length	span	span	L	0.2286	m	0.75	ft
Length	thou (millinch)	thou	L	0.0000254	m	0.000083333	ft
Length	toise (metric)	toise (metric)	L	2	m	6.562	ft
Length	yard	yd	L	0.9144	m	3.0000	ft
Linear Mass Density	denier	denier	ML ⁻¹	1.111E-07	kg/m	7.4664E-08	lb/ft
Linear Mass Density	kilogram per centimeter	kg/cm	ML ⁻¹	100	kg/m	67.204	lb/ft
Linear Mass Density	kilogram per meter	kg/m	ML ⁻¹	1	kg/m	0.67204	lb/ft

(continued)

Table 14.1 (continued)

Application/field	Unit name	Notation	SI dimension	SI/metric system		English/US system	
				Conversion factor	Unit	Conversion factor	Unit
Linear Mass Density	pound per foot	lb/ft	ML^{-1}	1.488	kg/m	1.0000	lb/ft
Linear Mass Density	pound per inch	lb/in	ML^{-1}	17.858	kg/m	12.00	lb/ft
Linear Mass Density	pound per yard	lb/yd	ML^{-1}	0.49606	kg/m	0.33337	lb/ft
Linear Mass Density	ton (metric) per kilometer	t/km or MT/km	ML^{-1}	1	kg/m	0.67204	lb/ft
Linear Mass Density	ton (metric) per meter	t/m or MT/m	ML^{-1}	1000	kg/m	672.04	lb/ft
Linear Momentum	foot pounds force per hour	ft lb _f /h or ft-lb/hr	MLT^{-1}	3.84E-05	kg m/s	2.7779E-04	ft-lb/sec
Linear Momentum	foot pounds force per minute	ft lb _f /min or ft-lb/min	MLT^{-1}	0.0023042	kg m/s	0.016667	ft-lb/sec
Linear Momentum	foot pounds force per second	ft lb _f /s or ft-lb/sec	MLT^{-1}	0.13825	kg m/s	1	ft-lb/sec
Linear Momentum	gram centimeters per second	g cm/s	MLT^{-1}	1.00E-05	kg m/s	7.2333E-05	ft-lb/sec
Linear Momentum	kilogram meters per second	kg m/s	MLT^{-1}	1	kg m/s	7.2333	ft-lb/sec
Luminance (self)	apostilb	asb	JL^{-2}	0.31831	cd/m ²	1.00E-04	L
Luminance (self)	blondel	Bl	JL^{-2}	0.31831	cd/m ²	1.00E-04	L
Luminance (self)	candela per square meter	cd/m ²	JL^{-2}	1	cd/m ²	3.1416E-04	L
Luminance (self)	foot-lambert	ft-L	JL^{-2}	3.426259	cd/m ²	0.0010764	L
Luminance (self)	lambert	L	JL^{-2}	3183.1	cd/m ²	1	L
Luminance (self)	luxon	luxon	JL^{-2}	1.00E+04	cd/m ²	3.14159	L
Luminance (self)	nit	nit	JL^{-2}	1	cd/m ²	3.1416E-04	L
Luminance (self)	stilb	sb	JL^{-2}	1.00E+04	cd/m ²	3.14159	L
Luminance (self)	troland	luxon	JL^{-2}	1.00E+04	cd/m ²	3.14159	L
Luminous Flux	candela steradian	cd sr	J	1	lumen		
Luminous Flux	lumen	lumen	J	1	lumen		

(continued)

Table 14.1 (continued)

Application/field	Unit name	Notation	SI dimension	SI/metric system		English/US system	
				Conversion factor	Unit	Conversion factor	Unit
Luminous Intensity	candela	cd	J	1	cd	0.981	Cd (int)
Luminous Intensity	candle (international)	Cd (int)	J	1.01937	cd	1	Cd (int)
Luminous Intensity	carcel	carcel	J	10	cd	9.81	Cd (int)
Luminous Intensity	Hefner unit	HK	J	0.903	cd	0.886	Cd (int)
Magnetic Field	ampere per meter	A/m	AL ⁻¹	1	A/m	0.3048	A/ft
Magnetic Field	lenz	lenz	AL ⁻¹	1	A/m	0.3048	A/ft
Magnetic Field	oersted	Oe	AL ⁻¹	79.57747	A/m	24.255	A/ft
Magnetic Field	praoersted	–	AL ⁻¹	11459.08	A/m	3492.7	A/ft
Magnetic Flux	kapp line	–	ML ² T ⁻² A ⁻¹	6.00E-05	Wb	6.00E-05	Wb
Magnetic Flux	line	line	ML ² T ⁻² A ⁻¹	1.00E-08	Wb	1.00E-08	Wb
Magnetic Flux	maxwell	Mx	ML ² T ⁻² A ⁻¹	1.00E-08	Wb	1.00E-08	Wb
Magnetic Flux	unit pole	unit pole	ML ² T ⁻² A ⁻¹	1.2566E-07	Wb	1.2566E-07	Wb
Magnetic Flux	weber	Wb	ML ² T ⁻² A ⁻¹	1	Wb	1	Wb
Magnetic Induction Field Strength	gamma	γ	MT ⁻² A ⁻¹	1.00E-09	T	1.00E-09	T
Magnetic Induction Field Strength	gauss	G	MT ⁻² A ⁻¹	1.00E-04	T	1.00E-04	T
Magnetic Induction Field Strength	line per square centimeter	line/cm ²	MT ⁻² A ⁻¹	1.00E-04	T	1.00E-04	T
Magnetic Induction Field Strength	maxwell per square centimeter	Mx/cm ²	MT ⁻² A ⁻¹	1.00E-04	T	1.00E-04	T
Magnetic Induction Field Strength	tesla	T	MT ⁻² A ⁻¹	1	T	1	T

(continued)

Table 14.1 (continued)

Application/field	Unit name	Notation	SI dimension	SI/metric system		English/US system	
				Conversion factor	Unit	Conversion factor	Unit
Magnetic Induction Field Strength	u.a.	u.a.	$MT^{-2}A^{-1}$	2.35052E+15	T	2.35052E+15	T
Magnetic Induction Field Strength	weber per square meter	Wb/m^2	$MT^{-2}A^{-1}$	1	T	1	T
Magnetic Moment	Bohr magneton	Bohr magneton	L^2A	9.2740E-24	J/T		
Magnetic Moment	joule per tesla	J/T	L^2A	1	J/T		
Magnetic Moment	nuclear magneton	nucl. Magneton	L^2A	5.0508E-27	J/T		
Magnetic Permeability	henrys per meter	H/m	$ML^2T^{-2}A^{-2}$	1	H/m		
Magnetic Permeability	newton per square ampere	N/A^2	$ML^2T^{-2}A^{-2}$	1	H/m		
Magnetomotive Force	abampere-turn	emu egs	A	10	A	10	A
Magnetomotive Force	ampere	A	A	1	A	1	A
Magnetomotive Force	ampere-turn	A-turn	A	2864.77	A	2864.77	A
Magnetomotive Force	gilbert	Gb	A	0.79577	A	0.79577	A
Mas+8:32s	slug	sl	M	14.594	kg	32.1744	lb _m
Mass	atomic mass unit (^{12}C)	$u(^{12}C)$ or amu	M	1.66050E-27	kg	3.66079E-27	lb _m
Mass	carat (metric)	ct	M	0.0002	kg	0.0004409	lb _m
Mass	cental	sh cwt, cH	M	45.359	kg	100.00	lb _m
Mass	centigram	cg	M	0.00001	kg	2.20463E-05	lb _m
Mass	clove (UK)	cl	M	3.6287	kg	8.000	lb _m

(continued)

Table 14.1 (continued)

Application/field	Unit name	Notation	SI dimension	SI/metric system		English/US system	
				Conversion factor	Unit	Conversion factor	Unit
Mass	drachm (apothecary)	dr (ap)	M	0.0038879	kg	0.0085714	lb _m
Mass	dram (avoirdupois)	dr (av)	M	0.0017718	kg	0.0039062	lb _m
Mass	dram (troy)	dr (troy)	M	0.0038879	kg	0.0085714	lb _m
Mass	grain	gr	M	0.000064799	kg	0.00014286	lb _m
Mass	gram	g	M	0.001	kg	0.0022046	lb _m
Mass	hundredweight, long or gross	cwt, lg cwt	M	50.802	kg	112.00	lb _m
Mass	hundredweight, short or net	sh cwt	M	45.359	kg	100.00	lb _m
Mass	kilogram	kg	M	1	kg	2.2046	lb _m
Mass	kip	kip	M	453.59	kg	1000	lb _m
Mass	microgram	μg	M	0.000000001	kg	2.20463E-09	lb _m
Mass	milligram	mg	M	0.000001	kg	2.20463E-06	lb _m
Mass	ounce (apothecary)	oz (ap)	M	0.031103	kg	0.068571	lb _m
Mass	ounce (avoirdupois)	oz	M	0.02835	kg	0.06250	lb _m
Mass	ounce (troy)	oz (troy)	M	0.031103	kg	0.068571	lb _m
Mass	pennyweight (troy)	dwt (troy)	M	0.0015552	kg	0.0034286	lb _m
Mass	pood, (Russia)	pood	M	16.38	kg	36.11	lb _m
Mass	pound (apothecary)	lb (ap)	M	0.37324	kg	0.82286	lb _m
Mass	pound (avoirdupois)	lb (av)	M	0.45359	kg	1.0000	lb _m
Mass	pound (troy)	lb (troy)	M	0.37324	kg	0.82286	lb _m
Mass	pound mass	lb _m	M	0.45359	kg	1.0000	lb _m

(continued)

Table 14.1 (continued)

Application/field	Unit name	Notation	SI dimension	SI/metric system		English/US system	
				Conversion factor	Unit	Conversion factor	Unit
Mass	quarter (UK)	qt	M	12.7	kg	28.0	lb _m
Mass	quintal, metric	q, dt	M	100	kg	220.46	lb _m
Mass	quital, US	quint (US)	M	45.359	kg	100.00	lb _m
Mass	scruple (avoirdupois)	scf	M	0.001575	kg	0.003472	lb _m
Mass	stone (UK)	st	M	6.3503	kg	14.0001	lb _m
Mass	ton, metric	t	M	1000	kg	2204.6	lb _m
Mass	ton, US, long	lg ton	M	1016	kg	2239.9	lb _m
Mass	ton, US, short	sh ton	M	907.18	kg	2000	lb _m
Mass Density	gram per cubic centimeter	g/cc or g/ml	ML ⁻³	1000	kg/m ³	62.428	lb/ft ³
Mass Density	gram per cubic decimeter	g/dm ³	ML ⁻³	1	kg/m ³	0.062428	lb/ft ³
Mass Density	gram per cubic meter	g/m ³	ML ⁻³	0.001	kg/m ³	6.2428E-05	lb/ft ³
Mass Density	gram per liter	g/l or g/L	ML ⁻³	1	kg/m ³	0.062428	lb/ft ³
Mass Density	kilogram per cubic meter	kg/m ³	ML ⁻³	1	kg/m ³	0.062428	lb/ft ³
Mass Density	ounce (avdp) per US gallon	oz/gal	ML ⁻³	7.489152	kg/m ³	0.46753	lb/ft ³
Mass Density	pound (avdp) per cubic foot	lb/cu ft or lb/ft ³	ML ⁻³	16.01846	kg/m ³	1	lb/ft ³
Mass Density	pound (avdp) per US gallon	lb/gal	ML ⁻³	119.826	kg/m ³	7.4805	lb/ft ³
Mass Density	pound (mass) per cubic inch	lb/cu in or lb/in ³	ML ⁻³	0.000276799	kg/m ³	1.7280E-05	lb/ft ³
Mass Density	ton (metric) per cubic meter	t/m ³ or MT/m ³	ML ⁻³	1000	kg/m ³	62.428	lb/ft ³
Mass Flow Rate	kilograms per day	kg/d	MT ⁻¹	1.1574E-05	kg/s	2.5521E-05	lb/sec
Mass Flow Rate	kilograms per hour	kg/h	MT ⁻¹	0.00027778	kg/s	0.0006125	lb/sec
Mass Flow Rate	kilograms per minute	kg/min	MT ⁻¹	0.016667	kg/s	0.03675	lb/sec
Mass Flow Rate	kilograms per second	kg/s	MT ⁻¹	1	kg/s	2.205	lb/sec

(continued)

Table 14.1 (continued)

Application/field	Unit name	Notation	SI dimension	SI/metric system		English/US system	
				Conversion factor	Unit	Conversion factor	Unit
Mass Flow Rate	metric tons per day	MT/d or MTD	MT^{-1}	0.01157	kg/s	0.02552	lb/sec
Mass Flow Rate	metric tons per hour	MT/h or MTD	MT^{-1}	0.2778	kg/s	0.6125	lb/sec
Mass Flow Rate	metric tons per minute	MT/h	MT^{-1}	16.67	kg/s	36.75	lb/sec
Mass Flow Rate	metric tons per second	MT/s	MT^{-1}	1000	kg/s	2205	lb/sec
Mass Flow Rate	metric tons per year (365 d)	MT/yr or MTY	MT^{-1}	3.171E-05	kg/s	6.992E-05	lb/sec
Mass Flow Rate	pounds per day	lb/d or lb/da or PPD	MT^{-1}	5.2490E-06	kg/s	1.1574E-05	lb/sec
Mass Flow Rate	pounds per hour	lb/h or lb/hr or PPH	MT^{-1}	1.2598E-04	kg/s	2.7778E-04	lb/sec
Mass Flow Rate	pounds per minute	lb/min or PPM	MT^{-1}	0.0075586	kg/s	0.016667	lb/sec
Mass Flow Rate	pounds per second	lb/s or lb/sec or PPS	MT^{-1}	0.45351	kg/s	1	lb/sec
Mass Flux	kilogram per square meter per day	kg/(m ² d)	$ML^{-2}T^{-1}$	1.1574E-05	kg/(m ² s)	2.3719E-06	lb/sqft/sec
Mass Flux	kilogram per square meter per hour	kg/(m ² h)	$ML^{-2}T^{-1}$	2.7778E-04	kg/(m ² s)	5.6925E-05	lb/sqft/sec
Mass Flux	kilogram per square meter per minute	kg/(m ² min)	$ML^{-2}T^{-1}$	0.016667	kg/(m ² s)	0.0034155	lb/sqft/sec
Mass Flux	kilogram per square meter per second	kg/(m ² s)	$ML^{-2}T^{-1}$	1	kg/(m ² s)	0.20493	lb/sqft/sec
Mass Flux	pound per square foot per day	lb/(ft ² d) or lb/sqft/da	$ML^{-2}T^{-1}$	5.6478E-05	kg/(m ² s)	1.1574E-05	lb/sqft/sec
Mass Flux	pound per square foot per hour	lb/(ft ² h) or lb/sqft/hr	$ML^{-2}T^{-1}$	0.0013555	kg/(m ² s)	2.7778E-04	lb/sqft/sec
Mass Flux	pound per square foot per minute	lb/(ft ² min) or lb/sqft/min	$ML^{-2}T^{-1}$	0.081329	kg/(m ² s)	0.016667	lb/sqft/sec

(continued)

Table 14.1 (continued)

Application/field	Unit name	Notation	SI dimension	SI/metric system		English/US system	
				Conversion factor	Unit	Conversion factor	Unit
Mass Flux	pound per square foot per second	lb/(ft ² s) or lb/sqft/sec	ML ⁻² T ⁻¹	4.8797	kg/(m ² s)	1	lb/sqft/sec
Mass Fraction of “i”	grains of “i” per pound total	gr/lb	DmIs	0.00014286	kg/kg	0.00014286	lb/lb
Mass Fraction of “i”	gram of “i” per kilogram total	g/kg	DmIs	0.001	kg/kg	0.001	lb/lb
Mass Fraction of “i”	kilogram of “i” per kilogram total	kg/kg	DmIs	1	kg/kg	1	lb/lb
Mass Fraction of “i”	pound of “i” per pound total	lb/lb	DmIs	1	kg/kg	1	lb/lb
Mass Transfer Coefficient	gram per square centimeter per second	g/cm ² /s	ML ⁻² T ⁻¹	0.1	kg/m ² /s	0.20482	lb/sqft/sec
Mass Transfer Coefficient	kilogram per square meter per second	kg/m ² /s	ML ⁻² T ⁻¹	1	kg/m ² /s	2.0482	lb/sqft/sec
Mass Transfer Coefficient	pounds force per cubic foot per hour	lb _f /ft ³ /h or lb _f /cft/hr	ML ⁻² T ⁻¹	15.709	kg/m ² /s	32.175	lb/sqft/sec
Mass Transfer Coefficient	pounds mass per square foot per hour	lb/(ft ² hr) or lb/sqft/hr	ML ⁻² T ⁻¹	0.00013562	kg/m ² /s	2.7777E-04	lb/sqft/sec
Mass Transfer Coefficient	pounds mass per square foot per second	lb/(ft ² s) or lb/sqft/sec	ML ⁻² T ⁻¹	0.48824	kg/m ² /s	1	lb/sqft/sec
Molality of Solute “i”	gram moles of “i” per kilogram	mol/kg	NM ⁻¹	1	mol/kg	0.001	lb-mol/lb
Molality of Solute “i”	kilogram mols of “i” per kilogram	kmol/kg	NM ⁻¹	1000	mol/kg	1	lb-mol/lb
Molality of Solute “i”	kmols of “i” per kilogram	kmol/kg	NM ⁻¹	1000	mol/kg	1	lb-mol/lb
Molality of Solute “i”	mols of “i” per gram	mol/g	NM ⁻¹	1000	mol/kg	1	lb-mol/lb
Molality of Solute “i”	pound moles of “i” per pound mass	mole/lb (mass)	NM ⁻¹	1000	mol/kg	1	lb-mol/lb

(continued)

Table 14.1 (continued)

Application/field	Unit name	Notation	SI dimension	SI/metric system		English/US system	
				Conversion factor	Unit	Conversion factor	Unit
Molar Concentration by Mass	gram mole or mole per gram	mol/g	N	1	kmol/kg	1	lb-mol/lb
Molar Concentration by Mass	gram mole or mole per kilogram	mol/kg	N	0.001	kmol/kg	0.001	lb-mol/lb
Molar Concentration by Mass	kilogram mole or kmol per kilogram	kmol/kg	N	1	kmol/kg	1	lb-mol/lb
Molar Concentration by Mass	micromole per gram	$\mu\text{mol/g}$	N	1.00E-06	kmol/kg	1.00E-06	lb-mol/lb
Molar Concentration by Mass	millimole per gram	mmol/g	N	0.001	kmol/kg	0.001	lb-mol/lb
Molar Concentration by Mass	picomole per gram	pmol/g	N	1.00E-12	kmol/kg	1.00E-12	lb-mol/lb
Molar Concentration by Mass	pound mole per pound	lb-mol/lb or mole/lb	N	1	kmol/kg	1	lb-mol/lb
Molar Flow Rate	gram mole per day	mol/d	NT ⁻¹	4.167E-05	kmol/h	9.188E-05	lb-mol/hr
Molar Flow Rate	gram mole per hour	mol/h	NT ⁻¹	0.001	kmol/h	0.002205	lb-mol/hr
Molar Flow Rate	gram mole per minute	mol/min	NT ⁻¹	0.06	kmol/h	0.1323	lb-mol/hr
Molar Flow Rate	gram mole per second	mol/s	NT ⁻¹	3.6	kmol/h	7.938	lb-mol/hr
Molar Flow Rate	kilogram mole or kmol per day	kmol/d	NT ⁻¹	0.04167	kmol/h	0.09188	lb-mol/hr
Molar Flow Rate	kilogram mole or kmol per hour	kmol/h	NT ⁻¹	1	kmol/h	2.205	lb-mol/hr
Molar Flow Rate	kilogram mole or kmol per minute	kmol/min	NT ⁻¹	60	kmol/h	132.3	lb-mol/hr
Molar Flow Rate	kilogram mole or kmol per second	kmol/s	NT ⁻¹	3600	kmol/h	7938	lb-mol/hr

(continued)

Table 14.1 (continued)

Application/field	Unit name	Notation	SI dimension	SI/metric system		English/US system	
				Conversion factor	Unit	Conversion factor	Unit
Molar Flow Rate	pound mole or lb-mol per day	lb-mol/d or mole/da	NT^{-1}	0.01890	kmol/h	0.04167	lb-mol/hr
Molar Flow Rate	pound mole or lb-mol per hour	lb-mol/h or mole/hr	NT^{-1}	0.4535	kmol/h	1	lb-mol/hr
Molar Flow Rate	pound mole or lb-mol per minute	lb-mol/min or mole/min	NT^{-1}	27.21	kmol/h	60	lb-mol/hr
Molar Flow Rate	pound mole or lb-mol per second	lb-mol/s or mole/sec	NT^{-1}	1633	kmol/h	3600	lb-mol/hr
Molar Flux	kmol per square meter per day	kmol/(m ² d)	$\text{NL}^{-2}\text{T}^{-1}$	1.1574E-05	kmol/(m ² s)	2.3719E-06	lb-mole/sqft/sec
Molar Flux	kmol per square meter per hour	kmol/(m ² h)	$\text{NL}^{-2}\text{T}^{-1}$	2.7778E-04	kmol/(m ² s)	5.6925E-05	lb-mole/sqft/sec
Molar Flux	kmol per square meter per minute	kmol/(m ² amin)	$\text{NL}^{-2}\text{T}^{-1}$	0.016667	kmol/(m ² s)	0.0034155	lb-mole/sqft/sec
Molar Flux	kmol per square meter per second	kmol/(m ² s)	$\text{NL}^{-2}\text{T}^{-1}$	1	kmol/(m ² s)	0.20493	lb-mole/sqft/sec
Molar Flux	pound mole per square foot per day	lb-mol/(ft ² d) or mole/sqft/da	$\text{NL}^{-2}\text{T}^{-1}$	5.6478E-05	kmol/(m ² s)	1.1574E-05	lb-mole/sqft/sec
Molar Flux	pound mole per square foot per hour	lb-mol/(ft ² h) or mole/sqft/hr	$\text{NL}^{-2}\text{T}^{-1}$	0.0013555	kmol/(m ² s)	2.7778E-04	lb-mole/sqft/sec
Molar Flux	pound mole per square foot per minute	lb-mol/(ft ² min) or mole/sqft/min	$\text{NL}^{-2}\text{T}^{-1}$	0.081329	kmol/(m ² s)	0.016667	lb-mole/sqft/sec
Molar Flux	pound mole per square foot per second	lb-mol/(ft ² s) or mole/sqft/sec	$\text{NL}^{-2}\text{T}^{-1}$	4.8797	kmol/(m ² s)	1	lb-mole/sqft/sec
Molar Heat Capacity	Btu per pound mole per degree Fahrenheit (or degree Rankine)	Btu/lb-mol/°F	$\text{L}^2\text{N}^{-1}\text{T}^{-2}\theta^{-1}$	4.1868	J/(mol K)	1	Btu/lb-mol/°F

(continued)

Table 14.1 (continued)

Application/field	Unit name	Notation	SI dimension	SI/metric system		English/US system	
				Conversion factor	Unit	Conversion factor	Unit
Molar Heat Capacity	calories per gram mole per kelvin (or degree Celsius)	cal/(mol K)	$L^2N^{-1}T^{-2}\theta^{-1}$	4.1868	J/(mol K)	1	Btu/lb-mol/°F
Molar Heat Capacity	joule per gram mole per kelvin (or degree Celsius)	J/(mol K)	$L^2N^{-1}T^{-2}\theta^{-1}$	1	J/(mol K)	0.23885	Btu/lb-mol/°F
Molarity of “i”	gram moles of “i” per cubic meter	mol/m ³ or c _i	NL ⁻³	1	mol/m ³	1.2846E-05	lb mol/ft ³
Molarity of “i”	gram moles of “i” per liter	mol/l	NL ⁻³	1000	mol/m ³	0.012846	lb mol/ft ³
Molarity of “i”	kilogram moles of “i” per cubic meter	kmol/m ³	NL ⁻³	1000	mol/m ³	0.012846	lb mol/ft ³
Molarity of “i”	kilogram moles of “i” per liter	kmol/l	NL ⁻³	1,000,000	mol/m ³	12.8462	lb mol/ft ³
Molarity of “i”	pound moles of “i” per cubic foot	lb mol/ft ³ or mole/cft	NL ⁻³	77,844	mol/m ³	1.0000	lb mol/ft ³
Molarity of “i”	pound moles of “i” per gallon (US)	lb mol/gal or mole/gal	NL ⁻³	10,406	mol/m ³	0.13368	lb mol/ft ³
Mole Fraction of “i”	gram mole of “i” per gram mole total	mol/mol	Dmils	1	mol/mol	1	lb mol/lb mol
Mole Fraction of “i”	kilogram mole of “i” per kilogram mole total	kmol/kmol	Dmils	1	mol/mol	1	lb mol/lb mol
Mole Fraction of “i”	kilomole of “i” per kilomole total	kmol/kmol	Dmils	1	mol/mol	1	lb mol/lb mol
Mole Fraction of “i”	pound mole of “i” per pound mole total	lb mol/lb mol	Dmils	1	mol/mol	1	lb mol/lb mol
Moment of Inertia	gram force centimeter square second	g cm ² s ²	ML ²	9.8067E-05	kg m ²	0.0023272	lb sq ft
Moment of Inertia	gram square centimeter	g cm ²	ML ²	1.00E-07	kg m ²	2.3730E-06	lb sq ft

(continued)

Table 14.1 (continued)

Application/field	Unit name	Notation	SI dimension	SI/metric system		English/US system	
				Conversion factor	Unit	Conversion factor	Unit
Moment of Inertia	kilogram force centimeter square second	$\text{kg}_f \text{ cm s}^2$	ML^2	0.098067	kg m^2	2.3272	lb sq ft
Moment of Inertia	kilogram force meter square second	$\text{kg}_f \text{ m s}^2$	ML^2	9.8067	kg m^2	232.72	lb sq ft
Moment of Inertia	kilogram square centimeter	kg cm^2	ML^2	$1.00\text{E}-04$	kg m^2	0.0023730	lb sq ft
Moment of Inertia	kilogram square meter	kg m^2	ML^2	1	kg m^2	23.730	lb sq ft
Moment of Inertia	ounce force inch square second	$\text{oz}_f \text{ in s}^2$	ML^2	0.0070616	kg m^2	0.16757	lb sq ft
Moment of Inertia	ounce mass square inch	oz in^2	ML^2	$1.8290\text{E}-05$	kg m^2	$4.3403\text{E}-04$	lb sq ft
Moment of Inertia	pound mass square foot	lb ft^2 or lb sq ft	ML^2	0.04214	kg m^2	1	lb sq ft
Moment of Inertia	pound mass square inch	lb in^2	ML^2	$2.9264\text{E}-04$	kg m^2	0.0069444	lb sq ft
Momentum Flow Rate	foot pounds per square hour	ft lb/h^2 or ft lb/hr^2	MLT^{-2}	$1.0671\text{E}-08$	kg m/s^2	$7.7160\text{E}-08$	ft lb/sec^2
Momentum Flow Rate	foot pounds per square minute	ft lb/min^2	MLT^{-2}	$3.8417\text{E}-05$	kg m/s^2	$2.7778\text{E}-04$	ft lb/sec^2
Momentum Flow Rate	foot pounds per square second	ft lb/s^2 or ft lb/sec^2	MLT^{-2}	0.1383	kg m/s^2	1	ft lb/sec^2
Momentum Flow Rate	gram centimeters per square second	g cm/s^2	MLT^{-2}	$1.00\text{E}-05$	kg m/s^2	$7.2307\text{E}-05$	ft lb/sec^2
Momentum Flow Rate	kilogram meters per square second	kg m/s^2	MLT^{-2}	1	kg m/s^2	7.2307	ft lb/sec^2
Momentum Flux	dynes per square centimeter	dyn/cm^2	$\text{ML}^{-1}\text{T}^{-2}$	10	N/m^2	0.020886	$\text{lb}_f/\text{sq ft}$
Momentum Flux	gram per centimeter per square second	g/cm/s^2	$\text{ML}^{-1}\text{T}^{-2}$	10	N/m^2	0.020886	$\text{lb}_f/\text{sq ft}$

(continued)

Table 14.1 (continued)

Application/field	Unit name	Notation	SI dimension	SI/metric system		English/US system	
				Conversion factor	Unit	Conversion factor	Unit
Momentum Flux	newton per square meter	N/m^2	$\text{ML}^{-1}\text{T}^{-2}$	1	N/m^2	0.0020886	$\text{lb}_f/\text{sq ft}$
Momentum Flux	pound force per square foot	$\text{lb}_f/\text{sq ft}$	$\text{ML}^{-1}\text{T}^{-2}$	478.8	N/m^2	1	$\text{lb}_f/\text{sq ft}$
Momentum Flux	pound mass per foot per square second	$\text{lb}_m/\text{ft}/\text{s}^2$ or $\text{lb}/\text{ft}/\text{sec}^2$	$\text{ML}^{-1}\text{T}^{-2}$	14.882	N/m^2	0.03108	$\text{lb}_f/\text{sq ft}$
Normality of Solution	gram equivalents per cubic meter	eq/m^3	NL^{-3}	1	eq/m^3	1.2846E-05	$\text{lb eq}/\text{ft}^3$
Normality of Solution	gram equivalents per liter	eq/l	NL^{-3}	1000	eq/m^3	0.012846	$\text{lb eq}/\text{ft}^3$
Normality of Solution	pound equivalents per cubic foot	$\text{lb eq}/\text{ft}^3$ or $\text{lb eq}/\text{cft}$	NL^{-3}	77,844	eq/m^3	1.0000	$\text{lb eq}/\text{ft}^3$
Normality of Solution	pound equivalents per gallon	$\text{lb eq}/\text{gal}$ (US)	NL^{-3}	10,406	eq/m^3	0.13368	$\text{lb eq}/\text{ft}^3$
Particle Density	particles per cubic centimeter	part/cm^3 or part/cc	L^{-3}	10,000	part/m^3	283.21	part/ft^3
Particle Density	particles per cubic foot	part/ft^3 or part/cft	L^{-3}	35.31	part/m^3	1.000000	part/ft^3
Particle Density	particles per cubic meter	part/m^3	L^{-3}	1	part/m^3	0.028321	part/ft^3
Particle Density	particles per gallon (US)	part/gal	L^{-3}	264.14	part/m^3	7.4806	part/ft^3
Particle Density	particles per liter	part/l	L^{-3}	1000	part/m^3	28.321	part/ft^3
Particle Density	particles per milliliter	part/ml	L^{-3}	10,000	part/m^3	283.21	part/ft^3
Permeability	darcy	darcy	L^2	9.8692E-13	m^2	1.0624E-11	sq ft
Permeability	square feet	ft^2 or sq ft	L^2	0.0929	m^2	1	sq ft
Permeability	square meters	m^2	L^2	1	m^2	10.764	sq ft
Photon Emission Rate	rayleigh	R	$\text{L}^{-2}\text{T}^{-1}$	1.00E+10	$1/(\text{m}^2 \text{ sec})$		
Photon Emission Rate	reciprocal square meter second	$1/(\text{m}^2 \text{ sec})$	$\text{L}^{-2}\text{T}^{-1}$	1	$1/(\text{m}^2 \text{ sec})$		
Power per Unit Mass or Specific Power	British thermal unit per hour per pound mass	$\text{Btu}/\text{h}/\text{lb}$ or $\text{Btu}/(\text{lb hr})$	L^2T^{-3}	0.64612	W/kg	1	$\text{Btu}/(\text{lb hr})$

