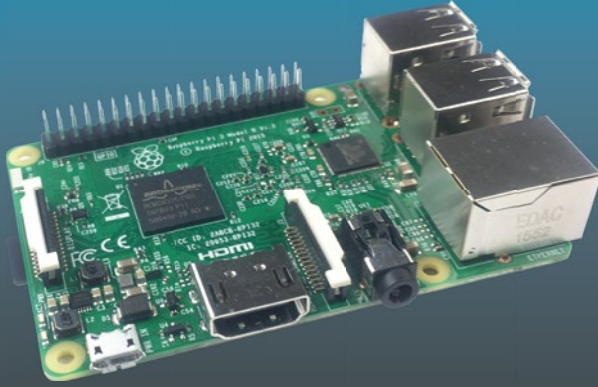# Deploying Raspberry Pi in the Classroom

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Deploying Raspberry Pi in the Classroom

Guy Hart-Davis

Apress®

Contents at a Glance

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About the Author

Guy Hart-Davis is the author of more than 100 computer books, including *Learn Office 2016 for Mac, Learn Excel 2016 for Mac, and Pro Office for iPad.*

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He has been programming and teaching how to program with Android, Perl, PHP (Hypertext Preprocessor), Java, VB (Visual Basic), Python, C/C++, and MySQL (Structured Query Language) for more than 20 years.

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- SPi Global for creating the index

Introduction

The Raspberry Pi has become a computing phenomenon. This single-board miniature computer, first released in February 2012 by the Raspberry Pi Foundation, has grown into a series of nearly a dozen models that have sold a total of more than 10 million units in five years.

Inexpensive to buy and to run, Raspberry Pi computers are great for enthusiasts, good for games, and fun for children. Raspberry Pi computers are also terrific in the classroom, enabling you to put on each desk an easily-manageable computer on which students can do everything from learning Internet use and essential office software skills, through grasping programming basics in an easy-to-learn format, to performing full-on programming in Python, Java, C, and other languages. Better yet, you can install all the software needed for those activities automatically alongside the operating system.

Who Is This Book For?

This book is for anybody who's looking to deploy Raspberry Pi computers in a classroom or lab situation.

Most likely you're a teacher or educator in a school or college, and that's the scenario this book and its examples aim at. But even if your situation and aims for deploying multiple Raspberry Pi computers are different, you'll find useful information in this book. For example, you might run a community computing club providing Internet access, or you might offer private computing lessons to small groups.

What Does This Book Cover?

This book contains eight chapters that take you from planning a classroom deployment of Raspberry Pi computers to managing the classroom and troubleshooting the computers.

Chapter 1, "Planning Your Raspberry Pi Classroom Deployment," walks you through planning your deployment or Raspberry Pi computers in your classroom or lab. The chapter briefly discusses what the Raspberry Pi boards are, the capabilities of the computers that you can build with them, and what Raspberry Pi computers are suitable for in the classroom. The chapter also discusses the key questions you will likely need to research and answer in order to plan your Raspberry Pi deployment: How you will use the Raspberry Pi computers, which ones to get, which operating system or systems to install, how to manage the computers, and so on.

Chapter 2, "Choosing Raspberry Pi Hardware," discusses the hardware you'll typically want for deploying a fleet of Raspberry Pi computers in a classroom. First, you'll need the Raspberry Pi boards, plus essential hardware—such as power sources, SD cards, and cases—to turn the boards into working computers. Next, you'll need peripherals, such as displays, keyboards, and pointing devices; your educational establishment may have some or all of these, so the chapter covers how to get existing (and possibly legacy) peripherals working with your Raspberry Pi computers. Last, you'll need wired (Ethernet) or wireless (Wi-Fi) network connections for the Raspberry Pi computers.

Chapter 3, "Choosing Operating Systems for Raspberry Pi," lays out your main choices of operating systems. Raspberry Pi computers can run an impressive range of operating systems, most of which are based on the widely used Linux operating system. The Raspberry Pi Foundation provides a helpful installer called NOOBS (New Out Of Box Software) that enables you to install not only Raspbian, the version of Linux customized for the Raspberry Pi, and Raspbian Lite but also two media-center operating systems—LibreELEC and OSMC—and Windows 10 IoT Core, a version of Windows for building projects and apps for devices. Beyond these, you can install other Linux desktop operating systems, Linux server operating systems, the blazing fast but rather limited RISC OS, and versions of the UNIX-like BSD operating system.

Chapter 4, "Brief Tutorial on Raspberry Pi Essentials," makes sure you know how to use and configure a Raspberry Pi computer running the Raspbian operating system. The chapter covers everything from startup, shutdown, and restart to configuring your pointing device, keyboard, and network connection; using the Raspberry Pi Configuration tool to configure the Raspberry Pi; navigating and customizing the desktop, exploring the file system using the File Manager app, and configuring File Manager to work the way you prefer.

Chapter 5, "Building the Raspberry Pi Computers and Installing Software," discusses how to build your Raspberry Pi computers—essentially, putting the Raspberry Pi boards into the cases you've chosen—and how to install operating systems on them. The chapter shows you how to get the NOOBS installer, use it to install Raspbian and the other operating systems that NOOBS supports, and how to perform "headless" installs on remote computers using Virtual Network Computing (VNC). You also learn how to use Recovery Mode and how to perform advanced moves with NOOBS, such as installing an operating system automatically and creating a custom version of Raspbian for your school.

Chapter 6, "Connecting the Raspberry Pi Computers to the Network," shows you how to set up your Raspberry Pi computers in your classroom or lab, connect them to your establishment's network, and verify that the computers and the network are working to your satisfaction. Coverage includes setting hostnames and static IP addresses and connecting to Wi-Fi networks.

Chapter 7, "Administering and Managing Your Raspberry Pi Network," shows you how to run your Raspberry Pi network either individually or by using the free PiNet server system. You'll learn how to create user accounts, how to set up remote access to computers you want to administer remotely, how to install and configure PiNet, and how to control your computers—and maybe your students—using the free Epoptes classroom-management app.

Chapter 8, "Troubleshooting Raspberry Pi Computers in the Classroom," shows you how to deal with the problems you're most likely to encounter with Raspberry Pi computers deployed in classroom situtations. The chapter starts by recommending a restart-and-replace strategy designed to keep your classroom functioning smoothly and avoid disruption from trying to troubleshoot problems that seem minor but turn thorny. The chapter then covers how to keep the system software on Raspberry Pi computers up to date; how to deal with issues involving startup, SD cards, and network connections; and how to resolve problems with displays, keyboards and pointing devices, and audio output.

The Appendix, "Raspberry Pi Resources and Training for Educators," gives you brief lists of resources for deploying, running, and managing Raspberry Pi computers, plus information on training for educators.

Involving Your Students

One of the great things about Raspberry Pi computers is that they're well suited to having students build them and set them up as well as simply use them as classroom computers. So this book suggests several points at which you may want to involve your students in setting up and maintaining your classroom deployment of Raspberry Pi computers. These include:

- **Building the Raspberry Pi computers.** Because each Raspberry Pi board contains a full computer system—processor, graphics processor, memory (RAM), networking, USB, and so on—which greatly reduces the potential for damage and mistakes. Building a Raspberry Pi computer involves only putting the Raspberry Pi board in a suitable case, not installing multiple sensitive components using a variety of technician tools.

- **Setting up the Raspberry Pi computers in the classroom.** Having students help you with setting up the Raspberry Pi computers at the workstations, distributing peripherals, and connecting the devices and cables can not only save you time but also develop students' skills.

- **Testing the Raspberry Pi computers and the network.** After setting up the computers and the network, you can have students power on the computers and run through a list of tests that you specify, to make sure that the computers are running correctly and that they are able to access the Internet.

These are activities that many students should be capable of. But the Raspberry Pi computers also offer many other opportunities for you to involve your older or more able students. For example, you may want to have more advanced students learn to troubleshoot problems that occur frequently with Raspberry Pi computers, or at least have them replace failed (or problem) SD cards, peripherals, or computers when the need arises.

Additions and Errata

If you have suggestions for additions or improvements you'd like to see in future editions of this book, please send them in. Go to the Apress website (`www.apress.com`), enter this book's number (9781484223031) in the Search box, and click the Go button. Click the book's cover or the View Book button to get to the book's page.

Click the Errata tab to display a list of the errata and additions available so far. On this tab, you'll also find the e-mail address to which you can submit corrections or suggestions for additions or improvements.

CHAPTER 1

■ ■ ■

Planning Your Raspberry Pi Classroom Deployment

In this chapter, we'll quickly look at how to plan your deployment of Raspberry Pi computers in the classroom.

We'll begin by making sure you know what the Raspberry Pi is. After that, we'll examine what the capabilities of Raspberry Pi computers are and what Raspberry Pi computers are suitable for in the classroom. Last, we'll look at the key questions you will likely need to research and answer to plan your Raspberry Pi deployment in the classroom.

Understanding What the Raspberry Pi Is

Raspberry Pi is a family of computers designed by the Raspberry Pi Foundation, a UK-based charity. The Raspberry Pi Foundation has released multiple models of Raspberry Pi, each with somewhat different specifications. Each Raspberry Pi model uses a System on a Chip (SoC), a single microchip that contains all the essential components of a computer system; for the Raspberry Pi, the SoC contains a processor and a graphics processing unit (GPU).

Each of the Raspberry Pi models is the size of a credit card, except for the Raspberry Pi Zero, which is half that size. This book refers to the standard-size Raspberry Pi models as "full-size" to distinguish them from the half-size Raspberry Pi Zero. Figure 1-1 shows the Raspberry Pi 3 Model B, which is the latest full-size Raspberry Pi model as of this writing.
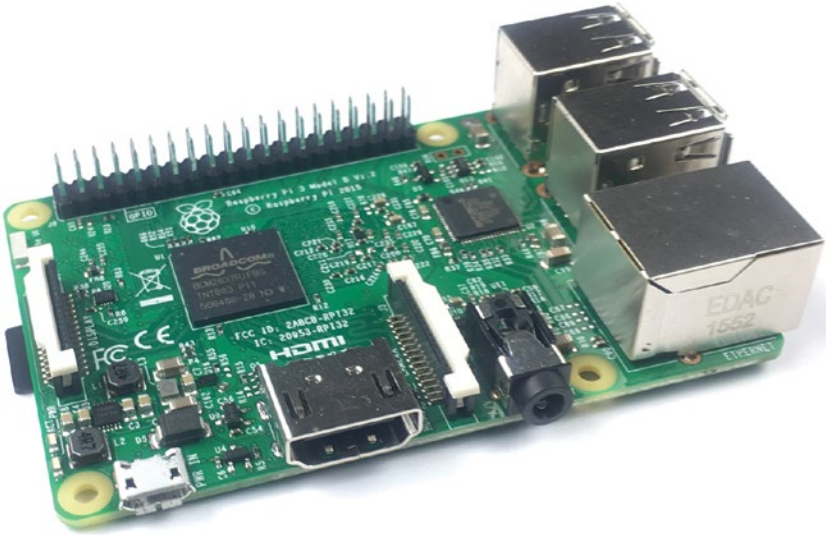
Figure 1-1. *Each Raspberry Pi model comes as a complete system on a board. This is the Raspberry Pi 3 Model B.*

Each Raspberry Pi model comes as a system on a board—a computer motherboard that has the processor, random access memory (RAM), graphics processor, network controller, USB (universal serial bus) controller, and so on built into it. The system is not upgradeable without technician-level skills.

Each Raspberry Pi board also has a wide variety of input and output connectors already connected to it, such as an HDMI (high-definition multimedia interface) connector for a monitor; USB ports for connecting keyboards, mouses, and other devices; and an Ethernet port for connecting a network cable. So all you need do to turn a Raspberry Pi board into a complete central processing unit (CPU) is to put it in a case. You can then connect a monitor, keyboard, mouse, and other components to the Raspberry Pi. Figure 1-2 shows the Raspberry Pi 3 Model B in a clear acrylic case, looking from an angle that shows the Ethernet port and the four USB ports.

Figure 1-2. *You can get a wide variety of cases for the Raspberry Pi models including clear cases and ones that give easy access to the internal ports.*

■ **Note** It's possible to run the Raspberry Pi boards without a case, but normally you'd want to do so only in a lab setting. If you're planning to deploy Raspberry Pi computers in the classroom or in other locations in the wild, you'll need to put cases on them.

Understanding the Capabilities of Raspberry Pi Computers

Despite its diminutive size, the Raspberry Pi is a full-size computer capable of running a "proper" operating system. The Raspberry Pi Foundation supplies a customized operating system called *Raspbian* for the Raspberry Pi models, but you can install and run other operating systems as well if you prefer. Raspbian is based on the widely used Debian distribution of Linux.

■ **Note**   Chapter 3 explains the main operating systems you can install and run on the Raspberry Pi models.

The standard-size Raspberry Pi models make a highly cost-effective solution for computing in schools, colleges, and clubs. The following subsections discuss some of the uses for which Raspberry Pi computers are suited.

The Raspberry Pi Zero *can* run desktop apps, but its diminutive size, fewer ports, and more limited connection options make it more suitable for projects. See the section "Planning and Executing Computing Projects," later in this chapter for examples of projects for both full-size Raspberry Pi boards and Raspberry Pi Zero boards.

Learning Desktop Computing Skills

A Raspberry Pi computer running the Raspbian operating system is a great tool for learning standard desktop computing skills. For example, using a Raspberry Pi computer, students can learn to

- Perform standard operations such as starting up, logging in and out, shutting down, and restarting.

- Navigate the desktop, run apps, and manage windows. Figure 1-3 shows the default Raspbian desktop, which you'll explore in detail in Chapter 4.

- Create documents using apps and manage files using the File Manager app.

- Browse the Web and communicate via e-mail.

- Work with the command-line interface either at the computer itself or by connecting via remote technologies such as Secure Shell (SSH).

- Connect peripherals and establish a network connection.

- Control services such as remote access and file sharing.

- Work remotely using the graphical interface via technologies such as Virtual Network Computing (VNC).
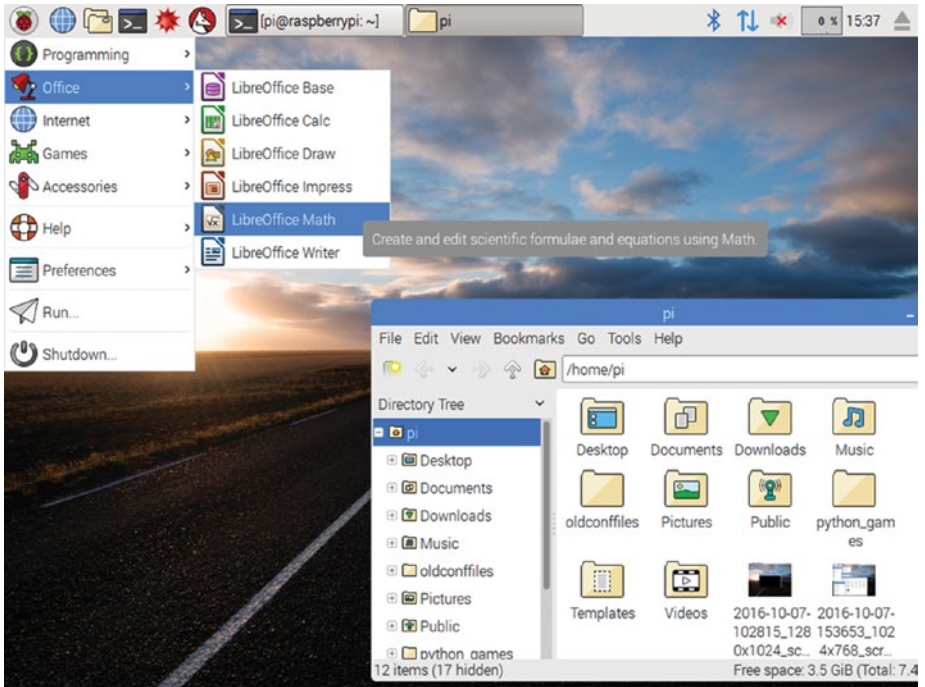
Figure 1-3. *Raspbian's default desktop has a taskbar-like panel at the top of the screen and a Menu button that provides access to apps, settings, and commands.*

■ **Note** The Raspbian interface varies somewhat between versions. Figure 1-3 shows the Raspbian version as of this writing (December 2016) in which the app windows have slightly rounded corners. Older versions of Raspbian, including those used by the PiNet server system (discussed in Chapter 7), have windows with square corners like those shown in some of the figures later in this chapter.

Learning Office Skills

Raspbian includes the LibreOffice software suite, which provides a full set of office apps for learning office skills such as word processing, creating spreadsheets, developing presentations, and building databases and entering data in them. LibreOffice contains the following six modules:

- *LibreOffice Base*: LibreOffice Base is a database app that enables you to build relational databases.

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- *LibreOffice Calc*: LibreOffice Calc is a spreadsheet app that lets you develop spreadsheet-based workbooks for calculations and data processing. Figure 1-4 shows LibreOffice Calc.
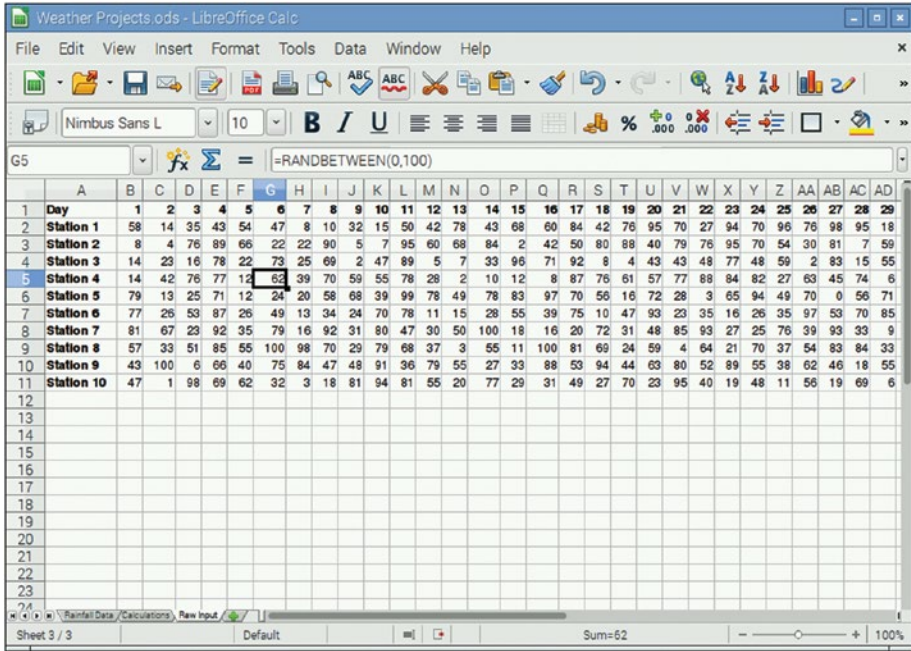
Figure 1-4. *The LibreOffice office software suite includes the LibreOffice Calc app for creating spreadsheets.*

- *LibreOffice Draw*: LibreOffice Draw is a drawing app that allows you to create diagrams, sketches, and plans.

- *LibreOffice Impress*: LibreOffice Impress is a presentation app that you can use to create slideshows and deliver presentations.

- *LibreOffice Math*: LibreOffice Math is a formula editor that enables you to create formulas and math elements for inclusion in your documents, spreadsheets, and presentations.

- *LibreOffice Writer*: LibreOffice Writer is a word-processing app that lets you create anything from short documents to long and complex documents including graphics, tables of contents, indexes, and other features.

The LibreOffice suite is a great tool for students to master because not only is it free, but it also runs on Windows and on the Mac as well as on Linux. So any student with a computer at home can use LibreOffice at home as well as at school. The LibreOffice modules don't have every single feature that their Microsoft Office equivalents have, but they have more than enough features for most needs, whether at home, at school, or at work.

LIBREOFFICE PROVIDES COMPATIBILITY WITH MICROSOFT OFFICE

Each LibreOffice app has a native file format; for example, the Writer app's native file format is called *ODF* (Open Document Format) *Text Document*, and the Calc app's native file format is called *ODF Spreadsheet*. But the LibreOffice apps also have impressively high compatibility with the Microsoft Office file formats, not to mention compatibility with other widely used formats (such as HTML).

For example, the Writer app can open documents in Microsoft Word's .docx format and .doc format and can save documents in these formats; similarly, the Calc app can open and save files in Excel's .xlsx and .xls file formats; and the Impress app can open and save files in PowerPoint's .pptx and .ppt file formats.

Learning the Essentials of Programming with Scratch
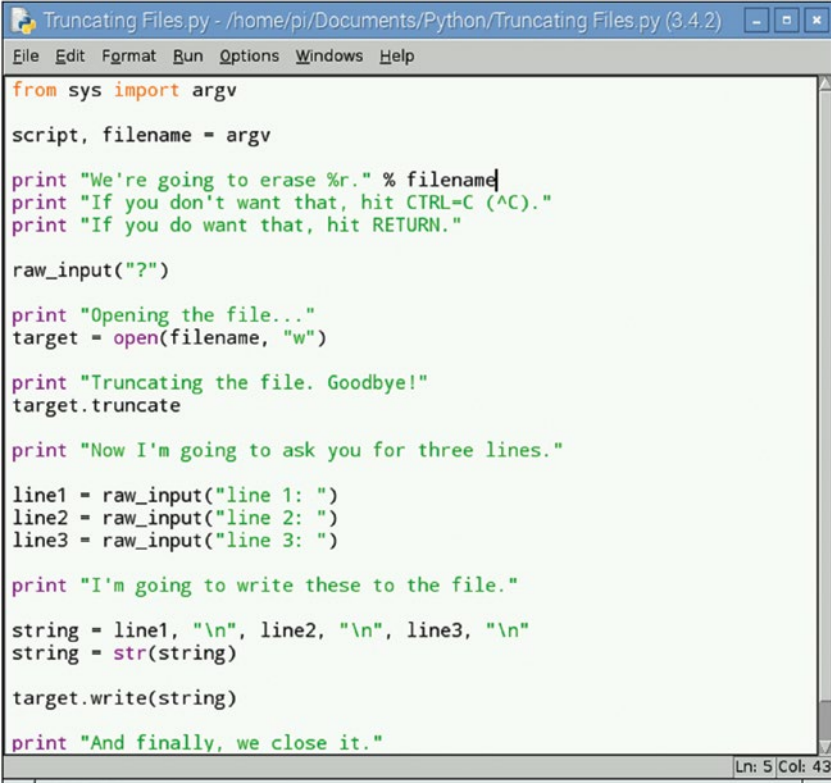
Raspbian includes the Scratch tool for teaching the fundamentals of programming in an engaging and accessible environment. Scratch was developed by the Lifelong Kindergarten Group at the Massachusetts Institute of Technology (MIT) Media Lab as a tool for teaching youngsters, but it works effectively for all ages. You can use Scratch inside or outside the classroom as a first step to grasping programming concepts without having to worry about syntax. Figure 1-5 shows the Scratch interface.
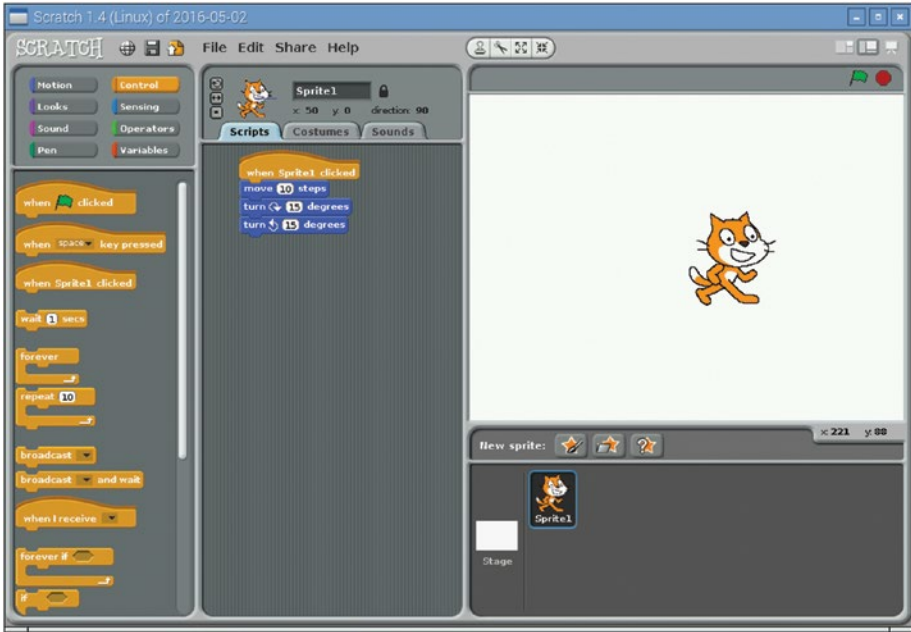
Figure 1-5. *Scratch is an easy-to-grasp and graphical tool for coming to grips with the essentials of programming.*

Programming in Python

Raspbian includes integrated development environment (IDE) apps for programming in Python, a programming language widely used for purposes such as 2-D games, web applications, and small databases. As of this writing, Raspbian includes versions of the IDLE (Integrated Development and Learning Environment) IDE for Python 2 and for Python 3. Figure 1-6 shows a Python script open in the IDLE IDE.

```python
from sys import argv

script, filename = argv

print "We're going to erase %r." % filename
print "If you don't want that, hit CTRL-C (^C)."
print "If you do want that, hit RETURN."

raw_input("?")

print "Opening the file..."
target = open(filename, "w")

print "Truncating the file. Goodbye!"
target.truncate

print "Now I'm going to ask you for three lines."

line1 = raw_input("line 1: ")
line2 = raw_input("line 2: ")
line3 = raw_input("line 3: ")

print "I'm going to write these to the file."

string = line1, "\n", line2, "\n", line3, "\n"
string = str(string)

target.write(string)

print "And finally, we close it."
```

Figure 1-6. *Raspbian includes the IDLE integrated development environment for coding in Python 2 and Python 3.*

Programming in Java

Raspbian includes two apps for programming in Java:

- *BlueJ*: BlueJ is an editor for creating code and working with objects. Figure 1-7 shows BlueJ with one of its sample projects open.
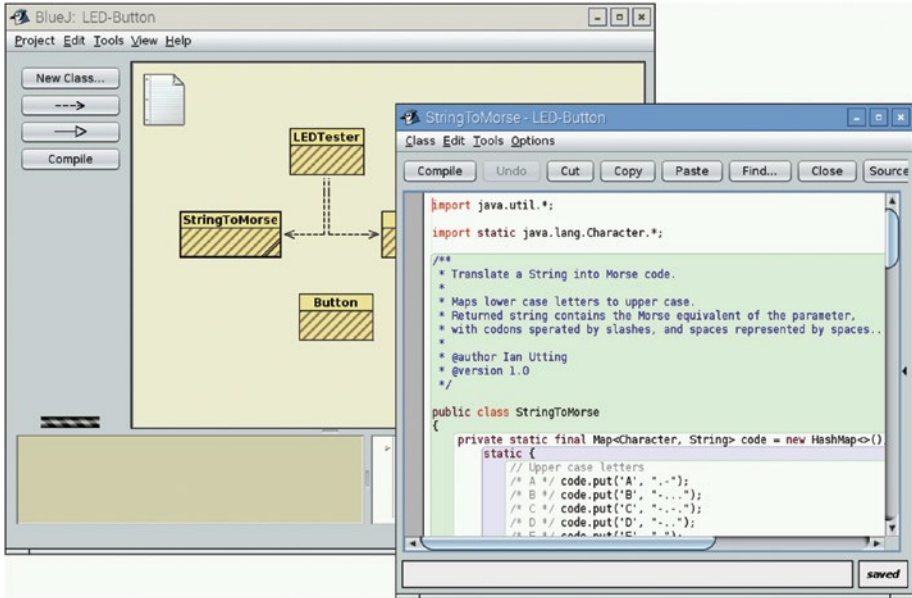
Figure 1-7. *BlueJ is an editor for programming in Java.*

- *Greenfoot*: Greenfoot is an IDE for building Java scenarios.
  Figure 1-8 shows Greenfoot with one of its sample projects,
  lunarlander, open and running.
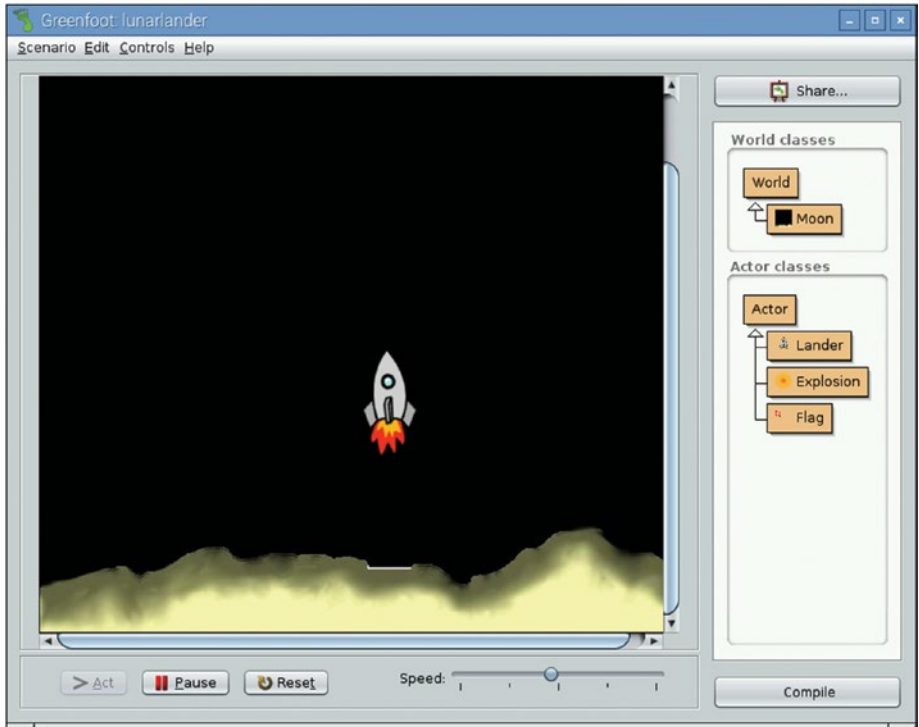
Figure 1-8. *Greenfoot is an IDE for building Java scenarios.*

Programming in C and Other Programming Languages

Raspbian includes the Geany IDE for programming in the C language and other programming languages, such as PHP (PHP Hypertext Preprocessor), HTML, and CSS (Cascading Style Sheets), and Perl. Geany has an accessible user interface (see Figure 1-9) and includes features such as auto-completion of terms and tags, syntax highlighting, and multiple document support.
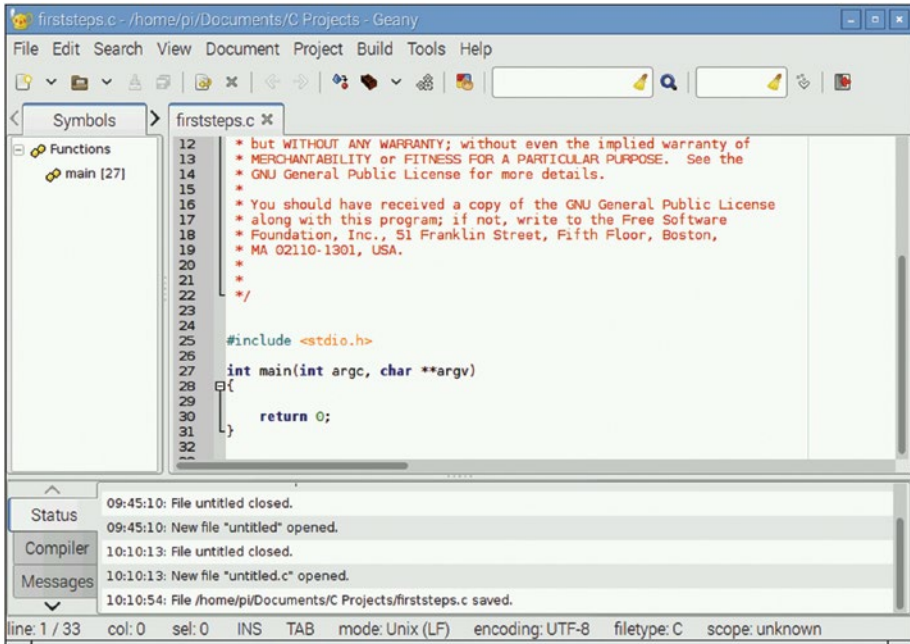
Figure 1-9. *The Geany IDE enables you to program in C and other programming languages on Raspberry Pi computers.*

Learning Programming with Other Apps

As well as the programming apps mentioned so far, Raspbian includes several other apps for learning programming:

- *Mathematica and Wolfram*: Mathematica is an app for mathematical computations. Mathematica uses the Wolfram Language, a programming language developed by Stephen Wolfram. You can also run the Wolfram app to open a Wolfram terminal.

- *Node-RED*: Node-RED is a flow-based app for linking together items in the Internet of Things. After launching Node-RED on a Raspberry Pi computer, you connect to Node-RED using a web browser and use the resulting web page to design the flow you need.

- *Sonic Pi*: Sonic Pi is a live coding music synthesizer: you write code in Sonic Pi to compose music. This can be a great way to get students who are interested in music involved in creating computer code.

Playing Games

Generally speaking, Raspberry Pi computers are not powerful enough to play action games, which tend to place heavy demands on the computer's hardware. But Raspbian does include Minecraft Pi, a custom version of the extremely popular Minecraft game; and the Python Games suite, which contains graphically simple games such as a memory puzzle, a slide puzzle, and Tetris-style games. These games give you a largely harmless way to encourage students to familiarize themselves with Raspberry Pi computers without feeling that they are having to work.

■ **Note**   Enthusiasts have ported other action games, such as the classic first-person shooter DOOM, to the Raspberry Pi as well.

Running Media Centers

The Raspberry Pi Foundation supports two operating systems, OSMC (Open Source Media Center) and LibreELEC (Libre Embedded Linux Entertainment Center), for easily implementing media centers on Raspberry Pi computers. The NOOBS (New Out Of Box Software) installer that the Raspberry Pi Foundation supplies for getting started with Raspberry Pi computers comes configured to download these media-center operating systems for you and install them, either on their own or alongside other operating systems, such as the standard Raspbian operating system.

We'll look at these media-center operating systems briefly in Chapter 3.

Planning and Executing Computing Projects

Being small and inexpensive, the Raspberry Pi boards are well suited for projects both inside and outside the classroom. This is especially true of the Raspberry Pi Zero, which is half the size of the full-size Raspberry Pi boards and was designed to be easy to include in projects.

The following are quick examples of computing projects you can perform with the full-size Raspberry Pi board and the Raspberry Pi Zero:

- *Create a media-center computer*: As mentioned in the previous section, you can use the OSMC operating system or the LibreELEC operating system to turn a Raspberry Pi computer into a media center.

- *Build a laptop computer:* The Pi-Top (`www.pi-top.com`) is a kit that enables you to build a laptop computer based on a Raspberry Pi 3 Model B board.

■ **Note**   Although the Pi-Top delivers a cute and functioning laptop computer once correctly assembled, it's perhaps most useful as a tool for teaching students about the components of a laptop.

- *Create a Tor router*: You can run a Raspberry Pi computer into a router for the Tor (The Onion Router) anonymizing network.

- *Create a digital picture frame*: By using either a screen designed for the Raspberry Pi or a spare display, you can create a digital picture frame that displays a slideshow of your chosen images.

- *Create a local FM transmitter*: By connecting either a full-size Raspberry Pi board or a Raspberry Pi Zero board to an FM radio, you can create a transmitter for broadcasting locally—provided that the authorities in your location permit broadcasting.

- *Create an AirPlay speaker*: By connecting a digital-to-analog (DAC) converter to a Raspberry Pi computer, you can create a device that enables you to stream audio wirelessly from your computer or iOS device (such as an iPhone or iPad) to a speaker.

Analyzing Your Needs and Making a Plan

At this point, you should be ready to begin analyzing your needs and making the outline of a plan for how you will deploy and use Raspberry Pi computers in the classroom. This section summarizes the questions you will likely need to answer and points you to other chapters and sections of the book as appropriate.

- *How will you use Raspberry Pi computers?* Will you set up a computing lab based on Raspberry Pi computers, or will you have a few Raspberry Pi computers to allow students to explore on their own?

- *How many Raspberry Pi computers do you need to get?* The answer to this will depend largely on the first question. If you're setting up a computing lab, having one Raspberry Pi computer per student for your maximum class size—plus a handful of extra Raspberry Pi computers for instructors and to handle accidents and attrition—would be ideal. If students will work in pairs, you'll need only half the maximum class size, plus those few extras.

- *Which Raspberry Pi models will you get?* In Chapter 2, I dig into the Raspberry Pi boards in detail and give recommendations— but here's an executive preview: Get the latest full-size Raspberry Pi board (as of this writing, the Raspberry Pi 3 Model B) for general computing, and get the Raspberry Pi Zero for projects that need its smaller size.

- *What operating system and software will you run?* In many cases, the best choice is the Raspbian operating system, which comes complete with the apps needed for most of the activities discussed earlier in this chapter such as learning to create office documents and learning to program. In other cases, you may prefer another operating system or other apps. See Chapter 3 for coverage of the main operating systems you can run on Raspberry Pi computers.

- *What other equipment will you need to get?* Each Raspberry Pi model comes as a bare board, so you will need cases, power supplies, displays, keyboards, pointing devices, and other equipment. See Chapter 2 for a full discussion of this topic.

- *How will you manage the Raspberry Pi computers?* For a small Raspberry Pi deployment, you may find it convenient enough to manage the computers individually, as needed. For a larger deployment, you may do better to use the custom PiNet server software to manage your network. In Chapter 7, I show you how to configure networking and how to manage the network, both without and with PiNet.

Getting a Raspberry Pi Computer

If you're thinking seriously about deploying Raspberry Pi computers in the classroom, it's probably time for you to get a Raspberry Pi computer if you don't already have one.

You can get a Raspberry Pi computer from a wide variety of retailers both online and offline. If your favorite electronics retailer doesn't carry the Raspberry Pi, see the section "Where to Buy Raspberry Pi Computers" in Chapter 2 for places to buy a Raspberry Pi online.

Once you've gotten a Raspberry Pi computer, go to Chapter 4 to learn the essentials of using Raspbian on the Raspberry Pi.

■ **Note**   Another possibility is to attend one of Google's Picademy training sessions for educators. Each Picademy attendee gets a Raspberry Pi model, together with other benefits. Go to the Picademy web site (`www.raspberrypi.org/picademy/`) to find details of Picademy sessions in your area.

CAN YOU USE A VIRTUAL MACHINE TO RUN RASPBIAN?

If you don't have a Raspberry Pi computer, you may be wondering if you can use a virtual machine to run Raspbian so that you can evaluate the operating system and its apps.

Running Raspbian on a virtual machine *is* possible, but as of this writing, it's so difficult as to be impractical. With luck, this may change.

The main problem is that most virtual-machine apps—such as VMWare, VirtualBox, and Parallels Desktop—emulate x86 computers. So if you want to run a Windows virtual machine on a Mac or on Linux, or a Linux virtual machine on Windows, a virtual-machine app is a great solution.

The Raspberry Pi, on the other hand, uses ARM (Advanced RISC [reduced instruction set computing] Machine) processors, which have a different architecture. The main virtual-machine app for hosting ARM virtual machines is QEMU (short for Quick Emulator).

You can download QEMU for free from the QEMU web site (`www.qemu.org`), but getting Raspbian running on QEMU is tricky; and even those who succeed, cannot get networking to work. If you are determined to try running Raspbian under emulation, search for instructions using terms such as *qemu raspberry pi*. But in general, you will do better to use a real Raspberry Pi computer, even if it is an older one or a Raspberry Pi Zero.