(continued)

Table 14.1 (continued)

Application/field	Unit name	Notation	SI dimension	SI/metric system		English/US system	
				Conversion factor	Unit	Conversion factor	Unit
Power per Unit Mass or Specific Power	calorie per second per gram	cal/s/g or cal/(g sec)	L^2T^{-3}	4186.8	W/kg	6479.9	Btu/(lb hr)
Power per Unit Mass or Specific Power	kilocalorie per hour per kilogram	kcal/h/kg or kcal/(kg hr)	L^2T^{-3}	1.163	W/kg	1.8000	Btu/(lb hr)
Power per Unit Mass or Specific Power	watt per kilogram	W/kg	L^2T^{-3}	1	W/kg	1.5477	Btu/(lb hr)
Power per Unit Volume or Power Density	British thermal unit per hour per cubic foot	Btu/h/ft ³ or Btu/hr/cft	$ML^{-1}T^{-3}$	10.35	W/m ³	1	Btu/hr/cft
Power per Unit Volume or Power Density	calorie per second per cubic centimeter	cal/s/cm ³ or cal/s/cc	$ML^{-1}T^{-3}$	4.1868E+06	W/m ³	4.0452E+05	Btu/hr/cft
Power per Unit Volume or Power Density	Chu per hour per cubic foot	Chu/h/ft ³ or Chu/hr/cft	$ML^{-1}T^{-3}$	18.63	W/m ³	1.8	Btu/hr/cft
Power per Unit Volume or Power Density	kilocalorie per hour per cubic centimeter	kcal/h/cm ³ or kcal/hr/cc	$ML^{-1}T^{-3}$	1.163	W/m ³	0.11237	Btu/hr/cft
Power per Unit Volume or Power Density	kilocalorie per hour per cubic foot	kcal/h/ft ³ or kcal/hr/cft	$ML^{-1}T^{-3}$	41.071	W/m ³	3.9682	Btu/hr/cft
Power per Unit Volume or Power Density	kilocalorie per second per cubic centimeter	kcal/s/cm ³ or kcal/s/cc	$ML^{-1}T^{-3}$	4.1868E+09	W/m ³	4.0452E+08	Btu/hr/cft

(continued)

Table 14.1 (continued)

Application/field	Unit name	Notation	SI dimension	SI/metric system		English/US system	
				Conversion factor	Unit	Conversion factor	Unit
Power per Unit Volume or Power Density	watt per cubic meter	W/m^3	$\text{ML}^{-1}\text{T}^{-3}$	1	W/m^3	0.096618	Btu/hr/cft
Power, Thermal Duty	abwatt (emu of power)	emu	ML^2T^{-3}	$1.00\text{E}-08$	W	$3.40951\text{E}-08$	Btu/hr
Power, Thermal Duty	boiler horsepower	HP (boiler)	ML^2T^{-3}	9809.5	W	$3.34456\text{E}+04$	Btu/hr
Power, Thermal Duty	British thermal unit (mean) per hour	Btu (mean)/hr or Btu/hr	ML^2T^{-3}	0.293297	W	1.00000	Btu/hr
Power, Thermal Duty	British thermal unit (mean) per minute	Btu/min or Btu (mean)/min	ML^2T^{-3}	17.597833	W	60.000	Btu/hr
Power, Thermal Duty	British thermal unit (thermochemical) per hour	Btu (therm)/hr or Btu/hr	ML^2T^{-3}	0.292875	W	0.99856	Btu/hr
Power, Thermal Duty	British thermal unit (thermochemical) per minute	Btu/min or Btu (therm)/min	ML^2T^{-3}	17.5725	W	59.914	Btu/hr
Power, Thermal Duty	calorie (mean) per hour	cal (mean)/hr	ML^2T^{-3}	0.00116389	W	0.0039683	Btu/hr
Power, Thermal Duty	calorie (thermochemical) per hour	cal (therm)/hr	ML^2T^{-3}	0.00116222	W	0.0039626	Btu/hr
Power, Thermal Duty	donkey erg per second	donkey erg/s	ML^2T^{-3}	250	W	852.38	Btu/hr
Power, Thermal Duty	foot pondal per second	ft pdl/s	ML^2T^{-3}	$1.00\text{E}-07$	W	$3.40951\text{E}-07$	Btu/hr
Power, Thermal Duty	foot pound force per hour	ft lb _f /hr	ML^2T^{-3}	0.04214	W	0.14368	Btu/hr
Power, Thermal Duty	foot pound force per minute	ft lb _f /min	ML^2T^{-3}	$3.7044\text{E}-04$	W	0.0012630	Btu/hr
Power, Thermal Duty	foot pound force per second	ft lb _f /s	ML^2T^{-3}	0.022597	W	0.077045	Btu/hr

(continued)

Table 14.1 (continued)

Application/field	Unit name	Notation	SI dimension	SI/metric system		English/US system	
				Conversion factor	Unit	Conversion factor	Unit
Power, Thermal Duty	horsepower (550 ft lb _f /s)	HP	ML ² T ⁻³	745.7	W	2542.5	Btu/hr
Power, Thermal Duty	horsepower (electric)	HP (elect)	ML ² T ⁻³	746	W	2543.5	Btu/hr
Power, Thermal Duty	horsepower (UK)	HP (UK)	ML ² T ⁻³	745.7	W	2542.5	Btu/hr
Power, Thermal Duty	kcal per hour	kcal/hr	ML ² T ⁻³	1.16389	W	3.96830	Btu/hr
Power, Thermal Duty	kilogram force meter per second	kg _f m/s	ML ² T ⁻³	9.80665	W	33.436	Btu/hr
Power, Thermal Duty	kilowatt	kW	ML ² T ⁻³	1000	W	3409.5	Btu/hr
Power, Thermal Duty	megawatt	MW	ML ² T ⁻³	1,000,000	W	3,409,51E+06	Btu/hr
Power, Thermal Duty	metric horsepower	HP (metric)	ML ² T ⁻³	735.499	W	2507.7	Btu/hr
Power, Thermal Duty	million British thermal units per hour (petroleum)	MMBtu/hr	ML ² T ⁻³	293,297	W	1.00000E+06	Btu/hr
Power, Thermal Duty	million kilocalorie per hour	MM kcal/hr	ML ² T ⁻³	1,163,890	W	3.96830E+06	Btu/hr
Power, Thermal Duty	prony	prony	ML ² T ⁻³	98.0665	W	334.36	Btu/hr
Power, Thermal Duty	ton of refrigeration (US)	CTR (US)	ML ² T ⁻³	3516.8	W	1.19906E+04	Btu/hr
Power, Thermal Duty	ton or refrigeration (UK)	CTR (UK)	ML ² T ⁻³	3922.7	W	1.33745E+04	Btu/hr
Power, Thermal Duty	volt-ampere	V/A	ML ² T ⁻³	1	W	3.40951	Btu/hr
Power, Thermal Duty	water horsepower	HP (water)	ML ² T ⁻³	746.043	W	2543.6	Btu/hr
Power, Thermal Duty	watt	W	ML ² T ⁻³	1	W	3.40951	Btu/hr
Power, Thermal Duty	watt (international, mean)	W (int, mean)	ML ² T ⁻³	1.00019	W	3.41016	Btu/hr
Power, Thermal Duty	watt (international, US)	watt (int, US)	ML ² T ⁻³	1.000165	W	3.41008	Btu/hr

(continued)

Table 14.1 (continued)

Application/field	Unit name	Notation	SI dimension	SI/metric system		English/US system	
				Conversion factor	Unit	Conversion factor	Unit
Pressure	atmosphere, standard	atm	$\text{ML}^{-1}\text{T}^{-2}$	101,325	Pa	14.696	lb_f/in^2
Pressure	bar	bar	$\text{ML}^{-1}\text{T}^{-2}$	1.00E+05	Pa	14.504	lb_f/in^2
Pressure	barye	barye	$\text{ML}^{-1}\text{T}^{-2}$	0.1	Pa	1.4504E-05	lb_f/in^2
Pressure	dyne per square centimeter	dyn/cm^2	$\text{ML}^{-1}\text{T}^{-2}$	0.1	Pa	1.4504E-05	lb_f/in^2
Pressure	foot of mercury (60 °F)	ft Hg (60 °F)	$\text{ML}^{-1}\text{T}^{-2}$	4.0526E+04	Pa	5.8778	lb_f/in^2
Pressure	foot of water (60 °F)	ft H ₂ O (60 °F)	$\text{ML}^{-1}\text{T}^{-2}$	2.9890E+03	Pa	0.43352	lb_f/in^2
Pressure	gigapascal	GPa	$\text{ML}^{-1}\text{T}^{-2}$	1.00E+09	Pa	145,038	lb_f/in^2
Pressure	hectopascal	hPa	$\text{ML}^{-1}\text{T}^{-2}$	100	Pa	0.014504	lb_f/in^2
Pressure	inch of mercury (60 °F)	in Hg (60 °F)	$\text{ML}^{-1}\text{T}^{-2}$	3.3864E+03	Pa	0.49115	lb_f/in^2
Pressure	inch of water (60 °F)	in H ₂ O (60 °F)	$\text{ML}^{-1}\text{T}^{-2}$	248.845	Pa	0.036092	lb_f/in^2
Pressure	kilogram force per square centimeter	at or kg_f/cm^2	$\text{ML}^{-1}\text{T}^{-2}$	9.8067E+04	Pa	14.223	lb_f/in^2
Pressure	kilogram force per square meter	kg_f/m^2	$\text{ML}^{-1}\text{T}^{-2}$	9.80665	Pa	0.0014223	lb_f/in^2
Pressure	kip force per square inch	KSI or ksi or kip/in^2	$\text{ML}^{-1}\text{T}^{-2}$	6.8948E+06	Pa	1000	lb_f/in^2
Pressure	megapascal	MPa	$\text{ML}^{-1}\text{T}^{-2}$	1.00E+06	Pa	145.04	lb_f/in^2
Pressure	meter of water (4 °C)	m H ₂ O (4 °C)	$\text{ML}^{-1}\text{T}^{-2}$	9.8064E+03	Pa	1.4223	lb_f/in^2
Pressure	microbar	μbar	$\text{ML}^{-1}\text{T}^{-2}$	0.1	Pa	1.4504E-05	lb_f/in^2
Pressure	millibar	mbar	$\text{ML}^{-1}\text{T}^{-2}$	100	Pa	0.014504	lb_f/in^2
Pressure	millimeter of mercury (4 °C)	mm Hg (4 °C)	$\text{ML}^{-1}\text{T}^{-2}$	133.322	Pa	0.019337	lb_f/in^2
Pressure	millimeter of water (4 °C)	mm H ₂ O (4 °C)	$\text{ML}^{-1}\text{T}^{-2}$	9.806375	Pa	0.0014223	lb_f/in^2
Pressure	newton per square meter	N/m^2	$\text{ML}^{-1}\text{T}^{-2}$	1	Pa	0.00014504	lb_f/in^2
Pressure	ounce force per square inch	OSI or osi or oz_f/in^2	$\text{ML}^{-1}\text{T}^{-2}$	430.922	Pa	0.062500	lb_f/in^2

(continued)

Table 14.1 (continued)

Application/field	Unit name	Notation	SI dimension	SI/metric system		English/US system	
				Conversion factor	Unit	Conversion factor	Unit
Pressure	pascal	Pa	$ML^{-1}T^{-2}$	1	Pa	0.00014504	lb_f/in^2
Pressure	pièze	pz	$ML^{-1}T^{-2}$	1000	Pa	0.14504	lb_f/in^2
Pressure	pound force per square foot	PSF or psf or lb_f/ft^2	$ML^{-1}T^{-2}$	47.880259	Pa	0.0069444	lb_f/in^2
Pressure	pound force per square inch	PSI or psi or lb_f/in^2	$ML^{-1}T^{-2}$	6.8948E+03	Pa	1.0000	lb_f/in^2
Pressure	torr	torr or mm Hg (0 ° C)	$ML^{-1}T^{-2}$	133.322	Pa	0.019337	lb_f/in^2
Radiation Dose Equivalent	rem	rem	L^2T^{-2}	0.01	Sv	1	rem
Radiation Dose Equivalent	sievert	Sv	L^2T^{-2}	1	Sv	100	rem
Radiation Exposure	coulomb per kilogram	C/kg	ATM^{-1}	1	C/kg	3876	R
Radiation Exposure	D unit	D unit	ATM^{-1}	0.0258	C/kg	100	R
Radiation Exposure	pastille dose (B unit)	B unit	ATM^{-1}	0.129	C/kg	500	R
Radiation Exposure	röntgen	R	ATM^{-1}	0.000258	C/kg	1	R
Radioactivity	becquerel	Bq	T^{-1}	1	Bq	2.7027E-11	Ci
Radioactivity	curie	Ci	T^{-1}	3.70E+10	Bq	1	Ci
Radioactivity	Mache unit	Mache	T^{-1}	13.32	Bq	3.5676E-10	Ci
Radioactivity	rutherford	Rd	T^{-1}	1.00E+06	Bq	2.7027E-05	Ci
Radioactivity	stat	stat	T^{-1}	1.34E-16	Bq	3.6300E-27	Ci
Second Moment of Area	inch quadrupled	in^4	L^4	4.1623E-07	m^4	4.8225E-05	ft^4
Second Moment of Area	centimeter quadrupled	cm^4	L^4	1.00E-08	m^4	1.1586E-06	ft^4

(continued)

Table 14.1 (continued)

Application/field	Unit name	Notation	SI dimension	SI/metric system		English/US system	
				Conversion factor	Unit	Conversion factor	Unit
Second Moment of Area	foot quadrupled	ft ⁴	L ⁴	0.0086310	m ⁴	1	ft ⁴
Second Moment of Area	meter quadrupled	m ⁴	L ⁴	1	m ⁴	115.86	ft ⁴
Second Radiation Constant (Planck)	meter kelvin	m K	L θ	1	m K		
Specific Enthalpy	British thermal unit (mean) per pound	Btu (mean)/lb	L ² T ⁻²	2327.8	J/kg	1.0014	Btu/lb
Specific Enthalpy	British thermal unit per pound	Btu/lb	L ² T ⁻²	2324.4	J/kg	1	Btu/lb
Specific Enthalpy	calorie per gram	cal/g	L ² T ⁻²	4186.8	J/kg	1.8012	Btu/lb
Specific Enthalpy	Chu per pound	Chu/lb	L ² T ⁻²	4186.8	J/kg	1.8012	Btu/lb
Specific Enthalpy	joule per kilogram	J/kg	L ² T ⁻²	1	J/kg	4.3021E-04	Btu/lb
Specific Enthalpy	kilojoule per kilogram	kJ/kg	L ² T ⁻²	1000	J/kg	0.43021	Btu/lb
Specific Gravity	Dimensionless	Dmils	Dmils	1	Dmils	1	Dmils
Specific Heat Capacity (Constant Pressure)	Btu per pound per degree Fahrenheit (or degree Rankine)	Btu/(lb °F)	L ² MT ⁻² θ^{-1}	4186.8	J/(kg K)	1	Btu/(lb °F)
Specific Heat Capacity (Constant Pressure)	calories per gram per kelvin (or degree Celsius)	cal/(g K)	L ² MT ⁻² θ^{-1}	4186.8	J/(kg K)	1	Btu/(lb °F)
Specific Heat Capacity (Constant Pressure)	joules per kilogram per kelvin (or degree Celsius)	J/(kg K)	L ² MT ⁻² θ^{-1}	1	J/(kg K)	0.00023885	Btu/(lb °F)
Specific Length	centimeter per gram	cm/g	LM ⁻¹	10	m/kg	14.883	ft/lb

(continued)

Table 14.1 (continued)

Application/field	Unit name	Notation	SI dimension	SI/metric system		English/US system	
				Conversion factor	Unit	Conversion factor	Unit
Specific Length	cotton count	cc	LM^{-1}	5.905E+08	m/kg	8.7882E+08	ft/lb
Specific Length	ft per pound	ft/lb	LM^{-1}	0.67192	m/kg	1	ft/lb
Specific Length	meters per kilogram	m/kg	LM^{-1}	1	m/kg	1.4883	ft/lb
Specific Length	newton meter	Nm	LM^{-1}	1000	m/kg	1488.3	ft/lb
Specific Length	worsted	worsted	LM^{-1}	8.8868E+08	m/kg	1.3226E+09	ft/lb
Specific Surface	square centimeter per gram	cm^2/g	L^2M^{-1}	0.1	m^2/kg	0.48823	sq ft/lb
Specific Surface	square foot per kilogram	ft^2/kg or $sq\ ft/kg$	L^2M^{-1}	0.092903	m^2/kg	0.45358	sq ft/lb
Specific Surface	square foot per pound	ft^2/lb or $sq\ ft/lb$	L^2M^{-1}	0.20482	m^2/kg	1	sq ft/lb
Specific Surface	square meter per gram	m^2/g	L^2M^{-1}	1000	m^2/kg	4882.3	sq ft/lb
Specific Surface	square meter per kilogram	m^2/kg	L^2M^{-1}	1	m^2/kg	4.8823	sq ft/lb
Specific Volume	cubic centimeter per gram	cm^3/g or cc/g	L^3M^{-1}	0.001	m^3/kg	0.016018	cf/ft
Specific Volume	cubic foot per kilogram	ft^3/kg or cf/kg	L^3M^{-1}	0.028317	m^3/kg	0.45359	cf/ft
Specific Volume	cubic foot per pound	ft^3/lb or cf/lb	L^3M^{-1}	0.062428	m^3/kg	1	cf/ft
Specific Volume	cubic meter per kilogram	m^3/kg	L^3M^{-1}	1	m^3/kg	16.018	cf/ft
Stress	dyne per square centimeter	dyn/cm^2	$ML^{-1}T^{-2}$	0.1	Pa	1.4504E-05	lb_f/in^2
Stress	gigapascal	GPa	$ML^{-1}T^{-2}$	1.00E+09	Pa	145,038	lb_f/in^2
Stress	hectopascal	hPa	$ML^{-1}T^{-2}$	100	Pa	0.014504	lb_f/in^2
Stress	kilogram force per square centimeter	at or kg_f/cm^2	$ML^{-1}T^{-2}$	9.8067E+04	Pa	14.223	lb_f/in^2
Stress	kilogram force per square meter	kg_f/m^2	$ML^{-1}T^{-2}$	9.80665	Pa	0.0014223	lb_f/in^2
Stress	kip force per square inch	KSI or ksi or kip_f/in^2	$ML^{-1}T^{-2}$	6.8948E+06	Pa	1000	lb_f/in^2
Stress	megapascal	MPa	$ML^{-1}T^{-2}$	1.00E+06	Pa	145.04	lb_f/in^2

(continued)

Table 14.1 (continued)

Application/field	Unit name	Notation	SI dimension	SI/metric system		English/US system	
				Conversion factor	Unit	Conversion factor	Unit
Stress	newton per square meter	N/m ²	ML ⁻¹ T ⁻²	1	Pa	0.00014504	lb _f /in ²
Stress	ounce force per square inch	OSI or osi or oz _f /in ²	ML ⁻¹ T ⁻²	430.922	Pa	0.062500	lb _f /in ²
Stress	pascal	Pa	ML ⁻¹ T ⁻²	1	Pa	0.00014504	lb _f /in ²
Stress	pound force per square foot	PSF or psf or lb _f /ft ²	ML ⁻¹ T ⁻²	47.880259	Pa	0.0069444	lb _f /in ²
Stress	pound force per square inch	PSI or psi or lb _f /in ²	ML ⁻¹ T ⁻²	6.8948E+03	Pa	1.0000	lb _f /in ²
Surface Mass Density	gram per square centimeter	kg/cm ²	ML ⁻²	10	kg/m ²	2.0482	lb _f /ft ²
Surface Mass Density	gram per square meter	g/m ²	ML ⁻²	0.001	kg/m ²	0.00020482	lb _f /ft ²
Surface Mass Density	kilogram per square meter	kg/m ²	ML ⁻²	1	kg/m ²	0.20482	lb _f /ft ²
Surface Mass Density	pound (mass) per square foot	lb/ft ²	ML ⁻²	4.882427	kg/m ²	1.0000	lb _f /ft ²
Surface Mass Density	pound (mass) per square inch	lb/in ²	ML ⁻²	703.07	kg/m ²	144.00	lb _f /ft ²
Surface Tension	dyne per centimeter	dyn/cm	MT ⁻²	0.001	N/m	6.8522E-05	lb _f /ft
Surface Tension	gram force per centimeter	g _f /cm	MT ⁻²	0.0102	N/m	6.9892E-04	lb _f /ft
Surface Tension	newton per meter	N/m	MT ⁻²	1	N/m	0.068522	lb _f /ft
Surface Tension	pound force per foot	lb _f /ft	MT ⁻²	14.594	N/m	1	lb _f /ft
Surface Tension	pound force per inch	lb _f /in	MT ⁻²	175.13	N/m	12	lb _f /ft
Temperature	degree Celsius (unit size)	C°	–	1	K	1.8	R°
Temperature	degree Fahrenheit (unit size)	F°	–	0.555556	K	1	R°
Temperature	degree Réaumur (unit size)	Re°	–	1.25	K	2.25	R°
Temperature	kelvin (absolute scale)	K	θ	1	K	1.8	°R
Temperature	Rankine (absolute scale)	°R	θ	0.555556	K	1	°R
Thermal Conductivity	Btu (IT) per inch per hour per degree Fahrenheit	Btu (IT)/(in hr °F)	MLT ⁻³ θ	0.207688	W/(cm K)	12.008	Btu/(ft hr °F)

(continued)

Table 14.1 (continued)

Application/field	Unit name	Notation	SI dimension	SI/metric system		English/US system	
				Conversion factor	Unit	Conversion factor	Unit
Thermal Conductivity	Btu (therm) per foot per hour per degree Fahrenheit	Btu/(ft hr °F)	MLT ⁻³ θ	0.017296	W/(cm K)	1.0000	Btu/(ft hr °F)
Thermal Conductivity	Btu (therm) per inch per hour per degree Fahrenheit	Btu/(in hr °F)	MLT ⁻³ θ	0.207549	W/(cm K)	12.000	Btu/(ft hr °F)
Thermal Conductivity	calorie (therm) per centimeter per second per degree Celsius	cal(IT)/(cm s °C)	MLT ⁻³ θ	4.184	W/(cm K)	241.91	Btu/(ft hr °F)
Thermal Conductivity	joule per second per centimeter per kelvin	J/(cm s K)	MLT ⁻³ θ	0.01	W/(cm K)	0.57817	Btu/(ft hr °F)
Thermal Conductivity	watt per centimeter per kelvin	W/(cm K)	MLT ⁻³ θ	1	W/(cm K)	57.817	Btu/(ft hr °F)
Thermal Conductivity	watt per meter per kelvin	W/(m K)	MLT ⁻³ θ	0.01	W/(cm K)	0.57817	Btu/(ft hr °F)
Time	blink	blink	T	0.864	s	0.864	s
Time	century	–	T	3.1558E+09	s	3.1558E+09	s
Time	chronon or tempon	–	T	1.00E–23	s	1.00E–23	s
Time	gigan or eon	Ga or eon	T	3.1558E+16	s	3.1558E+16	s
Time	hour	h or hr	T	3600	s	3600	s
Time	Julian year	a (jul) or yr	T	3.1557E+07	s	3.1557E+07	s
Time	mean solar day	da or d	T	86,400	s	86,400	s
Time	millenium	–	T	3.1558E+10	s	3.1558E+10	s
Time	minute	min	T	60	s	60	s
Time	second	s	T	1	s	1	s
Time	shake	shake	T	1.0000E–08	s	1.0000E–08	s

(continued)

Table 14.1 (continued)

Application/field	Unit name	Notation	SI dimension	SI/metric system		English/US system	
				Conversion factor	Unit	Conversion factor	Unit
Time	sidereal year (1900 AD)	a (sider) or yr	T	3.1552E+07	s	3.1552E+07	s
Time	tropical year	a (trop)	T	3.1557E+07	s	3.1557E+07	s
Time	wink	wink	T	3.33333E-12	s	3.33333E-12	s
Time	year	a or y or yr	T	3.1558E+07	s	3.1558E+07	s
Torque	centimeter kilogram force	cm kgf	ML ² T ⁻²	0.098067	N m	0.072330	ft lb _f
Torque	dyne centimeter	dyn cm	ML ² T ⁻²	1.00E-07	N m	7.3756E-08	ft lb _f
Torque	foot kilogram force	ft kgf	ML ² T ⁻²	2.9891	N m	2.2046	ft lb _f
Torque	foot pound force	ft lb _f	ML ² T ⁻²	1.3558	N m	1	ft lb _f
Torque	foot poundal	ft pdl	ML ² T ⁻²	0.042140	N m	0.031081	ft lb _f
Torque	in pound force	in lb _f	ML ² T ⁻²	0.11298	N m	0.083333	ft lb _f
Torque	inch ounce force	in oz _f	ML ² T ⁻²	0.0070616	N m	0.0052083	ft lb _f
Torque	meter kilogram force	m kgf	ML ² T ⁻²	9.8067	N m	7.2330	ft lb _f
Torque	newton centimeter	N cm	ML ² T ⁻²	0.01	N m	0.0073756	ft lb _f
Torque	newton meter	N m	ML ² T ⁻²	1	N m	0.73756	ft lb _f
Turbulence Energy Dissipation Rate	square foot per cubic second	ft ² /s ³ or sq ft/sec ³	L ² T ⁻³	0.0929	m ² /s ³	1	sq ft/sec ³
Turbulence Energy Dissipation Rate	square meter per cubic second	m ² /s ³	L ² T ⁻³	1	m ² /s ³	10.764	sq ft/sec ³
Velocity, Angular	degree per minute	deg/min or °/min	T ⁻¹	0.000290888	rad/s	0.016667	°/s
Velocity, Angular	degree per second	deg/s or °/s	T ⁻¹	0.0174533	rad/s	1.0000	°/s
Velocity, Angular	grade per minute	gon/min or grad/min	T ⁻¹	0.000261799	rad/s	0.015000	°/s

(continued)

Table 14.1 (continued)

Application/field	Unit name	Notation	SI dimension	SI/metric system		English/US system	
				Conversion factor	Unit	Conversion factor	Unit
Velocity, Angular	radian per minute	rad/min	T^{-1}	0.016667	rad/s	0.95495	°/s
Velocity, Angular	radian per second	rad/s	T^{-1}	1	rad/s	57.296	°/s
Velocity, Angular	revolution per minute	rev/m or rpm	T^{-1}	0.010472	rad/s	0.60000	°/s
Velocity, Angular	revolution per second	rev/s or rps	T^{-1}	6.283185	rad/s	360.00	°/s
Velocity, Angular	turn per minute	tr/min	T^{-1}	0.010472	rad/s	0.60000	°/s
Velocity, Linear	foot per hour	ft/h or ft/hr or fph	LT^{-1}	0.000084667	m/s	0.00027778	ft/s
Velocity, Linear	foot per minute	ft/min or fpm	LT^{-1}	0.00508	m/s	0.016667	ft/s
Velocity, Linear	foot per second	ft/s or fps	LT^{-1}	0.3048	m/s	1.0000	ft/s
Velocity, Linear	inch per second	in/s or ips	LT^{-1}	0.0254	m/s	0.083333	ft/s
Velocity, Linear	international knot	knot	LT^{-1}	0.0514444	m/s	0.16878	ft/s
Velocity, Linear	kilometer per hour	km/h or kph	LT^{-1}	0.027778	m/s	0.091135	ft/s
Velocity, Linear	kilometer per second	km/s	LT^{-1}	1000	m/s	3280.8	ft/s
Velocity, Linear	meter per second	m/s	LT^{-1}	1	m/s	3.2808	ft/s
Velocity, Linear	mile per hour	mi/h or mi/hr or mph	LT^{-1}	0.0444704	m/s	0.14590	ft/s
Viscosity, Dynamic	centipoise	cP or cPo	$ML^{-1}T^{-1}$	0.01	P	2.0885E-05	lb _f s/ft ²
Viscosity, Dynamic	dyne second per square centimeter	dyn s/cm ²	$ML^{-1}T^{-1}$	1	P	0.0020885	lb _f s/ft ²
Viscosity, Dynamic	kilopound second per square meter	kip s/m ²	$ML^{-1}T^{-1}$	98.0665	P	0.20482	lb _f s/ft ²
Viscosity, Dynamic	millipoise	mP or mPo	$ML^{-1}T^{-1}$	0.001	P	2.0885E-06	lb _f s/ft ²
Viscosity, Dynamic	newton second per square meter	N s/m ²	$ML^{-1}T^{-1}$	10	P	0.020885	lb _f s/ft ²

(continued)

Table 14.1 (continued)

Application/field	Unit name	Notation	SI dimension	SI/metric system		English/US system	
				Conversion factor	Unit	Conversion factor	Unit
Viscosity, Dynamic	pascal second	Pa s or Pl	$ML^{-1}T^{-1}$	10	P	0.020885	lb _f s/ft ²
Viscosity, Dynamic	poise	P or Po	$ML^{-1}T^{-1}$	1	P	0.0020885	lb _f s/ft ²
Viscosity, Dynamic	pound force hour per square foot	lb _f h/ft ² or lb hr/sq ft	$ML^{-1}T^{-1}$	1.72369E+06	P	3600	lb _f s/ft ²
Viscosity, Dynamic	pound force second per square foot	lb _f s/ft ² or lb sec/sq ft	$ML^{-1}T^{-1}$	478.803	P	1.0000	lb _f s/ft ²
Viscosity, Kinematic	centistokes	cSt	L^2T^{-1}	0.000001	m ² /s	1.0764E-05	ft ² /s
Viscosity, Kinematic	millistokes	mSt	L^2T^{-1}	0.0000001	m ² /s	1.0764E-06	ft ² /s
Viscosity, Kinematic	square centimeter per second	cm ² /s	L^2T^{-1}	0.0001	m ² /s	0.0010764	ft ² /s
Viscosity, Kinematic	square foot per hour	ft ² /h or ft ² /hr	L^2T^{-1}	2.58064E-05	m ² /s	0.00027778	ft ² /s
Viscosity, Kinematic	square foot per second	ft ² /s	L^2T^{-1}	0.092903	m ² /s	1.000	ft ² /s
Viscosity, Kinematic	square meters per second	m ² /s	L^2T^{-1}	1	m ² /s	10.764	ft ² /s
Viscosity, Kinematic	stokes	St	L^2T^{-1}	0.0001	m ² /s	0.0010764	ft ² /s
Volume	acre foot	ac-ft	L^3	1233.48	m ³	43.560	ft ³
Volume	acre inch	ac-in	L^3	102.79	m ³	3630.0	ft ³
Volume	barrel (US Liquid)	bbl (US liq)	L^3	0.1192405	m ³	4.2109	ft ³
Volume	barrel (US, Petro)	bbl	L^3	0.158987	m ³	5.6146	ft ³
Volume	board foot measure	BM or fbm	L^3	0.00235974	m ³	0.083334	ft ³
Volume	bushel (US Dry)	bu (US dry)	L^3	0.0352391	m ³	1.2445	ft ³
Volume	centiliter	cl or cL	L^3	0.00001	m ³	0.00035315	ft ³
Volume	cord	cord or cd	L^3	3.62456	m ³	128.00	ft ³

(continued)

Table 14.1 (continued)