Summary

In this chapter, we looked quickly at what the Raspberry Pi family of computers is, what the capabilities of Raspberry Pi boards are, and the sorts of uses to which you may want to put Raspberry Pi computers in the classroom. We also visited the key questions you will need to answer to plan your deployment of Raspberry Pi computers.

In Chapter 2, we'll go through how to choose Raspberry Pi hardware.

■ ■ ■

Choosing Raspberry Pi Hardware

Now that you've planned your Raspberry Pi deployment, your next move is to choose Raspberry Pi computers and the hardware to go with them.

In this chapter, we'll go through the hardware you'll typically want for deploying a fleet of Raspberry Pi computers in a classroom. We'll start with the Raspberry Pi boards themselves before moving along to essentials, including power sources, SD (Secure Digital) cards, and cases. These are all items you'll most likely need to buy unless your fairy godmother has produced a pallet of Pi components for you—in which case, you can skip most of this chapter.

After that, we'll look at peripherals your Raspberry Pi computers will need such as displays, keyboards, and pointing devices. Your educational establishment may have some or all of these, so we'll talk about what you'll need to get existing (and possibly legacy) peripherals working with your Raspberry Pi computers.

Finally, at the end of the chapter, we'll talk briefly about how to decide which network connection method to use for your Raspberry Pi computers.

Choosing the Best Raspberry Pi Models for Your Needs

To make the most of the Raspberry Pi in your classroom, you'll need to choose the Raspberry Pi model or models that best meet your needs. This section explains the different Raspberry Pi models available and suggest how to choose among them.

■ **Note**   This chapter largely assumes that you'll be running Raspbian, the default operating system that the Raspberry Pi Foundation supplies for the Raspberry Pi models. Chapter 3 explains the other operating systems that the Raspberry Pi can run and points out their advantages and disadvantages.

Raspbian is based on the Debian distribution of GNU (GNU's Not Unix)/Linux. This is the same distribution on which the widely used Ubuntu operating system is based.

Understanding the Raspberry Pi Models

So far, the Raspberry Pi Foundation has released three generations of full-size Raspberry Pi boards and the smaller Raspberry Pi Zero board. The first generation of Raspberry Pi has several different models, whereas the second and third generations each have only one model. The full-size Raspberry Pi boards are the size of a credit card, whereas the Raspberry Pi Zero is half that size.

Table 2-1 has the details on the Raspberry Pi board models.

■ **Note**   On release, the first Raspberry Pi models were known simply as "Raspberry Pi" rather than "Raspberry Pi 1." After the release of Raspberry Pi 2 models, people started referring to the first-generation Raspberry Pi computers as "Raspberry Pi 1" for clarity.

Table 2-1. *Raspberry Pi Board Models*

Model Name	Release Date	CPU	RAM	Graphics	USB Ports	Power Requirements
Raspberry Pi 1 Model A	February 2012	700 MHz single-core	256 MB	Broadcom VideoCore IV	1	1.5 W
Raspberry Pi 1 Model B	February 2012	700 MHz single-core	256 MB	Broadcom VideoCore IV	2	3.5 W
Raspberry Pi 1 Model A+	February 2013	700 MHz single-core	256 MB	Broadcom VideoCore IV	1	1.0 W
Raspberry Pi 1 Model A+ Revision 2	N/A	700 MHz single-core	512 MB	Broadcom VideoCore IV		1.0 W
Raspberry Pi 1 Model B revision 2	August 2012	700 MHz single-core	512 MB	Broadcom VideoCore IV		3.5 W
Raspberry Pi 1 Model B+	February 2013	700 MHz single-core	512 MB	Broadcom VideoCore IV	4	3.0 W
Raspberry Pi 2 Model B	February 2015	900 MHz quad-core	1 GB	Broadcom VideoCore IV	4	4.0 W
Raspberry Pi Zero	November 2015	1,000 MHz single-core	512 MB	Broadcom VideoCore IV	1 OTG	0.8 W
Raspberry Pi 3 Model B	February 2016	1,200 MHz quad-core	1 GB	Broadcom VideoCore IV with higher clock speeds	4	4.0 W

If you pore over Table 2-1, you'll probably take away four main things:

- *Rapid development*: The Raspberry Pi Foundation has released nine models inside 5 years. After releasing the Raspberry Pi 3 Model B in February 2016, the Raspberry Pi Foundation announced its intention to slow down releases.

- *Model B is the main Raspberry Pi*: Even though A comes before B alphabetically, the Model B is the main model of Raspberry Pi. The Model A boards are lower-specification variants of the early Raspberry Pi models.

- *Increasing power*: The Raspberry Pi has moved rapidly from a 700 MHz single-core processor with 256 MB RAM to a quad-core 1,200 MHz processor with 1 GB RAM. Even the Raspberry Pi Zero, which costs around $5, has a faster processor than and twice as much RAM as the original Raspberry Pi model.

- *Increasing power consumption*: Whereas some of the early Raspberry Pi models can manage on a single watt, the Raspberry Pi 3 Model B requires 4.0 W.

- *The Raspberry Pi Zero is a different beast*: The Raspberry Pi Zero is half the size of the main Raspberry Pi family and is designed for different purposes, such as projects.

■ **Note**   Each Raspberry Pi model comes with a fixed amount of RAM, so you can't upgrade the Pi by installing more RAM. This and other limitations mean that it's usually best to buy the most powerful Raspberry Pi model available.

Meeting the Raspberry Pi Boards

In this section, you learn what the Raspberry Pi boards look like and what components they have. We'll look in detail at the two Raspberry Pi boards you're most likely to be using—the Raspberry Pi 3 Model B and the Raspberry Pi Zero—and discuss the ways in which the earlier Raspberry Pi models differ from the Raspberry Pi 3 Model B.

Raspberry Pi 3 Model B

The Raspberry Pi 3 Model B is the latest Raspberry Pi model as of this writing. Figure 2-1 shows the Raspberry Pi 3 Model B with its main components labeled. These are the components:

- *CPU*: The CPU has a quad-core processor running at 1,200 MHz (1.2 GHz).

- *40-pin GPIO*: The GPIO (general-purpose input/output) pins enable you to connect various devices, such as sensors or buttons, to the Raspberry Pi board. These pins protrude from the board, so you can easily connect jumpers to them without soldering.

- *DSI display port*: DSI (Display Serial Interface) is a high-speed serial interface for connecting a display such as a touch screen.

- *Micro SD slot*: The micro SD slot is where you insert the micro SD card that acts as the Raspberry Pi computer's main storage.

- *Micro USB power port*: The Raspberry Pi board receives power from a power adapter via a standard micro USB port.

- *HDMI port*: This port lets you output video to any device with HDMI input, such as a display or a TV. You can use adapters and converters to use non-HDMI displays; we'll dig into this topic later in this chapter.

- *CSI camera port*: The CSI (Camera Serial Interface) port enables you to connect a camera for photography or use as a webcam.

- *Composite video and audio output port*: This port enables you to connect the Raspberry Pi to a display and speakers via a composite video and audio cable.

- *USB ports*: The four USB ports enable you to connect a keyboard, a pointing device, and other devices, such as external storage or a printer.

- *Ethernet port*: The Raspberry Pi 3 Model B has a 10/100 Ethernet port for connecting to wired networks.

DSI display port   40-pin GPIO   CPU   2 USB ports   2 USB ports   Ethernet port

Micro SD slot   Micro USB power port   HDMI port   CSI camera port   Composite video and audio port
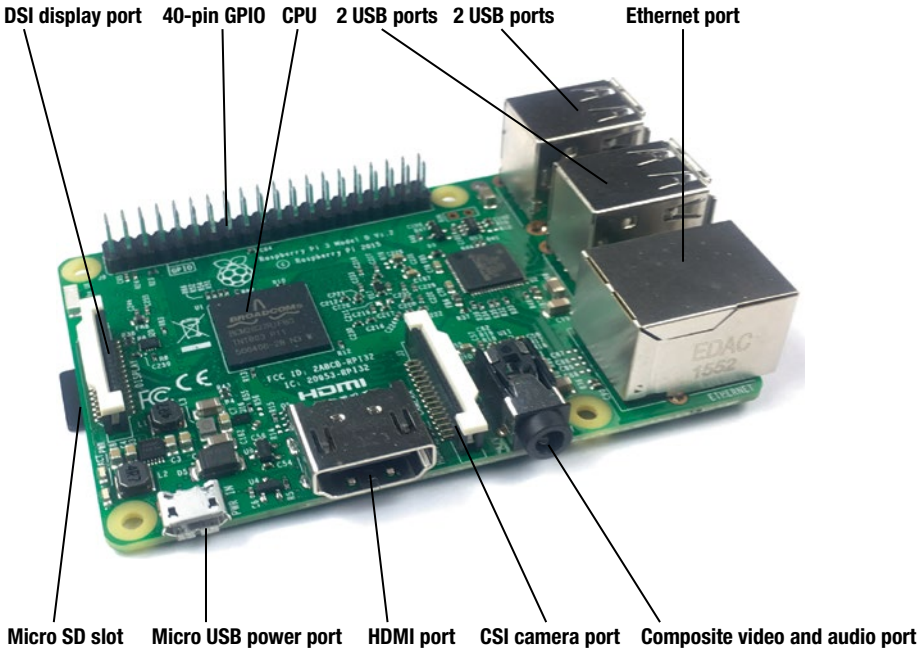
Figure 2-1. *The Raspberry Pi 3 Model B is the size of a credit card but has a full set of ports for input and output.*

■ **Note**   Early models of Raspberry Pi (such as the original Raspberry Pi) have an RCA (Radio Corporation of America) composite port and a separate 3.5 mm audio port instead of the combined audio and video port that the Raspberry Pi 3B, 2B, and B+ have.

Raspberry Pi Zero

The Raspberry Pi Zero is designed more for stand-alone projects such as radios, robots, and wearable computers than for regular computing use. Figure 2-2 shows the Raspberry Pi Zero board with its main components labeled. These are the components:

- *CPU*: The CPU, with a single-core processor running at 1,000 MHz (1GHz).

- *40-pin GPIO*: The GPIO connectors enable you to connect various devices, such as sensors or buttons, to the Raspberry Pi Zero board.

■ **Note**   Unlike on the Raspberry Pi boards, the GPIO connectors on the Raspberry Pi Zero are holes rather than pins, so normally you'll need to solder header pins to them when you connect devices. Some devices designed for the Raspberry Pi Zero fit over the whole board and fasten with screws to connect their built-in pins firmly to the GPIO holes without the need for soldering.

- *RCA composite video output*: These two holes enable you to output composite video and audio from the Raspberry Pi Zero. You'll need to solder pin headers to the holes, connect a composite video connector, and then connect a composite video cable.

- *RUN pins for reset switch*: These two holes enable you to connect a reset button to the Raspberry Pi Zero. As with the RCA composite video output, you'll need to solder pin headers to the holes.

- *DSI display port*: DSI is a high-speed serial interface for connecting a display such as a touch screen.

- *Micro SD slot*: As for the full-size Raspberry Pi boards, the Raspberry Pi Zero uses a micro SD card as its main storage.

- *Micro USB power port*: Also like the full-size Raspberry Pi boards, the Raspberry Pi Zero board uses a standard micro USB port to receive power from a power adapter.

- *Mini HDMI port*: Like a full-size board, this port lets you output video to any device with HDMI input, such as a display or a TV. For most devices, you'll need to use a mini-HDMI-to-HDMI cable or adapter, but these are inexpensive and easy to get.

- *CSI camera port*: The CSI port enables you to connect a camera for photography or to use as a webcam.

- *Composite video and audio output port*: This port enables you to connect the Raspberry Pi to a display and speakers via a composite video and audio cable.

- *Micro USB port*: The single micro USB port enables you to connect USB devices such as a keyboard, a pointing device, or a Wi-Fi adapter. For most devices, you'll need a micro-USB–to–USB cable or adapter, which you can find at any decent electronics store. Because there's only one port, you need to attach a hub if you need to connect multiple devices.

Micro SD slot   CPU   40-pin GPIO   RCA composite video output   RUN pins for reset switch

Mini HDMI port   Micro USB port   Micro USB power port   CSI camera port
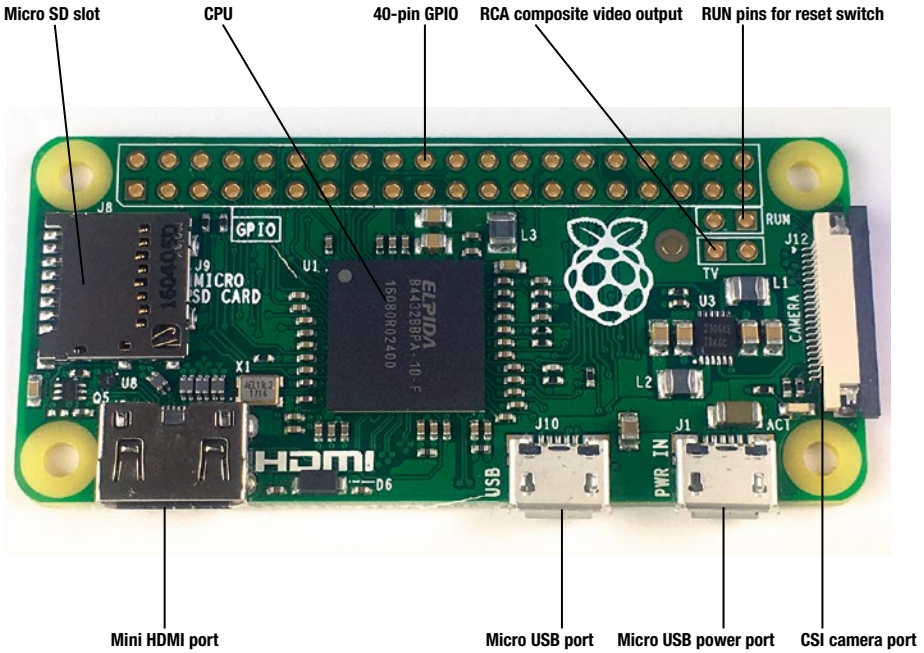
Figure 2-2. *The Raspberry Pi Zero is half the size of a credit card and has a minimal set of ports.*

■ **Note**   You can get a wide range of accessories designed for building projects with the Raspberry Pi Zero. See the sites listed in the next section.

Where to Buy Raspberry Pi Computers

You can buy Raspberry Pi computers pretty much anywhere in the world. Some brick-and-mortar retailers stock the Raspberry Pi, but most of the specialist Raspberry Pi stores are online. You can also find Raspberry Pi boards and accessories at major online retail stores such as Amazon and eBay.

The following subsections provide examples of specialist Raspberry Pi stores you may want to browse if you're buying in the United States, Canada, the United Kingdom (UK), or Australia. For a list of Raspberry Pi Approved Resellers all over the world, visit this URL: http://farnell.com/raspberrypi-consumer/approved-retailers.php.

SAVE MONEY BY BUYING RASPBERRY PI BUNDLES

When deciding where to buy your Raspberry Pi computers, look for bundles that include the accessories you need. Many retailers offer bundles that include essential components such as a power supply, an SD card (in many cases preloaded with the NOOBS installer), an HDMI cable, and other items.

Not all bundles are necessarily bargains, especially if you won't use every single component included in the bundle. So be sure to price the individual components and verify that buying the bundle will save you money overall.

US Stores

Here are four US-based stores that sell a wide range of Raspberry Pi boards and accessories.

- Adafruit (www.adafruit.com)
- Allied Electronics (www.alliedelec.com)
- Newark (www.newark.com)
- MCM Electronics (www.mcmelectronics.com)

Canada Stores

Here are three Canada-based stores for Raspberry Pi boards and accessories:

- Newark (canada.newark.com)
- HiPi Industries (buyapi.ca)
- Canada Robotix (canadarobotix.com)

UK Stores

Here are four UK stores from which you can buy Raspberry Pi boards and accessories:

- RS Components Ltd. (http://uk.rs-online.com)
- The Pi Hut (www.thepihut.com)
- Element14 (www.element14.com)
- ModMyPi (www.modmypi.com)

Australia Stores

Here are three stores for buying Raspberry Pi computers and accessories in Australia:

- RS Components (`au.rs-online.com`)

- Element 14 (`au.element14.com`)

- GPIO Australia (`www.buyraspberrypi.com.au`)

Choosing Power Sources for Your Raspberry Pi Computers

Like any computer, each of your Raspberry Pi computers will need a power supply. The power supply is external, with the Raspberry Pi receiving power through a standard micro USB port on the board.

You can supply power to your Raspberry Pi computers in several ways:

- Dedicated Raspberry Pi chargers

- Phone chargers

- USB ports and hubs

- Batteries

We'll look at each of these options in turn. But first, let's make sure you're clear on the power requirements of Raspberry Pi computers.

Understanding the Power Requirements of Raspberry Pi Computers

The power requirements of Raspberry Pi models vary widely. Table 2-2 provides a quick reference.

Table 2-2. *Power Requirements of the Raspberry Pi Computer Models*

Model Name	Power Requirements (W)
Raspberry Pi 1 Model A	1.5
Raspberry Pi 1 Model A+	1.0
Raspberry Pi 1 Model A+ Revision 2	1.0
Raspberry Pi 1 Model B	3.5
Raspberry Pi 1 Model B+	3.0
Raspberry Pi 1 Model B revision 2	3.5
Raspberry Pi 2 Model B	4.0
Raspberry Pi 3 Model B	4.0
Raspberry Pi Zero	0.8

Using Dedicated Raspberry Pi Chargers

For most of your Raspberry Pi computers, you should use dedicated chargers because these will give you the best performance and stability. The chargers can be either official chargers or third-party alternatives.

Using Official Raspberry Pi Chargers

The most straightforward way of powering the Raspberry Pi models is by using an official Raspberry Pi charger.

Because of their different power requirements, the different Raspberry Pi models have different official power supplies. For example, the Official micro USB Power Supply Unit for Raspberry Pi 3 Model B (to give it its full name) is designed for use only with the Raspberry Pi 3 Model B. This power supply (see Figure 2-3) includes four interchangeable socket adapters (for US, UK, Europe, and Australian sockets), comes in a choice of black or white, and costs around US$9.99 for a single unit. You can also buy a box of 60 power supplies (either black ones or white ones).

Figure 2-3. *The Official micro USB Power Supply Unit for Raspberry Pi 3 Model B includes quick-change socket adapters for US, UK, European, and Australian sockets.*

■ **Tip**   Label your power supplies when unboxing them, either using a label printer or a marker pen. If you're buying the official Raspberry Pi power supplies, the white power supplies are much easier to mark with a pen than the black power supplies.

Using Third-Party Raspberry Pi Power Supplies

Instead of an official Raspberry Pi power supply, you may want to get a third-party supply. Many different models are available from a wide range of suppliers, so you have plenty of choices.

For best results, get a power supply designed for the Raspberry Pi model with which you will use it. Even minor shortfalls in power can cause a Raspberry Pi computer to be unstable when running under load.

BUY HIGH-QUALITY POWER SUPPLIES AND USB CABLES

When choosing power supplies for your Raspberry Pi computers, make sure you get high-quality ones, even if you have to pay a little more for them. Low-quality power supplies can cause intermittent problems that will cost you valuable time to troubleshoot.

If the power supplies don't have built-in cables, also be sure to buy high-quality USB cables to deliver the power. This too is an area where it's not worth sacrificing reliability—and certainly not worth sacrificing safety—to save a small amount of money.

CHECKING WHETHER A POWER SUPPLY DELIVERS SUITABLE POWER FOR A RASPBERRY PI COMPUTER

Chances are that you—or your educational establishment's computer department—have various old power supplies patiently awaiting reuse or recycling. If you're short of dedicated Raspberry Pi power supplies, and you're prepared to do a little testing, you can quickly determine whether an old power supply is suitable for powering an Raspberry Pi computer.

To find out, grab your trusty multimeter and follow these steps:

1. Connect the power supply to the Raspberry Pi computer and power it on.

2. Set the voltage measuring dial to measure volts in single-digit numbers (as opposed to measuring, say, millivolts or hundreds of volts).

3. Place the red probe on the PP3 on the underside of the Raspberry Pi board (see Figure 2-4).

4. Place the black probe on the PP7.

5. Check the voltage shown on the multimeter. If it's in the range 4.75–5.25 V, the power supply should be good to use.

On older Raspberry Pi models, place the red probe in the TP1 (test point 1) hole and the black probe in the TP2 hole (see Figure 2-5).
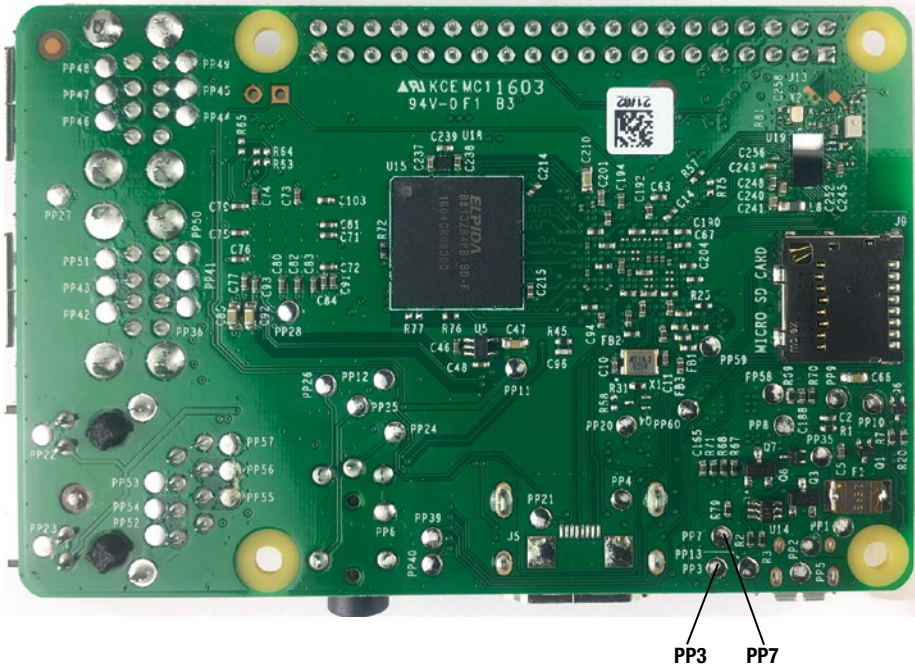
Figure 2-4. *On the Raspberry Pi 3 Model B, you can use the PP3 pad and PP7 pad on the underside of the board to test the voltage.*
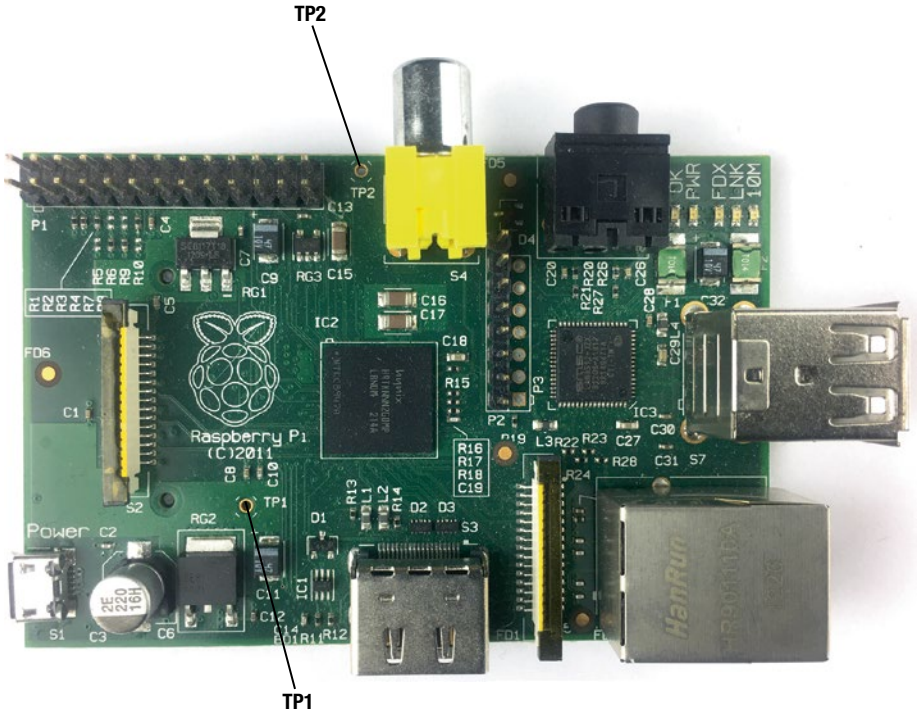
Figure 2-5. *On older models, such as the Raspberry Pi 1 Model B, you can use the TP1 hole and TP2 hole on the upper side of the board to test the voltage.*

Phone Chargers

You can also use some phone chargers to power some Raspberry Pi computers. Normally, you'll want to do this only in a pinch—for example, when you're a dedicated power supply short of the number of Raspberry Pi computers a class needs. Although many phone chargers *will* work, you'll get better results from using a charger designed specifically to meet the power requirements of the Raspberry Pi model you're using.

■ **Tip**   You can find a list of phone chargers on the RPi Verified Peripherals page (`http://elinux.org/RPi_VerifiedPeripherals#Power_adapters`). If you do use a phone charger, make sure it's a genuine one rather than an imitation because some nongenuine power supplies use substandard components that can damage your electrical equipment or cause fires. Be aware that inexpensive, multiport USB chargers may have ports that are labelled as delivering 5 V but in fact deliver a higher voltage when the charger is lightly loaded.

Running a Raspberry Pi Computer from a Battery

You can run a Raspberry Pi computer from a battery provided that the battery delivers enough power. Normally, running a full-size Raspberry Pi computer from a battery is something you'll want to do only when you must; but it can be handy for the Raspberry Pi Zero, both because you're more likely to use the smaller board for projects and because of its more modest power needs.

If you need to run a Raspberry Pi computer from a battery, the best type of battery to use is an external battery designed to recharge smartphones or tablets. You can find various projects online to build your own batteries suitable for running Raspberry Pi computers, but I'll leave you to investigate this topic on your own.

Running a Raspberry Pi Computer from a USB Hub

Another power possibility is to run a Raspberry Pi computer from a USB data hub or USB charging hub. This is a move that normally is best left to Raspberry Pi enthusiasts trying to streamline their home entertainment setups, but it can also be attractive in classroom situations where you have clusters of Raspberry Pi computers and a dearth of power sockets. By powering each cluster of Raspberry Pi computers from a USB charging hub, you can make those power sockets go that much further.

As you'd imagine, the USB hub needs to provide enough power for the Raspberry Pi computer or computers.

To power a single Raspberry Pi computer, you may be able to use a USB data hub that has its own power supply (as opposed to a hub that draws power from a computer or other source). To power multiple Raspberry Pi computers, you'll need a USB charging hub rather than a data hub. Look for a charging hub that delivers the same amperage—preferably 2.4 A—on each port; many charging hubs are designed for use with different classes of devices, such as tablets and smartphones, and deliver different amounts of power to different ports.

◼ **Tip**   See the RPi Powered USB Hubs page at `http://elinux.org/RPi_Powered_USB_Hubs` for information on hubs that do and don't work for powering Raspberry Pi computers.

The easiest way to find out whether a USB hub provides enough power is to plug in the Raspberry Pi computer and see if it will start up. If it does, run it for a while to make sure that it's running stably.

◼ **Caution**   Some USB hubs can "back-power" a Raspberry Pi by feeding power into its USB ports, enabling the Raspberry Pi to run without power being supplied to its micro USB power port. This is not a good idea because receiving power this way can cause damage to the Raspberry Pi board.

Choosing SD Cards

Whereas most stand-alone computers have built-in storage, such as a hard drive or a solid-state device (SSD), each Raspberry Pi model comes without any built-in storage. For storage, you insert a suitable SD card or micro SD card in the SD slot or micro SD slot on the Raspberry Pi.

◼ **Note**   This section uses the term *SD card* as a general term and specifies "standard SD card" or "micro SD card" only if it needs to be clear which type of SD card is involved.

Advantages and Disadvantages of Using SD Cards as the Main Storage

Using SD cards as the main storage for Raspberry Pi computers has several advantages:

- *Cost*: Not including a hard drive or SSD helps keep down the cost of the Raspberry Pi models.

- *Flexibility*: You can choose how much storage you need—up to a point.

- *Adaptability*: You can quickly switch from one operating system to another by shutting down the Raspberry Pi, inserting a different SD card, and then restarting the computer.

There are also several disadvantages to using SD cards:

- *Expense*: You need to buy an SD card to go with each Raspberry Pi computer.

- *Size limitations*: SD cards are limited in their amount of storage compared to hard drives and to SSDs. Whereas 6 TB hard drives and 2 TB SSDs are widely available, if on the expensive side, SD cards only go up to 256 GB at this writing, with 512 GB cards just starting to become available. Cards larger than 128 GB are disproportionately expensive, so you're better off extending the storage of the Raspberry Pi computer via USB if you must have more space.

- *Ease of removal and susceptibility to pilfering*: Most Raspberry Pi cases give direct access to the SD card slot, which is great for general use but not necessarily what you want in a classroom situation where small and desirable hardware items such as SD cards can quickly go missing.

Which Raspberry Pi Models Use Standard SD and Which Use Micro SD?

All current Raspberry Pi models, including the Raspberry Pi Zero, use a micro SD card. Two models of the first Raspberry Pi, the Raspberry Pi 1 Model A and Raspberry Pi 1 Model B, take a standard SD card; but the Raspberry Pi Foundation switched to micro SD cards after that, including for the Raspberry Pi 1 Model A+ and the Raspberry Pi 1 Model B+.

Given that most micro SD cards come with a standard adapter, you'll almost certainly want to buy micro SD cards, even if you have any Raspberry Pi computers that use standard SD cards.

Which SD Card, and What Size, Should You Get?

If you're buying Raspberry Pi computers, you may do best to buy the Raspberry Pi SD card from a Raspberry Pi stockist. This is a class 6 or better micro SD card (see the nearby sidebar, "Understanding SD Card Speeds and Technologies") with a capacity of 8 GB or 16 GB, which comes with the NOOBS installer already installed. The micro SD card includes a full-size SD adaptor, so you can use it in a full-size SD slot or SD reader if necessary.

8 GB is normally plenty of space for running the Raspberry Pi's operating system, installing apps, and storing some files. If you plan to install multiple operating systems on a Raspberry Pi computer, or if you will need to store a lot of files on it, go for 16 GB or 32 GB.

■ **Note**   The Raspberry Pi Foundation has tested SD cards up to 32 GB and reports that most of them work satisfactorily. You may be able to use 64 GB or larger SD cards, but you may have to take extra steps when setting them up with the operating system.

For classroom deployments, you'll typically do best to keep the SD card for operating systems and store data files elsewhere. For flexibility, it's better to have students store their data files either on the network or on their personal USB stick drives rather than on individual Raspberry Pi computers.

UNDERSTANDING SD CARD SPEEDS AND TECHNOLOGIES

SD is the abbreviation for Secure Digital. SD cards come in three sizes, many different write speeds, and several classes. You don't need to know all the details of SD card technology to use SD cards with the Raspberry Pi computers, but you'll likely find it helpful to understand the essentials.

First, SD cards come in three physical sizes, but only two of the three are widely used:

- **Full-Size SD**: Full-size SD cards are about the size of a large stamp (32 mm long by 24 mm wide, or roughly 1 1/4 in. by 1 in.) but shaped like a rectangle with one corner removed diagonally. Figure 2-6 shows a full-size SD card on the left. Full-size SD cards were the original SD cards. They have increased greatly in capacity over the years and are still widely used, especially in digital cameras, but they are gradually being overtaken by micro SD cards.

- **Mini SD**: Mini SD cards are about two-thirds the size of full-size SD cards, and almost square, at 20 mm wide by 21.5 mm long (roughly 0.8 in. square). The shape of mini SD cards is a rectangle with a corner removed, not diagonally but in a dogleg (see the middle card in Figure 2-6). Very few devices use mini SD cards, and the cards are hard to find, so it's hard to buy them by mistake; most e-tailers automatically give search results for micro SD cards if you search for "mini SD."

- **Micro SD**: Micro SD cards are much smaller than full-size cards, at 11 mm wide by 15 mm long (roughly 0.4 in. wide and 0.6 in. long). Like mini SD cards, micro SD cards have a two-stage corner removed; they also have a notch further back along the same side, as you can see in Figure 2-6, to engage with a spring-lock mechanisms. Micro SD cards are very widely used as of this writing, especially in smart phones.

Second, SD cards and micro SD cards are rated by their minimum sequential write speeds. There are three speed classes: the SD speed class, the UHS (Ultra High Speed) class, and the Video speed class. These three classes overlap, as you can see in Table 2-3.

Write speeds on SD cards tend to be much more widely differentiated that read speeds. SD cards of different classes typically have read speeds that are relatively close to each other. So even if the SD card you get has only a modest write speed, you may well get decent read speeds from it.

For the Raspberry Pi computers, a class 6 or class 10 SD card is usually the best bet. It's not worth getting an SD card faster than class 10 because the SD card slot on the Raspberry Pi is limited to around 25 MB/sec.

Table 2-3. *SD Card Sequential Write Speeds and Classes*

Sequential Write Speed (Minimum)	SD Speed Class	UHS Speed Class	Video Speed Class
2 MB/sec.	2	—	—
4 MB/sec.	4	—	—
6 MB/sec.	6	—	V6
10 MB/sec.	10	U1	V10
30 MB/sec.	—	U3	V30
60 MB/sec.	—	—	V60
90 MB/sec.	—	—	V90

Figure 2-6. *A standard SD card (left), a mini SD card (middle), and a micro SD card (right)*

KEEPING EXTRA SD CARDS FOR QUICK RECOVERY

Often, the quickest way to recover a Raspberry Pi computer is to replace the SD card with one that contains a fresh install of the operating system.

With this is mind, make sure you have at least a handful of extra SD cards that you can keep loaded with fresh installs so you can quickly replace the SD card on any Raspberry Pi computer that gets corrupted.

Choosing an SD Card Reader

To set up the full-size and micro SD cards you use with your Raspberry Pi computers, you'll need an SD card reader. If your computer already has an SD card reader built in, you can use that reader; but given that you'll likely be working extensively with SD cards, you might want to get an external reader anyway to save wear and tear.

If you decide to get an external SD card reader, look for one with two or more card slots, such as a reader that has one micro SD slot and one full-size SD slot. Such a reader will enable you not only to work with either micro SD cards or full-size SD cards without using an adapter but also to copy data straight from one SD card to another—for example, to clone a card so that you can use it to replace an SD card that has failed.

■ **Tip**   Whichever type of card reader you get, make sure it is USB 3.0 rather than USB 2.0. Even if the computer with which you'll mostly use the card reader has only USB 2.0, buy a USB 3.0 device to get higher speeds in the future.

Many SD card readers come as a USB stick, the kind that have a USB connector built into the end (see the card reader on the left in Figure 2-7), so you plug the stick straight into your computer. But you may do better with a standalone device that sits on your desk and connects to your computer via a USB cable (see the card reader on the right in Figure 2-7).

Figure 2-7. *A USB stick–type SD card reader (left) is handy and portable, but a desktop card reader (right) is easier to use for heavy-duty work with SD cards.*

Choosing and Using Cases

Each Raspberry Pi model comes as a bare board, so normally you'll need to put each Raspberry Pi board in a case before you can deploy it.

The good news is that a wide variety of cases are available to meet most, if not all, needs that case makers have identified so far.

The bad news is that so many cases are available that you may have a hard time deciding which to get.

This section suggests some criteria for choosing cases and then gives examples of different types of cases, starting with regular cases and moving on to cases designed to fulfill specific roles.

■ **Caution**   The Raspberry Pi 3 has almost exactly the same layout as the Raspberry Pi 2, which means that cases fit both models. But on the Raspberry Pi 3, the LEDs (light-emitting diodes) are in a different position, which means they may not be visible in all cases designed for the Raspberry Pi 2. So when choosing cases for the Raspberry Pi 3, it's best to go with cases designed specifically for that model.

Criteria for Choosing Cases

When choosing cases for Raspberry Pi computers, you'll likely want to consider the following factors:

- Stability

- Durability

- Case materials

- Ease of access to Raspberry Pi ports and SD card

- Ease of opening vs. security

- Cooling or heat management

- Special needs

Stability

Raspberry Pi computers are so small and light that you can put them almost anywhere. The downside to the small size and lack of weight is that you may need to secure Raspberry Pi computers in some way to prevent the weight of their cables from moving them around. This is especially true in a classroom situation (or anywhere else where students are involved).

Some Raspberry Pi cases are heavier than others, but usually the total weight is too little to count on for keeping the computer in place. Many cases have rubber feet, which provide adequate grip for careful use but won't resist any vigorous handling.

Some Raspberry Pi cases include recessed slots that enable you to secure the case by sliding it onto a pair of raised screw heads of the right size and with suitable spacing—the same type of securing slots that many extension sockets have.

■ **Tip**   Another way to keep your Raspberry Pi computers secured is to use VESA (Video Electronics Standards Association) mounts to mount them on the backs of monitors (or elsewhere). We'll explore this topic in the section "VESA Mounts and Cases," later in this chapter.

■ **Note**   What you may well wish for as a means of securing your Raspberry Pi computers in the classroom is a rack-mounted box that houses multiple Raspberry Pi boards. As of this writing, one or two are available, but none yet seems to deliver a quality solution. If this is the solution you need, you may have to follow the lead of people who are building their own Raspberry Pi racks. Search online for *raspberry pi rack mount* for pictures and discussion of the topic.

Durability

As with most consumer goods, some Raspberry Pi cases are much more durable than others. Durability (or otherwise) comes partly from design and partly from the materials used.

Some cases are obviously designed to be decorative or fun rather than protective. For example, some cases (such as the Pibow 3) consist of multiple thin layers of plastic or acrylic that you arrange in a stack to form the case. Each layer is relatively delicate, and the case as a whole provides only modest protection. Similarly, Lego cases are designed for fun rather than for strength.

Here are two examples of durable cases:

- *Official Raspberry Pi 3 Case*: This case is built of strong plastic and features a clip-on lid and clip-on side panels that give you easy access to the GPIO pins and to all the primary ports. Figure 2-8 shows the Official Raspberry Pi 3 Case with a Raspberry Pi board installed and the panels removed.

Figure 2-8.   *The Official Raspberry Pi 3 Case features removable top and side panels that give you easy access to the GPIO pins and other interior ports.*

- *Kodi Edition Raspberry Pi Case*: This case (see Figure 2-9) is built of aluminum, which gives both durability and an attractive look. The case features an integrated heat sink, as you can see in the lower photo in Figure 2-9.
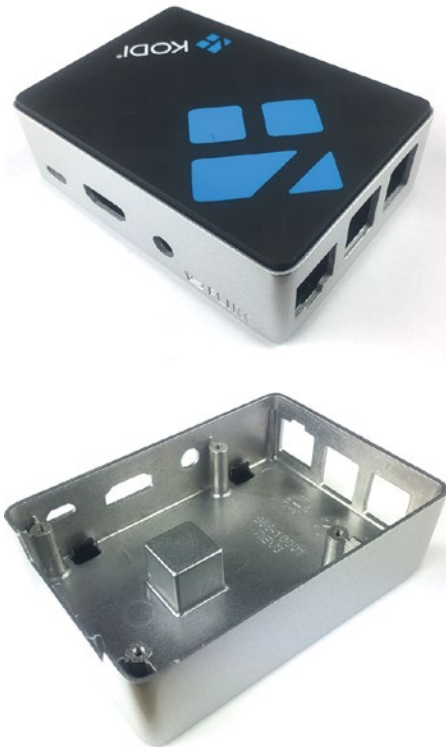
Figure 2-9. *The Kodi Edition Raspberry Pi Case (above, showing the top) is solidly built of aluminum and includes an integrated heat sink (below) to dissipate heat from the Raspberry Pi's processor.*

Materials

Raspberry Pi cases come in various different materials, including the following:

- *Plastic*: Many cases are made of plastic, which offers strength, ease of molding, and ease of coloring at an affordable price.