Application/field	Unit name	Notation	SI dimension	SI/metric system		English/US system	
				Conversion factor	Unit	Conversion factor	Unit
Volume	cord foot	cord-ft	L ³	0.4530695	m ³	16.000	ft ³
Volume	cubic centimeter	cm ³ or cc	L ³	0.000001	m ³	3.5315E-05	ft ³
Volume	cubic decameter	dam ³	L ³	1000	m ³	35314.7	ft ³
Volume	cubic decimeter	dm ³	L ³	0.001	m ³	0.035315	ft ³
Volume	cubic foot	cu ft or ft ³	L ³	0.0283168	m ³	1	ft ³
Volume	cubic inch	cu in or in ³	L ³	1.63871E-05	m ³	0.00057871	ft ³
Volume	cubic kilometer	km ³	L ³	1.00E+09	m ³	3.5315E+10	ft ³
Volume	cubic meter	m ³	L ³	1	m ³	35.315	ft ³
Volume	cubic micrometer	µm ³	L ³	1.00E-18	m ³	3.5315E-17	ft ³
Volume	cubic mile (US, Intl)	cu mi	L ³	4.16818E+09	m ³	1.4720E+11	ft ³
Volume	cubic millimeter	mm ³	L ³	1.00E-09	m ³	3.5315E-08	ft ³
Volume	cubic yard	cu yd or yd ³	L ³	0.7645549	m ³	27.000	ft ³
Volume	decastère	dast	L ³	10	m ³	353.15	ft ³
Volume	deciliter	dL or dL	L ³	0.0001	m ³	0.0035315	ft ³
Volume	fluid drachm (UK)	fl dr (UK)	L ³	3.55163E-06	m ³	0.00012542	ft ³
Volume	fluid dram (US)	fl dr (US liq)	L ³	3.69669E-06	m ³	0.00013055	ft ³
Volume	fluid ounce (US)	fl oz	L ³	2.95735E-05	m ³	0.0010444	ft ³
Volume	gallon (Imperial UK)	gal (UK) or Imp gal	L ³	0.00454609	m ³	0.16054	ft ³

(continued)

Table 14.1 (continued)

Application/field	Unit name	Notation	SI dimension	SI/metric system		English/US system	
				Conversion factor	Unit	Conversion factor	Unit
Volume	gallon (US Dry)	gal (US dry)	L ³	0.004404884	m ³	0.15556	ft ³
Volume	gallon (US Liquid)	gal	L ³	0.003785412	m ³	0.13368	ft ³
Volume	last	last	L ³	2.9095	m ³	102.75	ft ³
Volume	liter	l or L	L ³	0.001	m ³	0.035315	ft ³
Volume	microliter	μl or μL	L ³	1.00E−09	m ³	3.5315E−08	ft ³
Volume	milliliter	ml	L ³	0.000001	m ³	3.5315E−05	ft ³
Volume	Mohr centicube	cc	L ³	1.00238E−06	m ³	3.5399E−05	ft ³
Volume	pint (UK)	pt (UK)	L ³	0.000568262	m ³	0.020068	ft ³
Volume	pint (US Dry)	pt (US dry)	L ³	0.000550611	m ³	0.019445	ft ³
Volume	pint (US Liquid)	pt	L ³	0.000473176	m ³	0.016710	ft ³
Volume	quart (US Dry)	qt (US dry)	L ³	0.00110122	m ³	0.038889	ft ³
Volume	stère	st	L ³	1	m ³	35.315	ft ³
Volume	tablespoon (Metric)	tbsp (Metric)	L ³	1.50E−05	m ³	0.00052972	ft ³
Volume	tablespoon (US)	tbsp	L ³	1.47868E−05	m ³	0.00052219	ft ³
Volume	teaspoon (US)	tsp	L ³	4.92892E−06	m ³	0.00017406	ft ³
Volume Fraction of “i”	cubic centimeters of “i” per cubic meter total	cm ³ /m ³ or cc _i /m ³	Dm ³	0.0001	m ³ _i /m ³	0.0001	ft ³ _i /ft ³
Volume Fraction of “i”	cubic foot of “i” per cubic foot total	ft ³ _i /ft ³ or cft _i /cft	Dm ³	1	m ³ _i /m ³	1	ft ³ _i /ft ³

(continued)

Table 14.1 (continued)

Application/field	Unit name	Notation	SI dimension	SI/metric system		English/US system	
				Conversion factor	Unit	Conversion factor	Unit
Volume Fraction of “i”	cubic meters of “i” per cubic meter total	m_i^3/m^3	DmLs	1	m_i^3/m^3	1	$\text{ft}_i^3/\text{ft}^3$
Volume Fraction of “i”	gallons of “i” per gallon total	gal/gal	DmLs	1	m_i^3/m^3	1	$\text{ft}_i^3/\text{ft}^3$
Volumetric Calorific (Heating) Value	British thermal unit per cubic foot	Btu/ft ³ or Btu/cft	$\text{ML}^{-1}\text{T}^{-2}$	37,260	J/m ³	1	Btu/cft
Volumetric Calorific (Heating) Value	British thermal unit per gallon (UK)	Btu/gal (UK)	$\text{ML}^{-1}\text{T}^{-2}$	2.3209E+05	J/m ³	6.2288	Btu/cft
Volumetric Calorific (Heating) Value	British thermal unit per gallon (US)	Btu/gal (US)	$\text{ML}^{-1}\text{T}^{-2}$	1.9326E+05	J/m ³	6.8249E-05	Btu/cft
Volumetric Calorific (Heating) Value	calorie per cubic centimeter	cal/cm ³ or cal/cc	$\text{ML}^{-1}\text{T}^{-2}$	4.1868E+06	J/m ³	112.37	Btu/cft
Volumetric Calorific (Heating) Value	Chu per cubic foot	Chu/ft ³ or Chu/cft	$\text{ML}^{-1}\text{T}^{-2}$	67,067	J/m ³	1.8000	Btu/cft
Volumetric Calorific (Heating) Value	joule per cubic meter	J/m ³	$\text{ML}^{-1}\text{T}^{-2}$	1	J/m ³	2.6838E-05	Btu/cft
Volumetric Calorific (Heating) Value	kilocalorie per cubic foot	kcal/ft ³ or kcal/cft	$\text{ML}^{-1}\text{T}^{-2}$	1.4786E+05	J/m ³	3.9683	Btu/cft
Volumetric Calorific (Heating) Value	kilocalorie per cubic meter	kcal/m ³	$\text{ML}^{-1}\text{T}^{-2}$	4186.8	J/m ³	0.11237	Btu/cft
Volumetric Calorific (Heating) Value	therm (100 K Btu) per cubic foot	thm/cft	$\text{ML}^{-1}\text{T}^{-2}$	3.7260E+09	J/m ³	1.00E+05	Btu/cft
Volumetric Coefficient of Expansion	gram per cubic centimeter per kelvin (or degree Celsius)	g/cm ³ /K or g/cc/°C	$\text{ML}^{-3}\theta^{-1}$	1000	kg/m ³ /K	34.682	lb/cft/°F

(continued)

Table 14.1 (continued)

Application/field	Unit name	Notation	SI dimension	SI/metric system		English/US system	
				Conversion factor	Unit	Conversion factor	Unit
Volumetric Coefficient of Expansion	kilogram per cubic meter per kelvin (or degree Celsius)	$\text{kg/m}^3/\text{K}$ or $\text{kg/m}^3/^\circ\text{C}$	$\text{ML}^{-3}\theta^{-1}$	1	$\text{kg/m}^3/\text{K}$	0.034682	$\text{lb/cft/}^\circ\text{F}$
Volumetric Coefficient of Expansion	pound per cubic foot per degree Fahrenheit (or degree Rankine)	$\text{lb/ft}^3/^\circ\text{R}$ or $\text{lb/cft/}^\circ\text{F}$	$\text{ML}^{-3}\theta^{-1}$	28.833	$\text{kg/m}^3/\text{K}$	1	$\text{lb/cft/}^\circ\text{F}$
Volumetric Coefficient of Expansion	pound per cubic foot per kelvin (or degree Celsius)	$\text{lb/ft}^3/\text{K}$ or $\text{lb/cft/}^\circ\text{C}$	$\text{ML}^{-3}\theta^{-1}$	16.018	$\text{kg/m}^3/\text{K}$	0.55554	$\text{lb/cft/}^\circ\text{F}$
Volumetric Flow Rate	cubic feet per day	ft^3/d or cft/da or cfd	L^3T^{-1}	3.2778E-07	m^3/s	1.1574E-05	ft^3/s
Volumetric Flow Rate	cubic feet per hour	ft^3/h or cft/hr or cfh	L^3T^{-1}	7.8667E-06	m^3/s	0.00027778	ft^3/s
Volumetric Flow Rate	cubic feet per minute	ft^3/min or cft/min or cfm	L^3T^{-1}	0.0004720	m^3/s	0.016667	ft^3/s
Volumetric Flow Rate	cubic feet per second	ft^3/s or cft/sec or cfs	L^3T^{-1}	0.02832	m^3/s	1	ft^3/s
Volumetric Flow Rate	cubic meters per day	m^3/d	L^3T^{-1}	1.1574E-05	m^3/s	4.0869E-04	ft^3/s
Volumetric Flow Rate	cubic meters per hour	m^3/h	L^3T^{-1}	0.00027778	m^3/s	9.8085E-03	ft^3/s
Volumetric Flow Rate	cubic meters per minute	m^3/min	L^3T^{-1}	0.016667	m^3/s	0.58851	ft^3/s
Volumetric Flow Rate	cubic meters per second	m^3/s	L^3T^{-1}	1	m^3/s	35.311	ft^3/s
Volumetric Flow Rate	gallons per day	gal/d or gpd or gal/da	L^3T^{-1}	0.002628	l/min	0.00069444	gpm
Volumetric Flow Rate	gallons per hour	gal/h or gph or gal/hr	L^3T^{-1}	0.06308	l/min	0.016667	gpm
Volumetric Flow Rate	gallons per minute	gal/min or gpm	L^3T^{-1}	3.785	l/min	1	gpm

(continued)

Table 14.1 (continued)

Application/field	Unit name	Notation	SI dimension	SI/metric system		English/US system	
				Conversion factor	Unit	Conversion factor	Unit
Volumetric Flow Rate	gallons per second	gal/s or gps or gal/sec	$L^3 T^{-1}$	227.1	l/min	60	gpm
Volumetric Flow Rate	liters per day	l/d	$L^3 T^{-1}$	0.00069444	l/min	0.00018347	gpm
Volumetric Flow Rate	liters per hour	l/h	$L^3 T^{-1}$	0.016667	l/min	0.0044033	gpm
Volumetric Flow Rate	liters per minute	l/min	$L^3 T^{-1}$	1	l/min	0.26420	gpm
Volumetric Flow Rate	liters per second	l/s	$L^3 T^{-1}$	60	l/min	15.852	gpm
Volumetric Flux	cubic feet per square foot per day	$ft^3/(ft^2 d)$ or $cft/sqft/da$	LT^{-1}	3.5276E-06	$m^3/(m^2 s)$	1.1574E-05	$ft^3/(ft^2 s)$
Volumetric Flux	cubic feet per square foot per hour	$ft^3/(ft^2 h)$ or $cft/sqft/hr$	LT^{-1}	8.4663E-05	$m^3/(m^2 s)$	0.00027778	$ft^3/(ft^2 s)$
Volumetric Flux	cubic feet per square foot per minute	$ft^3/(ft^2 min)$ or $cft/sqft/min$	LT^{-1}	0.0050798	$m^3/(m^2 s)$	0.016667	$ft^3/(ft^2 s)$
Volumetric Flux	cubic feet per square foot per second	$ft^3/(ft^2 s)$ or $cft/sqft/sec$	LT^{-1}	0.30479	$m^3/(m^2 s)$	1	$ft^3/(ft^2 s)$
Volumetric Flux	cubic meters per square meter per day	$m^3/(m^2 d)$	LT^{-1}	1.1574E-05	$m^3/(m^2 s)$	3.7975E-05	$ft^3/(ft^2 s)$
Volumetric Flux	cubic meters per square meter per hour	$m^3/(m^2 h)$	LT^{-1}	0.00027778	$m^3/(m^2 s)$	9.1139E-04	$ft^3/(ft^2 s)$
Volumetric Flux	cubic meters per square meter per minute	$m^3/(m^2 min)$	LT^{-1}	0.016667	$m^3/(m^2 s)$	0.054683	$ft^3/(ft^2 s)$
Volumetric Flux	cubic meters per square meter per second	$m^3/(m^2 s)$	LT^{-1}	1	$m^3/(m^2 s)$	3.2810	$ft^3/(ft^2 s)$
Volumetric Flux	gallons per square foot per day	$gal/(ft^2 d)$ or $gal/sqft/da$	LT^{-1}	4.7138E-04	$l/(m^2 s)$	0.00069444	gpm/sqft

(continued)

Table 14.1 (continued)

Application/field	Unit name	Notation	SI dimension	SI/metric system		English/US system	
				Conversion factor	Unit	Conversion factor	Unit
Volumetric Flux	gallons per square foot per hour	gal/(ft ² h) or gal/sqft/hr	LT ⁻¹	0.011313	l/(m ² s)	0.016667	gpm/sqft
Volumetric Flux	gallons per square foot per minute	gal/(ft ² min) or gal/sqft/min or gpm/sqft	LT ⁻¹	0.67878	l/(m ² s)	1	gpm/sqft
Volumetric Flux	gallons per square foot per second	gal/(ft ² s) or gal/sqft/sec	LT ⁻¹	40.727	l/(m ² s)	60	gpm/sqft
Volumetric Flux	liters per square meter per day	l/(m ² d)	LT ⁻¹	1.1574E-05	l/(m ² s)	1.7051E-05	gpm/sqft
Volumetric Flux	liters per square meter per hour	l/(m ² h)	LT ⁻¹	0.00027778	l/(m ² s)	4.0922E-04	gpm/sqft
Volumetric Flux	liters per square meter per minute	l/(m ² min)	LT ⁻¹	0.016667	l/(m ² s)	0.0245533	gpm/sqft
Volumetric Flux	liters per square meter per second	l/(m ² s)	LT ⁻¹	1	l/(m ² s)	1.4732	gpm/sqft
Volumetric Mass Flow Rate	gram per second per cubic centimeter	g/(s cm ³) or g/s/cc or g/cc/sec	ML ⁻³ T ⁻¹	1000	kg/(s m ³)	62.430	lb/sec/cft
Volumetric Mass Flow Rate	kilogram per hour per cubic foot	kg/(h ft ³) or kg/hr/cft	ML ⁻³ T ⁻¹	0.0098096	kg/(s m ³)	6.1241E-04	lb/sec/cft
Volumetric Mass Flow Rate	kilogram per hour per cubic meter	kg/(h m ³) or kg/hr/cu.m	ML ⁻³ T ⁻¹	2.7778E-04	kg/(s m ³)	1.7342E-05	lb/sec/cft
Volumetric Mass Flow Rate	kilogram per second per cubic meter	kg/(s m ³) or kg/sec/cu.m	ML ⁻³ T ⁻¹	1	kg/(s m ³)	0.062430	lb/sec/cft
Volumetric Mass Flow Rate	pound per hour per cubic foot	lb/(h ft ³) or lb/hr/cft or PPH/cft	ML ⁻³ T ⁻¹	0.0044496	kg/(s m ³)	0.00027779	lb/sec/cft
Volumetric Mass Flow Rate	pound per minute per cubic foot	lb/(min ft ³) or lb/min/cft	ML ⁻³ T ⁻¹	0.26697	kg/(s m ³)	0.016667	lb/sec/cft

(continued)

Table 14.1 (continued)

Application/field	Unit name	Notation	SI dimension	SI/metric system		English/US system	
				Conversion factor	Unit	Conversion factor	Unit
Volumetric Mass Flow Rate	pound per second per cubic foot	lb/(s ft ³) or lb/sec/cft	ML ⁻³ T ⁻¹	16.018	kg/(s m ³)	1	lb/sec/cft
Wavenumber	diopter	D	L ⁻¹	1	1/m		
Wavenumber	kayser	K	L ⁻¹	100	1/m		
Wavenumber	reciprocal meter	1/m	L ⁻¹	1	1/m		

Conclusion

Base units in a measurement system are a handful of defined quantities from which all other measurements in the system can be derived. SI base units are mass (kg), length (m), time (s), thermodynamic temperature (K), luminous intensity (cd), electric current (A), and the chemical amount of a substance (mol). A similar set of base units is used in the English/US system. These base units are defined in terms of universal constants or properties which, for all practical purposes, remain the same in our common frames of reference.

The base units can be considered to give rise to secondary units which are used to develop all the other derived units. The secondary units include measurements like area, volume, velocity, acceleration, and plane angle. Many of the secondary units were considered base units throughout history. There is only a handful of the secondary units.

Combining the base and secondary units in various ways provides the wide array of derived units which find use in science and technology today. This range of units is illustrated in Table 14.1, with conversion factors provided in both SI and English/US units.

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Chapter 15

Common Modern Conversions



Abstract This chapter provides a series of common, modern approaches for both direct and indirect or non-linear conversions among units as a capstone to this history. Final units provided are for metric/SI, and English/U.S. systems.

Introduction

This final chapter provides a compendium of unit conversions which are commonly needed, especially in engineering calculations. These are drawn from several sources as listed in the “References” section.

There are three data sets in this chapter:

- *Abbreviations*—This section lists common abbreviations used for units of measurement and related terms or organizations.
- *Simple Conversion Factors*—Here is a conventional list of the most commonly needed conversion factors drawn from many sources.
- *Nonlinear or Complex Conversions*—Common conversions involving temperature, density, concentration, viscosity, sound, and coordinates are here.

We will start by establishing some bases for the abbreviations that are used in the conversion tables.

Common Abbreviations [1–23]

There are two tables provided in this section which provide fairly comprehensive listings of the common abbreviations for measurement units and related terms. These tables correlate with the abbreviations used in the balance of this chapter.

The specific tables here provide alphabetical listings of the abbreviations sorted by the name of a measurement unit or term (Table 15.1) and by the abbreviation for a unit or term (Table 15.2).

Table 15.1 Alphabetical listing of unit names and terms with corresponding abbreviations

Measurement unit	Common abbreviations
1st Bohr radius	a_0
absolute	abs
acre	Ac, ac
American Petroleum Institute	API
ampere	A, amp
angstrom	Å
anker	anker
anomalistic	anomal
apostilb	asb
apothecary	apoth, ap
are	a
arpent	arpent, arp
assay ton	AT
astronomic unit	AU, a.u.
astronomical	astr
atmosphere	atm
atomic mass unit	amu, u(xx)
atomic unit	u.a., a.u.
atomic unit of mass	m_e , amu
avoirdupois	av
bag	bag, bg
bar	bar
barn	b
barrel	bbl
barrel oil equivalent	bboe, boe
barrel per day	bbl/d, bbl/da, BPD, BPSD
becquerel	Bq
bicron sigma	$\mu\mu$
biot	biot
blondel	Bl
board foot (measure)	bd-ft, BF, fbm, BM
Bohr radius	a_0
British thermal unit	Btu
bucket	bk
bushel	bu
butt	but
cable	cbl
calibre	cal
calorie	cal
Canadian	Can

(continued)

Table 15.1 (continued)

Measurement unit	Common abbreviations
candela	Cd, cd
candle	Cd, cd
carat	ct
carbon 12	^{12}C
Celsius	C (usually °C)
Celsius heat unit	Chu
cement	cem
cental	sh cwt, cH
centare	cent
centigrade	C (usually °C)
centimeter-gram-second	cgs, CGS
centinch	cin
centner	sh cwt, cH
chain	ch
chaldron	chal
chopine	ch
circular inch	cin
circular mil	emil, circ mil
circular mile	c mi, circ mi
circular millimeter	cmm
circumference	circ
clove	cl
coffee spoon	csp
commercial ton of refrigeration	CTR
coomb	cmb
cord foot	cord, cd, cord-ft
cotton count	cc
coulomb	C
cran mease	cran
cranberries	cran
cubem	cu mi
cubic	[add exponent ³], cu
cubic centimeter	cc, ml
cubic foot	cu ft, cft
cubic foot per day	ft ³ /d, cu ft/da, cfd, CFD
cubic foot per minute	ft ³ /min, cu ft/min, cfm, CFM
cubic foot per second	ft ³ /s, cu ft/sec, cfs, CFS
cubic meter	CM, cm
cubit	cu
Cunningham	Cunn

(continued)

Table 15.1 (continued)

Measurement unit	Common abbreviations
cup	cup, C., c.
curie	Ci
dalton	Da
dash	dash
day	d, da, day, j
debye	D
decastère	dast
decistère	dst
degree	deg, °
dessert spoon	dsp
dimensionless	dmls
diopter	D
drachm	dr
dram	dr
drop	drop, drp, gtt
dyne	dyn
electromagnetic unit (system)	emu, “ab” prefix
electron	e
electron radius	r_o
electron volt	eV
electrostatic unit (system)	esu, “stat” prefix
English	Engl
equivalent	eq (chemical)
erg	erg
evaporated	evap
Fahrenheit	F (usually °F)
faraday	F
fathom	fath
fermi	F
firkin	fir
fluid	fl
foot	ft
foot candle	ft-cd, FC
foot per hour	ft/h, ft/hr, fph
foot per minute	ft/min, fpm
foot per second	ft/s, ft/sec, fps
force designation	[subscript _{<i>i</i>}]
forty foot equivalent unit	FEU, FEQ
franklin	Fr
frigorie	fg

(continued)

Table 15.1 (continued)

Measurement unit	Common abbreviations
fuel oil equivalent	FOE
furlong	fur
gallon	gal
gallon per minute	gal/min, GPM, gpm
gamma	γ
Gas Inspection Act Reg. (UK)	GIAR
gauss	G
geepound	si
geographical	geo
gigan	Ga
gilbert	Gb, Gi
gill	gi
gon	g, gon
grade	g, grad
grain	gr
gram	g
gravity	G
gray	Gy
Gregorian	greg
hand	hd
hartree	E_H a.u.
hectare	ha
hectare	ha
Hefner unit	HK
henry	H
hertz	Hz
hogshead	hhd, hg
horsepower	HP, hp
hour	h, hr
hundred	100, C, c
hundredweight	cwt
hydraulic	h
hydrogen 1	^1H
hyl	hyl, TME
imperial	imp, Imp
inch	in, “, i
inch per minute	in/min, ipm
inch per second	in/s, in/sec, ips
inch per year	in/y, in/yr, ipy
international	intl, int

(continued)

Table 15.1 (continued)

Measurement unit	Common abbreviations
International Standards Org.	ISO
International Steam Tables	IT
Ireland	Ire
jeweller's	jew
joule	J
Julian	jul
kelvin	K (no degree sign)
kilderkin	kil
kilocalorie	kcal, Cal
kilogram calorie	kcal, Cal
kilogram per square centimeter	at, kg _f /cm ²
kilometer	km
kilometer per hour	km/h, kph
kilopound	kip
kintal	sh cwt, cH
kip per square inch	Kip/in ² , kip/sq in, KSI
knot	kt, knot
lambda	λ
lambert	L
langley	Ly
league	lg
lenz	lenz
line	li, ln
link	lk
liquid	liq
liter	L, l
lux	lx
mass designation	[subscript _m]
maxwell	Mx
mercury	Hg
meter	m
metric	met
metric horsepower	CV, ch, hp (met)
mho	Ω
micron	μ, μm
mil	mil
mil per year	mil/y, mil/yr, mpy
mile	mi, m
mile per hour	mi/h, mi/hr, mph
milliliter	ml, cc

(continued)

Table 15.1 (continued)

Measurement unit	Common abbreviations
million	10 ⁶ , MM, M
minim	min
minute	min, ’
Mohr centicube	cc
mole	mol
month	m, mo
mug	hyl, TME
nanon	nm
nautical	naut
newton	N
noggin	ng
normal cubic meter	NCM
North Atlantic Treaty Organization	NATO
nuclear	nucl
nutritional	nutr
oersted	Oe
ohm	Ω
ounce	oz
oxygen 16	¹⁶ O
palm	plm
par	hyl, TME
parsec	pc
part per million	ppm
particle	part
pascal	Pa
pastille dose	B unit
peck	pk
pennyweight	dwt
per	/, P, p
percent	%
percent grade	% grad, %, gon
petroleum	petrol, pet
phot	ph
piéze	pz
pint	pt
point	pt
poise	P, Po
pond	p
pottle	pot
pound	lb

(continued)

Table 15.1 (continued)

Measurement unit	Common abbreviations
pound centigrade unit	pcu
pound mole	lbmol, lb-mol
pound per day	lb/d, lb/da, PPD
pound per hour	lb/h, lb/hr, PPH
pound per square foot	lb/ft ² , lb/sq ft, psf
pound per square foot	lb/ft ² , lb/sq ft, psf
pound per square inch	lb/in ² , lb/sq in, psi
pound per square inch	lb/in ² , lb/sq in, psi
poundal	pdl
puncheon	pun
Q unit	Q
quadrant	quadr
quadrillion Btus	quad
quart	qt
quarter	qtr, qt
quintal	q, dt, quint
rad (radiation)	rad
radian	rad
Rankine	R (usually °R)
Réaumur	Ré (usually °Ré)
revolution	rev
revolution per minute	rpm
right angle	⊥
rod	rd
röntgen	R
roquille	gi
round	tr, rev, r
rutherford	Rd, Ru
rydberg	Ry
sack	sk
salt spoon	ssp
scruple	sc, scr
second	s, “, sec, cc
section	sect
shipping	ship
sidereal	sider
sievert	Sv
slug	sl
span	sp
square	[add exponent ²], sq

(continued)

Table 15.1 (continued)

Measurement unit	Common abbreviations
standard cubic foot	scf
standard cubic meter	SCM
standard	std
star condition	*
statute	stat
steradian	sr
stère	st
sthène	sn
stilb	sb
stoke	St
stone	st
straight angle	—
survey	surv
Système international d'unités	SI
tablespoon	tbsp, Tsp, tls
teacupful	tcf
teaspoon	tsp
techma	hyl, TME
Technical Committee 12 (ISO)	TC 12
tesla	T
therm	thm, th
thermie	th
thermochemical	therm
thousand	10 ³ , 1000, thou, M, K
thousandth	thou, ‰
technische mass einheit	hyl, TME
ton	t, T
ton coal equivalent	tce
ton oil equivalent	toe
ton, long	t, LT
ton, metric	t, T, MT
ton, short	t, ST
torr	torr
township	twnshp
trinitrotoluene	TNT (explosive)
troland	Tr
tropical	trop
troy	troy, tr
tun	tu, tun
turn	turn, tr, tu, rev

(continued)

Table 15.1 (continued)

Measurement unit	Common abbreviations
twenty foot equivalent unit	TEQ, TEU
UdM	hyl, TME
United Kingdom	UK
United States	US
volt	V
volume	v, vol
water	H ₂ O, wtr
watt	W
weber	Wb
week	wk
weight	w, wt
Weights and Measures Act (UK)	WMA
wey	wey, wy
winchester	win
X unit	XU
yard	yd
year	y, yr, an, a

Table 15.2 Alphabetical listing of abbreviations and corresponding unit names and terms

Common abbreviations	Measurement unit
100	hundred
10 ³	thousand
10 ⁶	million
1000	thousand
“	inch
“	second
“ab” prefix	electromagnetic unit (system)
“stat” prefix	electrostatic unit (system)
%	percent
%	percent grade
% grad	percent grade
*	star condition
/	per
[add exponent ²], sq	square
[add exponent ³]	cubic
[subscript _f]	force designation
[subscript _m]	mass designation
—	straight angle

(continued)

Table 15.2 (continued)

Common abbreviations	Measurement unit
$\perp$	right angle
$^{\circ}$	degree
‰	thousandth
^{12}C	carbon 12
^{16}O	oxygen 16
^1H	hydrogen 1
A	ampere
a	are
a	year
$\text{\AA}$	angstrom
a.u.	astronomic unit
a.u.	atomic unit
abs	absolute
Ac	acre
ac	acre
amp	ampere
amu	atomic mass unit
amu	atomic unit of mass
an	year
anker	anker
anomal	anomalous
a_0	1st Bohr radius
a_0	Bohr radius
ap	apothecary
API	American Petroleum Institute
apoth	apothecary
arp	arpent
arpent	arpent
asb	apostilb
astr	astronomical
AT	assay ton
at	kilogram per square centimeter
atm	atmosphere
AU	astronomic unit
av	avoirdupois
b	barn
B unit	pastille dose
bag	bag
bar	bar
bbl	barrel

(continued)

Table 15.2 (continued)

Common abbreviations	Measurement unit
bbl/d	barrel per day
bbl/da	barrel per day
bboe	barrel oil equivalent
bd-ft	board foot (measure)
BF	board foot (measure)
bg	bag
biot	biot
bk	bucket
Bl	blondel
BM	board foot (measure)
boe	barrel oil equivalent
BPD	barrel per day
BPSD	barrel per stream day
Bq	becquerel
Btu	British thermal unit
bu	bushel
but	butt
C	coulomb
C	hundred
c	hundred
C (usually °C)	Celsius
C (usually °C)	centigrade
c mi	circular mile
C.	cup
c.	cup
cal	calibre
cal	calorie
Cal	kilocalorie
Cal	kilogram calorie
Can	Canadian
cbl	cable
cc	cotton count
cc	cubic centimeter
cc	milliliter
cc	Mohr centicube
cc	second
Cd	candela
cd	candela
Cd	candle
cd	candle

(continued)

Table 15.2 (continued)

Common abbreviations	Measurement unit
cd	cord foot
cem	cement
cent	centare
cf	cubic foot per day
CFD	cubic foot per day
cfm	cubic foot per minute
CFM	cubic foot per minute
cfs	cubic foot per second
CFS	cubic foot per second
cft	cubic foot
cgs	centimeter-gram-second
CGS	centimeter-gram-second
cH	cental
cH	centner
ch	chain
ch	chopine
cH	kintal
ch	metric horsepower
chal	chaldron
Chu	Celsius heat unit
Ci	curie
cin	centinch
cin	circular inch
circ	circumference
circ mi	circular mile
circ mil	circular mil
cl	clove
CM	cubic meter
cm	cubic meter
cmb	coomb
cmil	circular mil
cmm	circular millimeter
cord	cord foot
cord-ft	cord foot
cran	cran mease
cran	cranberries
csp	coffee spoon
ct	carat
CTR	commercial ton of refrigeration
cu	cubic

(continued)

Table 15.2 (continued)

Common abbreviations	Measurement unit
cu	cubit
cu ft	cubic foot
cu ft/da	cubic foot per day
cu ft/min	cubic foot per minute
cu ft/sec	cubic foot per second
cu mi	cubem
Cunn	Cunningham
cup	cup
CV	metric horsepower
cwt	hundredweight
d	day
D	debye
D	diopter
Da	dalton
da	day
dash	dash
dast	decastère
day	day
deg	degree
dmls	dimensionless
dr	drachm
dr	dram
drop	drop
drp	drop
dsp	dessert spoon
dst	decistère
dt	quintal
dwt	pennyweight
dyn	dyne
e	electron
E_H a.u.	hartree
emu	electromagnetic unit (system)
Engl	English
eq (chemical)	equivalent
erg	erg
esu	electrostatic unit (system)
eV	electron volt
evap	evaporated
F	faraday
F	fermi

(continued)

Table 15.2 (continued)