■ **Tip**   If you have a 3D printer, you may want to search for 3D printable cases for your Raspberry Pi computers.

- *Acrylic*: Acrylic is also widely used, especially for clear or partly clear cases. Figure 2-10 shows a Vilros Clear Case, which features a cutout section giving access to the GPIO pins.

Figure 2-10. *Acrylic cases enable you to admire the Raspberry Pi's components as you compute. This Vilros Clear Case has a cutout that gives access to the GPIO pins.*

- *Wood*: Wood might not be the first material that comes to mind for a computer case, but you can find a surprising number of cases made from various types of wood, including plywood and bamboo. Wood cases can look unusual or attractive, but they may not be suitable to the rough-and-tumble of classroom life.

- *Metal*: Metal cases tend to be more expensive than cases made of lesser materials, but they score highly for durability. Some metal cases (such as the Kodi Edition Raspberry Pi Case shown in Figure 2-9) also include built-in heat sinks that are good for cooling hot-running Raspberry Pi boards.

■ **Caution**   When choosing a case for the Raspberry Pi 3, be aware that any solid metal case will tend to block the Wi-Fi and Bluetooth signals. If you're planning to use USB for the keyboard and pointing device and Ethernet for the network connection, this may not be a concern, but it's worth bearing in mind.

Ease of Access to Raspberry Pi Ports and SD Card

Most Raspberry Pi cases provide access to all the external ports on the Raspberry Pi board for which they're designed.

Many cases also provide access to the SD card slot, enabling you to change the card easily without opening the case. Normally, being able to change the SD card is handy; but in some classroom situations, you might want to prevent users from being able to access and remove the SD cards—in this instance, cases that cover the SD card slot will be preferable. You can also get cases with lockable SD card covers, which offer you the best of both worlds.

Some cases also provide access to the internal ports, which is handy if you'll need to use them. For example, the Official Raspberry Pi 3 Case has a removable side plate that enables you to access the GPIO pins.

Ease of Opening Vs. Security

Some cases are designed to be easy to open, which can be great if you will need to work with the Raspberry Pi board frequently. But if you need to keep your students from doing so, you may want to look instead for cases that screw shut or lock shut.

Cooling or Heat Management

Raspberry Pi boards are intended to run without cooling; but if your Raspberry Pi computers live in high ambient temperatures, you run demanding software on them, or both, you may find that they overheat.

For serious cooling (including for overclocking Raspberry Pi computers), look for cases that include fans, such as the Raspberry Pi 3 and Raspberry Pi 2 /B+ Metal Case with Cooling Fan from Eleduino (`www.eleduino.com`; around US$15) or the Jbtek Transparent Acrylic Raspberry Pi B+/Raspberry Pi 2 Case with External Fan (retailers such as Amazon.com; around US$10), which also works for the Raspberry Pi 3.

For modest amounts of silent cooling, get a case with a built-in heat sink, such as the Kodi Edition Raspberry Pi Case.

■ **Note**   Another cooling option is to fix heat sinks to the Raspberry Pi's CPU and other main chips. You can get heat-sink sets for a few dollars from online Raspberry Pi retailers.

Specialty Cases

Depending on how you plan to deploy your Raspberry Pi computers, you may want to look into getting specialty cases. Here are a couple of examples:

- *Touch screen display cases*: You can get a wide variety of touch screens designed for use with the Raspberry Pi boards. These touch screens range from tiny (such as 2.4 in. models) through medium (such as 7 in. models) to large (10 in. or larger models). To protect a touch screen and turn it into a tablet computer, you can get a custom case, such as the Premium Case for Raspberry Pi 7" Touch Screen shown in Figure 2-11 with the Raspberry Pi 7-Inch Touch Screen Display.

Figure 2-11. *Touch screen cases, such as the Premium Case for Raspberry Pi 7" Touch Screen (top) enable you to turn a touch screen, such as the Raspberry Pi 7-Inch Touch Screen Display (bottom), into a tablet computer.*

- *Stackable cases*: You can find some stackable cases for Raspberry Pi boards. As of this writing, perhaps the best example is the Multi-Pi Stackable Raspberry Pi Case from ModMyPi. Each kit enables you to stack two Raspberry Pi boards, but you can connect multiple kits together to make towering structures.

VESA Mounts and Cases

The diminutive size of Raspberry Pi computers means that you can put them just about anywhere, but it also means that they're in danger of being overwhelmed by their cables. Once you've connected a power cable, an HDMI cable, an Ethernet cable, and even a modest couple of USB cables, there's more than enough weight of cable to move the Raspberry Pi computer and its case.

One effective way of constraining a Raspberry Pi computer and getting it out of harm's way is to mount it on the back of a display or TV using a VESA mount. Many displays and TVs have VESA mounting holes built in. So if you're not using the VESA mounting holes to mount the display, you can use them to secure a Raspberry Pi computer.

You can get either a case with a built-in VESA mount or a VESA mount that works with various cases. If you plan to mount a Raspberry Pi computer permanently on a display, a case with a built-in mount tends to be a neater solution.

Here are two examples of VESA mounts and cases:

- *Adafruit VESA Mount Plus*: This is a mount for the Raspberry Pi 2 Model B, Model B+, and Model A+. It has 75 mm and 100 mm VESA holes.

- *OmniVESA*: This is a straightforward VESA mounting board with 75 mm and 100 mm VESA holes. OmniVESA works with either a bare Raspberry Pi board or with many standard-size cases.

■ **Tip**   VESA mounts and VESA mount cases are great for fixing Raspberry Pi computers to fixed objects other than displays—for example, you might want to attach Raspberry Pi computers to desks, to a computer cart, or to the wall to prevent them wandering. All you need is your trusty screwdriver and some 4 mm wood screws instead of the M4 machine screws.

WHAT IS VESA, AND WHAT IS A VESA MOUNT?

VESA is the acronym for Video Electronics Standards Association, a technical standards organization that has developed and promoted a wide variety of computer display standards since its establishment in 1989. Many of the VESA-developed standards, such as the VESA Local Bus video bus and the VESA Advanced Feature Connector (VAFC) connector for video cards, have been swamped by the tsunami of technology; but the VESA mount is still extremely widely used.

The VESA mount, formally known as either the Flat Display Mounting Interface (FDMI) or VESA Mounting Interface Standard (MIS), has four screw holes on either a square or X-shaped mount. VESA mounts use different hole spacings and screw sizes for different sizes and weights of displays.

- **VESA 75:** 75 mm by 75 mm, with M4 screws, for up to 17.5 lb.

- **VESA 100:** 100 mm by 100 mm, with M4 screws, for up to 30.8 lb.

- **VESA 200:** 200 mm by 200 mm, with M6 screws, for up to 110 lb.

- **VESA 200:** 200 mm by 200 mm or larger, with M8 screws, for up to 250 lb.

Most VESA mounts for Raspberry Pi boards and cases have 100 mm VESA holes, 75 mm VESA holes, or both.

Adding a Camera Module

You can connect a camera module to a Raspberry Pi computer to provide graphical input. The camera module is great if you want to use a Raspberry Pi computer for projects such as a webcam or surveillance camera, but it can also be good for more mundane activities such as taking user photos.

Figure 2-12 shows the Raspberry Pi Camera Module V2 attached to a Raspberry Pi 3 Model B.

Figure 2-12. *Connect a camera module to a Raspberry Pi computer when you need to get graphical input.*

Choosing Wi-Fi and Bluetooth Adapters for Older Raspberry Pi Models

The Raspberry Pi 3 Model B has built-in Wi-Fi and Bluetooth 4.1. The Wi-Fi interface uses the 2.4 GHz spectrum and supports the 802.11b, 802.11g, and 802.11n Wi-Fi standards, which means that you can connect to most Wi-Fi networks. The exceptions are Wi-Fi networks that use other standards, such as 802.11a and 802.11ac, both of which use the 5 GHz spectrum; if you need to connect to such networks, you'll need to add a Wi-Fi adapter capable of those standards.

■ **Note**   The 802.11a is an older standard that is used in relatively few networks; 802.11ac is a new, higher-speed standard that seems likely to find widespread use over the next few years.

Older Raspberry Pi models mostly have Ethernet connectivity built in but don't have Wi-Fi or Bluetooth. If you need Wi-Fi capability, Bluetooth capability, or both, you can add these by connecting suitable adapters.

For Wi-Fi, look first at the Official Raspberry Pi WiFi Adapter, which costs around US$10 and supports the three most widely used Wi-Fi standards (802.11b, 802.11g, and 802.11n). If this adapter doesn't suit your needs, you can find plenty of others, such as the Raspberry Pi WiPi Wireless Adapter and the USB WiFi Adapter for the Raspberry Pi.

For Bluetooth, you can find many Bluetooth USB dongles that work with the Raspberry Pi. Go to a Raspberry Pi specialist dealer to find Bluetooth USB dongles designed specifically for the Raspberry Pi, or consult the RPi USB Bluetooth Adapters page (http://elinux.org/RPi_USB_Bluetooth_adapters) to make sure that the adapter you plan to buy works with the Raspberry Pi.

Choosing Displays

Each Raspberry Pi model apart from the Raspberry Pi Zero comes with a standard HDMI connector for connecting the computer to a display or a TV. The Raspberry Pi Zero comes with a mini HDMI connector that offers essentially the same capabilities but with a smaller footprint.

HDMI Displays: The Clearest Choice

If you're going to buy displays for your Raspberry Pi computers, displays with an HDMI input are the obvious choice. For a full-size Raspberry Pi computer, you can use a standard HDMI cable. For a Raspberry Pi Zero, you can use a mini HDMI–to-HDMI adapter or cable instead.

■ **Tip**   Apart from simplicity, HDMI connections have a second advantage: HDMI carries sound as well as video, so you can play audio through the display's or TV's speakers or through speakers you have connected to it. With most other video output types, you need to use a separate cable to get audio out of the Raspberry Pi.

■ **Note**   The HDMI ports on the Raspberry Pi models support the Consumer Electronics Control (CEC) feature, which enables the sending of commands via HDMI. For example, if you connect your Raspberry Pi computer to your TV via HDMI, you can use the TV's remote control to send commands via HDMI to the Raspberry Pi computer, as well as to other connected devices such as your set-top box or DVD player.

If your school already has displays, you should be able to use them with the Raspberry Pi computers, but you may need to get converter cables or adapters. The following sections cover the four main possibilities: DVI (Digital Visual Interface), DisplayPort, VGA (Video Graphics Array), and composite video. Figure 2-13 shows DisplayPort, HDMI, and VGA inputs on a monitor; whereas Figure 2-14 shows DVI and VGA inputs.

Figure 2-13. *DisplayPort (left), HDMI (center), and VGA (right) ports on a monitor*

Figure 2-14. *DVI (left) and VGA (right) ports on a monitor*

■ **Tip**   Before you start ordering cables, adapters, or converters, examine your displays carefully and list the input ports that each of them has. Many displays offer two input ports (often DVI and VGA) or three input ports (often DVI, VGA, and HDMI, but sometimes DVI, DisplayPort, and HDMI). DisplayPort and HDMI ports can look confusingly similar, especially if you're peering at the back of a monitor in a dark corner, so take your time to make sure you know what you're dealing with.

Connecting to Displays via DVI

DVI is a digital technology, and it uses the same digital format for video that HDMI uses. This means that you can take the video output from an Raspberry Pi's HDMI port and deliver it to the DVI port on a display by using a cable that has an HDMI connector at one end, a DVI connector at the other, and the correct arrangement of wires. In the world of display technology, this is about as simple as life gets.

Unfortunately, getting the audio from the HDMI output is a different matter. To get the audio, you need an active HDMI-to-DVI converter that separates the audio from the video and outputs the audio over an audio connection, such as an analog cable. These converters are widely available, but they cost roughly as much as a Raspberry Pi; so you may prefer to run a separate audio cable from the Raspberry Pi computer's audio output instead.

Connecting to Displays via DisplayPort

Like DVI, DisplayPort is a digital technology—but unlike DVI, DisplayPort doesn't use the same digital video format as HDMI: so you can't get HDMI video output to a DisplayPort input by simply using a cable that has the right connections and wiring.

(In case you're wondering, briefly, the difference is that whereas HDMI and DVI use separate data channels for each color, DisplayPort renders the whole image and transmits it in separate packets.)

Instead, you need an active HDMI-to-DisplayPort adapter that adapts the HDMI signal to a DisplayPort signal. Such adapters are readily available, but given that most cost US$50 to $100, they're barely economical unless you're committed to using a display that requires DisplayPort input. When you can buy a new HDMI monitor for less than $100, you can make a strong case for buying a monitor instead of an adapter.

■ **Caution**   There are lots of inexpensive, passive DisplayPort-to-HDMI adapters available—but be warned that most of them work only in one direction, taking DisplayPort output from a computer and delivering HDMI input to a display or TV. To take HDMI output from an Raspberry Pi and deliver DisplayPort input for a display, you normally need an active adapter, which usually costs substantially more.

Connecting to Displays via VGA

VGA uses analog-based signals for transferring display information, so you need to use a converter to convert the digital HDMI signal to an analog signal in VGA format. These converters are widely available and start from about US$10. Even some inexpensive models include an audio output that delivers an analog audio signal extracted from the HDMI output, which saves you running an audio cable from the Raspberry Pi's audio-out port.

■ **Caution**   You cannot use a passive HDMI-to-VGA cable or adapter to connect a Raspberry Pi to a VGA monitor. Instead, you need an active HDMI-to-VGA cable or adapter. It's best to get an active cable or adapter with an external power supply, even though this means that you need another power socket available.

■ **Note**   For VGA and composite connections, you may need to edit the Raspberry Pi's config.txt file to get video output on the display. We'll look at how to edit the config.txt file in Chapter 5.

Connecting to Displays via Composite

The last means of video connection you might need to use for a display is a composite connection. This connection uses the RCA port on the Raspberry Pi and outputs an audio and video signal.

The cable you need for a composite connection depends on whether your display has a single composite input or separate video and audio inputs:

- *Single composite input*: Get a composite cable with a single RCA connector at each end. The RCA connectors on these cables are usually yellow.

- *Separate video and audio inputs*: Get a cable that has a single RCA connector at the Raspberry Pi's end and three RCA connectors at the other end: a yellow RCA connector for the video channel and red and white (or red and black) RCA connectors for the two audio channels. On the audio, red is the right channel, and white or black is the left channel.

Choosing Keyboards and Pointing Devices

Each Raspberry Pi computer you deploy in a classroom will normally need a keyboard and a pointing device. USB, PS/2 (from IBM Personal System/2 computers), and Bluetooth keyboards and pointing devices will all work.

■ **Note**   You may be able to dispense with a dedicated keyboard and pointing device for any Raspberry Pi computer you will administer remotely. And for lab setups, you may want to use a keyboard-video-mouse switch, usually known as a KVM switch, to share a single keyboard, pointing device, and monitor among several computers.

USB: The First Choice for Keyboards and Pointing Devices

Generally speaking, USB should be your first choice of connection technology for keyboards and pointing devices. USB keyboards and pointing devices are widely available, and Raspbian has a good selection of drivers for them. Normally, you can plug a standard keyboard and pointing device into a Raspberry Pi computer and simply have them work.

RASPBERRY PI ZERO: CONSIDERATIONS FOR KEYBOARD AND POINTING DEVICES

Because of the Raspberry Pi Zero's minimalist configuration, there are a couple of considerations when connecting a keyboard and pointing device.

First, because there's no full-size USB port, you'll need to get a USB to micro-USB On-The-Go converter shim to connect a standard USB device. Such a shim is a tiny device that slides inside the standard USB connector so that the shim is hidden apart from the micro-USB connector.

Second, a shim enables you to connect only a single device; so if you need to connect multiple devices, you'll need either a separate USB hub or a device with a built-in hub. For example, various keyboards include a couple of USB ports to make it easy to connect a mouse.

Specialist Raspberry Pi retailers sell hubs designed to mount on the Raspberry Pi Zero. The USB ports on such hubs connect to the testing ports on the Raspberry Pi Zero without soldering, so you can still use the micro-USB port for other purposes.

Using PS/2 Keyboards and Pointing Devices

If you have PS/2 keyboards and pointing devices rather than USB ones, you can connect them using PS/2–to-USB adapters.

If you need to connect both a PS/2 keyboard and a PS/2 pointing device, look for an adapter designed to pipe both keyboard and mouse input into a single USB port.

Using Bluetooth Keyboards and Pointing Devices

Bluetooth is another possibility for keyboards and pointing devices. Bluetooth can be a good solution for the Raspberry Pi 3 (which has built-in Bluetooth) or for another Raspberry Pi model to which you've added Bluetooth capability via an adapter.

■ **Caution**   Bluetooth keyboards and pointing devices can be great for reducing clutter on your desk or for allowing you to move the keyboard or pointing device freely away from the computer. But in a classroom situation, you may find that cabled devices are easier for two reasons. First, you can see clearly which keyboard and pointing device is connected to which Raspberry Pi computer. Second, you won't have to worry about keyboards and pointing devices running out of battery power or simply being switched off—deliberately or otherwise—at the wrong times.

Choosing a Network Connection Method

You can connect your Raspberry Pi computers to the network either via the Ethernet port or via Wi-Fi. Which you choose to use will likely depend on Raspberry Pi models, your classroom setup, and your educational establishment's network setup.

The Raspberry Pi 3 and most Raspberry Pi models apart from the Raspberry Pi Zero have an Ethernet port. The Raspberry Pi 3 is the only model with built-in Wi-Fi, but you can easily add Wi-Fi by connecting a USB adapter or USB dongle, as discussed earlier in this chapter.

If you choose to go with Ethernet, you'll need an Ethernet cable for each Raspberry Pi computer. If your classroom isn't equipped with enough Ethernet ports for all the Raspberry Pi computers, you'll also need one or more Ethernet switches to connect the computers to the network.

■ **Note**   The ports on full-size Raspberry Pi boards are Fast Ethernet (100 Mbps) rather than Gigabit Ethernet; but if you're buying Ethernet hardware, you should buy Gigabit Ethernet hardware to get good network performance overall. This is especially important if you will use the PiNet server software (discussed in Chapter 7) to manage your classroom deployment of Raspberry Pi computers.

If you decide on Wi-Fi rather than Ethernet, you'll need a Wi-Fi adapter for each Raspberry Pi computer other than the Raspberry Pi 3 models. If your educational establishment has enough wireless capacity, that may be all you need; if not, you may need to add one or more wireless access points to get the Raspberry Pi computers connected to the network.

Summary

In this chapter, you've learned about the hardware you're likely to want for deploying Raspberry Pi computers in the classroom. You know the key differences among the Raspberry Pi boards; you know which Raspberry Pi model to choose; and you know how to select power sources, SD cards, and cases for your Raspberry Pi computers. You should also have identified which displays, keyboards, pointing devices, and other peripherals to use; and you should have decided whether to use wired or wireless networking.

In the next chapter, we'll look at the software choices for your Raspberry Pi deployment.

■ ■ ■

Choosing Operating Systems for Raspberry Pi

After choosing the hardware for your Raspberry Pi deployment, you'll need to decide which operating system or systems to run on the computers. Raspberry Pi computers can run a wide range of operating systems, from the customized Raspbian operating system supplied by the Raspberry Pi Foundation to media-center operating systems and specialized RISC operating systems.

In this chapter, we'll start by looking at Raspbian and the other operating systems that you can install alongside it automatically in a multi-boot configuration by using the NOOBS installer. We'll then move along to examine some of the many other distributions of Linux that you can install manually on Raspberry Pi computers before turning our attention briefly to non-Linux operating systems.

One thing before we start: If you have already decided to install Raspbian on your Raspberry Pi computers, you may want to skip this chapter for now, download the NOOBS installer, and run NOOBS to install Raspbian and nothing else. For many classroom deployments, this is a sensible approach—and perhaps the best approach. But if you want more flexibility, read on to find out about using NOOBS to create a multi-boot setup that includes other operating systems, such as the LibreELEC media-center OS or the Windows 10 IoT Core development OS, and about exploring the wealth of other Raspberry Pi-compatible operating systems that you can download for free.

Meeting NOOBS, Raspbian, LibreELEC, OSMC, and Windows 10 IoT Core

The Raspberry Pi Foundation provides an installer called NOOBS (short for New Out Of Box Software) for installing one or more operating systems on Raspberry Pi computers. As of this writing, NOOBS supports the following four operating systems:

- Raspbian

- LibreELEC

- OSMC

- Windows 10 IoT Core

By using NOOBS (see Figure 3-1), you can install any one, any two, any three, or all four of those operating systems on a Raspberry Pi computer's SD card. If you install multiple operating systems, NOOBS creates a multi-boot setup that lets you choose, each time you start an RPC, which operating system to launch. NOOBS handles the partitioning of the SD card and also enables you to create a data partition on the SD card if you wish.
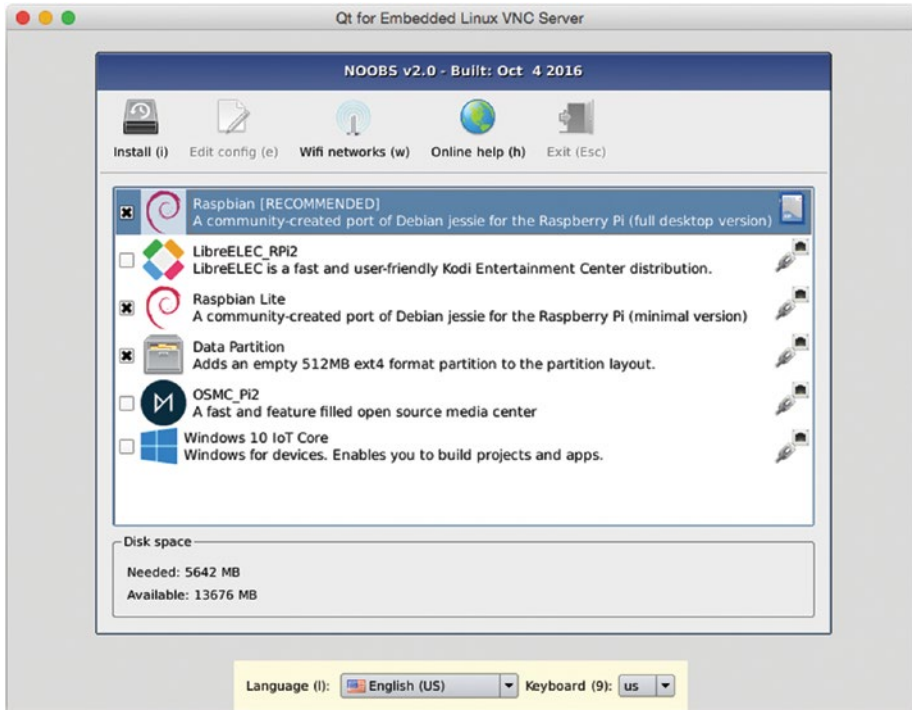
Figure 3-1. *The NOOBS installer enables you to install Raspbian, LibreELEC, OSMC, and Windows 10 IoT Core either singly or in a multi-boot configuration. You can also create a data partition.*

We'll look at the details of using NOOBS in Chapter 5, so here we'll stay with the big picture. But in case you're wondering where to get NOOBS, you can either buy an SD card containing NOOBS from a Raspberry Pi retailer or simply download NOOBS from the Raspberry Pi Foundation web site (http://downloads.raspberrypi.org/NOOBS_latest).

Raspbian

The Raspbian operating system is a version of the widely used Debian distribution of Linux. The Raspberry Pi Foundation has customized Raspbian to make it run well on Raspberry Pi boards. Raspbian (see Figure 3-2) includes a wide selection of apps, ranging from the LibreOffice productivity suite to integrated development environments for the Python programming language. These features make Raspbian the best choice for many

Raspberry Pi classroom deployments. So you'll likely want to explore Raspbian to see if it will meet your needs. If so, Raspbian is easy to install and manage; if not, you have plenty of other choices of operating systems.
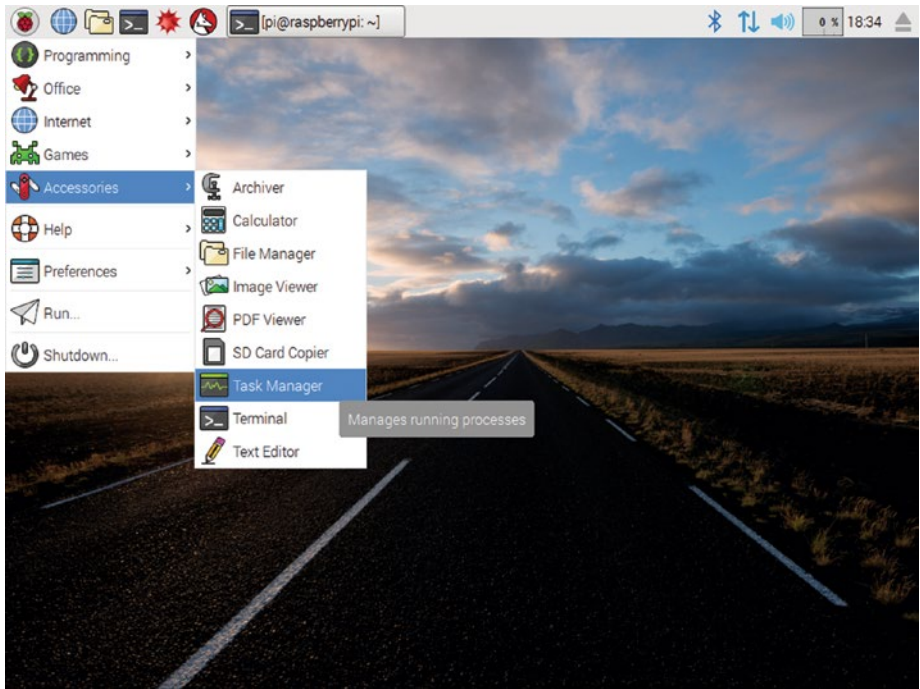
Figure 3-2. *The Raspbian operating system is a Linux distribution customized to suit the Raspberry Pi boards.*

Raspbian Lite

As you'll readily guess from its name, Raspbian Lite is a "lite"—stripped-down—version of Raspbian. Raspbian Lite doesn't include a GUI, so it boots to the command line. You might want to use Raspbian Lite to get the best performance out of an older Raspberry Pi computer. You could also use Raspbian Lite to encourage—or perhaps force—your students to develop experience working at the command line.

Raspbian Lite also doesn't include any apps, so the installation takes up much less space than regular Raspbian. Unless you're stuck with pitifully low-capacity SD cards, however, the amount of space that full-fat Raspbian takes up shouldn't be a concern.

Another reason to install Raspbian Lite is to use Raspbian with a different graphical interface than LXDE (Lightweight X11 Desktop Environment), which Raspbian uses by default. For example, you can install the XFCE (originally XForms Common Environment) graphical interface or the MATE (from South American plant yerba mate) graphical interface on Raspbian. You'd do this to get your preferred graphical interface— or the graphical interface you want your students to learn—on the Raspberry Pi computer while still running Raspbian (Lite) underneath.

■ **Note**   XFCE and MATE running on Raspbian Lite take up similar amounts of memory to LXDE running on regular Raspbian. So you're not likely to get better performance by installing Raspbian Lite and an alternative graphical interface.

LibreELEC

LibreELEC, short for Libre Embedded Linux Entertainment Center, is a full-featured media center app that runs on Raspberry Pi boards. LibreELEC runs the Kodi media center, whose home screen (shown in Figure 3-3 with the default skin, which is called *Confluence*) gives you quick access to five main categories: Pictures, Videos, Music, Programs, and Settings.

■ **Note**   LibreELEC is a fork of OpenELEC, the Open Embedded Linux Entertainment Center.
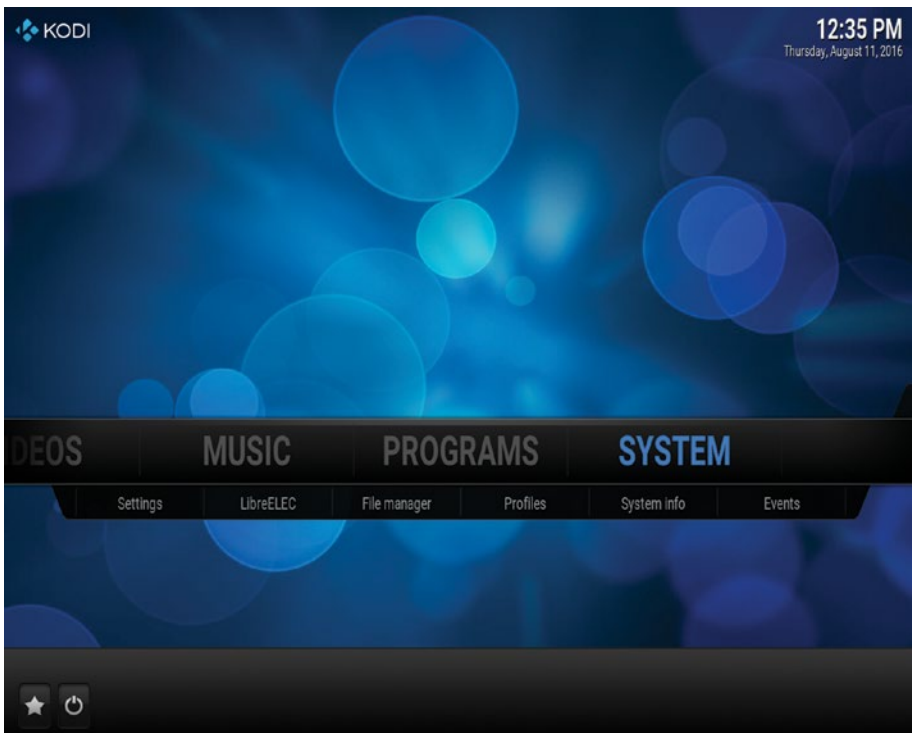
Figure 3-3. *The home screen of the Kodi media center, here running on LibreELEC and using the Confluence skin, gives you access to Pictures, Videos, Music, Programs, and System.*

To configure LibreELEC itself (as opposed to configuring Kodi), you select System on the home screen and then click LibreELEC on the pop-up bar. You can then click the appropriate settings category (such as the System category, the Network category, or the Connections category) in the left pane and work with the settings that appear in the right pane. Figure 3-4 shows the System category of LibreELEC settings.
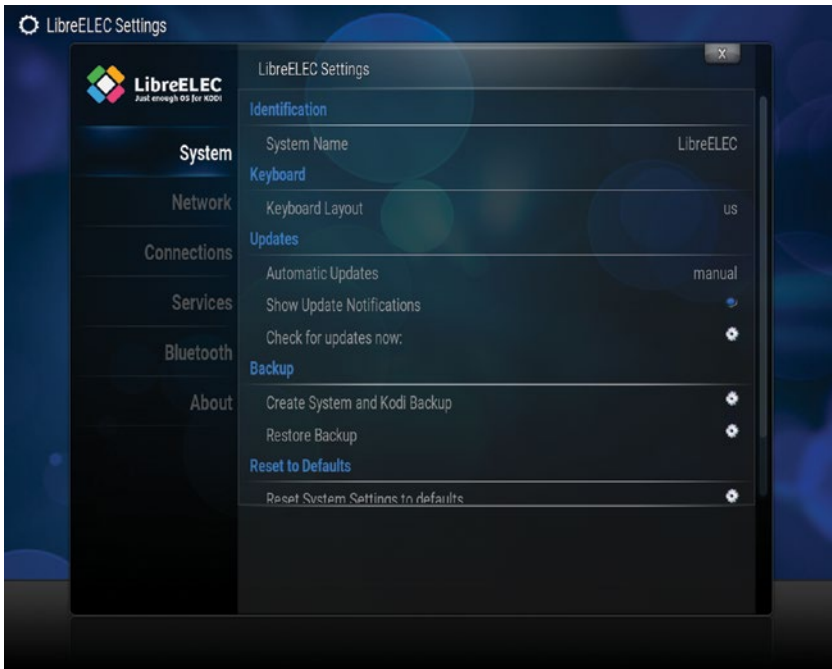
Figure 3-4. *Use the LibreELEC Settings screen to configure LibreELEC under Kodi.*

OSMC

OSMC (the abbreviation stands for Open Source Media Center) is a version of the Debian Linux distribution customized to use the Kodi media center as its main app. When you boot OSMC on a Raspberry Pi computer, you see Kodi as the graphical interface. Figure 3-5 shows Kodi with the OSMC skin applied; you can also apply other skins, such as the Confluence skin, which is included in OSMC and makes Kodi look like Figure 3-3 (earlier in this chapter).
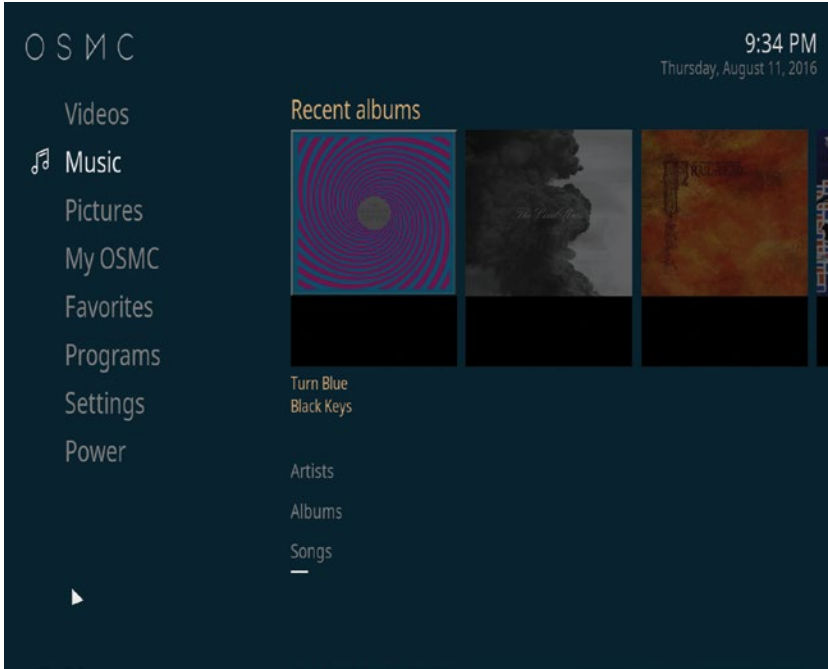
Figure 3-5. OSMC is a Debian Linux distribution that uses Kodi as its graphical interface. Here, Kodi is configured with the OSMC skin.

WHAT IS THE DIFFERENCE BETWEEN LIBREELEC AND OSMC?

If you want to implement a media center, or have your students implement one, you'll likely want to install and test both LibreELEC and OSMC. Both are capable media centers and run well on Raspberry Pi computers, especially on the Raspberry Pi 3 Model B. Both use the Kodi media center app as the graphical interface.

The main difference between LibreELEC and OSMC is that LibreELEC is a stripped-down operating system designed to run only Kodi, whereas OSMC implements Kodi on top of a full version of the Debian Linux distribution. As a result, OSMC has greater capabilities than LibreELEC; but if you simply want a media center, you may not need these capabilities.

All other things being equal, LibreELEC should give better performance than OSMC on the same hardware. So if you are using an older Raspberry Pi board, such as a Raspberry Pi 2 Model B, LibreELEC may be the better choice.

Windows 10 IoT Core

IoT is the abbreviation for Internet of Things, the term for everyday objects—such as refrigerators, thermostats, and home-automation systems—having Internet connectivity so that you can interact with and control them remotely. As of this writing, IoT is a major area of development, but it is also raising major security concern because of nonexistent or woeful security on many devices.

Understanding What Windows 10 IoT Core Is

Windows 10 IoT Core is a lightweight version of Windows 10 intended for developers, hackers, and hobbyists who want to use Raspberry Pi boards as a device for prototyping IoT devices. Windows 10 IoT Core appears almost entirely different from the full versions of Windows 10 that run on tablets, laptops, desktops, and servers: although much of the code under the hood is the same, Windows 10 IoT Core has a completely different user interface from the full versions of Windows 10.

Understanding How You Use Windows 10 IoT Core

The other operating systems we've examined in this chapter all run on the Raspberry Pi, and you would normally use them directly on the Raspberry Pi. For example, if you install and run the Raspbian operating system, you can sit at the Raspberry Pi computer and use File Manager to manage files or use the LibreOffice suite of apps to create word processing documents, spreadsheets, or presentations. You can also access the Raspberry Pi remotely in various ways that we'll explore in Chapter 5.

Windows 10 IoT Core is more complicated. Here's how you use it:

- You need a Raspberry Pi computer and a "normal" Windows 10 computer—that is, a computer running a full version of Windows 10, such as Windows 10 Home or Windows 10 Pro.

- You install Windows 10 IoT Core on a Raspberry Pi computer. As of this writing, the Raspberry Pi 2 Model B and the Raspberry Pi 3 Model B are officially supported; with its extra speed, the Raspberry Pi 3 Model B is the better bet.

- You boot the Raspberry Pi computer into Windows 10 IoT Core. Figure 3-6 shows the Device Info screen for a Raspberry Pi 3 Model B board in Windows 10 IoT Core.
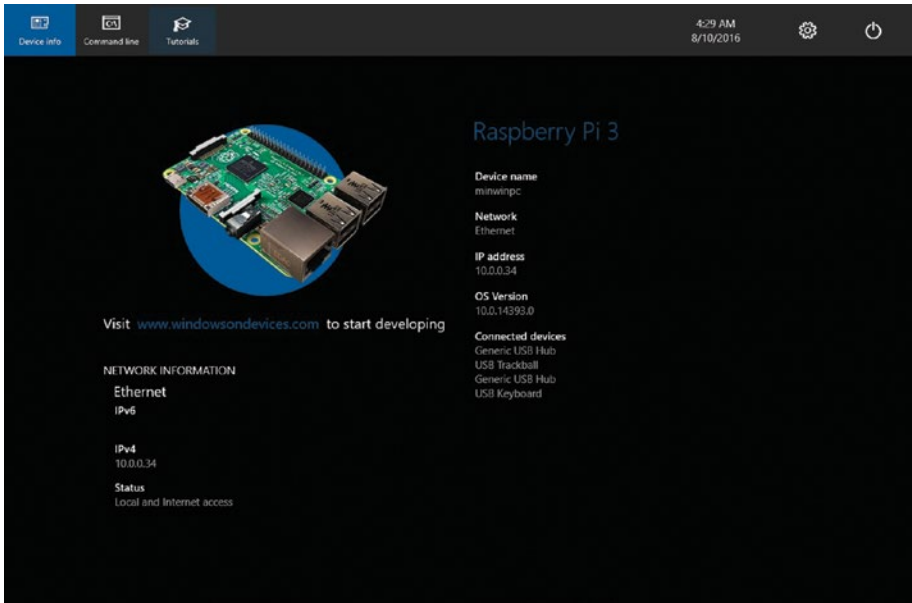
Figure 3-6. *Windows 10 IoT Core has a stripped-down interface. The Device Info screen shows network information, the device's name, the OS version, and a list of connected devices.*

- You boot the Windows 10 computer into Windows 10 as usual.

- You run Visual Studio 2015 on the Windows 10 computer.

■ **Note** Visual Studio is one of Microsoft's tools for developing apps. Visual Studio comes in three different editions: Visual Studio Community, Visual Studio Professional, and Visual Studio Enterprise. Visual Studio Community is intended for developers building non-enterprise apps and is free. You can download Visual Studio Community from the Visual Studio web site (`www.visualstudio.com`).

- You develop code and an interface for your app in Visual Studio.

- You load the code onto the Raspberry Pi computer from the Windows 10 computer and run the app. The app's interface appears on the screen connected to the Raspberry Pi computer, and you can interact with it.

Exploring Other Linux Operating Systems

Apart from the operating systems to which NOOBS gives you direct access, you can also run other operating systems on Raspberry Pi computers.