Common abbreviations	Measurement unit
F (usually °F)	Fahrenheit
fath	fathom
fbm	board foot (measure)
FC	foot candle
FEQ	forty foot equivalent unit
FEU	forty foot equivalent unit
fg	frigorie
fir	firkin
fl	fluid
FOE	fuel oil equivalent
fph	foot per hour
fpm	foot per minute
fps	foot per second
Fr	franklin
ft	foot
ft/h	foot per hour
ft/hr	foot per hour
ft/min	foot per minute
ft/s	foot per second
ft/sec	foot per second
ft ³ /d	cubic foot per day
ft ³ /min	cubic foot per minute
ft ³ /s	cubic foot per second
ft-cd	foot candle
fur	furlong
g	gamma
G	gauss
g	gon
g	grade
g	gram
G	gravity
Ga	gigan
gal	gallon
gal/min	gallon per minute
Gb	gilbert
geo	geographical
Gi	gilbert
gi	gill
gi	roquille
GIAR	Gas Inspection Act Reg. (UK)

(continued)

Table 15.2 (continued)

Common abbreviations	Measurement unit
gon	gon
gon	percent grade
GPM	gallon per minute
gpm	gallon per minute
gr	grain
grad	grade
greg	Gregorian
gtt	drop
Gy	gray
H	henry
h	hour
h	hydraulic
H ₂ O	water
ha	hectare
ha	hectare
hd	hand
hg	hogshead
Hg	mercury
hhd	hogshead
HK	Hefner unit
HP	horsepower
hp	horsepower
hp (met)	metric horsepower
hr	hour
hyl	hyl
hyl	mug
hyl	par
hyl	techma
hyl	technische mass einheit
hyl	UdM
Hz	hertz
i	inch
imp	imperial
Imp	imperial
in	inch
in/min	inch per minute
in/s	inch per second
in/sec	inch per second
in/y	inch per year
in/yr	inch per year

(continued)

Table 15.2 (continued)

Common abbreviations	Measurement unit
int	international
intl	international
ipm	inch per minute
ips	inch per second
ipy	inch per year
Ire	Ireland
ISO	International Standards Org.
IT	International Steam Tables
j	day
J	joule
jew	jeweller's
jul	Julian
K	thousand
K (no degree sign)	kelvin
kcal	kilocalorie
kcal	kilogram calorie
kg/cm ²	kilogram per square centimeter
kil	kilderkin
kip	kilopound
kip/in ²	kip per square inch
kip/sq in	kip per square inch
km	kilometer
km/h	kilometer per hour
knot	knot
kph	kilometer per hour
KSI	kip per square inch
kt	knot
l	lambda
L	lambert
L	liter
l	liter
lb	pound
lb/d	pound per day
lb/da	pound per day
lb/ft ²	pound per square foot
lb/h	pound per hour
lb/hr	pound per hour
lb/in ²	pound per square inch
lb/sq ft	pound per square foot
lb/sq in	pound per square inch

(continued)

Table 15.2 (continued)

Common abbreviations	Measurement unit
lenz	lenz
lg	league
li	line
liq	liquid
lk	link
ln	line
LT	ton, long
lx	lux
Ly	langley
m	meter
μ	micron
m	mile
M	million
M	thousand
m, mo	month
m_e	atomic unit of mass
met	metric
mi	mile
mi/gal	mile per gallon
mi/h	mile per hour
mi/hr	mile per hour
mil	mil
mil/y	mil per year
mil/yr	mil per year
min	minim
min, '	minute
ml	cubic centimeter
ml	milliliter
mm	bicron sigma
μm	micron
MM	million
mol	mole
mpg	mile per gallon
mph	mile per hour
mpy	mil per year
MT	ton, metric
Mx	maxwell
N	newton
NATO	North Atlantic Treaty Organization
naut	nautical

(continued)

Table 15.2 (continued)

Common abbreviations	Measurement unit
NCM	normal cubic meter
ng	noggin
nm	nanon
nucl	nuclear
nutr	nutritional
Oe	oersted
oz	ounce
P	per
p	per
P	poise
p	pond
Pa	pascal
part	particle
pc	parsec
pcu	pound centigrade unit
pdL	poundal
pet	petroleum
petrol	petroleum
ph	phot
pk	peck
plm	palm
Po	poise
pot	pottle
PPD	pound per day
PPH	pound per hour
ppm	part per million
psf	pound per square foot
psi	pound per square inch
pt	pint
pt	point
pun	puncheon
pz	piéze
Q	Q unit
q	quintal
qt	quart
qt	quarter
qtr	quarter
quad	quadrillion Btus
quadr	quadrant
quint	quintal

(continued)

Table 15.2 (continued)

Common abbreviations	Measurement unit
R	röntgen
r	round
R (usually °R)	Rankine
rad	rad (radiation)
rad	radian
rd	rod
Rd	rutherford
Ré (usually °Ré)	Réaumur
rev	revolution
rev	round
rev	turn
r_o	electron radius
rpm	revolution per minute
Ru	rutherford
Ry	rydberg
s	second
sb	stilb
sc	scruple
scf	standard cubic foot
SCM	standard cubic meter
scr	scruple
sec	second
sect	section
sh cwt	cental
sh cwt	centner
sh cwt	kintal
ship	shipping
si	geepound
SI	Système international d'unités
sider	sidereal
sk	sack
sl	slug
sn	sthéne
sp	span
sr	steradian
ssp	salt spoon
st	stère
St	stoke
st	stone
stat	statute

(continued)

Table 15.2 (continued)

Common abbreviations	Measurement unit
std	standard
surv	survey
Sv	sievert
T	tesla
t	ton
T	ton
t	ton, long
t	ton, metric
T	ton, metric
T.	tablespoon
tbsp	tablespoon
TC 12	Technical Committee 12 (ISO)
tce	ton coal equivalent
tcf	teacupful
TEQ	twenty foot equivalent unit
TEU	twenty foot equivalent unit
th	therm
th	thermie
therm	thermochemical
thm	therm
thou	thousand
thou	thousandth
tls	tablespoon
TME	hyl
TME	mug
TME	par
TME	techma
TME	technische mass einheit
TME	UdM
TNT (explosive)	trinitrotoluene
toe	ton oil equivalent
tr	round
Tr	troland
tr	troy
tr	turn
trop	tropical
troy	troy
Tsp	tablespoon
tsp	teaspoon
tu	tun

(continued)

Table 15.2 (continued)

Common abbreviations	Measurement unit
tu	turn
tun	tun
turn	turn
twnshp	township
Ω	mho
u(xx)	atomic mass unit
u.a.	atomic unit
UK	United Kingdom
US	United States
V	volt
v	volume
vol	volume
W	watt
w	weight
Wb	weber
wey	wey
win	winchester
wk	week
WMA	Weights and Measures Act (UK)
wt	weight
wtr	water
wy	wey
XU	X unit
y	year
yd	yard
yr	year
Ω	ohm

Table 15.1—Alphabetical Listing of Unit Names and Terms with Corresponding Abbreviations

Table 15.2—Alphabetical Listing of Abbreviations and Corresponding Unit Names and Terms

Common Conversion Factors [1–23]

Table 15.3 provides direct, linear conversion factors for the most commonly used measurement units. This table actually was the initial objective of this book when work started. It has been distilled down from a table with over 8000 entries. The primary measurement systems of concern here are metric/SI and English/U.S.

Table 15.3 Common conversion factors

Starting Unit	Desired Unit	Factor
From	To	Multiply By
$^{\circ}\text{C m}^2/\text{kW}$	$^{\circ}\text{C m}^2 \text{ h/kcal}$	0.00116222
$^{\circ}\text{C m}^2/\text{kW}$	$^{\circ}\text{F ft}^2 \text{ h/Btu}$	0.00567826
$^{\circ}\text{C m}^2 \text{ h/kcal}$	$^{\circ}\text{C m}^2/\text{kW}$	860.421
$^{\circ}\text{F}/100 \text{ ft}$	mK/m	18.22689
$^{\circ}\text{F ft}^2 \text{ h/Btu}$	$^{\circ}\text{C m}^2/\text{kW}$	176.110
$^{\circ}\text{R}$	K	0.555555556
A		
A	statampere	2.9979E+09
a	yr	1
$\text{\AA}$	cm	1.00E-08
$\text{\AA}$	ft	3.2808E-10
$\text{\AA}$	in	3.9370E-09
$\text{\AA}$	m	1.00E-10
$\text{\AA}$	μ	1.00E-04
$\text{\AA}$	mil	3.9370E-06
$\text{\AA}$	nm	0.1
A (int mean)	A	0.99985
A/cm^2	A/in^2	6.452
A/cm^2	A/m^2	1.00E+04
A/in^2	A/cm^2	0.1550
A/in^2	A/m^2	1550
A/m^2	A/cm^2	1.00E-04
A/m^2	A/in^2	6.452E-04
A h	F	0.037311
A h (abs)	C (abs)	3600
A turn	Gb	1.2566
A turn/cm	A turn/in	2.540
A turn/cm	A turn/m	100
A turn/cm	Gb/cm	1.257
A turn/in	A turn/cm	0.3937
A turn/in	A turn/m	39.37
A turn/in	Gb/cm	0.4950
A turn/m	A turn/cm	0.01
A turn/m	A turn/in	0.02540
A turn/m	Gb/cm	0.01257
abampere	A	10
abcoulomb	F	1.0364E-04
abcoulomb	statcoulomb	2.9980E+10
abfarad	F	1.00E+09

(continued)

Table 15.3 (continued)

Starting Unit	Desired Unit	Factor
From	To	Multiply By
abhenry	H	1.00E−09
Ac	ch ² (Gunter’s)	10
Ac	ft ²	4.3560E+04
Ac	ha	0.40469
Ac	hm ²	0.40469
Ac	km ²	0.0040469
Ac	lk ² (Gunter’s)	100000
Ac	m ²	4046.9
Ac	mi ²	0.0015625
Ac	rd	160
Ac	yd ²	4840
Ac ft	ft ³	4.3560E+04
Ac ft	gal	3.2585E+05
Ac ft	m ³	1233.48
Ac in	ft ³	3630.00
Ac in	m ³	102.790
amu (¹² C)	kg	1.6605E−27
are	Ac	0.02471
are	m ²	100
are	yd ²	119.60
at	bar	0.983665
at	bar	0.980665
at	kPa	98.066500
at	kPa	98.0665
at	lb _f /in ²	14.223
at	MPa	0.098067
at	MPa	0.0980665
at	Pa	9.8067E+04
atm	bar	1.01325
atm	cm Hg	76.00
atm	dyn/cm ²	1.01325E+06
atm	ft H ₂ O (4 °C)	33.90
atm	ft H ₂ O (60 °F)	33.932
atm	g/cm ²	1033.3
atm	in H ₂ O (4 °C)	406.8
atm	in Hg (0 °C)	29.921
atm	kg/cm ²	1.0332
atm	kg/m ²	1.0332E+04
atm	kPa	101.325

(continued)

Table 15.3 (continued)

Starting Unit	Desired Unit	Factor
From	To	Multiply By
atm	lb _f /ft ²	2116.3
atm	lb _f /in ²	14.696
atm	mm Hg (0 °C)	760.00
atm	MPa	0.101325
atm	N/m ²	1.01325E+05
atm	Pa	1.01325E+05
atm	t/ft ²	1.058
atm	t/in ²	0.007348
atm	torr	760.00
AU	km	1.4960E+08
B		
bag (cement)	lb	94
bar	at	1.01972
bar	atm	0.986923267
bar	dyn/cm ²	1.00E+06
bar	ft H ₂ O (4 °F)	33.4484
bar	in H ₂ O (4 °C)	401.381
bar	in Hg	29.53
bar	kg/m ²	1.020E+04
bar	kg _f /cm ²	1.01972
bar	kPa	100
bar	lb _f /ft ²	2089
bar	lb _f /in ²	14.50377439
bar	mm Hg (0 °C)	750.06
bar	MPa	0.1
bar	N/m ²	1.00E+05
bar	Pa	1.00E+05
bar	torr	750.06
baryl	dyn/cm ²	1
bbl (petrol)	ft ³	5.61459
bbl (petrol)	gal	42
bbl (petrol)	m ³	0.158987
bbl (UK cement)	lb	376
bbl (UK, cem)	kg	170.55
bbl (UK, cem)	lb _m	376
bbl (US liq)	ft ³	4.21095
bbl (US liq)	gal	31.5
bbl (US liq)	m ³	0.119241
bbl (US, dry)	ft ³	4.07727

(continued)

Table 15.3 (continued)

Starting Unit	Desired Unit	Factor
From	To	Multiply By
bbl (US, dry)	in ³	7056
bbl (US, dry)	m ³	0.115455
bbl (US, dry)	qt (dry)	105.0
bbl/Ac ft	dm ³ /m ³	0.1288931
bbl/Ac ft	L/m ³	0.1288931
bbl/d	dm ³ /s	0.001840131
bbl/d	L/s	0.001840131
bbl/d (petrol)	gal/h (US)	1.75
bbl/d (petrol)	gal/min (US)	0.02917
bbl/d (petrol)	m ³ /d	0.158987
bbl/d (petrol)	m ³ /h	0.00662447
bbl/d (petrol)	t/a (metric)	58.0304
bbl/d/psi	m ³ /d/kPa	0.02305916
bbl/ft	m ³ /m	0.5216119
bbl/h	dm ³ /s	0.04416314
bbl/h	L/s	0.04416314
bbl/h	m ³ /h	0.158987
bbl/in	m ³ /m	6.259342
bbl/MMscf	dm ³ /kmol	0.13301
bbl/MMscf	L/kmol	0.13301
bd ft	ft ³	0.083333333
bd-ft	in ³	144 sq in × 1 in
bg (UK cem)	kg	42.638
bg (UK cem)	lb _m	94
bhp	Btu/h	33,480
bhp	kW	9.803
boe	Btu (ISO)	5.8006E+06
boe	J	6.1200E+09
bolt (US cloth)	ft	120.00
bolt (US cloth)	m	36.576
BPD (see bbl/d)		
BPH (see bbl/h)		
BPSD	ft ³ /h	0.233975
Btu	cal	252.0
Btu	Cal	0.252
Btu	Chu	1.8
Btu	erg	1.0544E+10
Btu	ft lb _f	778.1692
Btu	ft ³ atm	3676

(continued)

Table 15.3 (continued)

Starting Unit	Desired Unit	Factor
From	To	Multiply By
Btu	hp-h	0.0003930148
Btu	J	1055.056
Btu	kcal	0.2519958
Btu	kg m	107.5858
Btu	kJ	1.055056
Btu	kW h	2.930711E-04
Btu	kW h	2.93071E-04
Btu	L atm	10.406
Btu	lb C to CO ₂	6.88E-05
Btu	lb H ₂ O (evap 212 °F)	0.001036
Btu/°F (60 °F)	cal/°C	453.6
Btu/bhp h	W/kW	0.3930148
Btu/ft ² h °F	cal/cm ² s °C	1.3562E-04
Btu/ft ² h °F	hp/ft ² °F	3.9275E-04
Btu/ft ² h °F	W/m ² °C	5.68247
Btu/ft ² h °F	W/m ² K	5.68247
Btu/ft ³	kJ/dm ³	0.0372590
Btu/ft ³	kJ/L	0.0372590
Btu/ft ³	kJ/m ³	37.2590
Btu/ft ³	kW h/m ³	0.0103497
Btu/ft ³	MJ/m ³	0.0372590
Btu/gal (UK)	Btu/ft ³	6.2288
Btu/gal (UK)	J/m ³	2.3209E+05
Btu/gal (UK)	kJ/dm ³	0.232080
Btu/gal (UK)	kJ/L	0.232080
Btu/gal (UK)	kJ/m ³	232.080
Btu/gal (UK)	kW h/dm	0.0644667
Btu/gal (UK)	MJ/m ³	0.232080
Btu/gal (US)	Btu/ft ³	5.1868
Btu/gal (US)	J/m ³	1.9326E+05
Btu/gal (US)	kJ/dm ³	0.278716
Btu/gal (US)	kJ/L	0.278716
Btu/gal (US)	kJ/m ³	278.716
Btu/gal (US)	kW h/dm ³	0.0774212
Btu/gal (US)	MJ/m ³	0.278716
Btu/h	cal/s	0.069999
Btu/h	ft lb/min	12.961
Btu/h	ft lb/sec	0.2162
Btu/h	hp	3.9275E-04

(continued)

Table 15.3 (continued)

Starting Unit	Desired Unit	Factor
From	To	Multiply By
Btu/h	W	0.293288
Btu/h (mean)	ft lb _f /h	791.75
Btu/h (mean)	ft lb _f /min	12.979
Btu/h (mean)	ft lb _f /s	0.21632
Btu/h (mean)	hp (550 ft lb _f /s)	3.9332E-04
Btu/h (mean)	W	0.29330
Btu/h ft ²	kW/m ²	0.00315459
Btu/h ft ²	kW/m ²	0.003154591
Btu/h ft ² (°F/ft)	W/m ² (°C/m)	1.730735
Btu/h ft ² (°F/ft)	W/m ² (°C/m)	1.730735
Btu/h ft ² (°F/in)	W/m ² (°C/m)	0.1442279
Btu/h ft ² °F	hp/ft ² °F	0.000394
Btu/h ft ² °F	kW/m ² °C	0.005678263
Btu/h ft ² °R	kW/m ² K	0.005678263
Btu/h ft ³	kW/m ³	0.01034971
Btu/h ft ³ °F	kW/m ³ °C	0.01862947
Btu/lb	J/g	2.32600
Btu/lb	J/kg	2326.0
Btu/lb	kJ/kg	2.32600
Btu/lb	kW h/kg	6.46111E-04
Btu/lb	MJ/kg	0.00232600
Btu/lb °F	cal/g °C	1
Btu/lb °F	cal/g K	1
Btu/lb °F	J/g °C	4.18680
Btu/lb °F	J/kg K	4186.8
Btu/lb °F	kJ/kg °C	4.18680
Btu/lb °F	J/g K	4.18680
Btu/lb °R	kJ/kg K	4.18680
Btu/lbmol	Btu/scf	0.00258540
Btu/lbmol	cal/mol	0.55556
Btu/lbmol	J/kmol	2326.0
Btu/lbmol	J/mol	2.3260
Btu/lbmol	kcal/kmol	555.56
Btu/lbmol	kJ/kmol	2.32600
Btu/lbmol °F	Btu/NCF °F	0.0025854
Btu/lbmol °F	cal/mol K	1
Btu/lbmol °F	J/mol K	4.1868
Btu/lbmol °F	kJ/kmol	2.326
Btu/lbmol °F	kJ/kmol °C	4.18680

(continued)

Table 15.3 (continued)

Starting Unit	Desired Unit	Factor
From	To	Multiply By
Btu/lbmol °F	MJ/kmol	0.002326
Btu/lbmol °F	W h/mol °C	0.0011622
Btu/min	ft lb/sec	12.96
Btu/min	hp	0.02356
Btu/min	kW	0.01758427
Btu/min	W	17.584
Btu/min ft ²	kW/ft ²	0.1758
Btu/min ft ²	W/in ²	0.1221
Btu/s	kW	1.055056
Btu/s	W	1055.056
Btu/s ft ²	kW/m ²	11.35653
Btu/s ft ² (°F/in)	cal/s cm ² (°C/cm)	1.24050
Btu/s ft ² °F	kW/m ² °C	20.44175
Btu/s ft ³	kW/m ³	37.25895
Btu/s ft ³ °F	kW/m ³ °C	67.06611
bu (US, dry)	ft ³	1.24446
bu (US, dry)	in ³	2150.4
bu (US, dry)	L	35.239
bu (US, dry)	m ³	0.035239
bu (US, dry)	pk	4
bu (US, dry)	pt (dry)	64
bu (US, dry)	qt (dry)	32
bucket (dry)	cm ³	1.818E+04
C		
C	F	1.0364E-05
C	statcoulomb	2.998E+09
C/cm ²	C/in ²	64.52
C/cm ²	C/m ²	1.00E+04
C/in ²	C/cm ²	0.1550
C/in ²	C/m ²	1550
C/m ²	C/cm ²	1.00E-04
C/m ²	C/in ²	6.45E-04
C° (unit size)	F° (unit size)	1.8
C° (unit size)	K (unit size)	1
C° (unit size)	R° (unit size)	1.8
cal	erg	4.1868E+07
cal	ft lb _f	3.0880
cal	hp h	1.5596E-06
cal	J	4.1840

(continued)

Table 15.3 (continued)

Starting Unit	Desired Unit	Factor
From	To	Multiply By
cal	kJ	0.004184
cal	kW h	1.1630E-06
cal	L-atm	0.041293
cal	W h	1.1630E-03
cal (mean)	Btu (mean)	0.0039683
cal/g	Btu/lb	1.7989
cal/g	J/g	4.18600
cal/g	J/kg	4186.0
cal/g	kJ/kg	4.18600
cal/g °C	Btu/lb °F	1
cal/g K	J/g K	4.18600
cal/g K	kJ/kg K	4.18600
cal/h cm ²	kW/m ²	0.01162222
cal/h cm ² (°C/cm)	Btu/h ft ² (°F/in)	0.8064
cal/h cm ² (°C/cm)	W/m ² (°C/m)	0.1162222
cal/h cm ² °C	kW/m ² × °C	0.01162222
cal/h cm ³	kW/m ³	1.162222
cal/lb	J/kg	9.22414
cal/ml	kJ/dm ³	4186.00
cal/mL	kJ/dm ³	4184
cal/ml	kJ/L	4186.00
cal/mL	kJ/L	4184
cal/ml	kJ/m ³	4186.00
cal/ml	MJ/m ³	4.18600
cal/mol	Btu/lbmol	1.7988
cal/mol	J/mol	4.186
cal/mol	W h/mol	0.0011622
cal/mol °C	Btu/NCF °F	0.0025854
cal/mol °C	kJ/kmol °C	4.18600
cal/s	Btu/h	14.286
cal/s	erg/s	4.186E+07
cal/s	ft lb _f /min	185.16
cal/s	hp	0.00561452
cal/s	W	4.18675
cal/s cm ² (°C/cm)	Btu/h ft ² (°F/in)	2903.0
cal/s cm ² (°C/cm)	W/m ² (°C/m)	418.4
cal/s cm ² °C	Btu/h ft ² °F	7380
cal/s cm ² °C	kW/m ² × °C	41.84
cal/s cm ² °C	W/m × °C	418.4

(continued)

Table 15.3 (continued)

Starting Unit	Desired Unit	Factor
From	To	Multiply By
cal/s cm ³	Btu/h ft ³	4.0452E+05
cal/s cm ³	μW/m ³ (micro)	4.18E+12
cal/s g	Btu/h lb	6479.9
cal/s g	W/kg	4186.8
cc	ft ³	3.5399E−05
cc	gal (US)	0.0002642
cc	in ³	0.06102
cc	L	0.001
cc	m ³	1.00E−06
cc	pt (US liq)	0.002113
cc	qt (US liq)	0.001057
cc	yd ³	1.308E−06
cd	carcel	0.1
cd	Cd (int)	0.98100
Cd (int)	cd	1.0194
Cd/cm ²	L	3.1420
Cd/in ²	L	0.4870
cd/m ²	L	3.1416E−04
cent	m ²	1.00
CFD (see ft ³ /d)		
cft (see ft ³)		
cg	g	0.01
ch	in	792
ch	m	20.1168
ch (surv)	ft	66.000
ch (surv)	m	20.117
ch (surv)	yd	22.000
ch h	kJ	2647.78
ch h	kW h	0.7354999
ch h	MJ	2.64778
Chu	Btu (ISO)	1.8001
Chu	kJ	1.899101
Chu	kW h	5.27528E−04
circumference	rad	6.283185
cL	dr	2.705
cL	ft ³	3.5315E−04
cL	in ³	0.6103
cL	L	0.01
cL	m ³	1.00E−05

(continued)

Table 15.3 (continued)

Starting Unit	Desired Unit	Factor
From	To	Multiply By
cL	oz (US fluid)	0.3382
cm	ft	0.032808
cm	in	0.3937
cm	km	1.00E-05
cm	m	0.01
cm	μ (micron)	10,000
cm	mi	6.214E-06
cm	mil	393.7
cm	mm	10
cm	yd	0.01094
cm H ₂ O (4 °C)	kPa	0.00980638
cm H ₂ O (4 °C)	lb _f /in ²	0.014223
cm H ₂ O (4 °C)	Pa	98.064
cm Hg	atm	0.01316
cm Hg	ft H ₂ O	0.4461
cm Hg	kg/cm ²	136.0
cm Hg	kg/m ²	136.0
cm Hg	lb/ft ²	27.85
cm Hg	lb/in ²	0.1934
cm/s	ft/h	118.110
cm/s	ft/min	1.96850
cm/s	ft/s	0.0328084
cm/s	in/min	23.6220
cm/s	in/s	0.393701
cm/s	km/h	0.036
cm/s	kt	0.1943
cm/s	m/min	0.60
cm/s	m/s	0.01
cm/s	mi/h	0.02237
cm/s	mi/min	3.728E-04
cm/s ²	ft/s ²	0.0328084
cm/s ²	G	0.0010197
cm/s ²	km/h s	0.036
cm/s ²	m/s ²	0.01
cm/s ²	mi/h s	0.022369
cm dyn	cm g	0.001020
cm dyn	lb ft	7.376E-08
cm dyn	m kg	1.020E-08
cm g	cm dyn	980.7

(continued)

Table 15.3 (continued)

Starting Unit	Desired Unit	Factor
From	To	Multiply By
cm g	lb ft	7.233E-05
cm g	m kg	1.00E-05
cm kg _f	ft lb _f	0.072330
cm kg _f	N m	0.098067
cm ²	circ mil	1.973E+05
cm ²	ft ²	0.0010764
cm ²	in ²	0.1550
cm ²	m ²	1.00E-04
cm ²	mi ²	3.861E-11
cm ²	mm ²	100
cm ²	yd ²	1.196E-04
cm ² /g	ft ² /lb	0.48823
cm ² /g	m ² /g	1.00E-04
cm ² /g	m ² /kg	0.1
cm ² /s	ft ² /s	0.0010764
cm ² /s	m ² /s	0.0010764
cm ² /s	mm ² /s	100
cm ³	ft ³	3.5315E-05
cm ³	gal (US)	2.642E-04
cm ³	in ³	0.061020
cm ³	L	0.001
cm ³	m ³	1.00E-06
cm ³	ml	1
cm ³	oz (UK fluid)	0.035195095
cm ³	oz (US fluid)	0.033814022
cm ³	pt (US liq)	0.002113
cm ³	qt (US liq)	0.001057
cm ³	yd ³	1.308E-06
cmil	cm ²	5.0670E-06
cmil	ft ²	5.4542E-09
cmil	in ²	7.854E-07
cmil	m ²	5.0671E-10
cmil	mil ²	0.7854
cord	cord-ft	8
cord	ft ³	128.000
cord	m ³	3.62456
cord-ft	ft ³	16.000
cord-ft	m ³	0.45307
cP	g/s cm	0.01

(continued)

Table 15.3 (continued)

Starting Unit	Desired Unit	Factor
From	To	Multiply By
cP	kg/h m	3.6
cP	kg/s m	0.001
cP	lb/h ft	2.4191
cP	lb/s ft	0.000672
cP	lb _f s/ft ²	2.0885E-05
cP	N s/m ²	0.001
cP	P	0.01
cP	Pa s	0.001
cSt	ft ² /s	1.0764E-05
cSt	m ² /s	1.00E-06
cSt	mm ² /s	1
cu (curie)	C/min	1.10E+12
cu (curie)	events/min	2.20E+12
cu ft (see ft ³)		
cu in (see in ³)		
cubem	km ³	4.168182
CV h	kJ	2647.78
CV h	kW h	0.7354999
CV h	MJ	2.64778
cwt (long)	kg	50.802
cwt (long)	lb	112.00
cwt (long)	lb	112.0000
cwt (short)	kg	45.359
cwt (short)	lb	100
cwt (short)	lb _m	100.00
cwt (short)	oz (av)	1600
cwt (short)	t (long)	0.0446429
cwt (short)	t (metric)	0.0453592
cwt (UK)	kg	50.80234
cwt (US)	kg	45.35924
cwt, lg cwt	t (US long)	0.05
D		
d (day)	s	8.64000E+04
Da	g	1.6606E-24
Da	kg	1.6606E-27
Da	lb _m	3.6609E-27
darcy	ft ²	1.0624E-11
darcy	m ²	9.8692E-13
darcy	μm ² (micro)	0.986923

(continued)

Table 15.3 (continued)

Starting Unit	Desired Unit	Factor
From	To	Multiply By
deg (angle)	quadr	0.011111
deg (angle)	rad	0.017453
deg (angle)	rev	0.0027778
deg (angle)	sec (angle)	3600
deg/s	rad/s	0.017453
deg/s	rev/min	0.16667
deg/s	rev/s	0.0027778
dg	g	0.1
Dg	g	10
dL	ft ³	0.0035315
dL	L	0.1
dL	m ³	1.00E-04
dm	ft	0.32808
dm	m	0.1
Dm	m	10
dr (ap or tr)	kg	0.0038879
dr (ap or tr)	lb _m	0.0085714
dr (ap or tr)	oz (ap or tr)	0.12500
dr (ap or tr)	oz (av)	0.1371429
dr (av)	g	1.771845
dr (av)	gr	27.34375
dr (av)	kg	0.0017718
dr (av)	lb _m	0.0039062
dr (av)	oz (av)	0.0625
dr (UK fluid)	ft ³	1.2542E-04
dr (UK fluid)	m ³	3.5516E-06
dr (US fluid)	cm ³	3.6967
dr (US fluid)	ft ³	1.3055E-04
dr (US fluid)	m ³	3.6967E-06
drp	ft ³	1.740E-05
drp	L	4.929E-04
dwt (tr)	g	1.55517
dwt (tr)	gr	24
dwt (tr)	kg	0.0015552
dwt (tr)	lb (av)	0.0034286
dwt (tr)	lb (tr)	0.0041667
dwt (tr)	oz (tr)	0.05
dyn	g	1.020E-03
dyn	J/cm	1.00E-07

(continued)

Table 15.3 (continued)

Starting Unit	Desired Unit	Factor
From	To	Multiply By
dyn	J/m	1.00E-05
dyn	kg	1.020E-06
dyn	lb _f	2.2481E-06
dyn	mN	0.01
dyn	N	1.00E-05
dyn	pdl	7.2330E-05
dyn/cm	erg/mm ²	0.01
dyn/cm	mN/m	1
dyn/cm	N/m	0.001
dyn/cm ²	atm	9.8690E-07
dyn/cm ²	bar	1.00E-06
dyn/cm ²	in H ₂ O	4.0150E-04
dyn/cm ²	in Hg	2.9530E-05
dyn/cm ²	lb _f /ft ²	0.020886
dyn/cm ²	lb _f /in ²	1.4504E-05
dyn/cm ²	N/m ²	10
dyn/cm ²	Pa	0.1
dyn × s/cm ²	Pa s	0.1
dyn cm	ft lb _f	7.3756E-08
dyn cm	N m	1.00E-07
dyn s/cm ²	N s/m ²	0.1
E		
ell	cm	114.30
ell	ft	3.7500
ell	in	45.00
ell	m	1.1430
em (Pica)	cm	0.4233
em (Pica)	in	0.167
eq/l	eq/m ³	1000
eq/l	lbeq/ft ³	0.012846
eq/m ³	eq/l	0.001
eq/m ³	lbeq/ft ³	1.2846E-05
eq/m ³	lbeq/gal (US)	9.6098E-05
erg	Btu	9.480E-11
erg	cal	2.389E-08
erg	dyn cm	1
erg	ft lb _f	7.367E-08
erg	g cm	1.020E-03
erg	hp h	3.7250E-14

(continued)

Table 15.3 (continued)

Starting Unit	Desired Unit	Factor
From	To	Multiply By
erg	J	1.00E-07
erg	kcal	2.389E-11
erg	kg m	1.020E-08
erg	kW h	2.7780E-14
erg	W h	2.7780E-10
erg/a	GW	3.170979E-24
erg/a	TW	3.170979E-27
erg/cm ²	mJ/m ²	1
erg/s	Btu (mean)/h	3.4095E-07
erg/s	Btu/min	5.688E-06
erg/s	dyn cm/s	1
erg/s	ft lb _f /min	4.427E-06
erg/s	ft lb _f /s	7.376E-08
erg/s	hp	1.341E-10
erg/s	kcal/min	1.433E-09
erg/s	kW	1.00E-10
erg/s	W	1.00E-07
F		
F	A h	26.801
F	abcoulomb	9648.5
F	C	9.6485E+04
F	Fr	2.8926E+14
F	μF (micro)	1.00E+06
F	statcoulomb	2.8926E+14
F	statfarad	8.9847E+11
F/s	A (abs)	9.6500E+04
F° (unit size)	C° (unit size)	0.555555556
F° (unit size)	K (unit size)	0.55556
F° (unit size)	R° (unit size)	1
fath	ft	6
fath	m	1.828804
FOE bbl	MMBtu/bbl	6.4
ft	cm	30.48
ft	km	3.0480E-04
ft	m	0.30480
ft	mi (naut)	1.6458E-04
ft	mi (stat)	1.8939E-04
ft	mi (US surv)	1.8940E-04
ft	mil	1.2000E+04

(continued)

Table 15.3 (continued)

Starting Unit	Desired Unit	Factor
From	To	Multiply By
ft	mm	304.80
ft	nm	3.0480E+08
ft	rod	0.060606
ft	yd	0.33333
ft (metric)	ft	1.0925
ft (metric)	m	0.33300
ft H ₂ O	atm	0.02950
ft H ₂ O	in H ₂ O	12
ft H ₂ O	in Hg	0.88260
ft H ₂ O	kg/cm ²	0.03048
ft H ₂ O	kg/m ²	304.8
ft H ₂ O	lb _f /ft ²	62.43
ft H ₂ O	mm Hg	22.20
ft H ₂ O	torr	22.20
ft H ₂ O (4 °C)	lb _f /in ²	0.43352
ft H ₂ O (4 °C)	Pa	2989.0
ft Hg (32 °F)	lb _f /in ²	5.8938
ft Hg (32 °F)	Pa	4.0637E+04
ft/°F	m/K	0.54864
ft/100 ft	% grade	1
ft/bbl	m/m ³	1.917134
ft/d	m/d	0.3048
ft/d	mm/s	0.003527778
ft/ft ³	m/m ³	10.76391
ft/gal (US)	m/m ³	80.51964
ft/h	cm/s	0.008466667
ft/h	ft/s	2.7778E-04
ft/h	m/s	8.4667E-05
ft/h	mm/s	0.08466667
ft/mi	m/km	0.1893939
ft/mi	m/km	0.1893939
ft/min	cm/s	0.5080
ft/min	ft/s	0.016667
ft/min	km/h	0.018288
ft/min	m/min	0.3048
ft/min	m/s	0.0050800
ft/min	mi/h	0.01136
ft/s	cm/s	30.48
ft/s	ft/h	3600.0

(continued)

Table 15.3 (continued)

Starting Unit	Desired Unit	Factor
From	To	Multiply By
ft/s	ft/min	60
ft/s	km/h	1.097271
ft/s	km/s	3.0480E-04
ft/s	kt	0.5924
ft/s	m/min	18.288
ft/s	m/ms	3.048E-04
ft/s	m/s	0.30480
ft/s	mi/h	0.618182
ft/s	mi/min	0.01136
ft/s ²	cm/s ²	30.48
ft/s ²	km/h s	1.097
ft/s ²	m/s ²	0.30480
ft/s ²	mi/h s	0.6818
ft cd	lm/m ²	10.76391
ft cd	lx	10.76391
ft lb (see also ft lb _f or lb _f ft)		
ft lb _f	Btu	0.001285068
ft lb _f	cal	0.3238
ft lb _f	dyn cm	1.3558E+07
ft lb _f	erg	1.356E+07
ft lb _f	hp h	5.050505E-07
ft lb _f	in lb _f	12
ft lb _f	in oz _f	192.00
ft lb _f	J	1.355818
ft lb _f	kcal	3.238316E-04
ft lb _f	kg m	0.138255
ft lb _f	kJ	0.001355818
ft lb _f	kW h	3.766161E-07
ft lb _f	N m	1.355818
ft lb _f /gal	kJ/m ³	0.358169
ft lb _f /h	Btu/h (mean)	0.0012630
ft lb _f /h	W	3.7044E-04
ft lb _f /min	Btu/h (mean)	0.077045
ft lb _f /min	Btu/min	0.001286
ft lb _f /min	ft lb _f /s	0.016667
ft lb _f /min	hp	3.030E-05
ft lb _f /min	kcal/min	3.240E-04
ft lb _f /min	kW	2.280E-05
ft lb _f /min	W	0.02259697

(continued)

Table 15.3 (continued)

Starting Unit	Desired Unit	Factor
From	To	Multiply By
ft lb _f /s	Btu/h	4.6263
ft lb _f /s	Btu/min	0.07704
ft lb _f /s	hp	0.001818
ft lb _f /s	kcal/min	0.01941
ft lb _f /s	kW	0.001356
ft lb _f /s	W	1.3558
ft pdl	Btu	3.9941E-05
ft pdl	ft lb _f	0.031081
ft pdl	J	0.042140
ft pdl	L atm	0.0004159
ft ²	Ac	2.2957E-05
ft ²	ch ² (Gunt)	2.2957E-04
ft ²	ch ² (Rams)	1.00E-04
ft ²	ch ² (surv)	2.2957E-04
ft ²	cm ²	929.0304
ft ²	cmil	1.8335E+08
ft ²	ft ² (US surv)	1.00
ft ²	ha	9.2903E-06
ft ²	hm ²	9.2903E-06
ft ²	in ²	144
ft ²	km ²	9.2903E-08
ft ²	m ²	0.09290304
ft ²	mi ²	3.587E-04
ft ²	mi ² (US naut)	2.7052E-08
ft ²	mi ² (US surv)	3.5870E-08
ft ²	mm ²	9.2903E+04
ft ²	μm ² (micro)	9.2903E+10
ft ²	rod ²	0.0036731
ft ²	sect	3.5870E-08
ft ²	yd ²	0.1111
ft ² /h	ft ² /s	2.7778E-04
ft ² /h	mm ² /s	25.8064
ft ² /in ³	m ² /cm ³	0.005699291
ft ² /lb sec	m ² /N s	0.020885
ft ² /s	cm ² /s	929.03
ft ² /s	cSt	92,903
ft ² /s	ft ² /h	3600.0
ft ² /s	mm ² /s	92,903
ft ² /s	St	929.03

(continued)

Table 15.3 (continued)

Starting Unit	Desired Unit	Factor
From	To	Multiply By
ft ³	Ac ft (US)	2.2957E−05
ft ³	Ac in (US)	2.7548E−04
ft ³	bbl (petrol)	0.17811
ft ³	bbl (US dry)	0.24526
ft ³	bbl (US liq)	0.23748
ft ³	bu (US dry)	0.8036
ft ³	cm ³	2.8317E+04
ft ³	cord	0.0078125
ft ³	cord-ft	0.062500
ft ³	cu mi (int, stat)	6.7935E−12
ft ³	dm ³	28.3168
ft ³	dr (UK fluid)	7972.90
ft ³	dr (US fluid)	7660.04
ft ³	gal (UK)	6.22882
ft ³	gal (US dry)	6.42850
ft ³	gal (US liq)	7.48051
ft ³	in ³	1727.99
ft ³	L	28.3168
ft ³	m ³	0.0283168
ft ³	mL	2.8317E+07
ft ³	mm ³	2.8317E+07
ft ³	oz (UK fluid)	996.614
ft ³	oz (US fluid)	957.506
ft ³	pk (UK)	3.11441
ft ³	pk (US dry)	3.21425
ft ³	pt (UK)	49.8305
ft ³	pt (US dry)	51.4280
ft ³	pt (US liq)	59.8441
ft ³	qt (UK)	24.9154
ft ³	qt (US dry)	25.7140
ft ³	qt (US liq)	29.9220
ft ³	sc (UK fluid)	2.3919E+04
ft ³	yd ³	0.037037
ft ³ /d	dm ³ /s	3.277413E−04
ft ³ /d	ft ³ /s	1.1574E−05
ft ³ /d	gal/min	0.0051948
ft ³ /d	L/min	0.019667
ft ³ /d	L/s	3.277413E−04
ft ³ /d	m ³ /d	0.0283169

(continued)

Table 15.3 (continued)

Starting Unit	Desired Unit	Factor
From	To	Multiply By
ft^3/d	m^3/h	0.00117987
ft^3/ft	m^3/m	0.0929034
$\text{ft}^3/\text{ft}^2 \text{ h}$	$\text{m}^3/\text{m}^2 \text{ s}$	$8.4663\text{E}-05$
$\text{ft}^3/\text{ft}^2 \text{ min}$	$\text{m}^3/\text{m}^2 \text{ s}$	0.0050798
$\text{ft}^3/\text{ft}^2 \text{ s}$	$\text{m}^3/\text{m}^2 \text{ s}$	0.30479
ft^3/h	bbl/d (petrol)	4.2740
ft^3/h	dm^3/s	0.007865791
ft^3/h	ft^3/s	$2.7778\text{E}-04$
ft^3/h	gal/min	0.12468
ft^3/h	L/min	0.47200
ft^3/h	L/s	0.007865791
ft^3/h	m^3/h	0.0283169
ft^3/h	m^3/s	$7.8667\text{E}-06$
ft^3/kg	ft^3/lb	0.45359
ft^3/kg	m^3/kg	0.028317
ft^3/lb	dm^3/kg	62.42796
ft^3/lb	L/kg	62.42796
ft^3/lb	m^3/g	$6.242796\text{E}-05$
ft^3/lb	m^3/kg	0.06242796
ft^3/lbmol	m^3/kmol	0.06242796
ft^3/min	cm^3/s	472.0
ft^3/min	dm^3/s	0.4719474
ft^3/min	ft^3/s	0.016667
ft^3/min	gal/min (US)	7.4805
ft^3/min	gal/s (US)	0.1247
ft^3/min	L/min	28.320
ft^3/min	L/s	0.4719474
ft^3/min	lb $\text{H}_2\text{O}/\text{min}$	62.43
ft^3/min	m^3/min	0.02832
ft^3/min	m^3/min	0.02832
ft^3/min	m^3/s	$4.7200\text{E}-04$
ft^3/s	dm^3/s	28.31685
ft^3/s	ft^3/d	$8.6400\text{E}+04$
ft^3/s	ft^3/h	3600
ft^3/s	ft^3/min	60
ft^3/s	gal/d	$6.4633\text{E}+05$
ft^3/s	gal/h	$2.6930\text{E}+04$
ft^3/s	gal/min	448.84
ft^3/s	gal/s	7.4807

(continued)

Table 15.3 (continued)

Starting Unit	Desired Unit	Factor
From	To	Multiply By
ft ³ /s	L/d	2.4469E+06
ft ³ /s	L/h	1.0195E+05
ft ³ /s	L/min	1699.2
ft ³ /s	L/s	28.31685
ft ³ /s	m ³ /d	2446.8
ft ³ /s	m ³ /h	101.95
ft ³ /s	m ³ /min	1.6992
ft ³ /s	m ³ /s	0.028320
ft ³ /s	MM gal/d (US 10 ⁶)	0.64633
ft ³ atm	ft lb _f	2116.3
ft ³ atm	L atm	28.316
fur	ft	660.00
fur	m	201.17
fur	mi	0.125
fur	rod	40.0
G		
g	dyn	980.7
g	gr	15.43
g	J/cm	9.807E-05
g	J/m	0.0098070
g	kg	0.001
g	lb _m	0.0022046
g	mg	1000
g	N	0.0098070
g	oz (av)	0.0352740
g	oz (tr)	0.0321507
g	pdl	0.07093
G (gauss)	line/in ²	6.452
G (gauss)	T (tesla)	1.00E-04
G (gauss)	Wb/cm ²	1.00E-08
G (gauss)	Wb/in ²	6.452E-08
G (gauss)	Wb/m ²	1.00E-04
g/cm	lb/in	0.0056
g/cm s	cP	100
g/cm s	kg/m s	0.1000
g/cm s	lb _f s/ft ²	0.00209
g/cm s	lb _m /ft h	242
g/cm s	lb _m /ft s	0.0672
g/cm s ²	lb _f /sq ft	0.020886

(continued)

Table 15.3 (continued)

Starting Unit	Desired Unit	Factor
From	To	Multiply By
g/cm s^2	N/m^2	10
g/cm^2	kg/m^2	10
g/cm^2	lb/ft^2	2.0482
g/cm^3	g/mL	1
g/cm^3	kg/dm^3	1
g/cm^3	lb/ft^3	62.42797373
g/cm^3	lb/gal	8.345406355
g/cm^3	lb/in^3	0.03613
g/cm^3	lb/mil ft	$3.405\text{E}-07$
g/dm^3	kg/m^3	1
g/dm^3	lb/bbl	0.350507008
g/dm^3	lb/ft^3	0.062428
g/dm^3	$\text{lb}_\text{m}/\text{gal (US)}$	8.3452
g/gal (UK)	kg/m^3	0.2199692
g/gal (US)	kg/m^3	0.264172
g/L	gr/gal (US)	58.417
g/L	kg/m^3	1
g/L	lb/bbl	0.350507008
g/L	lb/ft^3	0.062428
g/L	$\text{lb/M gal (US 1000)}$	8.345
g/L	ppm (w)	1000
g/m^3	lb/ft^3	$6.2428\text{E}-05$
g/m^3	lb/M bbl (1000)	0.350507008
g/m^3	mg/gal (US)	3.785412534
g/mL	g/cm^3	1
g/mL	kg/dm^3	1
g/mL	kg/L	1
g/mL	kg/m^3	1000
g/mL	lb/ft^3	62.428
g/mL	lb/ft^3	62.42797373
g/mL	lb/gal	8.345406355
g/mL	lb/gal (UK)	10.02240609
g/mol	amu	1
g/mol	kg/kmol	1
g/mol	lb/lbmol	1
g cm	Btu	$9.30\text{E}-08$
g cm	erg	980.7
g cm	J	$9.807\text{E}-05$
g cm	kcal	$2.343\text{E}-08$

(continued)

Table 15.3 (continued)

Starting Unit	Desired Unit	Factor
From	To	Multiply By
g cm	kg m	1.00E-05
g cm/s	ft lb _f /s	7.2333E-05
g cm/s	kg m/s	1.00E-05
g cm/s ²	ft lb _f /s ²	7.2307E-05
g cm/s ²	kg m/s ²	1.00E-05
gal (accel)	m/s ²	0.01
gal (UK liq)	gal (US liq)	1.20095
gal (UK)	dm ³	4.546092
gal (UK)	ft ³	0.160544
gal (UK)	gal (US)	1.20095
gal (UK)	L	4.546092
gal (UK)	m ³	0.0045461
gal (US dry)	ft ³	0.155557
gal (US dry)	m ³	0.0044049
gal (US liq)	cm ³	3785.4
gal (US liq)	ft ³	0.133681
gal (US liq)	gal (UK liq)	0.83267
gal (US liq)	in ³	231.0
gal (US liq)	L	3.7854
gal (US liq)	m ³	0.0037854
gal (US liq)	yd ³	0.004951
gal (US)	cm ³	3785
gal (US)	dm ³	3.785412
gal (US)	ft ³	0.1337
gal (US)	gal (UK)	0.83267
gal (US)	in ³	231.0
gal (US)	L	3.785412
gal (US)	m ³	0.003785412
gal (US)	pt (US liq)	8
gal (US)	qt (US liq)	4
gal (US)	yd ³	0.004951
gal H ₂ O	lb H ₂ O	8.3453
gal/100 mi (UK)	km/L	35.4
gal/100 mi (UK)	mi/gal (US)	83.267
gal/100 mi (US)	km/L	42.51
gal/100 mi (US)	mi/gal (US)	100
gal/d (US)	ft ³ /s	1.5472E-06
gal/d (US)	gal/min	6.9444E-04
gal/d (US)	L/min	0.0026285

(continued)

Table 15.3 (continued)

Starting Unit	Desired Unit	Factor
From	To	Multiply By
gal/d (US)	m ³ /s	4.3808E−08
gal/ft (UK)	ft ²	0.16054
gal/ft (UK)	m ²	0.014915
gal/ft (US)	ft ²	0.13368
gal/ft (US)	m ²	0.012419
gal/ft ³ (UK)	dm ³ /m ³	160.5437
gal/ft ³ (UK)	L/m ³	160.5437
gal/ft ³ (US)	dm ³ /m ³	133.6806
gal/ft ³ (US)	L/m ³	133.6806
gal/h (UK)	dm ³ /s	0.001262803
gal/h (UK)	L/s	0.001262803
gal/h (UK)	m ³ /h	0.00454609
gal/h (UK)	m ³ /h	0.004546092
gal/h (US)	dm ³ /s	0.001051503
gal/h (US)	dm ³ /s	0.001051503
gal/h (US)	ft ³ /s	3.7133E−05
gal/h (US)	gal/min (US)	0.016667
gal/h (US)	L/min	0.063083
gal/h (US)	L/s	0.001051503
gal/h (US)	m ³ /h	0.00378541
gal/h (US)	m ³ /s	1.0514E−06
gal/h ft (UK)	m ³ /s m	4.143055E−06
gal/h ft (US)	m ² /s	3.449814E−06
gal/h ft (US)	m ³ /s m	3.449814E−06
gal/h ft ² (UK)	m ³ /s m ²	1.35927E−05
gal/h ft ² (US)	m/s	1.131829E−05
gal/h ft ² (US)	m ³ /s m ²	1.131829E−05
gal/h hp (US)	dm ³ /kW h	5.076321
gal/h hp (US)	dm ³ /MJ	1.410089
gal/h hp (US)	mm ³ /J	1.410089
gal/h in (UK)	m ³ /s m	4.97167E−05
gal/h in (US)	m ² /s	4.139776E+01
gal/h in (US)	m ³ /s m	4.139776E+01
gal/h in ² (UK)	m ³ /s m ²	0.001957349
gal/h in ² (US)	m/s	0.001629833
gal/h in ² (US)	m ³ /s m ²	0.001629833
gal/lb (UK)	dm ³ /kg	10.22241
gal/lb (UK)	L/kg	10.22241
gal/lb (US)	dm ³ /kg	8.345404

(continued)

Table 15.3 (continued)

Starting Unit	Desired Unit	Factor
From	To	Multiply By
gal/lb (US)	L/kg	8.345404
gal/Mbbl (1000)	cm ³ /m ³	23.80952
gal/Mbbl (1000)	mL/m ³	23.80952
gal/Mbbl (UK 1000)	cm ³ /m ³	28.59403
gal/mi (UK)	ft ³ /ft	3.0406E-05
gal/mi (UK)	m ³ /m	2.8248E-06
gal/mi (US)	dm ³ /100 km	235.2146
gal/mi (US)	ft ³ /ft	2.5318E-05
gal/mi (US)	L/100 km	235.2146
gal/mi (US)	m ³ /m	2.3521E-06
gal/min (UK)	dm ³ /s	0.0757682
gal/min (UK)	L/s	0.0757682
gal/min (UK)	L/s	0.0757682
gal/min (UK)	m ³ /h	0.272766
gal/min (UK)	m ³ /h	0.272765500
gal/min (US)	dm ³ /s	0.0630902
gal/min (US)	ft ³ /h	8.0208
gal/min (US)	ft ³ /min	0.13368
gal/min (US)	ft ³ /s	0.002228
gal/min (US)	gal/d	1440
gal/min (US)	gal/h	60
gal/min (US)	L/min	3.7850
gal/min (US)	L/s	0.0630902
gal/min (US)	m ³ /h	0.227125
gal/min ft (UK)	m ² /s	2.485833E-04
gal/min ft (US)	m ² /s	2.069888E-04
gal/min ft ² (UK)	m/s	8.15562E-04
gal/min ft ² (UK)	m ³ /s m ²	0.000815562
gal/min ft ² (US)	m ³ /s m ²	6.79097E-04
gal/Mscf (1000)	dm ³ /kmol	3.16691
gal/Mscf (1000)	L/kmol	3.16691
gal/t (US shale yld)	dm ³ /t (metric)	4.172702
gal/t (US shale yld)	L/t (metric)	4.172702
Gb (gilbert)	A turn	0.79577
Gb/cm (gilbert)	A turn/cm	0.79577
Gb/cm (gilbert)	A turn/in	2.021
Gb/cm (gilbert)	A turn/m	79.58
g _f s ²	g cm	980.665
gi (UK gill)	cm ³	142.07

(continued)

Table 15.3 (continued)

Starting Unit	Desired Unit	Factor
From	To	Multiply By
gi (US gill)	L	0.1183
gi (US gill)	pt (US liq)	0.25
gon	deg (angle)	0.90000
gon	rad	0.01571
gon	rad	0.015708
GPa	lb _f /in ²	1.4504E+05
GPa	Pa	1.00E+09
GPM (see gal/min)		
gr (ap)	kg	6.4799E−05
gr (ap)	lb _m	0.00014286
gr (av)	dr (av)	0.03657143
gr (av)	kg	6.4799E−05
gr (av)	lb _m	0.00014286
gr (av)	mg	64.79891
gr (tr)	dwt (tr)	0.04167
gr (tr)	g	0.0648
gr (tr)	gr (av)	1
gr (tr)	kg	6.4799E−05
gr (tr)	lb _m	0.00014286
gr (tr)	oz (av)	0.0020833
gr (tr)	oz (tr)	0.0020833
gr/100 ft ³	mg/m ³	22.88351
gr/ft ³ (av)	lb/ft ³	1.4286E−04
gr/ft ³ (av)	mg/m ³	2288.351
gr/gal (UK)	kg/m ³	0.014254
gr/gal (UK)	ppm (w)	14.286
gr/gal (US)	g/m ³	17.11806
gr/gal (US)	kg/m ³	0.017118
gr/gal (US)	lb/ft ³	0.0010686
gr/gal (US)	lb/MMgal (US 10 ⁶)	142.86
gr/gal (US)	mg/dm ³	17.11806
gr/gal (US)	ppm (w)	17.118
grad	deg (angle)	0.90000
grad	rad	0.015708
grad	rad	0.01571
gram calorie (see cal)		
H		
H	abhenry	1.00E+09
h	d	0.04167
H	mH	1000

(continued)

Table 15.3 (continued)

Starting Unit	Desired Unit	Factor
From	To	Multiply By
h	min	60
h	min	60
h	s	3600
H	stathenry	1.1127E-12
h	wk	0.005952
ha	Ac	2.471
ha	ft ²	1.0764E+05
ha	m ²	1.00E+04
ha	sect	0.003861022
hand	cm	10.16
hg	g	100
hg	kg	0.10
hg	lb _m	0.22046
hhd (UK liq)	ft ³	10.11400
hhd (US liq)	ft ³	8.42189
hhd (US liq)	gal (US liq)	63
hhd (US liq)	m ³	0.23848
hhp (hydraulic)	kW	0.746043
hL	L	100
hm	ft	328.08
hm	m	100
hp	Btu/min	42.44
hp	ft lb _f /s	550
hp	ft-lb _f /min	3.3000E+04
hp	HP (metric)	1.014
hp	kcal/min	10.547
hp	kW	0.74548
hp	W	745.45
hp (550)	kW	0.7456999
hp (boiler)	Btu/h	33,479
hp (boiler)	kW	9.809
hp (elect)	Btu/h	2543.5
hp (elect)	kW	0.746
hp (elect)	W	746.00
hp (metric)	Btu/h	2507.7
hp (metric)	ch (metric)	1.00
hp (metric)	CV (metric)	1.00
hp (metric)	hp (550)	0.9863
hp (metric)	kW	0.7354999

(continued)

Table 15.3 (continued)

Starting Unit	Desired Unit	Factor
From	To	Multiply By
hp/ft ³	kW/m ³	26.33414
hp h	Btu	2544.434
hp h	cal	6.416E+05
hp h	erg	2.6845E+13
hp h	ft lb _f	1.98E+06
hp h	J	2.68452E+06
hp h	kcal	641.1865
hp h	kg m	2.737E+05
hp h	kJ	2684.52
hp h	kW h	0.7456999
hp h	MJ	2.68452
hundredweight (see cwt)		
hW	W	100
Hz	s ⁻¹	1
I		
in	cm	2.540
in	ft	0.083333
in	m	0.025400
in	mi	1.5780E-05
in	mil	1000
in	mm	25.400
in	pt	72.254
in	yd	0.02778
in H ₂ O (39.2 °F)	kPa	0.249082
in H ₂ O (4 °C)	at	0.002540
in H ₂ O (4 °C)	atm	0.002458
in H ₂ O (4 °C)	bar	0.002451
in H ₂ O (4 °C)	in Hg	0.073550
in H ₂ O (4 °C)	kg/cm ²	0.00254
in H ₂ O (4 °C)	kg/m ²	25.400
in H ₂ O (4 °C)	lb _f /ft ²	5.204
in H ₂ O (4 °C)	lb _f /in ²	0.036126
in H ₂ O (4 °C)	mm Hg	1.85
in H ₂ O (4 °C)	oz _f /in ²	0.5781
in H ₂ O (4 °C)	Pa	249.08
in H ₂ O (4 °C)	torr	1.85
in H ₂ O (60 °F)	kPa	0.24884
in H ₂ O (60 °F)	lb _f /in ²	0.036092
in H ₂ O (60 °F)	Pa	248.85

(continued)

Table 15.3 (continued)

Starting Unit	Desired Unit	Factor
From	To	Multiply By
in Hg	atm	0.03342
in Hg	bar	0.0339
in Hg	ft H ₂ O	1.133
in Hg	in H ₂ O	13.596
in Hg	kg/cm ²	0.03453
in Hg	kg/m ²	345.3
in Hg	lb _f /ft ²	70.73
in Hg	lb _f /in ²	0.4912
in Hg	mm Hg	25.4
in Hg	torr	25.4
in Hg (32 °C)	Pa	3386.4
in Hg (60 °F)	kPa	3.37685
in/min	cm/s	0.04233333
in/min	ft/s	0.0013889
in/min	m/s	4.2333E−04
in/min	mm/s	0.4233333
in/s	cm/s	2.54
in/s	ft/s	0.083333
in/s	m/s	0.025400
in/s	mm/s	25.4
in/yr	mm/a	25.4
in ²	circ mil	1.273E+06
in ²	cm ²	6.452
in ²	ft ²	0.0069444
in ²	m ²	0.00064516
in ²	mil ²	1.00E+06
in ²	mm ²	645.2
in ²	yd ²	7.716E−04
in ² /s	ft ² /s	0.0069444
in ² /s	m ² /s	0.0069444
in ² /s	mm ² /s	645.16
in ³	cm ³	16.39
in ³	ft ³	5.7871E−04
in ³	gal (US liq)	0.004329
in ³	L	0.01639
in ³	m ³	1.6387E−05
in ³	mil ft	1.061E+05
in ³	mm ³	16387
in ³	pt (US liq)	0.03463

(continued)

Table 15.3 (continued)

Starting Unit	Desired Unit	Factor
From	To	Multiply By
in ³	qt (US liq)	0.01732
in ³	yd ³	2.1430E-05
in ⁴	cm ⁴	41.62314
J		
J	boe	1.6340E-10
J	Btu (IT)	9.4782E-04
J	Chu (15 °C)	5.2657E-04
J	erg	1.00E+07
J	ft lb _f	0.7375621
J	ft pdl	23.730
J	hp h	3.725061E-07
J	kcal	2.388459E-04
J	kg _f m	0.101972
J	kJ	0.001
J	kW h	2.7778E-07
J	L atm	0.0098692
J	lb _f ft	0.737562
J	lb _f in	8.851100
J	W h	2.778E-04
J	W s	1
J/cm	dyn	1.000E+07
J/cm	g	1.020E+04
J/cm	J/m	100
J/cm	lb _f	22.48
J/cm	N	100
J/cm	pdl	723.3
J/g	Btu/lb	0.429923
J/g	cal/g	0.239006
J/g °C	Btu/lb °F	0.2388459
J/g °C	kcal/kg °C	0.2390057
J/g °C	kW h/kg °C	0.000277778
J/g K	Btu/lb °R	0.2388459
J/g K	cal/g K	0.239006
J/g K	kcal/kg °C	0.239006
J/kg	Btu/lb	4.2992E-04
J/kg	cal/g	2.3889E-04
J/kg	Chu/lb	2.3885E-04
J/kmol	Btu/lbmol	0.42992
J/kmol	J/mol	1000

(continued)

Table 15.3 (continued)

Starting Unit	Desired Unit	Factor
From	To	Multiply By
J/kmol	J/mol	1000
J/m ³	Btu/ft ³	2.6838E-05
J/m ³	Btu/gal (US)	5.1744E-06
J/m ³	cal/cm ³	2.3885E-07
J/m ³	kcal/m ³	2.3885E-04
J/mol	Btu/lbmol	0.429923
J/mol	cal/mol	0.23885
J/mol	kcal/kmol	0.23885
J/s	W	1
K		
K	°R	1.8
K	°R	1.8
K (unit size)	C° (unit size)	1
K (unit size)	F° (unit size)	1.8
K (unit size)	R° (unit size)	1.80000
kcal	Btu	3.968321
kcal	ft lb _f	3088.025
kcal	hp h	0.00159607
kcal	J	4186.8
kcal	kg m	426.9348
kcal	kJ	4.1868
kcal	kW h	0.001163
kcal/ft ² h	Btu/ft ² h	3.9682
kcal/ft ² h	W/m ²	12.518
kcal/ft ³	Btu/ft ³	3.9683
kcal/h	Btu/h	3.9683
kcal/h	W	1.162222
kcal/h	W	1.1639
kcal/h cm ² °C	kW/m ² °C	1.162222
kcal/h m ² (°C/m)	W/m ² (°C/m)	1.162222
kcal/h m ² °C	Btu/h ft ² °F	0.2048
kcal/h m ² °C	kW/m ² °C	0.001162222
kcal/kg °C	J/g °C	4.18400
kcal/kg °C	kJ/kg °C	4.18400
kcal/kg °C	kJ/kg °C	4.18400
kcal/kmol	Btu/lbmol	0.0018000
kcal/kmol	J/mol	4.18675
kcal/m ² h	Btu/ft ² h	0.36867
kcal/m ² h	W/m ²	1.1630

(continued)

Table 15.3 (continued)