As you know, the Raspbian operating system is based on the Debian distribution of Linux. Many other Linux distributions are available for the Raspberry Pi, although only some distributions are current as of this writing.

The first subsection discusses desktop versions of Linux, whereas the second subsection discusses server versions of Linux.

■ **Tip** If you plan to test several—or indeed many—of the operating systems discussed here, make sure you have plenty of spare SD cards. Although it's possible to set up multi-boot systems with multiple operating systems running off a single SD card, it's much easier to install a single operating system on each SD card and switch the cards as necessary. Or, if you have a fleet of Raspberry Pi computers at your disposal, simply install a single operating system on each and switch between the computers when you need to switch operating systems.

Exploring Other Linux Desktop Operating Systems

Most the versions of Linux available for the Raspberry Pi are desktop operating systems. This section introduces you to some of the current versions that normally represent the best choices for Raspberry Pi computers.

■ **Note** You can download the five Ubuntu versions discussed here—Lubuntu, Xubuntu, Ubuntu MATE, Ubuntu Server Minimal, and Ubuntu Server Standard—from the Ubuntu Pi Flavour Maker web site (`https://ubuntu-pi-flavour-maker.org`).

Lubuntu

Lubuntu is a lightweight Linux distribution that uses the LXDE (Lightweight X11 Desktop Environment) desktop environment, the same desktop environment that Raspbian uses by default. Lubuntu runs on the Raspberry Pi 2 Model B and the Raspberry Pi 3 Model B boards but not on earlier Raspberry Pi boards. Lubuntu typically uses only about half as much RAM as does Xubuntu (discussed later in this section), so it is a good choice for getting decent performance in a full-featured version of Linux. Figure 3-7 shows Lubuntu.
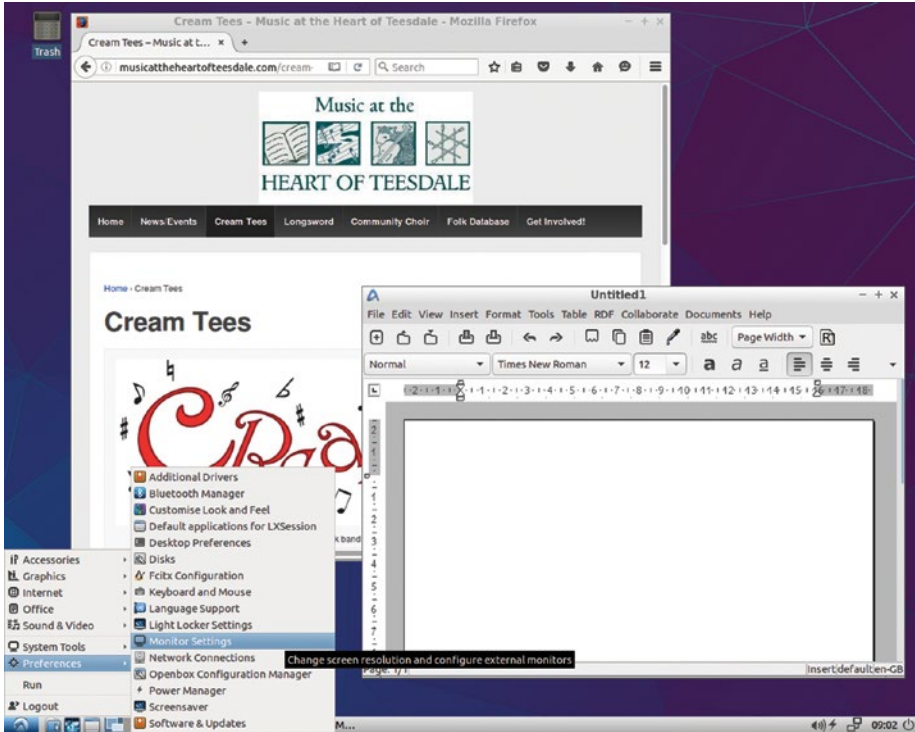
Figure 3-7. *Lubuntu is a lightweight distribution of Ubuntu. Lubuntu uses the LXDE desktop environment.*

Xubuntu

Xubuntu is a version of Ubuntu Linux that uses the Xfce (formerly XForms Common Environment) desktop environment instead of the Unity graphical shell that regular Ubuntu uses. Because Xubuntu is a relatively demanding version of Linux, it's a better choice for the Raspberry Pi 3 Model B than for the Raspberry Pi 2 Model B.

Xubuntu (see Figure 3-8) comes with Internet apps, such as the Firefox browser and the Thunderbird e-mail client, media player apps, and graphics viewers. Xubuntu doesn't include the LibreOffice productivity suite, but you can install it easily.
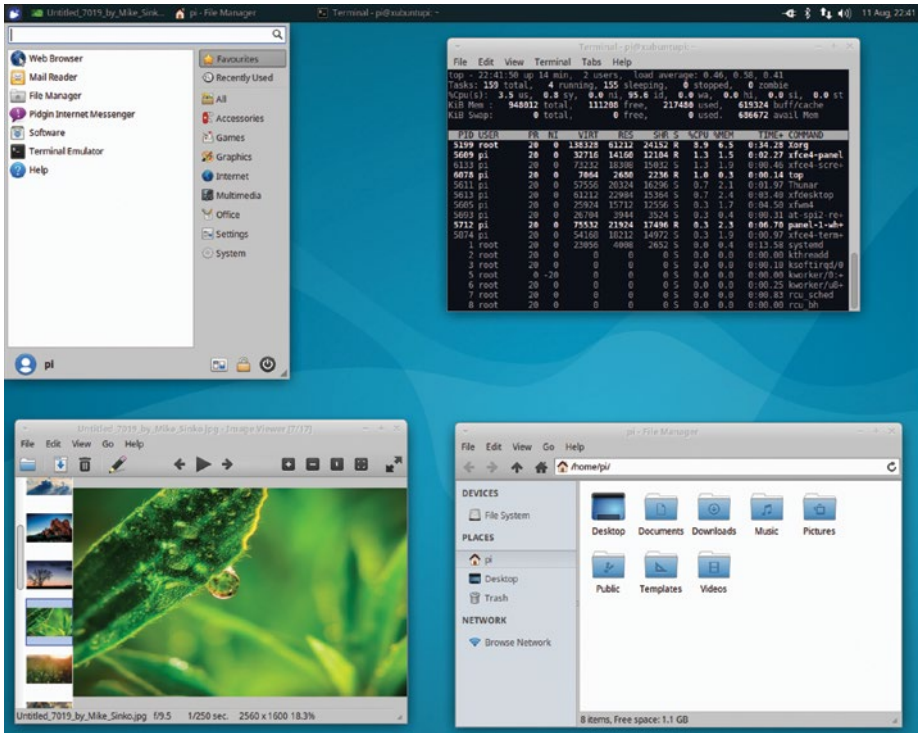
Figure 3-8. *Xubuntu runs the Xfce desktop environment on Ubuntu Linux.*

Ubuntu MATE

Ubuntu MATE is an official derivative of the widely used Ubuntu version of Linux. Ubuntu MATE differs from regular Ubuntu in that it uses the MATE (from Yerba maté, holly species) desktop environment rather than the Unity graphical shell.

Apart from this major difference, Ubuntu MATE (see Figure 3-9) provides a similar range of software to Raspbian and seems to run at similar speed. Ubuntu MATE includes the Firefox browser, the Thunderbird e-mail client, LibreOffice, the Python language and the IDLE development environment, the VLC media player, and even the Minecraft Pi game. These apps make Ubuntu MATE a viable alternative to Raspbian for either general use or educational use, especially for those who prefer a different graphical look.
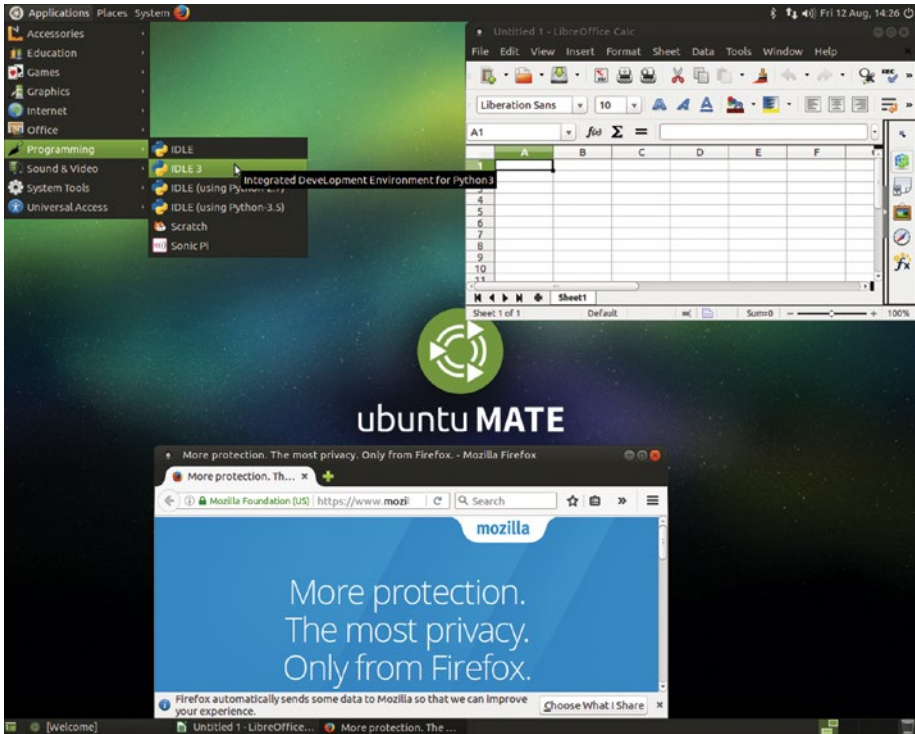
Figure 3-9. *Ubuntu MATE uses the MATE desktop environment instead of Ubuntu's regular graphical shell, Unity. Ubuntu MATE comes with a good selection of apps and tools.*

USING FULLPAGEOS FOR KIOSK-STYLE DISPLAYS WITH RASPBERRY PI COMPUTERS

Sometimes you may need to use a Raspberry Pi computer to run a kiosk-style display—for example, for a project you share with the school, or as an information resource on a parents' evening.

You can set up a kiosk-style display with Raspbian, but you'll need to spend some time locking down the computer to make sure that nobody can take unwanted actions on the Raspberry Pi.

If you don't want to spend time turning off the screen saver, configuring the display size, and switching the Raspberry Pi into full-screen mode, try FullPageOS instead. FullPageOS is customized to display a Chromium window full screen. FullPageOS takes only minor setup to connect to your school's Wi-Fi network and display the internal or external web page you want to show.

You can download FullPageOS from GitHub (https://github.com/guysoft/FullPageOS).

OpenWrt

OpenWrt is a Linux-based embedded operating system that enables you to turn a Raspberry Pi computer into a network router. This is a specialized use of the Raspberry Pi, but if you need a small and easily configurable wireless router, you may want to investigate OpenWrt.

Exploring Linux Server Operating Systems

Although Raspberry Pi computers are diminutive in size, they are nonetheless capable of running full server operating systems. A Raspberry Pi computer server can be a great tool in the classroom, either for learning or for actually serving files.

If you want to run a server on a Raspberry Pi computer, your best bet as of this writing is Ubuntu Server. You can download either Ubuntu Server Minimal or Ubuntu Server Standard from the Ubuntu Pi Flavour Maker web site (`https://ubuntu-pi-flavour-maker.org`).

The Ubuntu Server Minimal image is set up to download such packages as needed from online archives during installation, so it is a smaller file to download; by contrast, Ubuntu Server Standard includes more files in the downloaded image, so the installation should run more quickly without having to download packages. Unless keeping down the size of the downloaded file is critical, Ubuntu Server Standard is normally the better choice.

Ubuntu Server installs without a graphical interface, so you must either administer the server from the command line (either locally or remotely) or install a graphical interface yourself.

■ **Note**　Ubuntu Server Standard includes the Raspberry Pi Python Stack, a set of software components that enable you to work with the Python programming language.

Exploring Non-Linux Operating Systems

As you've seen so far in this chapter, Raspberry Pi computers can run a wide variety of Linux distributions. But Raspberry Pi computers aren't limited to Linux: you can also install and run non-Linux operating systems.

This section introduces you to three non-Linux operating systems for the Raspberry Pi: RISC (reduced instruction set computing) OS, FreeBSD (Berkeley Software Distribution), and NetBSD.

RISC OS for Raspberry Pi

RISC OS Open Limited makes available builds of RISC OS for Raspberry Pi computers. As of this writing, RISC OS runs on the Raspberry Pi 1 and Raspberry Pi 2 Model B boards. A version of RISC OS for Raspberry Pi 3 Model B is in development.

RISC OS boots and runs extremely fast, even on Raspberry Pi 1 boards, making it an interesting choice for exploring alternative operating systems on older hardware. RISC OS is also interesting in that its look, feel, and approach are considerably different than those of most current operating systems. However, although RISC OS includes some apps, the operating system's capabilities are fairly modest compared to those of the other operating systems we've been looking at in this chapter.

UNDERSTANDING THE DIFFERENCE BETWEEN RISC AND CISC

RISC (pronounced "risk") is the acronym for reduced instruction set computing, computing that uses a relatively small set of instructions and aims to execute those instructions more quickly. The contrasting term is CISC (pronounced "sisk"), which stands for complex instruction set computing.

As you may remember from Chapter 1, Raspberry Pi boards use ARM processors, where ARM is the acronym for Acorn RISC Machines. So each Raspberry Pi is a RISC computer. By contrast, the Intel processors that power most Windows PCs and recent Macs are CISC processors.

RaspBSD, FreeBSD, and NetBSD

FreeBSD and NetBSD are two Unix-like operating systems descended from the Berkeley Software Distribution (BSD), a derivative of Research Unix. Both are open source operating systems favored by IT professionals for their reliability and security.

■ **Note**   FreeBSD and NetBSD are described as "Unix-like" rather than as actual versions of Unix because of legal restrictions on the use of the term "Unix."

You can download FreeBSD images via FTP (File Transfer Protocol) from the FreeBSD Project (freebsd.org), but finding the right build for a Raspberry Pi board can be tricky. You may find it easier to download the RaspBSD operating system, which is based on FreeBSD and tailored for the Raspberry Pi, from the RaspBSD web site (www.raspbsd.org).

Similarly, you can download NetBSD from the NetBSD Project (www.netbsd.org). Here, too, you will need to be patient to find the right platform (which is called *evbarm*) and the appropriate version for your Raspberry Pi model.

FreeBSD, RaspBSD, and NetBSD normally install without a graphical interface, but you can install an interface such as Xorg manually.

Summary

In this chapter, you've met the main operating systems for Raspberry Pi computers, from the Raspberry Pi Foundation's custom Raspbian operating system through widely used distributions of Linux to specialized operating systems (such as OpenWrt). You've looked briefly at the NOOBS installer, which you can use to install any or all of Raspbian, LibreELEC, OSMC, and Windows 10 IoT Core, either as a single operating system or in a multi-boot configuration.

You should now be in a position to choose which operating system or operating systems you will explore for your Raspberry Pi deployment.

In Chapter 4, I'll give you a brief tutorial on the essentials of using a Raspberry Pi computer with Raspbian.

Brief Tutorial on Raspberry Pi Essentials

This chapter makes sure you know the essentials of using and configuring a Raspberry Pi computer. We'll begin with startup, shutdown, and restart; move along to other actions you can take from the login screen; and then meet the desktop and its components. From there, we'll look at how to configure your pointing device, keyboard, and network connection; work with the wide-ranging Raspberry Pi Configuration tool; and then examine how to configure and navigate the desktop. Toward the end of the chapter, I'll show you how to explore the file system using the File Manager app and how to configure File Manager to suit the way you prefer to work.

Startup, Shutdown, and Restart

To get your Raspberry Pi computer to do anything, you'll need to start it up. When you finish using the computer, you may want to shut it down. You may also need to restart the computer to apply configuration changes or clear up minor software problems that occur.

Starting Up the Raspberry Pi Computer

To start the Raspberry Pi computer, power it on. The Raspberry Pi has no power button, so you power it on by connecting the power supply to the Raspberry Pi's micro USB power jack and to a power socket.

■ **Tip**   For more graceful powering on, connect the Raspberry Pi computer to an extension socket that includes a switch for each plug.

When the Raspberry Pi computer is receiving power, a red LED lights up on the corner of the board near the power connector. The Raspberry Pi begins to boot, at which point the monitor displays a long sequence of bootup information. This is normal, and if you've worked with Linux, it will likely look familiar; if you're more used to less verbose operating systems, such as Windows or OS X, it may seem disconcerting at first.

■ **Note**   If you see a red light on the Raspberry Pi board but nothing on the display, power the Raspberry Pi off and verify that the SD card is fully inserted in the card holder. If the SD card is fully inserted, but you get the same problem when you reconnect the power, turn the power off again, remove the SD card, and make sure that it contains the operating system.

Shutting Down the Raspberry Pi Computer

When you finish using the Raspberry Pi computer, you can shut it down like this:

1. Click the Menu button to open the menu (see Figure 4-1).
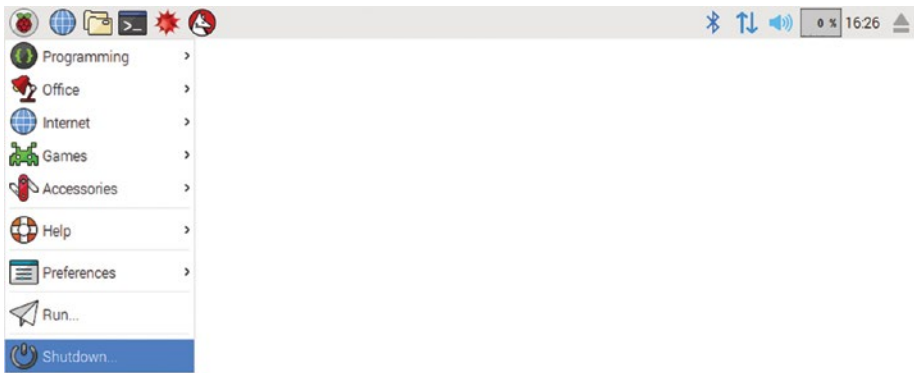
Figure 4-1. *Click the Menu button to open the menu, and then click the Shutdown command.*

2. Click the Shutdown command to display the Shutdown Options dialog box (see Figure 4-2).
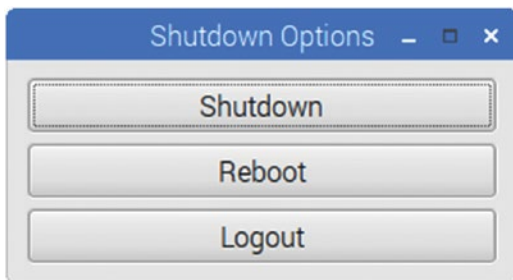
Figure 4-2. *Click the Shutdown button in the Shutdown Options dialog box to shut down the Raspberry Pi computer.*

3.   Click the Shutdown button.

■ **Caution**   Always shut down your Raspberry Pi computers by using the Shutdown command from the desktop or by using the `sudo halt` command from the command line. Although simply turning off the power (or disconnecting the power supply) does shut an Raspberry Pi computer down effectively, doing so can cause corruption on the SD card; so it's not a wise move unless the Raspberry Pi computer has stopped responding to the keyboard and mouse.

Restarting the Raspberry Pi Computer

You can restart the Raspberry Pi computer to apply configuration changes you've made or to resolve minor software problems that occur.

To restart the Raspberry Pi computer, follow these steps:

1.   Click the Menu button to open the menu.

2.   Click the Shutdown command to display the Shutdown Options dialog box.

3.   Click the Restart button. The Raspberry Pi computer restarts, displaying boot messages as it does so, and then displays the desktop (if it is configured to log in automatically) or the login screen (if it is not).

Logging Out and Logging In Again

When you are ready to stop using the Raspberry Pi computer but you don't want to shut it down, you can log out. You can then log in again when you want to resume using the computer.