Starting Unit	Desired Unit	Factor
From	To	Multiply By
kcal/m ³	Btu/ft ³	0.11237
kcal/m ³	kJ/dm ³	0.00418400
kcal/m ³	kJ/m ³	4.18400
kcal/m ³	MJ/m ³	0.00418400
kcal/min	ft-lb _f /min	3085.9
kcal/min	hp	0.09351
kcal/min	kW	0.069733
kcal/min	W	69.733
kcal/mol	kJ/kmol	4186.8
kcal/s	Btu/s	3.968
kcal/s	ft-lb _f /s	3086
kcal/s	hp	5.6145
kcal/s	kW	4.1867
kcal/s	W	4186.7
kg	cwt (long)	0.0196843
kg	cwt (short)	0.0220463
kg	cwt (UK)	0.0196841
kg	cwt (US)	0.0220462
kg	dr (ap)	257.208
kg	dr (av)	564.398
kg	dr (tr)	257.208
kg	dwt (tr)	643.004
kg	g	1000
kg	gr (ap)	1.54323E+04
kg	gr (av)	1.54323E+04
kg	gr (tr)	1.54323E+04
kg	lb	2.2046225
kg	lb _m	2.2046225
kg	mg	1.00E+06
kg	oz (ap)	32.1512
kg	oz (av)	35.2734
kg	oz (troy)	32.1512
kg	sl	0.0685213
kg	t (long)	9.8420E-04
kg	t (metric)	0.001
kg	t (short)	0.0011023
kg	ton (UK)	9.8420E-04
kg/cm ²	atm	0.9678
kg/cm ²	bar	0.980665

(continued)

Table 15.3 (continued)

Starting Unit	Desired Unit	Factor
From	To	Multiply By
kg/cm ²	dyn/cm ²	9.80665E+05
kg/cm ²	ft H ₂ O	32.81
kg/cm ²	in H ₂ O	393.69
kg/cm ²	in Hg	28.96
kg/cm ²	kPa	98.0665
kg/cm ²	lb/ft ²	2048
kg/cm ²	lb/in ²	14.22
kg/cm ²	mm Hg	735.51
kg/cm ²	MPa	0.0980665
kg/cm ²	torr	735.51
kg/d	kg/s	1.1574E−05
kg/d	lb/s	2.5547E−05
kg/dm ³	g/cm ³	1
kg/dm ³	kg/m ³	1000
kg/dm ³	lb/ft ³	62.42797373
kg/dm ³	lb/gal (UK)	10.02240609
kg/dm ³	lb/gal (US)	8.345406355
kg/h	kg/s	2.7778E−04
kg/h	lb/h	2.20462
kg/h	lb/s	6.1239E−04
kg/h	t/d (US short)	1.10231
kg/kW h	lb/h hp	1.64399
kg/m	lb/ft	0.67204
kg/m ²	atm	9.678E−05
kg/m ²	bar	0.009807
kg/m ²	ft H ₂ O	0.003281
kg/m ²	in Hg	0.002896
kg/m ²	kg/cm ²	0.1
kg/m ²	lb _f /ft ²	0.204816
kg/m ²	lb _f /in ²	0.0014223
kg/m ²	lb _f /yd ²	1.8433
kg/m ² d	lb/ft ² s	2.3719E−06
kg/m ² h	lb/ft ² s	5.6925E−05
kg/m ² min	lb/ft ² s	0.0034155
kg/m ² s	g/cm ² s	10
kg/m ² s	lb/ft ² h	737.75
kg/m ² s	lb/ft ² s	0.20493
kg/m ³	b/ft ³	0.062428
kg/m ³	g/dm ³	1

(continued)

Table 15.3 (continued)

Starting Unit	Desired Unit	Factor
From	To	Multiply By
kg/m^3	g/gal (UK)	4.546090998
kg/m^3	g/gal (US)	3.785412534
kg/m^3	g/L	1
kg/m^3	lb/in^3	$3.6127\text{E}-05$
kg/m^3	lb/mil ft	$3.405\text{E}-10$
$\text{kg/m}^3\ ^\circ\text{C}$	$\text{g/cm}^3\ \text{K}$	0.001
$\text{kg/m}^3\ ^\circ\text{C}$	$\text{lb/cft } ^\circ\text{F}$	0.034682
$\text{kg/m}^3\ \text{K}$	$\text{g/cm}^3\ \text{K}$	0.001
kg/min	kg/s	0.016667
kg/min	lb/s	0.036693
kg/s	kg/d	$8.6400\text{E}+04$
kg/s	kg/h	3600
kg/s	kg/min	60
kg/s	lb/d	$1.9051\text{E}+05$
kg/s	lb/h	7936.64
kg/s	lb/min	132.277
kg/s	lb/s	2.20462
kg/s	$\text{MM lb/yr (10}^6\text{)}$	0.190479
kg/s	t/d (metric)	86.4
kg/s m^3	lb/h ft^3	224.74
kg/s m^3	lb/s ft^3	0.062430
kg m	Btu	0.009294911
kg m	erg	$9.8040\text{E}+07$
kg m	ft lb_f	7.233
kg m	hp h	$3.65304\text{E}-06$
kg m	J	9.80665
kg m	J	9.80665
kg m	kcal	0.002342
kg m	kW h	$2.72407\text{E}-06$
kg m/cm^2	J/cm^2	0.0980665
kg_f	dyn	$9.80665\text{E}+05$
kg_f	dyn	$9.80665\text{E}+05$
kg_f	lb_f	2.2046
kg_f	N	9.80665
kg_f	N	9.80665
kg_f	pdl	70.93
kg_f	pdl	70.93
kg_f	t (short)	0.001102
kg_f/cm^2	bar	0.980665

(continued)

Table 15.3 (continued)

Starting Unit	Desired Unit	Factor
From	To	Multiply By
kg_f/cm^2	kPa	98.0665
kg_f/cm^2	lb_f/in^2	14.223
kg_f/cm^2	MPa	0.0980665
kg_f/cm^2	Pa	$9.8067\text{E}+04$
kg_f/cm^3	lb_f/cft	$6.2428\text{E}+04$
kg_f/cm^3	N/m^3	$9.8067\text{E}+06$
kg_f/m^2	lb_f/in^2	0.0014223
kg_f/m^2	Pa	9.8067
kg_f/m^3	lb_f/cft	0.062428
kg_f/m^3	N/m^3	9.80665
kg_f/mm^2	MPa	9.80665
kg_f/mm^2	N/mm^2	9.80665
kg_f/mm^2	Pa	$9.80665\text{E}+06$
$\text{kg}_f \text{ m}$	Btu	0.0092949
$\text{kg}_f \text{ m}$	J	9.80665
$\text{kg}_f \text{ m}$	N m	9.80665
$\text{kg}_f \text{ m}/\text{m}$	N m/m	9.80665
$\text{kg}_f \text{ m}/\text{s}$	Btu/h	33.436
$\text{kg}_f \text{ m}/\text{s}$	W	9.8067
$\text{kg}_f \text{ s}/\text{m}^2$	$\text{N s}/\text{m}^2$	9.80665
$\text{kg}_f \text{ s}/\text{m}^2$	Pa s	9.80665
kilogram calorie (see kcal)		
kilogram mole (see kmol)		
kip	kg	453.59
kip	lb_m	1000
kip_f	lb_f	1000
kip_f	N	4448.2
kJ	Btu	0.947817
kJ	cal	239.006
kJ	ch h (metric)	$3.77675\text{E}-04$
kJ	Chu	0.526565
kJ	ft lb_f	737.562
kJ	hp h	$3.72506\text{E}-04$
kJ	J	1000
kJ	kcal	0.239006
kJ	kW h	$2.77778\text{E}-04$
kJ/dm^3	Btu/ft^3	26.8392
kJ/dm^3	Btu/gal (US)	3.58788
kJ/dm^3	kcal/m^3	239.006

(continued)

Table 15.3 (continued)

Starting Unit	Desired Unit	Factor
From	To	Multiply By
kJ/kg	Btu/lb	0.429923
kJ/kg	cal/g	0.239006
kJ/kg	J/kg	1000
kJ/kg °C	Btu/lb °F	0.2388459
kJ/kg °C	kcal/kg °C	0.2390057
kJ/kg °C	kW h/kg °C	0.000277778
kJ/kg K	Btu/lb °R	0.238846
kJ/kg K	cal/g K	0.239006
kJ/kg K	kcal/kg °C	0.239006
kJ/kmol	Btu/lbmol	0.429923
kJ/kmol	kcal/mol	0.000239006
kJ/kmol °C	Btu/lbmol °F	0.2388459
kJ/kmol °C	cal/mol °C	0.2390057
kJ/L	Btu/ft ³	26.8392
kJ/L	Btu/gal (US)	3.58788
kJ/L	kcal/m ³	239.005736
kJ/m ³	Btu/ft ³	0.026839
kJ/m ³	Btu/gal (US)	0.00358788
kJ/m ³	ft lb _f /gal (US)	2.79198
kJ/m ³	kcal/m ³	0.239006
kL	L	1000
kln	Mx	1000
km	cm	1.00E+05
km	ft	3280.8
km	in	3.937E+04
km	m	1000
km	mi	0.6214
km	mi (naut)	0.539957
km	mm	1.00E+06
km	yd	1094
km/dm ³	mi/gal (US)	2.35215
km/gal (UK)	mi/gal (US)	0.51740
km/gal(US)	mi/gal (US)	0.62137
km/h	cm/s	27.78
km/h	ft/min	54.68066
km/h	ft/s	0.91135
km/h	kt	0.539957
km/h	m/min	16.66667
km/h	m/s	0.27778

(continued)

Table 15.3 (continued)

Starting Unit	Desired Unit	Factor
From	To	Multiply By
km/h	mi/h	0.6213712
km/h s	cm/s ²	27.78
km/h s	ft/s ²	0.9113
km/h s	m/s ²	0.2778
km/h s	mi/h s	0.6214
km/L	km/gal (UK)	4.5461
km/L	km/gal(US)	3.7854
km/L	mi/gal (US)	2.35215
km/s	ft/s	3280.8
km/s	m/s	1000
km ²	Ac	247.1
km ²	cm ²	1.00E+10
km ²	ft ²	1.0764E+07
km ²	in ²	1.550E+09
km ²	m ²	1.00E+06
km ²	mi ²	0.3861
km ²	yd ²	1.196E+06
km ³	ft ³	3.5315E+10
km ³	m ³	1.00E+09
km ³	mi ³	0.239913
kmol	lbmol	2.2046225
kmol	mol	1000
kmol	NCM (0 °C)	23.644463
kmol	scf	836.610056
kmol	SCM (15 °C)	22.413584
kmol/d	kmol/h	0.041667
kmol/d	lbmol/h	0.091875
kmol/h	lbmol/h	2.20462
kmol/h	mol/h	1000
kmol/kg	lbmol/lb	1
kmol/kg	mol/g	1
kmol/m ² h	kmol/m ² s	2.7778E-04
kmol/m ² h	lbmol/ft ² s	5.6925E-05
kmol/m ² s	lbmol/ft ² s	0.20493
kmol/m ³	lbmol/ft ³	0.062427974
kmol/m ³	lbmol/gal (US)	0.008345406
kmol/m ³	scf/bbl	133.0103841
kmol/s	lbmol/h	7936.64
kmol/s	MMscf/d (10 ⁶)	72.2831

(continued)

Table 15.3 (continued)

Starting Unit	Desired Unit	Factor
From	To	Multiply By
kmol/s	MMscf/d (10^6)	72.2831
kN	t _f (US)	0.112404
kPa	at	0.010197162
kPa	atm	0.009869233
kPa	bar	0.01
kPa	cm H ₂ O (4 °C)	10.19744289
kPa	in H ₂ O (39.2 °F)	4.014742133
kPa	in H ₂ O (60 °F)	4.01864652
kPa	in Hg (60 °F)	0.296133971
kPa	kg _f /cm ²	0.010197162
kPa	lb _f /ft ²	20.88543379
kPa	lb _f /in ²	0.145037744
kPa	mm Hg (0 °C)	7.50061505
kPa	torr (0 °C)	7.50061505
kPa/m	lb _f /in ² /100 ft	4.420751183
kPa/m	lb _f /in ² ft	0.044207512
KPH (see km/h)		
ksi	lb _f /in ²	1000
ksi	Pa	6.8948E+06
kt (knot)	ft/h	6080
kt (knot)	ft/s	1.689
kt (knot)	km/h	1.8532
kt (knot)	mi/h (naut)	1
kt (knot)	mi/h (stat)	1.151
kt (knot)	yd/h	2027
kW	Btu/h	3409.5
kW	Btu/min	56.8690
kW	Btu/s	0.947817
kW	ch (metric)	1.35962
kW	CV (metric)	1.35962
kW	ft lb _f /min	4.425E+04
kW	ft-lb _f /s	737.6
kW	hhp (hydraulic)	1.34041
kW	hp	1.34102
kW	kcal/min	14.34
kW	t (refrig)	0.284345
kW	W	1000
kW/m ²	Btu/ft ² h	316.998
kW/m ²	cal/h × cm ²	86.0421

(continued)

Table 15.3 (continued)

Starting Unit	Desired Unit	Factor
From	To	Multiply By
$\text{kW/m}^2 \text{ } ^\circ\text{C}$	$\text{Btu/h ft}^2 \text{ } ^\circ\text{F}$	176.110
$\text{kW/m}^2 \text{ } ^\circ\text{C}$	$\text{cal/h cm}^2 \text{ } ^\circ\text{C}$	86.0421
kW/m^3	Btu/h ft^3	96.6211
kW/m^3	cal/h cm^3	0.860421
kW/m^3	hp/ft^3	0.0379735
$\text{kW/m}^3 \text{ } ^\circ\text{C}$	$\text{Btu/h ft}^3 \text{ } ^\circ\text{F}$	53.6784
kW h	Btu	3412.14
kW h	cal	8.59850E+05
kW h	ch h (metric)	1.35962
kW h	Chu	1895.63
kW h	CV h (metric)	1.35962
kW h	erg	3.600E+13
kW h	ft lb _f	2.655E+06
kW h	h hp	1.34102
kW h	J	3.6000E+06
kW h	kcal	859.8452
kW h	kg m	3.671E+05
kW h	kJ	3600
kW h	lb H ₂ O (62–212 °F)	22.75
kW h	lb H ₂ O (evap 212 °F)	3.53
kW h	MJ	3.6
kW h/kg	Btu/lb	1547.72
$\text{kW h/kg } ^\circ\text{C}$	J/g °C	3600
$\text{kW h/kg } ^\circ\text{C}$	kJ/kg °C	3600
kW h/m^3	Btu/ft ³	96.6211
L		
L	bu (US dry)	0.02833
L	cm ³	1000
L	dm ³	1
L	ft ³	0.03531
L	gal (UK)	0.219969
L	gal (US liq)	0.2641720
L	in ³	61.02
L	m ³	0.001
L	oz (US fluid)	33.82
L	pt (UK)	1.759755
L	pt (US liq)	2.113376
L	qt (UK)	0.879877
L	qt (US liq)	1.056688261

(continued)

Table 15.3 (continued)

Starting Unit	Desired Unit	Factor
From	To	Multiply By
L	yd ³	0.001308
L (lambert)	Cd/in ²	2.054
L (lambert)	cd/m ²	3183.1
L (lambert)	luxon	0.31831
L (lambert)	nit	3183.1
L (lambert)	sb	0.31831
L (liter)	ft ³	3.5315E−08
L (liter)	m ³	1.00E−09
L/100 km	gal/mi (UK)	0.00354006
L/100 km	gal/mi (US)	0.00425144
L/d	ft ³ /s	4.0868E−07
L/d	gal/min	0.00018347
L/d	m ³ /s	1.1574E−08
L/h	ft ³ /s	9.8083E−06
L/h	gal/min	0.0044033
L/h	m ³ /s	2.7778E−07
L/kg	ft ³ /lb	0.016018464
L/kg	gal/lb (UK)	0.09782429
L/kg	gal/lb (US)	0.119826434
L/km	mi/gal (US)	2.3521
L/kmol	bbl/MMscf (10 ⁶)	7.518231712
L/kmol	gal/Mscf (1000)	0.31576521
L/kW h	gal/h hp	0.196993
L/kW h	m ³ /kW h	0.001
l/m ² h	gal/min ft ²	4.0922E−04
l/m ² h	l/m ² s	2.7778E−04
L/m ³	gal/ft ³ (US)	0.007480517
L/m ³	ppm (vol)	1000
L/min	ft ³ /d	50.847
L/min	ft ³ /h	2.1186
L/min	ft ³ /min	0.035311
L/min	ft ³ /s	5.8851E−04
L/min	gal/min (US)	0.26420
L/min	m ³ /h	0.06000
L/min	m ³ /s	1.6667E−05
L/MJ	gal/h hp	0.709175
L/MJ	m ³ /kW h	0.0036
L/mol	m ³ /kmol	1
L/s	bbl/d	543.440

(continued)

Table 15.3 (continued)

Starting Unit	Desired Unit	Factor
From	To	Multiply By
L/s	ft ³ /d	3051.19
L/s	ft ³ /s	0.0353147
L/s	gal/h (US)	951.020
L/s	gal/min (US)	15.852
L/t (metric)	bbl/t (US shale yld)	0.00570602
L/t (metric)	gal/t (US shale yld)	0.239652868
L atm	Btu	0.096037
L atm	ft lb _f	74.7400000
L atm	ft ³ atm	0.03532
L atm	J	101.33
lb	kg	0.4535924
lb	kg	0.4535922
lb	lb _m	1
lb (ap)	kg	0.37324
lb (ap)	lb _m	0.82286
lb (av)	dr	256
lb (av)	g	453.5924
lb (av)	gr	7000
lb (av)	kg	0.45359
lb (av)	lb (tr)	1.21528
lb (av)	lb _m	1.0000
lb (av)	oz (av)	16
lb (av)	oz (tr)	14.5833
lb (av)	t (short)	5.00E-04
lb (tr)	dwt (tr)	240
lb (tr)	g	373.2417
lb (tr)	gr	5760
lb (tr)	kg	0.37324
lb (tr)	lb (av)	0.822857
lb (tr)	lb _m	0.822857
lb (tr)	oz (av)	13.1657
lb (tr)	oz (tr)	12
lb (tr)	t (long)	3.6735E-04
lb (tr)	t (metric)	3.7324E-04
lb (tr)	t (short)	4.1143E-04
lb H ₂ O	ft ³	0.01602
lb H ₂ O	gal	0.119852
lb H ₂ O	in ³	27.6826
lb H ₂ O/min	ft ³ /s	2.670E-04

(continued)

Table 15.3 (continued)

Starting Unit	Desired Unit	Factor
From	To	Multiply By
lb/bbl	g/dm ³	2.85301
lb/bbl	g/L	2.85301
lb/bbl	kg/m ³	2.85301
lb/cft °F	kg/m ³ °C	28.833
lb/d	kg/s	5.2490E-06
lb/d	lb/s	1.1574E-05
lb/ft	kg/m	1.488164
lb/ft h	N s/m ²	4.13379E-04
lb/ft h	Pa s	4.13379E-04
lb/ft ²	at	0.48824
lb/ft ²	atm	4.725E-04
lb/ft ²	ft H ₂ O	0.01602
lb/ft ²	in Hg	0.01414
lb/ft ²	kg/cm ²	0.48824
lb/ft ²	kg/m ²	4.8824
lb/ft ²	kg/m ²	4.882428
lb/ft ²	kPa	0.04788026
lb/ft ²	lb/in ²	0.006944
lb/ft ²	lb/in ²	0.0069444
lb/ft ²	lb/yd ²	9.0000
lb/ft ² h	kg/m ² s	0.0013555
lb/ft ² h	lb/ft ² s	2.7777E-04
lb/ft ² s	g/cm ² s	0.48824
lb/ft ² s	kg/m ² s	4.882428
lb/ft ² s	lb/ft ² h	3600
lb/ft ³	g/cm ³	0.01602
lb/ft ³	g/dm ³	16.01846
lb/ft ³	g/L	16.01846
lb/ft ³	g/m ³	1.601846E+04
lb/ft ³	g/mL	0.016018
lb/ft ³	gr/gal (US)	935.76
lb/ft ³	gr/gal (US)	935.76
lb/ft ³	kg/dm ³	0.01601846
lb/ft ³	kg/L	0.016018
lb/ft ³	kg/m ³	16.018
lb/ft ³	kg/m ³	16.02
lb/ft ³	lb/gal (US)	0.13368
lb/ft ³	lb/in ³	5.7870E-04
lb/ft ³	lb/in ³	5.787E-04

(continued)

Table 15.3 (continued)

Starting Unit	Desired Unit	Factor
From	To	Multiply By
lb/ft ³	oz/gal (US)	2.1389
lb/ft ³	t/m ³ (metric)	0.016018
lb/ft ³ °F	g/cm ³ °C	0.028833
lb/ft ³ °F	kg/m ³ °C	28.833
lb/gal (UK)	kg/m ³	99.776
lb/gal (UK)	lb/ft ³	6.2288
lb/gal (US)	g/cm ³	0.1198264
lb/gal (US)	kg/dm ³	0.1198264
lb/gal (US)	kg/L	0.1198264
lb/gal (US)	kg/m ³	119.83
lb/gal (US)	lb/ft ³	7.4805
lb/h	kg/h	0.4535924
lb/h	kg/s	1.259979E-04
lb/h	lb/s	2.7778E-04
lb/h ft ³	kg/s m ³	0.0044496
lb/h ft ³	lb/s ft ³	0.00027779
lb/h hp	kg/kW h	0.6082774
lb/h hp	kg/MJ	0.1689659
lb/in	g/cm	178.6
lb/in ²	kg/m ²	703.1
lb/in ²	kPa	6.894757
lb/in ²	lb/ft ²	144
lb/in ²	MPa	0.006894757
lb/in ²	Pa	6895
lb/in ²	atm	0.06804
lb/in ²	bar	0.06894757
lb/in ²	ft H ₂ O	2.307
lb/in ²	in Hg	2.036
lb/in ²	kg/m ²	703.07
lb/in ²	lb/ft ²	144.00
lb/in ³	g/cm ³	27.68
lb/in ³	kg/m ³	2.7680E+04
lb/in ³	lb/ft ³	1728
lb/lbmol	amu	1
lb/lbmol	g/mol	1
lb/lbmol	kg/kmol	1
lb/Mbbl (1000)	g/m ³	2.85301
lb/Mbbl (1000)	mg/dm ³	2.85301
lb/Mgal (US 1000)	g/m ³	119.8264

(continued)

Table 15.3 (continued)

Starting Unit	Desired Unit	Factor
From	To	Multiply By
lb/Mgal (US 1000)	mg/dm ³	119.8264
lb/min	kg/s	0.007559873
lb/min	lb/s	0.016667
lb/min H ₂ O	ft ³ /s	0.000267
lb/s	kg/min	27.253
lb/s	kg/s	0.4535924
lb/s	lb/min	60
lb/s	t/d (metric)	39.191
lb/s	t/s (metric)	4.5360E-04
lb/s ft ³	g/s cm ³	0.016018
lb eq/ft ³	eq/L	77.844
lb eq/ft ³	lb eq/gal (US)	7.4807
lb eq/gal (US)	eq/m ³	10406
lb ft	J	1.355818
lb ft	kJ	0.001355818
lb ft (see also ft lb, ft lbf or lbf ft)		
lb ft/in ²	J/cm ²	0.002101522
lb ft/s	kg × m/s	0.138255
lb ft ²	kg × m ²	0.04214011
lb ft ² /sec	g cm ² /s	4.2141E+05
lb ft ² /sec	kg m ² /s	0.042141
lb _f	dyn	4.4482E+05
lb _f	kg _f	0.45359
lb _f	kip _f	0.001
lb _f	N	4.448222
lb _f	t (short)	0.0005
lb _f /100 ft ²	Pa	47.88026
lb _f /ft	N/m	14.594
lb _f /ft ²	kPa	0.04788026
lb _f /ft ³	dyn/cm ³	15.709
lb _f /ft ³	kg _f /m ³	16.018
lb _f /ft ³	lb _f /cft	1728
lb _f /ft ³	N/m ³	157.087
lb _f /h ft ²	kg/s m ²	0.00135623
lb _f /in	N/m	175.13
lb _f /in ²	at	0.070307
lb _f /in ²	atm	0.068046
lb _f /in ²	bar	0.06894757
lb _f /in ²	barye	6.8948E+04

(continued)

Table 15.3 (continued)

Starting Unit	Desired Unit	Factor
From	To	Multiply By
lb _f /in ²	dyn/cm ²	6.8948E+04
lb _f /in ²	ft H ₂ O (4 °C)	2.3067
lb _f /in ²	in H ₂ O (4 °C)	27.681
lb _f /in ²	in Hg (32 °F)	2.0360
lb _f /in ²	kg _f /cm ²	0.070307
lb _f /in ²	kg _f /m ²	703.07
lb _f /in ²	kPa	6.894757
lb _f /in ²	mm Hg (0 °C)	51.715
lb _f /in ²	MPa	0.006894757
lb _f /in ²	N/m ²	6894.8
lb _f /in ²	torr	51.715
lb _f /in ² 100 ft	kPa/m	0.2262059
lb _f /in ² ft	kPa/m	22.62059
lb _f /in ³	N/m ³	2.7145E+05
lb _f ft	cm dyn	1.3560E+07
lb _f ft	cm g _f	1.3825E+04
lb _f ft	kJ	0.001355818
lb _f ft	m kg _f	0.13825
lb _f ft/in	N m/m	53.37866
lb _f ft ²	g _f cm ²	4.2140E+05
lb _f ft ²	kg m ²	0.042140
lb _f ft ²	kg _f m s ²	0.0042971
lb _f in	N m	0.1129848
lb _f in/in	N m/m	4.448222
lb _f s/ft ²	cP	4.7880E+04
lb _f s/ft ²	dyn s/cm ²	478.80
lb _f s/ft ²	g/cm s	4788
lb _f s/ft ²	kg/m s	47.88
lb _f s/ft ²	kg ³ /s m ²	4.882428
lb _f s/ft ²	lb _m /ft h	1.158E−05
lb _f s/ft ²	lb _m /ft s	32.174
lb _f s/ft ²	mP	4.7880E+05
lb _f s/ft ²	mPa s	4.7880E+04
lb _f s/ft ²	N s/m ²	47.88026
lb _f s/ft ²	P	4788
lb _f s/ft ²	Pa s	47.88026
lb _f s/in ²	N s/m ²	6894.757
lb _f s/in ²	Pa s	6894.757
lb _f s ²	ft lb _f	32.174

(continued)

Table 15.3 (continued)

Starting Unit	Desired Unit	Factor
From	To	Multiply By
lbft ² /s ²	kJ	4.214011E−05
lb _m	amu	2.7316E+26
lb _m	ct	2267.95
lb _m	cwt (long)	0.008929
lb _m	cwt (short)	0.010000
lb _m	dr (ap)	116.667
lb _m	dr (av)	256.005
lb _m	dr (tr)	116.667
lb _m	dwt (tr)	291.660
lb _m	dyn	4.44823E+05
lb _m	g	4.5359E+08
lb _m	gr (ap)	7000
lb _m	gr (av)	7000
lb _m	gr (jew)	9071.80
lb _m	gr (tr)	6999.95
lb _m	J/cm	0.04448
lb _m	J/m	4.448
lb _m	kg	0.45359
lb _m	kip	0.001
lb _m	lb (ap)	1.21528
lb _m	lb (tr)	1.21528
lb _m	mg	4.5359E+08
lb _m	momme	120.957
lb _m	N	4.448
lb _m	oz (ap)	14.5835
lb _m	oz (av)	16
lb _m	oz (tr)	14.5835
lb _m	pdl	32.17
lb _m	sl	0.031081
lb _m	t (short)	0.0005
lb _m /ft h	cP	0.4134
lb _m /ft h	g/cm s	0.004134
lb _m /ft h	kg/m s	0.0004134
lb _m /ft h	lb _f /s ft ²	8.634E−06
lb _m /ft h	lb _m /ft s	0.000278
lb _m /ft h	P	0.004134
lb _m /ft s	cP	1488
lb _m /ft s	g/cm s	14.88
lb _m /ft s	kg/s m	1.488164

(continued)

Table 15.3 (continued)

Starting Unit	Desired Unit	Factor
From	To	Multiply By
lb _m /ft s	lb _f s/ft ²	0.0311
lb _m /ft s	lb _m /ft h	3600
lb _m /ft s	N s/m ²	1.488164
lb _m /ft s	P (poise)	14.88
lb _m /ft s	Pa s	1.488164
lbmol	kmol	0.4535924
lbmol	mol	453.60
lbmol	scf	379.45
lbmol/ft ² s	kmol/m ² s	4.8797
lbmol/ft ³	kmol/L	0.01601846
lbmol/ft ³	kmol/m ³	16.01846
lbmol/ft ³	lbmol/gal (US)	0.133677
lbmol/ft ³	mol/L	16.01846
lbmol/ft ³	mol/m ³	1.6018E+04
lbmol/gal (UK)	kmol/m ³	99.77644
lbmol/gal (US)	kmol/m ³	119.8264
lbmol/gal (US)	lbmol/ft ³	0.13368
lbmol/h	kmol/h	0.453592
lbmol/h	kmol/s	1.25998E-04
lbmol/h	mol/s	0.12598
lbmol/s	kmol/s	0.4535924
lg (US stat)	m	4828.0
lg (US stat)	mi	3.0
li/cm ² (lines)	G (gauss)	1
li/cm ² (lines)	T (tesla)	1.00E-04
li/in ² (lines)	G (gauss)	0.1550
li/in ² (lines)	Wb/cm ²	1.550E-09
li/in ² (lines)	Wb/in ²	1.00E-08
li/in ² (lines)	Wb/m ²	1.550E-05
lk (eng)	ft	1
lk (eng)	in	12
lk (US surv)	in	7.92
lk (US surv)	m	0.20117
lumen	Cd (sph)	0.07958
lumen	cd sr	1
lumen	W	0.001496
lumen/ft ²	ft Cd	1
lumen/ft ²	lumen/m ²	10.76
luxon	cd/m ²	1.00E+04

(continued)

Table 15.3 (continued)

Starting Unit	Desired Unit	Factor
From	To	Multiply By
lx	ft Cd	0.092903
LY (light year)	km	9.46091E+12
LY (light year)	mi	5.90E+12
M		
m	Å (angstrom)	1.00E+10
m	ch (US surv)	0.049710
m	cm	100
m	dm	10
m	ell	0.87489
m	fath	0.54681
m	ft	3.2808
m	in	39.370
m	km	0.001
m	lg (intl naut)	1.7999E-04
m	μ (micron)	1.00E+06
m	mi	6.2137E-04
m	mi (intl naut)	5.3996E-04
m	nm	1.00E+09
m	rod	0.19884
m	toise	0.51307
m	toise (metric)	0.50000
m	vara	1.179
m	yd	1.0936
μ (micron)	Å (angstrom)	10000
μ (micron)	cm	0.0001
μ (micron)	m	1.00E-06
m/h	ft/s	9.1135E-04
m/h	m/s	2.7778E-04
m/min	cm/s	1.667
m/min	ft/min	3.28084
m/min	ft/s	0.05468066
m/min	km/h	0.06
m/min	kt	0.03238
m/min	m/s	0.0166667
m/min	mi/h	0.03728227
m/s	ft/min	196.8504
m/s	ft/s	3.28084
m/s	km/h	3.6000
m/s	km/min	0.06

(continued)

Table 15.3 (continued)

Starting Unit	Desired Unit	Factor
From	To	Multiply By
m/s	km/s	0.001
m/s	knot (int)	1.9438
m/s	m/min	60
m/s	mi/h	2.237
m/s	mi/min	0.03728
m/s ²	cm/s ²	100
m/s ²	ft/s ²	3.28084
m/s ²	km/h s	3.6
m/s ²	mi/h s	2.237
m kg _f	cm dyn	9.807E+07
m kg _f	cm g	1.00E+05
m kg _f	ft lb _f	7.2330
m ²	Ac (US surv)	2.4711E-04
m ²	ch ² (US surv)	0.0024711
m ²	cm ²	10000
m ²	ft ²	10.764
m ²	ha	0.0001
m ²	hm ²	0.0001
m ²	in ²	1550
m ²	km ²	1.00E-06
m ²	mi ²	3.861E-07
m ²	mi ² (int, naut)	2.9155E-07
m ²	mm ²	1.00E+06
m ²	rod ²	0.039537
m ²	sect	3.8610E-07
m ²	twshp	1.0725E-08
m ²	yd ²	1.196
m ² /g	cm ² /g	1.00E+04
m ² /g	ft ² /lb	4882.3
m ² /g	m ² /kg	1000
m ² /h	ft ² /s	0.0029900
m ² /h	m ² /s	0.0029900
m ² /h	mm ² /s	277.778
m ² /s	cSt	92903
m ² /s	ft ² /h	3600.0
m ³	Ac ft	8.1071E-04
m ³	bbl (petrol)	6.28981
m ³	bu (US dry)	28.3776
m ³	cm ³	1.00E+06

(continued)

Table 15.3 (continued)

Starting Unit	Desired Unit	Factor
From	To	Multiply By
m ³	dm ³	1000
m ³	ft ³	35.3147
m ³	gal (US dry)	227.021
m ³	gal (US liq)	264.172
m ³	in ³	6.1024E+04
m ³	L	1000
m ³	pt (US dry)	1816.17
m ³	pt (US liq)	2113.38
m ³	qt (US dry)	908.084
m ³	qt (US liq)	1056.69
m ³	yd ³	1.30795
m ³ /g	ft ³ /lb	16018.46352
m ³ /h	bbl/d	150.955
m ³ /h	bbl/h	6.28981
m ³ /h	ft ³ /h	35.3147
m ³ /h	ft ³ /s	9.8085E−03
m ³ /h	gal/h (US)	264.172
m ³ /h	gal/min (US)	4.4033
m ³ /kg	cm ³ /g	1000
m ³ /kg	ft ³ /lb	16.01846352
m ³ /kmol	ft ³ /lbmol	16.01846352
m ³ /kW × h	mm ³ /J	277.7778
m ³ /kW h	dm ³ /kW h	1000
m ³ /kW h	dm ³ /MJ	277.7778
m ³ /min	ft ³ /s	0.58851
m ³ /min	gal/min (US)	264.20
m ³ /s m ²	gal/min ft ²	1472.54
m ³ /s m ²	ft ³ /s ft ²	3.28084
μbar	Pa	0.1
μcal/s cm ² (micro)	mW/m ²	41.84
mdarcy	μm ² (micro)	9.86923E−04
m _e (electron)	kg	9.1094E−31
m _e (electron)	lb _m	2.0083E−30
μF (micro)	F	1.00E−06
mg	g	0.001
mg	gr	0.01543236
Mg	kg	1000
μg (micro)	g	1.00E−06
mg/dm ³	gr/gal (US)	0.058417835

(continued)

Table 15.3 (continued)

Starting Unit	Desired Unit	Factor
From	To	Multiply By
mg/dm ³	lb/Mbb1 (1000)	0.350507008
mg/dm ³	lb/Mgal (US 1000)	0.008345406
mg/gal (US)	g/m ³	0.264172
mg/gal (US)	mg/L	0.264172
mg/kg	ppm (wt)	1
mg/L	gr/gal (US)	0.058417835
mg/L (H ₂ O)	ppm (wt)	1
mg/m ³	gr/ft ³	4.36996E-04
mH	H	0.001
mi	cm	1.609E+05
mi	ft	5280.0
mi	ft	5280
mi	km	1.609
mi	m	1609.3
mi	yd	1760
mi (naut)	ft	6080.27
mi (naut)	km	1.853
mi (naut)	m	1853
mi (naut)	mi (stat)	1.1516
mi (naut)	yd	2027
mi (stat)	cm	1.609E+05
mi (stat)	ft	5280
mi (stat)	in	6.336E+04
mi (stat)	km	1.609344
mi (stat)	m	1609
mi (stat)	mi (naut)	0.8684
mi (stat)	yd	1760
mi/gal (UK)	km/dm ³	0.3540064
mi/gal (UK)	km/L	0.3540064
mi/gal (US)	km/dm ³	0.4251437
mi/h	cm/s	44.70
mi/h	ft/min	88
mi/h	ft/s	1.466667
mi/h	km/h	1.609344
mi/h	km/min	0.02682
mi/h	kt	0.8689
mi/h	m/min	26.8224
mi/h	m/s	0.44470
mi/h	mi/min	0.016667

(continued)

Table 15.3 (continued)

Starting Unit	Desired Unit	Factor
From	To	Multiply By
mi/h sec	cm/s ²	44.70
mi/h sec	ft/s ²	1.467
mi/h sec	km/h s	1.609
mi/h sec	m/s ²	0.44704
mi/min	cm/s	2682
mi/min	ft/s	88
mi/min	km/min	1.609
mi/min	kt	0.8684
mi/min	mi/h	60
mi ²	Ac	640
mi ²	ft ²	2.788E+07
mi ²	km ²	2.589988
mi ²	m ²	2.590E+06
mi ²	yd ²	3.098E+06
mil	cm	0.002540
mil	ft	8.3333E−05
mil	in	0.001
mil	m	2.5400E−05
mil	yd	2.778E−05
mil ft	in ³	9.425E−06
mil ²	circ mil	1.273
mil ²	cm ²	6.452E−06
mil ²	in ²	1.00E−06
min	h	0.01666667
min (angle)	deg (angle)	0.016667
min (angle)	quad	1.852E−04
min (angle)	rad (angle)	2.9089E−04
min (angle)	sec (angle)	6.000E+01
MJ	hp h	0.372506
MJ	kW h	0.277778
MJ/kg	Btu/lb	429.923
MJ/kmol	Btu/lbmol	429.923
MJ/m	t _f mi/ft	0.021288726
MJ/m ³	Btu/ft ³	26.8392
MJ/m ³	Btu/gal (US)	3.58788
MJ/m ³	kcal/m ³	239.006
mL	cm ³	1
mL	ft ³	3.5315E−05
mL	in ³	0.061020

(continued)

Table 15.3 (continued)

Starting Unit	Desired Unit	Factor
From	To	Multiply By
mL	m ³	1.00E-06
μL (micro)	L	1.00E-06
μL (micro)	m ³	1.00E-12
ml (see cm ³)		
mL/gal (US)	dm ³ /m ³	0.264172
Mli (lines)	Mx (maxwell)	1.00E+06
mm	cm	0.1
mm	ft	3.2808E-06
mm	in	0.03937
mm	km	1.00E-06
mm	m	0.001
mm	mi	6.214E-07
mm	mil	39.37
mm	yd	0.001094
MM Btu/h (10 ⁶)	Btu/h	1.00E+06
MM Btu/h (10 ⁶)	W	2.9330E+05
MM gal/d (US 10 ⁶)	ft ³ /s	1.54723
mm Hg (0 °C)	atm	0.001320
mm Hg (0 °C)	bar	0.0013
mm Hg (0 °C)	ft H ₂ O (4 °C)	0.0446
mm Hg (0 °C)	in H ₂ O (4 °C)	0.535
mm Hg (0 °C)	in Hg	0.039
mm Hg (0 °C)	kg/cm ²	0.0014
mm Hg (0 °C)	kPa	0.1333224
mm Hg (0 °C)	kPa	0.1333224
mm Hg (0 °C)	lb _f /in ²	0.019337
μm Hg (0 °C)	Pa	0.1333224
mm Hg (0 °C)	Pa	133.32
MM kcal/h (10 ⁶)	Btu/h (mean)	3.9683E+06
MM kcal/h (10 ⁶)	W	1.1639E+06
MM lb/y (10 ⁶)	kg/s	5.249912
MM lb/yr (10 ⁶)	t/a (metric)	453.5924
MM scfd	kmol/s	0.0138345
MM y (10 ⁶)	Ma	1
mm/a	in/yr	0.0393701
mm/s	in/s	0.0393701
mm ²	circ mil	1973
mm ²	cm ²	0.01
mm ²	darcy	1.01325

(continued)

Table 15.3 (continued)

Starting Unit	Desired Unit	Factor
From	To	Multiply By
mm ²	ft ²	1.0764E-05
mm ²	in ²	0.001550
mm ² /s	cSt	1
mm ² /s	ft ² /h	0.0387501
mm ² /s	ft ² /s	1.07639E-05
MMBtu/bbl	FOE bbl	0.156250
MMBtu/h	MW	0.2930711
MMgal/day (US 10 ⁶)	ft ³ /s	1.54723
mo	s	2.5920E+06
mol	kmol	0.001
mol	kmol	0.001
mol	lbmol	0.0022046
mol/h	kmol/h	0.001
mol/h	lbmol/h	0.0022046
mol/kg	kmol/kg	0.001
mol/kg	lbmol/lb	0.001
momme	kg	0.00375
momme	lb _m	0.0082674
mP	lb _f s/ft ²	2.0885E-06
MPa	atm	9.869232667
MPa	bar	10
MPa	kg _f /cm ²	10.19716213
MPa	lb _f /in ²	145.0377439
MPa	Pa	1.00E+06
mPa s	lb _f s/ft ²	2.0885E-05
mPa s	P	0
MPH (see mi/h)		
μS (micro)	S	1.00E-06
mSt	ft ² /s	1.0764E-06
MW	Btu/h (mean)	3.4095E+06
MW	MM Btu/h (10 ⁶)	3.41214
MW	W	1.0000E+06
Mx (maxwell)	kli (lines)	0.001
Mx (maxwell)	Wb	1.00E-08
myg	kg	10
mym	ft	3.2808E+04
mym	km	10
mym	m	1.00E+04
myW	kW	10

(continued)

Table 15.3 (continued)

Starting Unit	Desired Unit	Factor
From	To	Multiply By
MΩ	μΩ (micro)	1.00E+12
MΩ	Ω	1.00E+06
μΩ (micro)	MΩ	1.00E−12
μΩ (micro)	Ω	1.00E−06
mS/m	mS/m	1
mΩ in	Ω cm	2.5400E−06
N		
N	dyn	1.00E+05
N	kg _f	0.101972
N	kip _f	2.2481E−04
N	lb _f	0.224809
N	oz _f	3.5969
N	pdl	7.2330
N	t (short)	1.1240E−04
N/A ²	H/m	1
N/kg	dyn/g	100
N/m	dyn/cm	1000
N/m ²	dyn/cm ²	0.1
N/m ²	g/cm s ²	0.1
N/m ²	lb _f /ft ²	0.0020886
N/m ²	lb _f /in ²	1.45038E−04
N/m ²	lb _m /ft s ²	0.067195
N/m ²	Pa	1
N cm	ft lb _f	0.0073756
N cm	N m	0.01
N m	cm kg _f	10.197
N m	dyn cm	1.00E+07
N m	ft lb _f	0.737562
N m	in lb _f	8.85075
N m	in oz _f	141.61
N m	kg _f m	0.101972
N m	N cm	100
N s/m ²	cP	1000
N s/m ²	dyn s/cm ²	10
N s/m ²	lb/ft h	2419.09
N s/m ²	lb/ft s	0.671969
N s/m ²	lb _f s/ft ²	0.0208854
N s/m ²	P	10
NCM (0 °C)	bbl (petrol)	6.289

(continued)

Table 15.3 (continued)

Starting Unit	Desired Unit	Factor
From	To	Multiply By
NCM (0 °C)	kmol	0.042298
NCM (0 °C)	lbmol	0.093249
NCM (0 °C)	scf	37.3246
NCM (15 °C)	scf (60 °F)	35.383200
NCM/t (15 °C metric)	scf/bbl (60 °F petrol)	SG/0.1782
neper	dB	8.686
O		
Oe	A/ft	24.255
Oe	A/m	79.57747
oz (ap)	kg	0.031103
oz (ap)	lb _m (av)	0.068571
oz (av)	dr (av)	16
oz (av)	g	28.349527
oz (av)	gr (av)	437.5
oz (av)	kg	0.02835
oz (av)	lb (av)	0.0625
oz (av)	lb _m (av)	0.06250
oz (av)	oz (tr)	0.9115
oz (av)	t (long)	2.790E-05
oz (av)	t (metric)	2.835E-05
oz (av)	t (short)	2.835E-05
oz (tr)	dwt (tr)	20
oz (tr)	g	31.10348
oz (tr)	gr	480
oz (tr)	kg	0.031103
oz (tr)	lb (tr)	0.08333
oz (tr)	lb _m (av)	0.068571
oz (tr)	oz (av)	1.09714
oz (UK fluid)	cm ³	28.41305
oz (UK fluid)	ft ³	0.0010034
oz (UK fluid)	m ³	2.8413E-05
oz (UK fluid)	m ³	2.84131E-05
oz (US fluid)	cm ³	29.57353
oz (US fluid)	ft ³	0.0010444
oz (US fluid)	in ³	1.805
oz (US fluid)	L	0.02957
oz (US fluid)	L	0.02957353
oz (US fluid)	m ³	2.9574E-05
oz (US fluid)	m ³	2.95735E-05
oz (US fluid)	mL	29.57353

(continued)

Table 15.3 (continued)

Starting Unit	Desired Unit	Factor
From	To	Multiply By
oz _f /in ²	dyn/cm ²	4309
oz _f /in ²	lb _f /in ²	0.0625
oz _f /in ²	Pa	430.92
P		
P	cP	100
P	dyn s/cm ²	1
P	g/cm s	1
P	kg/m s	0.1
P	lb _f h/ft ²	5.80151E-07
P	lb _f s/ft ²	0.0020885
P	lb _m /ft h	242
P	lb _m /ft s	0.0672
P	N s/m ²	0.1
P	Pa s	0.1
Pa	atm	9.8692E-06
Pa	bar	1.00E-05
Pa	dyn/cm ²	10
Pa	ft H ₂ O (4 °C)	3.3456E-04
Pa	kg _f /m ²	0.10197
Pa	lb _f /ft ²	0.0208854
Pa	lb _f /in ²	1.4504E-04
Pa	mm Hg (0 °C)	0.0075006
Pa	MPa	1.00E-06
Pa	N/m ²	1
Pa	torr	0.0075006
Pa s	cP	1000
Pa s	dyn s/cm ²	10
Pa s	kg _f s/m ²	0.101972
Pa s	lb/h lb	2419.09
Pa s	lb/s ft	0.671969
Pa s	lb _f s/ft ²	0.0208854
Pa s	P	10
parsec	km	3.084E+13
parsec	mi	1.9E+13
pcu (15 °C)	Btu	1.8000
pcu (15 °C)	J	1899.1
pcu/h ft ² °C	Btu/h ft ² °F	1
pdl	dyn	1.3826E+04
pdl	g _f	14.1
pdl	J/m	0.13825

(continued)

Table 15.3 (continued)

Starting Unit	Desired Unit	Factor
From	To	Multiply By
pdl	kg _f	0.01410
pdl	lb _f	0.031081
pdl	N	0.13825
pdl ft	N m	0.04214011
pk (US dry)	bu	0.25
pk (US dry)	ft ³	0.31111
pk (US dry)	in ³	537.605
pk (US dry)	m ³	0.0088098
pk (US dry)	qt (US dry)	8
Plank's quantum	erg s	6.624E-27
pound mole (see lbmol)		
ppm (wtr)	gr/gal (UK)	0.07015
ppm (wtr)	gr/gal (US)	0.0584
ppm (wtr)	lb/MM gal (10 ⁶)	8.345
PSF (see lb _f /ft ²)		
PSI (see lb _f /in ²)		
pt (UK liq)	ft ³	0.020068
pt (UK liq)	m ³	5.6826E-04
pt (UK)/h hp	dm ³ /kW h	0.7620504
pt (UK)/h hp	dm ³ /MJ	0.2116806
pt (US dry)	ft ³	0.019445
pt (US dry)	in ³	33.60
pt (US dry)	m ³	5.5061E-04
pt (US liq)	cm ³	473.2
pt (US liq)	ft ³	0.016710
pt (US liq)	gal (US liq)	0.125
pt (US liq)	in ³	28.87
pt (US liq)	m ³	4.7318E-04
pt (US liq)	qt (US liq)	0.5
pt/Mbbl (UK 1000)	cm ³ /m ³	3.574253
Q		
qt (UK)	ft ³	0.040136
qt (UK)	m ³	0.0011365
qt (US dry)	ft ³	0.038889
qt (US dry)	in ³	67.20
qt (US dry)	m ³	0.0011012
qt (US liq)	cm ³	946.4
qt (US liq)	ft ³	0.033420
qt (US liq)	gal (US liq)	0.25
qt (US liq)	in ³	57.75
qt (US liq)	m ³	9.4635E-04

(continued)

Table 15.3 (continued)

Starting Unit	Desired Unit	Factor
From	To	Multiply By
quad (angle)	deg (angle)	90
quad (angle)	min (angle)	5400
quad (angle)	rad (angle)	1.5708
quad (angle)	sec (angle)	3.290E+05
quad (heating value)	Btu (ISO)	1.0000E+15
quad (heating value)	J	1.0551E+18
quart sect	ft ²	6.9696E+06
quart sect	m ²	6.4750E+05
R		
R° (unit size)	C° (unit size)	0.55556
R° (unit size)	F° (unit size)	1
rad (angle)	circle	0.15915
rad (angle)	deg (angle)	57.296
rad (angle)	gon	63.662
rad (angle)	grad	63.662
rad (angle)	min (angle)	3437.7
rad (angle)	quad (angle)	0.63662
rad (angle)	rev	0.15915
rad (angle)	sec (angle)	2.0626E+05
rad (angle)	turn	0.15915
rad (radiation)	Gy	0.01
rad/min	deg/s	0.95495
rad/s	deg/min	3437.7
rad/s	deg/s	57.296
rad/s	rev/min	9.54929
rad/s	rev/s	0.15915
rad/s ²	deg/min ²	2.0626E+05
rad/s ²	deg/s ²	57.296
rad/s ²	rev/min s	9.54929
rad/s ²	rev/min ²	572.96
rad/s ²	rev/sec ²	0.15915
ream	sheets	500
rev	deg (angle)	360
rev	quad	4
rev	rad (angle)	6.28318531
rev/min	deg/sec	6
rev/min	rad/s	0.1047198
rev/min s	rad/s ²	0.1047198
rev/min ²	rad/s ²	0.001745329
rev/s	deg/sec	360

(continued)

Table 15.3 (continued)

Starting Unit	Desired Unit	Factor
From	To	Multiply By
rev/s	rad/s	6.283185
rev/s	rev/min	60
rev/sec ²	deg/min ²	1.2960E+06
rev/sec ²	rad/s ²	6.283185
rev/sec ²	rev/min s	60
rev/sec ²	rev/min ²	3600
rhe	ft ² /lb sec	47.881
rhe	m ² /N s	1
rod (surv)	ch (Gunter's)	0.25
rod (surv)	ft	16.500
rod (surv)	m	5.0292
rod (surv)	yd	5.5
rod ²	ft ²	272.25
rod ²	m ²	25.293
S		
s (second)	a (year)	3.1688E-08
S	abmho	1.00E-09
s	billion years	3.1688E-17
s	century	3.1688E-10
s	d (day)	1.1574E-05
s	eon	3.1688E-17
s	h	2.7778E-04
S	mho	1
s	millennium	3.1688E-11
s	million years	3.1688E-14
s	min	0.016667
s	mo	3.8580E-07
S	statmho	8.9876E+11
s	y (year)	3.1688E-08
sb	cd/m ²	1.00E+04
sb	L	3.1416
sc (UK fluid)	ft ³	4.1808E-05
sc (UK fluid)	m ³	1.1839E-06
scf (60 °F)	kmol	0.0011953
scf (60 °F)	lbmol	0.00263539
scf (60 °F)	NCM (0 °C)	0.026792
scf (60 °F)	SCM (15 °C)	0.028262
scf/b	NCM/m ³	0.1685
scf/bbl	kmol/m ³	0.00751821
scf/min	NCM/h (0 °C)	1.6075

(continued)

Table 15.3 (continued)

Starting Unit	Desired Unit	Factor
From	To	Multiply By
SCM	kmol	0.0446158
SCM (0 °C)	kmol	0.0446158
SCM (15 °C)	kmol	0.0422932
SCM (15 °C)	scf	35.3830
SCM/MT (15 °C)	scf/bbl	SG/0.1782
scr (av)	gr	20
scr (av)	kg	0.001575
scr (av)	lb _m (av)	0.003472
sec (angle)	deg (angle)	2.7778E-04
sec (angle)	min (angle)	1.667E-02
sec (angle)	quad	3.087E-04
sec (angle)	rad (angle)	4.8481E-06
sect	ft ²	2.7879E+07
sect	ha	258.9988
sect	m ²	2.5900E+06
sl	g-lb (gee-pound)	1.0000
sl	kg	14.594
sl	lb _m	32.1744
sph	sr	12.5663
sq ft (see ft ²)		
sq in (see in ²)		
sr	(deg) ² (angle)	3282.8
sr	(gon) ²	4052.8
St	ft ² /s	0.0010764
St	m ² /s	1.00E-04
statampere	A	3.3356E-10
statcoulomb	F	3.4571E-15
statfarad	F	1.1130E-12
stathenry	H	8.98755E+11
stathenry	H (US intl)	8.9831E+11
statmho	S	1.1127E-12
statohm	Ω	8.9876
statvolt	V	299.79
T		
t (long)	kg	1016.05
t (long)	lb	2240
t (long)	t (metric)	1.016047
t (long)	t (short)	1.1200
t (metric)	kg	1000
t (metric)	lb	2204.6

(continued)

Table 15.3 (continued)

Starting Unit	Desired Unit	Factor
From	To	Multiply By
t (metric)	lb _f	2204.6
t (metric)	N	9806.7
t (metric)	t (short)	1.1023114
t (refrig)	kW	3.516853
t (short)	kg	907.1843
t (short)	kN	8.896443
t (short)	lb	2000
t (short)	t (long)	0.89287
t (short)	t (metric)	0.90718
t (UK)	kN	9.964016
t (UK)	t (long)	1
t (UK)	t (metric)	1.016047
t/a (metric)	MM lb/yr (10^6)	0.00220462
t/a (metric)	t/y (short)	1.1023114
t/d (metric)	kg/s	0.011574
t/d (metric)	lb/s	0.025516
t/d (short)	kg/h	0.9071847
t/d (short)	kg/s	0.01049982
t/ft ² (short)	lb _f /in ²	2000
t/ft ² (short)	t/m ² (metric)	9.764855
t/h (short)	kg/s	0.2519958
t/h (short)	t/h (metric)	0.9071847
t/min (short)	kg/s	15.11974
t/y (short)	t/a (metric)	0.9071847
t _f (long)	kN	9.964016
t _f (short)	kN	8.896443
t _f /ft ² (short)	MPa	0.09576052
t _f /in ² (short)	MPa	13.78951
t _f ft (short)	kN m	2.711636
t _f mi (short)	MJ	14.31744
therm (refy)	Btu	1.00E+06
thm (therm)	kJ	1.055056E+05
thm (therm)	kW h	29.30711
thm (therm)	MJ	105.5056
thm (US)	Btu (ISO)	9.9976E+04
thm (US)	J	1.0548E+08
thm/bbl	FOE bbl	0.156250
thm/cft	Btu/ft ³	1.00E+05
thm/cft	J/m ³	3.7260E+09
thm/gal (UK)	kJ/dm ³	2.32080E+04

(continued)

Table 15.3 (continued)

Starting Unit	Desired Unit	Factor
From	To	Multiply By
thm/gal (UK)	kJ/L	2.32080E+04
thm/gal (UK)	kJ/m ³	2.32080E+07
thm/gal (UK)	kW h/dm ³	6.44667
thm/gal (UK)	MJ/m ³	2.32080E+04
toise	ft	6.3945
toise	m	1.9490
toise (metric)	ft	6.5617
toise (metric)	m	2.0000
torr	kPa	0.1333224
torr	lb _f /in ²	0.019337
torr	Pa	133.32
turn (angle)	deg (angle)	360.00
turn (angle)	rad (angle)	6.2832
twshp	ft ²	1.0036E+09
twshp	m ²	9.3240E+07
U		
V		
V	abvolt	1.00E+08
V	statvolt	0.0033356
V	V (US intl)	0.99967
V (intl)	J (abs)	1.593E−19
V (intl)	V (abs)	1.0003
V (intl)	J	9.654E+04
V (US intl)	V	1.0003
V A	Btu/h	3.4095
V A	W	1
W		
W	abwatt	1.00E+08
W	Btu/h (60 °F)	3.4134
W	Btu/min (60 °F)	0.056889
W	cal (15 °C)/h	860.11
W	donkey	0.0040000
W	erg/s	1.00E−07
W	ft lb _f /min	44.254
W	ft lb _f /s	0.73756
W	hp (550)	0.001341
W	hp (boiler)	1.0194E−04
W	hp (metric)	0.0013596
W	J/s	1
W	kcal/min	0.01434

(continued)

Table 15.3 (continued)

Starting Unit	Desired Unit	Factor
From	To	Multiply By
W	kW	0.001
W	MM Btu/h (10^6)	3.4095E-06
W	MM kcal/h (10^6)	8.5919E-07
W	MW	1.0000E-06
W	V A	1
W/cm K	Btu/ft h °F (therm)	57.818
W/cm K	Btu/in h °F (therm)	4.8181
W/cm K	cal/cm s °C (therm)	0.23901
W/cm K	J/cm s K	100
W/cm ²	W/m ²	1.00E+04
W/cm ² (°C/cm)	Btu/h ft ² (°F/in)	694.0
W/cm ² °C	Btu/h ft ² °F	1760
W/in ² °F	Btu/h ft ² °F	490
W/kg	Btuh lb	1.5477
W/kg	cal/s g	2.3885E-04
W/kg	kcal/h kg	0.85985
W/m °C	Btu/h ft ² (°F/ft)	0.577789
W/m °C	Btu/h ft ² (°F/in)	6.93347
W/m °C	kcal/h m ² (°C/m)	0.860421
W/m K	Btu/ft h °F (therm)	0.57818
W/m K	W/cm K	0.01
W/m ²	Btu/ft ² h	0.31700
W/m ²	cal/cm ² s	2.3885E-05
W/m ²	kcal/ft ² h	0.079885
W/m ²	kcal/m ² h	0.85985
W/m ² (°C/m)	Btu/h ft ² (°F/ft)	0.577789
W/m ² (°C/m)	Btu/h ft ² (°F/in)	6.93347
W/m ² (°C/m)	kcal/h m ² (°C/m)	0.860421
W/m ² °C	Btu/ft ² h °F	0.1762
W/m ² K	Btu/ft ² h °F	0.1762
W/m ³	Btu/h ft ³	0.096618
W/m ³	cal/s cm ³	2.3885E-07
W/m ³	kcal/h ft ³	0.024348
watt (US intl)	W	1.0002
Wb (weber)	kli (lines)	1.00E+05
Wb (weber)	Mx (maxwell)	1.00E+08
Wb/in ²	G (gauss)	1.55E+07
Wb/in ²	li/in ² (line)	1.00E+08
Wb/in ²	Wb/cm ²	0.1550
Wb/in ²	Wb/m ²	1550

(continued)

Table 15.3 (continued)

Starting Unit	Desired Unit	Factor
From	To	Multiply By
Wb/m ²	G (gauss)	1.00E+04
Wb/m ²	li/in ² (line)	6.452E+04
Wb/m ²	T (tesla)	1
Wb/m ²	Wb/cm ²	1.00E−04
Wb/m ²	Wb/in ²	6.452E−04
wk	d	7
wppm	mg/kg	1
wt%	g/kg	10
wt%	kg/kg	0.01
X		
Y		
yd	cm	91.44
yd	ft	3
yd	in	36
yd	km	9.1440E−04
yd	m	0.9144
yd	mi (naut)	4.9340E−04
yd	mi (stat)	5.6820E−04
yd ²	Ac	2.066E−04
yd ²	cm ²	8361
yd ²	ft ²	9
yd ²	in ²	1296
yd ²	m ²	0.8361274
yd ²	mi ²	3.228E−07
yd ³	ft ³	27
yd ³	gal (US liq)	202
yd ³	in ³	4.6656E+04
yd ³	L	764.5
yd ³	m ³	0.76455
yd ³	pt (US liq)	1615.9
yd ³	qt (US liq)	807.9
yd ³ /min	ft ³ /s	0.45
yd ³ /min	gal/s (US)	3.366
yd ³ /min	L/s	12.74
Z		
Greek Letters		
Ω	abohm	1.00E+09
Ω	MΩ	1.00E−06
Ω	S	1
Ω (int mean)	Ω (abs)	1.0005

Engineering, although a few others have been included because they are commonly used. Factors are listed alphabetically by abbreviation. If you are unsure of the appropriate abbreviation, check Tables 15.1 and 15.2.

When looking up conversion factors for derived units, remember that the factors can be in different orders or reduced according to the rules of mathematics. For instance, ft lb can also be lb ft. Btu/ft² h °F can also be Btu/h ft² °F. An effort was made to keep dimensions in the order: L·M·T·Θ... followed by derived units in both numerator and denominator, but there are some exceptions based on common usage.

Some units have almost the same abbreviation for different purposes. Pound is a good example since it may be expressed as lb (usually means pound weight *avoirdupois*), lb_m (pound mass), and lb_f (pound force). The table is fairly flexible; but if you can't find a factor listed in one form, try another.

Some units have different “flavors” depending on the basis. “Btu” is a good example. There are definitions of Btu from multiple organizations with slightly different values. A lot of the differences result from the standard measurement conditions used. For the most part here, “mean”, “thermochemical”, or IT values have been used. The differences are in the fourth significant figure.

Since the table is intended to represent the most common conversions, the detailed qualifiers for each unit are limited to keep the table as compact as possible in a useful size. Factors listed have been compiled from all the listed references; hence, the reference numbers are not repeated here.

The conversion factors in the table have been checked and re-checked; but there may still be errors. If a factor doesn't look right, check it independently.

Most of these conversions are also available via the internet at several sites. Errors were identified in these conversions in some cases; so, in critical applications be sure to verify the conversion is correct if it does not look right to you. Some suggested online converters that appear to have good accuracy, a wide selection of units, and an easy-to-use interface are:

- Engineering Toolbox—https://www.engineeringtoolbox.com/unit-converter-d_185.html
- Calculator.org—<http://www.calculator.org/properties.aspx>

Common Indirect and Non-linear Conversions

[1, 4, 5, 15, 21, 23]

Some units of measurement use scales which are non-linear or scales which are defined uniquely for a specific purpose. These units cannot be converted by simply multiplying by a conversion factor. This section addresses the most common, non-linear or indirect conversions generally encountered.

Temperature

On an absolute temperature scale basis, both the metric/SI and English/U.S. systems are zero at absolute zero. The two systems then use different scale increments; but a simple, linear conversion can be applied to move between the kelvin scale (K) in the metric system and the Rankine scale (°R) in the English system.

The more commonly used temperature scales, Celsius (°C) and Fahrenheit (°F), do not have a common zero value, so a little simple math is involved. For temperature scale interconversions, the simplest approach is to use the following equations:

$$^{\circ}F = [1.8(^{\circ}C) + 32] = [1.8(K) - 459.67] = [^{\circ}R - 459.67] \quad (15.1)$$

$$^{\circ}C = [K - 273.15] = [(^{\circ}F - 32)/1.8] = [(^{\circ}R/1.8) - 273.15] \quad (15.2)$$

$$K = [^{\circ}C + 273.15] = [^{\circ}R/1.8] = [(^{\circ}F + 459.67)/1.8] \quad (15.3)$$

$$^{\circ}R = [^{\circ}F + 459.67] = [1.8K] = [1.8^{\circ}C + 491.67] \quad (15.4)$$

Density

Several scales have been developed over the years to define density or specific gravity in a convenient way for certain purposes. Most of these depended on measurement by hydrometer. There are several scales; but the common scales included here are:

- *Baumé* (°Bé)—used in industry for bulk liquid chemicals. There are scales for materials lighter and heavier than water (Bé light and heavy).
- *API* (°API)—developed by the American Petroleum Institute for hydrocarbon liquids.
- Various scales commonly for juice, sugar, winemaking, and brewing
 - *Balling* (°B)—approximates the % sucrose in aqueous solution.
 - *Brix* (°Bx)—a corrected version of the Balling scale for % sucrose in solution.
 - *Plato* (°P)—another scale for % sucrose in aqueous solution.
 - *Oeschle* (°Oe)—estimates sucrose in aqueous solutions as grams per liter at 20 °C.
 - *Klosterneuburger Mostwaage* (°KMW)—intended to provide the exact sugar content of a must for winemaking on a weight basis, this scale is related to the Oeschle scale.
 - *Potential Alcohol*—another measure for winemaking and brewing, essentially derived from sugar content.

- *Twaddle* ($^{\circ}TW$)—for liquids heavier than water.

The density scales are primarily based on hydrometer readings, so correction for the measurement temperature is required. Hence, there are tables below for these corrections. Modern practice uses other measurement methods which may or may not require temperature corrections.

Conversion of the density scales to specific gravity can be accomplished most easily using the definitions of the scales, along with a few charts. Conversions are provided for each scale in the following:

- *Baumé scales*—these are most easily defined using the equations below. Table 15.4 provides the correction factors for temperature when the measurement is made at a temperature other than 60 $^{\circ}F$ (15.6 $^{\circ}C$).

$$\text{Heavy} : (SG^{60}_{/60}) = 145 / (145 - ^{\circ}Bé) \quad (15.5)$$

$$\text{Light} : (SG^{60}_{/60}) = 140 / (130 + ^{\circ}Bé) \quad (15.6)$$

- *API Gravity*—the defining equations for API gravity are below as Eqs. 15.7 and 15.8. These are the easiest way to convert between $^{\circ}API$ and specific gravity. There is a correction required for specific gravity if the API gravity is measured at a temperature other than 60 $^{\circ}F$ (15.6 $^{\circ}C$) and that correction is in Table 15.5.

$$^{\circ}API = 141.5 / (SG^{60^{\circ}F}_{/60^{\circ}F}) - 131.5 \quad (15.7)$$

$$SG^{60^{\circ}F}_{/60^{\circ}F} = 141.5 / (131.5 + ^{\circ}API) \quad (15.8)$$

- *Miscellaneous Density Scales*—conversions from other measurement scales to specific gravity can be accomplished in a manner similar to conversions for Baumé and API scales using the equations below. The temperature corrections are shown in Table 15.6.
- Balling and Brix scales—these essentially use the same equation for conversion within the accuracy of the measurement, hence the approximate conversions are:

$$^{\circ}B \approx ^{\circ}Bx = 231.6 * ((SG^{20^{\circ}C}_{/20^{\circ}C}) - 0.9977) \quad (15.9)$$

$$SG^{20^{\circ}C}_{/20^{\circ}C} = (^{\circ}B / 231.6) + 0.9977 \approx (^{\circ}Bx / 231.6) + 0.9977 \quad (15.10)$$

- Plato scale—equations for conversion between specific gravity at 20 $^{\circ}C$ (68 $^{\circ}F$) and $^{\circ}P$ can be accomplished approximately by Eqs. 15.11 and 15.12, with temperature correction per Table 15.6.

Table 15.4 Approximate aqueous specific gravity adjustments to 60 °F (15.6 °C) for °Bé

Temp., °F	50	59	60	68	77	86	95	104	122	140	158	176	194	212
Temp., °C	10	15	15.6	20	25	30	35	40	50	60	70	80	90	100
Meas SG at T	Add to get SG ⁶⁰ / ₆₀													
0.70	-0.0008	-0.0001	0.0000	0.0006	0.0013	0.0019	0.0026	0.0033	0.0047	0.0060	0.0074	0.0088	0.0101	0.0115
0.80	-0.0010	-0.0002	0.0000	0.0006	0.0014	0.0022	0.0030	0.0038	0.0054	0.0070	0.0086	0.0103	0.0119	0.0135
0.90	-0.0012	-0.0002	0.0000	0.0007	0.0016	0.0025	0.0034	0.0044	0.0062	0.0080	0.0099	0.0117	0.0136	0.0154
1.00	-0.0014	-0.0003	0.0000	0.0007	0.0018	0.0028	0.0038	0.0049	0.0070	0.0090	0.0111	0.0132	0.0153	0.0174
1.10	-0.0015	-0.0004	0.0000	0.0008	0.0019	0.0031	0.0043	0.0054	0.0077	0.0100	0.0124	0.0147	0.0170	0.0193
1.20	-0.0017	-0.0004	0.0000	0.0008	0.0021	0.0034	0.0047	0.0059	0.0085	0.0110	0.0136	0.0161	0.0187	0.0213
1.30	-0.0019	-0.0005	0.0000	0.0009	0.0023	0.0037	0.0051	0.0065	0.0093	0.0120	0.0148	0.0176	0.0204	0.0232
1.40	-0.0021	-0.0006	0.0000	0.0009	0.0025	0.0040	0.0055	0.0070	0.0100	0.0130	0.0161	0.0191	0.0221	0.0251
1.50	-0.0023	-0.0006	0.0000	0.0010	0.0026	0.0043	0.0059	0.0075	0.0108	0.0140	0.0173	0.0206	0.0238	0.0271
1.60	-0.0025	-0.0007	0.0000	0.0010	0.0028	0.0045	0.0063	0.0080	0.0115	0.0150	0.0185	0.0220	0.0255	0.0290
1.70	-0.0026	-0.0008	0.0000	0.0011	0.0030	0.0048	0.0067	0.0086	0.0123	0.0160	0.0198	0.0235	0.0273	0.0310
1.80	-0.0028	-0.0008	0.0000	0.0011	0.0031	0.0051	0.0071	0.0091	0.0131	0.0170	0.0210	0.0250	0.0290	0.0329
1.90	-0.0030	-0.0009	0.0000	0.0012	0.0033	0.0054	0.0075	0.0096	0.0138	0.0180	0.0223	0.0265	0.0307	0.0349
2.00	-0.0032	-0.0010	0.0000	0.0013	0.0035	0.0057	0.0079	0.0101	0.0146	0.0190	0.0235	0.0279	0.0324	0.0368

Table 15.5 Approximate hydrocarbon specific gravity adjustments to 60°F (15.6°C) for °API

Density Meas g/cc	At temperature listed, add value to density to get approximate SG 60/60							
	140 °F	120 °F	100 °F	80 °F	60 °F	40 °F	20 °F	0 °F
0.50	0.048	0.037	0.025	0.013	0.000	−0.010	−0.022	−0.033
0.55	0.048	0.036	0.024	0.013	0.000	−0.011	−0.022	−0.034
0.60	0.047	0.036	0.024	0.012	0.000	−0.011	−0.023	−0.034
0.65	0.047	0.035	0.024	0.012	0.000	−0.011	−0.023	−0.035
0.70	0.046	0.035	0.023	0.011	0.000	−0.012	−0.024	−0.035
0.75	0.046	0.034	0.023	0.011	0.000	−0.012	−0.024	−0.036
0.80	0.046	0.034	0.022	0.011	0.000	−0.013	−0.024	−0.036
0.85	0.045	0.033	0.022	0.010	0.000	−0.013	−0.025	−0.037
0.90	0.045	0.033	0.021	0.010	0.000	−0.014	−0.025	−0.037
0.95	0.044	0.033	0.021	0.009	0.000	−0.014	−0.026	−0.037
1.00	0.044	0.032	0.020	0.009	0.000	−0.015	−0.026	−0.038
1.05	0.043	0.032	0.020	0.008	0.000	−0.015	−0.027	−0.038
1.10	0.043	0.031	0.020	0.008	0.000	−0.015	−0.027	−0.039

Table 15.6 Approximate aqueous specific gravity adjustments to 20 °C (68 °F) for miscellaneous density scales

Temperature		Add to SG to get SG ²⁰ / ₂₀
°C	°F	
10	50	−0.003
15	59	−0.002
20	68	0.000
25	77	0.002
30	86	0.004
35	95	0.005
40	104	0.007
45	113	0.009

$$^{\circ}P = 259 - (259 / (SG^{20} / _{20})) \tag{15.11}$$

$$SG^{20} / _{20} = 259 / (259 - ^{\circ}P) \tag{15.12}$$

- **Oechsle scale**—equations for conversion between grams of sugar per liter in a must at 20 °C (68 °F) and °Oe can be accomplished approximately by Eqs. 15.13 and 15.14, with temperature correction per Table 15.6.

$$^{\circ}\text{Oe} = [\text{g/L must at } 20^{\circ}\text{C}(68^{\circ}\text{F})] - [\text{g/L water at } 20^{\circ}\text{C}(68^{\circ}\text{F})] \quad (15.13)$$

$$^{\circ}\text{Oe} \approx [\text{g/L must at } 20^{\circ}\text{C}(68^{\circ}\text{F})] - 1000 \quad (15.14)$$

- Klosterneuburger Mostwaage scale—the regressed equation relating $^{\circ}\text{KMW}$ with readings in $^{\circ}\text{Oe}$ is below as Eq. 15.15. Temperature correction per Table 15.6 must be applied to the $^{\circ}\text{Oe}$ measurement.

$$^{\circ}\text{Oe} = 0.022 * (^{\circ}\text{KMW})^2 + 4.54 * (^{\circ}\text{KMW}) \quad (15.15)$$

- Potential Alcohol scale—potential alcohol is related to the specific gravity of a must or wort approximately per Eq. 15.16 below. One of the other methods for determining specific gravity of the fluid needs to be applied to use this regressed equation. Potential alcohol is on a volume basis.

$$\%PA = 1000 * (SG^{20}_{/20} - 1) / ((7.75 - 3.75 * (SG^{20}_{/20} - 1.007))) \quad (15.16)$$

- Twaddell scale—Equations 15.17 and 15.18 approximate conversions around this scale. The calculated specific gravity must be adjusted to 20°C using the correction factors in Table 15.6.

$$^{\circ}Tw = ((SG^{20}_{/20} - 1) / 0.005) \quad (15.17)$$

$$(SG^{20}_{/20}) = 1 + 0.005 * ^{\circ}Tw \quad (15.18)$$

Concentration

There are numerous ways in which concentrations are expressed. Some are similar to density units (e.g. mg/L); while others include chemical properties or mixed units (e.g. mol/L). Table 15.7 provides conversion equations among the most common units for concentration.

In Table 15.7, the symbols are defined as follows:

- ρ_{xxx} = density. The subscripts ($_{xxx}$) indicate different bases:
 - tot: grams per liter density of the total unit reference volume. For a solution, this would be the combined solution density. The designation “tot” is used for the general case.
 - i: grams per liter density of a species of interest by itself only. In solutions, this density may be difficult to determine, especially if the solution is non-ideal.

Table 15.7 Conversion formulas for common concentration units

Converting From		Converting To (Multiply by:)	
Unit	Abbrev.	Weight Fraction	Volume Fraction
Percentages, %			
Weight	w%	$\times 0.01$	$\sim \times 0.01 \times (\rho_{\text{tot}}/\rho_i)$
Volume	v%	$\sim \times 0.01 \times (\rho_i/\rho_{\text{tot}})$	$\times 0.01$
Mole	mol%	$\sim \times 0.01 \times (\text{MW}_i/\text{MW}_{\text{tot}})$	Gases: $\sim \times 0.01$ General: $\sim \times 0.01 \times (\rho_{\text{tot}}/\rho_i) \times (\text{MW}_i/\text{MW}_{\text{tot}})$
Fractions			
Weight	wt frac	$\times 1$	$\sim \times (\rho_{\text{tot}}/\rho_i)$
Volume	vol frac	$\sim \times (\rho_i/\rho_i)$	$\times 1$
Mole	mol frac	$\sim \times (\text{MW}_i/\text{MW}_{\text{tot}})$	Gases: $\sim \times 1$ General: $\sim \times (\rho_{\text{tot}}/\rho_i) \times (\text{MW}_i/\text{MW}_{\text{tot}})$
Chemical Properties			
Molarity	mol/L	$\sim \times \text{MW}_i/\rho_{\text{soln}}$	$\sim \times \text{MW}_i/\rho_i$
Molality	mol/g	$\sim \times \text{MW}_i$	$\sim \times \text{MW}_i \times \rho_{\text{soln}}/\rho_i$
Normality	eq/L	$\sim \times Z_i \times \text{MW}_{i,\text{eq}}/\rho_{\text{soln}}$	$\sim \times Z_i \times \text{MW}_{i,\text{eq}}/\rho_i$
Miscellaneous			
grains/gallon	gr/gal	$\sim \times 1/(7000 \times \rho_{\text{soln,gal}})$	$\sim \times 1/(7000 \times \rho_{\text{soln,gal}}) \times (\rho_{\text{soln}}/\rho_i)$
grains/cubic foot	gr/cft	$\sim \times 1/(7000 \times \rho_{\text{tot,cft}})$	$\sim \times 1/(7000 \times \rho_{\text{tot,cft}}) \times (\rho_{\text{tot}}/\rho_i)$
milli grams/liter	mg/L	$\sim \times 1/(1000 \times \rho_{\text{soln,liter}})$	$\sim \times 1/(1000 \times \rho_{\text{soln,liter}}) \times (\rho_{\text{soln}}/\rho_i)$
milli grams/cubic meter	mg/m ³	$\sim \times 1/(1000 \times \rho_{\text{tot,cu meter}})$	$\sim \times 1/(1000 \times \rho_{\text{tot,cu meter}}) \times (\rho_{\text{tot}}/\rho_i)$
Particle density	part/L	$\sim \times V_{\text{avg,part}} \times \rho_{\text{part}}/\rho_{\text{tot}}$	$\sim \times V_{\text{avg,part}} \times \rho_{\text{part}}/\rho_{\text{tot}} \times (\text{MW}_{\text{tot}}/\text{MW}_{\text{part}})$

- soln: grams per liter density of a combined solution unit reference volume. This includes the solute(s) and solvent together. Similar to “tot” above.
 - soln,gal: pounds per gallon density of a solution unit reference volume.
 - tot,cft: pounds per cubic foot density for a total unit reference volume.
 - soln,liter: grams per liter density of a solution unit reference volume.
 - tot,cu meter: grams per cubic meter density for a total unit reference volume.
 - part: grams per liter density for an individual particle contained in a unit volume. This is for the particle only and may be an average weighted by the particle distribution.
- MW_{xx} = *molecular weight in grams per mole*. The subscripts (_{xx}) indicate different bases:
 - tot: average molecular weight for the total unit reference volume. In solutions this is for the combined solution, including the solute(s) and solvent. This is the sum of the molecular weight for each component in a mixture times its mole fraction in the mixture totaling to 1 mol fraction.
 - i: molecular weight for the species “i” which concentration is of interest. If several species are of interest, the average molecular weight of the species, weighted by mole fraction, is used. The sum of the mole fractions must equal 1.
 - soln: average molecular weight of the total solution reference volume. Similar to “tot” above, but was applied specifically to solutions.
 - i,eq: the combining or equivalent weight of a species in chemical reactions. For ionic reactions, $MW_{i,eq}$ is the molecular weight of a component divided by its valence in the reactions.
 - part: the average or effective molecular weight of a particle in a volume of material. This may not always be meaningful. It is only used for converting particle density to mole fraction. If the suspended particles were an identifiable compound(s), say, urea, then it would have a meaning.
 - Z_i = *the dimensionless*, effective valence of a compound or element in chemical reactions. Essentially this is the number of electrons a material can contribute, accept, or share in a reaction. It is used in determining the equivalent or combining weight of a material.
 - $V_{avg,part}$ = *the average volume per solid particle* in a liquid or suspended in a gas in units of liters per particle. This will be a very tiny number numerically in most cases. This measure is specifically for the solid particles of interest. It is used to determine the actual volume of particles represented by the particle density. This may be hard to determine. If you have a particle size distribution for the particles, you can estimate the volume of particles of each size in the unit volume (assuming spheres), add these together to get the total liters occupied by the particles, and divide by the total number of particles in the unit volume.

Viscosity

Two types of viscosities are defined:

- *Dynamic* (μ)—measures resistance to shear. Typical units are centipoise (cP) and lb/ft sec.
- *Kinematic* (ν)—calculated from dynamic viscosity divided by specific gravity. Typical units are centistokes (cSt) and ft²/sec.

Dynamic and kinematic viscosities can be converted directly between units for the same type of viscosity using factors available in Table 15.3. There are, however, special measurement devices which provide viscosity readings in non-linear units specific to the device. The devices make measurements based on efflux rate through an orifice or shear rate between two plates or other approaches that relate to viscosity. The measurement units from the devices can then be converted to dynamic and kinematic viscosities, but they are often reported directly.

The most common viscosity scales reported and the resulting units are:

- *Saybolt Universal*—Saybolt Seconds Universal (SUS or SSU) at 100 and 210 °F
- *Saybolt Furol*—Saybolt Seconds Furol (SFS or SSF) at 122 and 210 °F
- *Redwood*—Redwood seconds with temperature specified
- *Redwood Admiralty*—RA seconds with temperature specified
- *Engler*—Engler degrees
- *Barbey*—Barbey degrees (log scale)

Table 15.8 provides equations for converting among the various viscosity measurement scales pivoting around conversion to centistokes. Refer to the table description for how to use this table.

Sound

Sound measurement units are based on the power supplied by the pressure waves generated by a sound. The sound pressure is weighted using factors meant to represent human auditory capabilities at specific frequencies.

The power supplied by a sound wave can be expressed in watts per square meter (W/m²) in the SI system. The actual sound pressure, since it is a wave phenomenon, is converted to a root-mean square of the pressure from the sound wave to obtain the sound measurement units. The units unique to sound measurement are commonly decibels, phons, sones, and Nepers.

Tables 15.9 and 15.10 provide conversions and correspondence among the common sound scales.

Table 15.8 Conversion equation coefficients for kinematic viscosity measurements $y = ax^2 + bx + c$

From	To	Applicable range, cSt		a	b	c
cSt	SUS @100 °F	2	2000	5.1568E-06	4.6201	5.9639
	SUS @210 °F	1.77	2000	1.0434E-05	4.6429	7.8713
	SFS @122 °F	48	2000	1.4970E-06	0.46795	1.9847
	SFS @210 °F	50	2000	5.7335E-06	0.48103	-0.52377
	Redwood	4	2000	-2.8327E-07	4.0456	7.6269
	RW Adm	50	2000	2.0785E-08	0.40517	1.1004
	°Engler	2	2000	2.4106E-07	0.13242	0.16781
	°Barbey [#]	1	2000	-2.5766E-05	-0.99977	8.7323
SUS @100 °F	cSt	2	2000	-5.1196E-08	0.21644	-1.2846
SUS @210 °F		1.77	2000	-1.0189E-07	0.21537	-1.6863
SFS @122 °F		48	2000	-1.4335E-05	2.1369	-4.2333
SFS @210 °F		50	2000	-4.8234E-05	2.0777	1.1667
Redwood		4	2000	5.1996E-09	0.24717	-1.8801
RW Adm		50	2000	-2.9446E-07	2.4681	-2.7142
°Engler		2	2000	-9.9964E-05	7.5508	-1.2486
°Barbey [#]		1	2000	-2.5688E-05	-0.99978	8.7323

Where: y = “To” unit value [for Barbey only → ln(°Barbey) or ln(cSt)]; x = “From” unit value [for Barbey only → ln(cSt) or ln(°Barbey)]; a, b, and c are coefficients from table
Note that for Barbey degrees, the correlation is for the ln(x) and ln(y). Remember to use e^y to get the final answer in the desired units for Barbey viscosity

Coordinates

There are many different approaches to defining coordinates for a point in a two-dimensional plane or a three-dimensional space. This type of information is especially important in navigation and for property definitions in our terrestrial environment; but it is also critical for activities such as navigation in space or finite element analysis in engineering. The common systems involve combinations of distances and angles to define a specific location or shape.

Table 15.11 provides a summary of the equations for interconverting coordinates among several commonly encountered systems:

- 2-D Cartesian
- 2-D Polar
- 3-D Cartesian or Rectangular
- 3-D Cylindrical
- 3-D Spherical

Table 15.9 Equivalent sound pressure levels in air at 1 atmosphere for various sounds

Sound pressure (Air, 1 Atm static)				Units (2E-5 Pa Ref)			Reference sound	
Pa, RMS	bar, RMS	psi, RMS	decibels, dB	phon	sones	Neper, Np		
1.00E-06	1.00E-11	1.45E-10	-26.0			-226		
1.90E-06	1.90E-11	2.76E-10	-20.4			-178	Anechoic chamber, Microsoft, dBA	
2.00E-05	2.00E-10	2.90E-09	0.0			0	Auditory threshold at 1000 Hz	
6.32E-05	6.32E-10	9.17E-09	10.0	-16	0.02	87	Leaves or calm breathing	
2.00E-04	2.00E-09	2.90E-08	20.0	13	0.15	174	Very quiet room, varies 20-30 dB	
0.00200	2.00E-08	2.90E-07	40.0	40	1	347	Normal talking at 1 m, varies 40-60 dB	
0.00632	6.32E-08	9.17E-07	50.0	50	2	434		
0.0200	2.00E-07	2.90E-06	60.0	60	4	521	Television set at 1 m	
0.0632	6.32E-07	9.17E-06	70.0	70	8	608	EPA continuous exposure limit, passenger car, varies 60-80 dB	
0.200	2.00E-06	2.90E-05	80.0	80	16	695	Major road at 10 meters, varies 80-90 dB	
0.356	3.56E-06	5.16E-05	85.0	90	32	738	Hearing damage, long term	
2.00	2.00E-05	2.90E-04	100	100	64	869	Jackhammer at 1 m	
6.32	6.32E-05	9.17E-04	110	110	128	955	Chainsaw at 1 m, loudest human voice at 1 inch	
20.0	2.00E-04	0.00290	120	120	256	1042	Hearing damage, instantaneous risk	
63.2	6.32E-04	0.00917	130	130	512	1129	Trumpet at 0.5 m, pain threshold, varies 130-140 dB	
100	0.00100	0.0145	134	134	676	1164	Jet engine at 100 meters, varies 110-140 dB	
200	0.00200	0.0290	140	140	1024	1216		
632	0.00632	0.0917	150	150	2047	1303	Jet engine at 1 m	
1700	0.0170	0.247	159	159	3714	1377	Stun grenade, varies 158-172 dB	
7265	0.0727	1.054	171	171	8905	1487	0.30-06 Rifle firing at 1 m	
1.01E+05	1.01	14.7	194	194	43519	1686	Theoretical limit for 1 atm sound	
1.00E+06	10.0	145	214	214	172704	1859	Shockwave, >191 dB	

Table 15.10 Equivalent general sound pressure units in air at 1 atmosphere

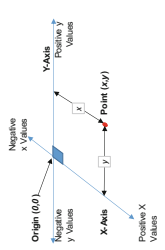
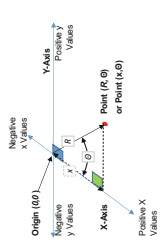
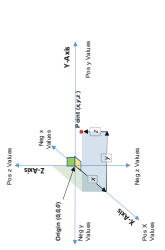
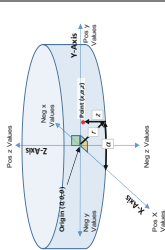
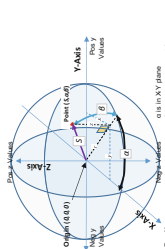
Sound pressure (Air, 1 Atm static)			Units (2E-5 Pa Ref)			
Pa, RMS	bar, RMS	psi, RMS	decibels, dB	phon	sone	Neper, Np
1.00E-06	1.00E-11	1.45E-10	-26.0			-226
1.00E-05	1.00E-10	1.45E-09	-6.0			-52
1.00E-04	1.00E-09	1.45E-08	14.0			121
0.001	1.00E-08	1.45E-07	34.0			295
0.01	1.00E-07	1.45E-06	54.0	54	3	469
0.10	1.00E-06	1.45E-05	74.0	74	11	643
1	1.00E-05	1.45E-04	94.0	94	42	816
10	1.00E-04	0.00145	114	114	169	990
100	0.00100	0.0145	134	134	675	1164
1000	0.0100	0.145	154	154	2698	1337
1.00E+04	0.100	1.45	174	174	10794	1511
1.00E+05	1.00	14.5	194	194	43176	1685
1.00E+06	10.0	145	214	214	172704	1859

The global positioning system provides a special case for coordinates on the earth’s surface. It is not quite the same as the 3-D spherical system above; hence Fig. 15.1 is also provided illustrating the global coordinate system concept based on latitude and longitude.

Gas Law Constant [4, 15, 23]

It is often difficult to locate the appropriate constant R to use in the ideal gas law ($PV = nRT$). You can remember one of the constants and then convert everything to the units for pressure, volume, moles, and temperature that go with that constant or you can use Table 15.12 to identify a constant that will work with the units you have.

Table 15.11 Equations for conversion among common coordinate systems

Equations for Conversion to: (Remember to adjust angles as noted in text to ensure valid angle conversions.)					
Initial system	2-D Cartesian, Rectangular	2-D Polar	3-D Cartesian, Rectangular	3-D, Cylindrical	3-D, Spherical
System conversions diagram					
2-D Cartesian, Rectangular	(x, y)	$R = \sqrt{x^2 + y^2}$ $\Theta = \tan^{-1}(y/x)$ $x = R \cos \Theta$ $y = R \sin \Theta$ <i>Adjust angle if necessary</i>	Not applicable	Not applicable	Not applicable
2-D Polar	$x = R \cos(\Theta)$ $y = R \sin(\Theta)$ or $x \tan(\Theta)$ <i>Adjust angle if necessary</i>	(R, Θ) or (x, Θ)	Not applicable	Not applicable	Not applicable
3-D Cartesian, Rectangular	Not applicable	Not applicable	(x, y, z)	$r = \sqrt{x^2 + y^2}$ $\alpha = \tan^{-1}(y/x)$ $z = z$ <i>Adjust angle if necessary</i>	$r = \sqrt{x^2 + y^2}$ $S = \sqrt{r^2 + z^2}$ $\alpha = \tan^{-1}(y/x)$ $\beta = \cos^{-1}(z/S)$ or $\tan^{-1}(r/z)$ <i>Adjust angle if necessary</i>
3-D Cylindrical	Not applicable	Not applicable	$x = r \cos(\alpha)$ $y = r \sin(\alpha)$ $z = z$ <i>Adjust angle if necessary</i>	(r, α, z)	$S = \sqrt{r^2 + z^2}$ $\alpha = \alpha$ $\beta = \tan^{-1}(z/r)$ <i>Adjust angle if necessary</i>
3-D Spherical	Not applicable	Not applicable	$x = S \sin(\beta) \cos(\alpha)$ $y = S \sin(\beta) \sin(\alpha)$ $z = S \cos(\beta)$ <i>Adjust angle if necessary</i>	$r = S \sin(\beta)$ $\alpha = \alpha$ $z = S \cos(\beta)$ <i>Adjust angle if necessary</i>	(S, α, β)

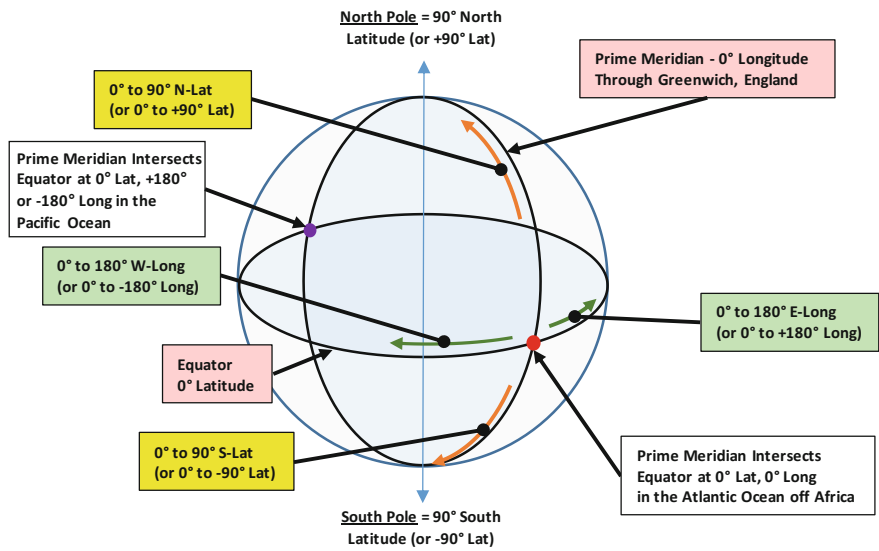


Fig. 15.1 Global system of latitude and longitude for defining positions on the earth

Table 15.12 Ideal gas law constants for various combinations of units

Temp. units	Press. units	Vol. units	Weight units	Energy units	R value
Kelvin	—	—	mol	cal	1.9872
	—	—	mol	J (abs)	8.3144
	—	—	mol	J (int'l)	8.3130
	atm	cm ³	mol	cm ³ atm	82.057
	atm	L	mol	L atm	0.08205
	mm Hg	L	mol	L mm Hg	62.361
	bar	L	mol	L bar	0.08314
	kg/cm ²	L	mol	L kg/cm ²	0.08478
	atm	ft ³	lbmol	ft ³ atm	1.314
	mm Hg	ft ³	lbmol	ft ³ mm Hg	998.9
	—	—	lbmol	Chu or pcu	1.9872
Rankine	—	—	lbmol	Btu	1.9872
	—	—	lbmol	hp h	0.0007805
	—	—	lbmol	kW h	0.0005819
	atm	ft ³	lbmol	ft ³ atm	0.7302
	in Hg	ft ³	lbmol	ft ³ in Hg	21.85
	mm Hg	ft ³	lbmol	ft ³ mm Hg	555.0
	lb/in ² abs	ft ³	lbmol	ft ³ lb/in ²	10.73
	lb/ft ² abs	ft ³	lbmol	ft lb	1545.0

Conclusion

This chapter is a capstone to the study of the history of measurement. We've looked at the overall development of measurement from the earliest approaches to our modern systems. We've considered the available measurement methods along the way and their impacts. We've seen the growth of need for increasing standardization, accuracy, and precision. The evolution and spread of measurement units and techniques from locale to locale worldwide has been highlighted.

The origins and thinking behind each of the primary, base units of measurement has been explored. We have seen how the base units have changed over the centuries and how the base units are combined to form derived units which measure additional critical parameters. We have concluded with a good, useful collection of common measurement conversions for today.

Hopefully, you have appreciated the richness and diversity of the landscape upon which measurement units originated and have grown. Metrology is not a static science. It is continuing to develop as new measurement capabilities and needs arise to meet society's demands in the future.

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