To log out, follow these steps:

1.   Click the Menu button to open the menu.

2.   Click the Shutdown command to display the Shutdown Options dialog box.

3.   Click the Logout button. The login screen appears.

When you are ready to log back in, follow these steps:

1.   If the monitor attached to the Raspberry Pi computer has gone blank, click the mouse button or press a key on the keyboard to wake the display.

2.   Type your username in the Username box (the upper box).

3.   Press the Tab key to move the insertion point to the lower box.

4. Type your password.

5. Click the Log In button.

Taking Other Actions from the Login Screen

As its name suggests, the login screen is primarily for logging in, but you can also take several other actions by using the panel at the top:

- *Change the keyboard layout*: If the Raspberry Pi computer is set up with multiple keyboard layouts, you can click the current keyboard listing and then click the keyboard layout you want to use. For example, you might need to change from the QWERTY layout to the Dvorak layout.

- *Choose the session type*: Click the Session pop-up menu and then click the session you want. For example, you may want to run an Openbox session instead of an LXDE session (the default).

- *Restart the Raspberry Pi computer or power it down*: Click the Power pop-up menu and then click the action you want to take, such as Restart or Shut Down.

■ **Tip**   You can also start powering down the Raspberry Pi computer by pressing Alt+F4 from the login screen. When you press Alt+F4, the Shutdown Options dialog box opens. Click the Shutdown button to shut down the computer.

Meeting the Desktop

The Raspberry Pi has a straightforward desktop setup. Figure 4-3 shows the main components of the desktop with labels.
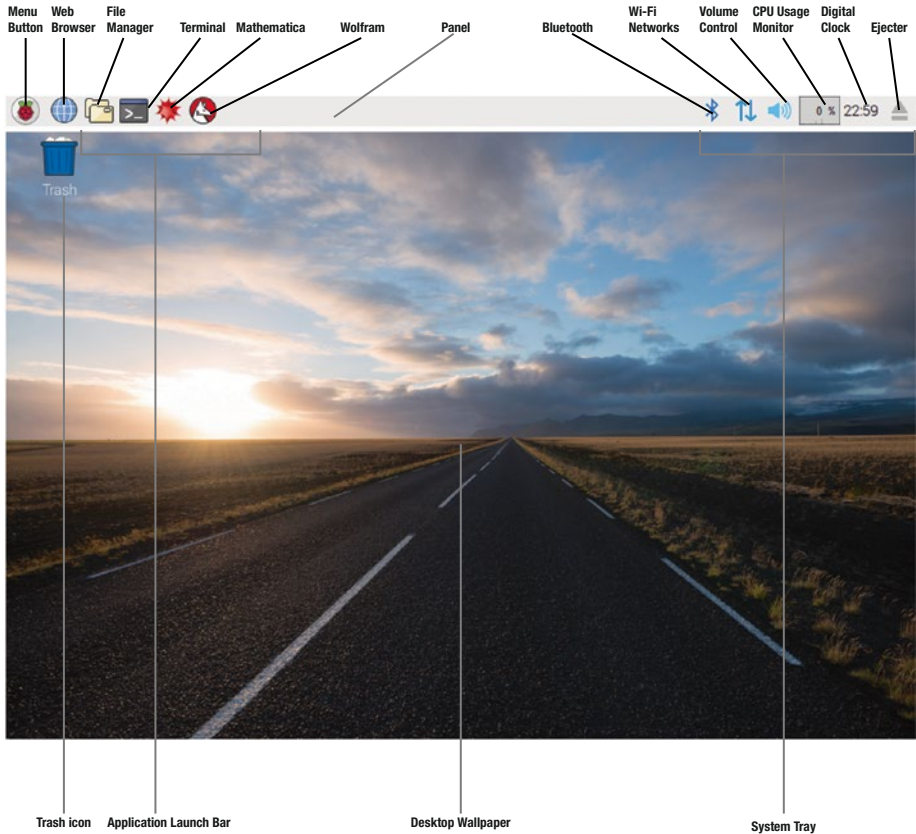
Figure 4-3. *Components of the standard Raspberry Pi desktop*

These are the components of the desktop:

- *Menu button*: The Menu button gives you access to the Raspberry Pi's menu system like the Start button on Windows does.

- *Panel*: The panel is the strip that contains the Menu button and the Application Launch Bar; the task bar of running windows (none in Figure 4-3); and the System Tray, which contains icons such as Bluetooth, Wi-Fi Networks, Volume Control, and Ejecter. The panel appears across the top of the screen at first, but you can move it to another edge of the screen if you prefer.

- *Application Launch Bar*: This area contains the selection of apps you want to be able to launch quickly. The default selection of apps on the example Raspberry Pi computer is Web Browser, File Manager, Terminal, Mathematica, and Wolfram, which are explained in the following bulleted paragraphs.

- *Web Browser*: This is a lightweight web browser that offers useful features such as tabbed browsing.

- *File Manager*: This is an easy-to-use file manager that you'll use to meet the Raspbian file system later in this chapter.

- *Terminal*: This is the LXTerminal app, which provides a command line that you can use to give commands.

- *Mathematica*: This is a mathematical computation app developed by Wolfram Research.

- *Wolfram*: This is an app for working with Wolfram Language, a programming language.

- *Bluetooth*: This pop-up menu enables you to make the Raspberry Pi computer discoverable via Bluetooth and to add and remove Bluetooth devices.

■ **Note** The Bluetooth item appears only if the Raspberry Pi computer has Bluetooth capability. Similarly, the Wi-Fi Networks item appears only if the Raspberry Pi computer has Wi-Fi capability.

- *Wi-Fi Networks*: This pop-up menu enables you to connect the Raspberry Pi computer to available Wi-Fi networks. You can also quickly display brief information about the computer's network connections, such as the IP (Internet Protocol) address (if any) assigned to the Ethernet port.

- *Volume*: This pop-up panel lets you adjust the volume or mute the sound entirely. You can switch output devices by right-clicking the Volume icon and then clicking the appropriate output device on the shortcut menu—for example, HDMI or Analog.

- *CPU Usage Monitor*: This readout gives you a quick indication of how hard the CPU is working. You can display either the histogram and the CPU percentage or just the histogram.

- *Digital Clock*: This applet displays the time and gives quick access to the date picker.

- *Ejecter*: This applet enables you to eject connected drives, including the SD card from which the Raspberry Pi computer is running.

- *Desktop wallpaper*: The desktop wallpaper provides a backdrop for your work onscreen. You can change the image for the desktop wallpaper, configure how the image appears, or use only a background color.

- *Trash icon*: The Trash icon gives you instant access to the Trash folder, which contains files you have deleted but that the file system has not yet removed.

■ **Note**   Depending on the localization, the Trash icon may have a different name, such as Wastebasket.

We'll come back to the desktop in the section "Configuring and Navigating the Desktop," later in this chapter. For now, let's make sure your pointing device, keyboard, and network connection are configured to your satisfaction.

Configuring the Pointing Device, Keyboard, and Network Connection

To explore your Raspberry Pi's system, you'll need to have your pointing device and keyboard in working order. To access network resources or the Internet, you'll need to have a working network connection. In this section, we'll look at how to configure these three items.

Configuring the Pointing Device and the Keyboard

If the pointing device—mouse, trackpad, or whatever—and the keyboard are working to your satisfaction, skip this section. Otherwise, take a minute to configure the pointing device and the keyboard.

Opening the Mouse and Keyboard Settings Dialog Box

Follow these steps to open the Mouse and Keyboard Settings dialog box:

1. Click the Menu button to display the menu.

2. Highlight the Preferences item to display the Preferences submenu.

3. Click the Mouse and Keyboard Settings item to display the Mouse and Keyboard Settings dialog box.

Configuring the Pointing Device

The Mouse and Keyboard Settings dialog box has two tabs, the Mouse tab (which appears first) and the Keyboard tab. Figure 4-4 shows the Mouse tab.
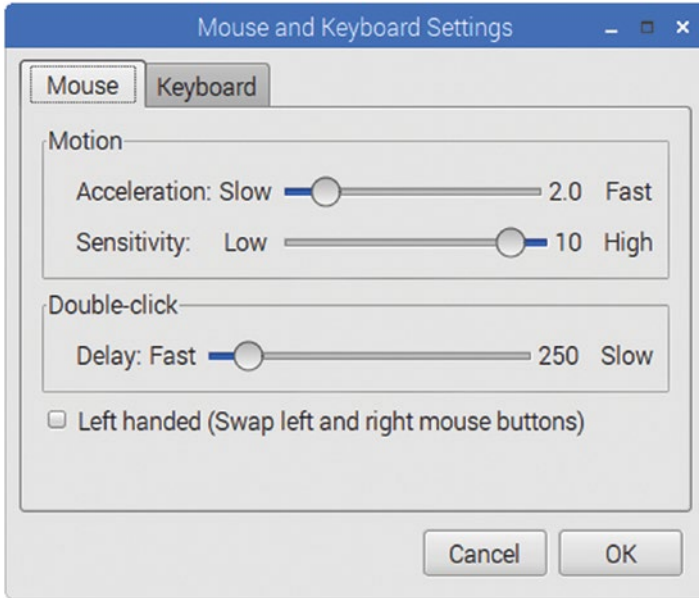
Figure 4-4. *On the Mouse tab of the Mouse and Keyboard Settings dialog box, you can configure pointer acceleration, pointer sensitivity, and the double-click speed. You can also swap the left and right mouse buttons.*

These are the settings you can configure on the Mouse tab:

- *Acceleration*: Drag this slider along the Slow–Fast axis to set the amount of mouse acceleration—how quickly the pointer picks up speed when you start moving the mouse or other pointing device.

- *Sensitivity*: Drag this slider along the Low–High axis to control the mouse sensitivity—how far the pointer moves on the screen when you move the mouse or other pointing device.

- *Delay*: Drag this slider along the Fast–Slow axis to set the double-click speed. The default setting is close to the Fast end.

- *Left handed (Swap left and right mouse buttons)*: Select this check box to swap the logical positions of left and right mouse buttons, as you would do for using the mouse with the left hand instead of the right hand.

Configuring the Keyboard

To configure the keyboard, click the Keyboard tab at the top of the Mouse and Keyboard Settings dialog box. The contents of the Keyboard tab appear (see Figure 4-5), and you can configure the following settings:

- *Repeat delay*: Drag this slider along the Short–Long axis to set the time it takes for the keyboard to start repeating a character when you hold down a key.
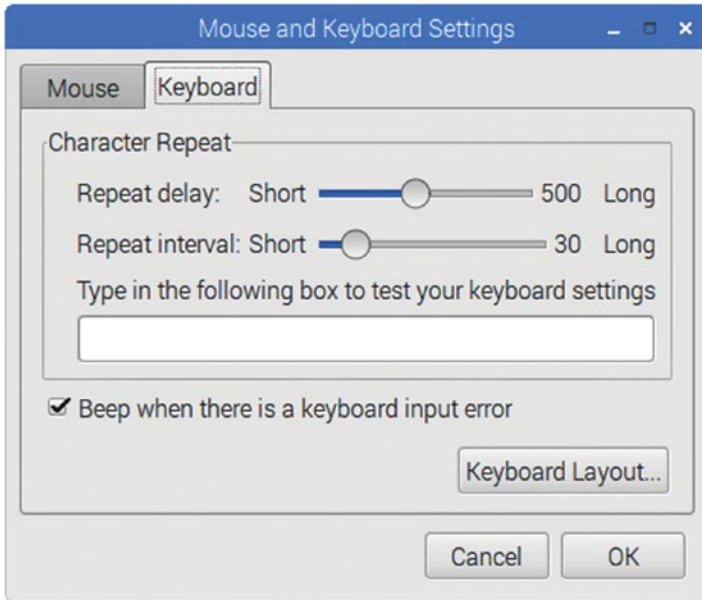
Figure 4-5. *On the Keyboard tab of the Mouse and Keyboard Settings dialog box, you can configure the repeat delay, the repeat interval, and whether the Raspberry Pi computer beeps on keyboard input errors. Click the Keyboard Layout button if you need to change the keyboard layout.*

- *Repeat interval*: Drag this slider along the Short–Long axis to set the interval between repetitions.

- *Test box*: Click in the "Type in the following box to test your keyboard settings" box and try holding down keys to make sure the repeat settings are set to your liking.

- *Beep when there is a keyboard input error*: Select this check box if you want the Raspberry Pi computer to beep when a keyboard input error occurs.

- *Keyboard Layout*: Click this button to display the Keyboard Layout dialog box (see Figure 4-6). You can then choose your country or region in the Country box on the left and the keyboard layout in the Variant box on the right. For example, you might select the United States item in the Country list and the English (Dvorak) item in the Variant list if you use U.S. English with the Dvorak keyboard layout. Click in the test box at the bottom of the dialog box and try typing to test the layout. Click the OK button when you've finished making your choices; the Mouse and Keyboard Settings dialog box then appears again.
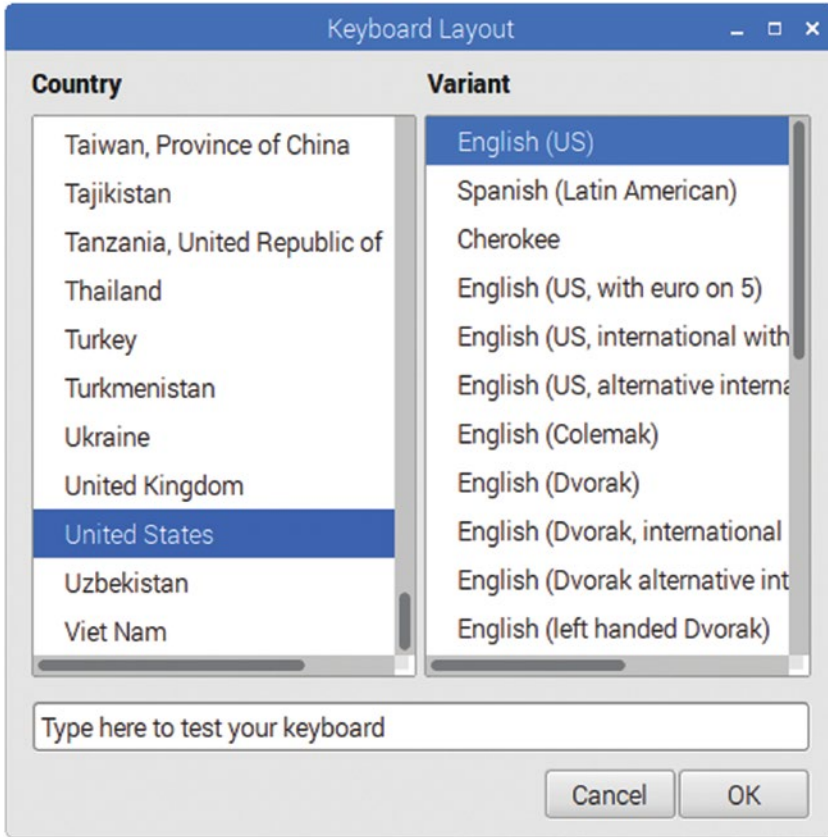
Figure 4-6. *In the Keyboard Layout dialog box, select your country or region, and then select the keyboard layout you want. Use the test box to test that you've chosen the layout you intended.*

When you finish choosing mouse and keyboard settings, click the OK button to close the Mouse and Keyboard Settings dialog box.

Configuring the Network Connection

Most full-size Raspberry Pi models come with an Ethernet port, enabling you to connect the computer easily to a wired network by plugging an Ethernet cable into the port and into a network switch or router.

If you need to connect to a wireless network instead, you can use the built-in Wi-Fi on the Raspberry Pi 3 Model B or a USB Wi-Fi dongle or adapter connected to another model of Raspberry Pi. Click the Wi-Fi Networks icon on the panel to display the list of available wireless networks (see Figure 4-7), and then click the network to which you want to connect.
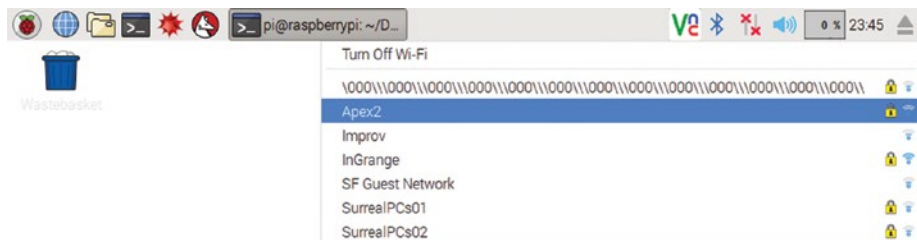
Figure 4-7. To connect to a Wi-Fi network, click the Wi-Fi Networks icon and then click the appropriate network on the list.

If the Wi-Fi network requires a password, a dialog box opens, showing the network's name in its title bar (see Figure 4-8). Type the password in the Pre Shared Key box, and then click the OK button.
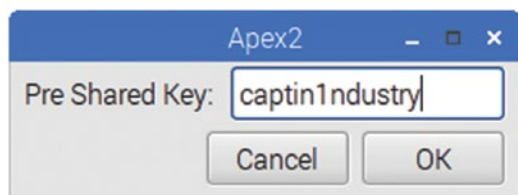
Figure 4-8. Type the password for the wireless network in this dialog box, whose title bar shows the network's name, and then click the OK button.

When the Raspberry Pi computer has connected to the Wi-Fi network, you can hold the pointer over the Wi-Fi Networks icon on the panel to see the network's status, including the name of the connected Wi-Fi network and the IP address and subnet mask the Raspberry Pi computer is using (see Figure 4-9). The *subnet mask* is a number (24 in this case) that determines to which subnet on the network the IP address belongs.
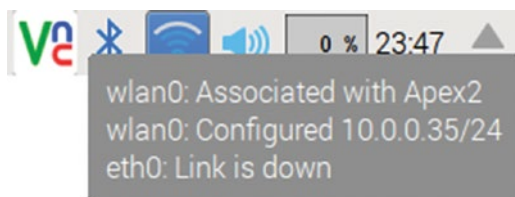
Figure 4-9. You can view the Wi-Fi network name and the network address of the Wi-Fi adapter by holding the pointer over the Wi-Fi Networks icon on the panel.

Understanding DHCP

A default installation of Raspbian comes set to get network settings via Dynamic Host Configuration Protocol (DHCP), so if your network uses DHCP, your Raspberry Pi computer should have automatically acquired an IP address and set the network mask and gateway.

■ **Note**   Dynamic Host Configuration Protocol (DHCP) is a network protocol for assigning IP addresses automatically to computers and devices on a network. Briefly, when a computer or device set to use DHCP tries to connect to a network, it requests an IP address and other network configuration settings from a DHCP server and then starts using that IP address and settings. The DHCP server maintains a pool of IP addresses, assigning them to clients on request and reclaiming IP addresses that clients have stopped using. By using DHCP, you save time and effort over having to set IP addresses manually.

Assigning a Static IP Address to a Raspberry Pi Computer

Instead of using DHCP to request an IP address dynamically from the DHCP server's pool, you can assign a static IP address to the Raspberry Pi. You would need to assign a static IP address if your network doesn't use DHCP, but you might also want to assign a static IP address to make sure that the Raspberry Pi always has the same IP address.

You can specify a static IP address either by working in the Network Preferences pane or by editing the DHCP configuration file in a text editor. I'll show you both methods because whereas the Network Preferences pane is usually the easier method, you can edit the DHCP configuration file from a command prompt, including via SSH, which is often useful.

Before you start, make sure you know the network information you'll need:

- *IP address for the Raspberry Pi computer*: This is an IP address in the appropriate address block, such as 10.0.0.99 or 192.168.1.101.

- *Router address*: You'll need the IP address of the router unless you set the computer to detect it.

- *DNS server address*: You'll also need the IP address of the DNS server unless you set the computer to detect it.

Follow these steps to specify a static IP address using the Network Preferences pane:

1. Right-click the Wi-Fi Networks icon on the panel to display the shortcut menu.

2. Click the WiFi Networks (dhcpcdui) Settings item to display the Network Preferences dialog box (shown in Figure 4-10 with some settings chosen).
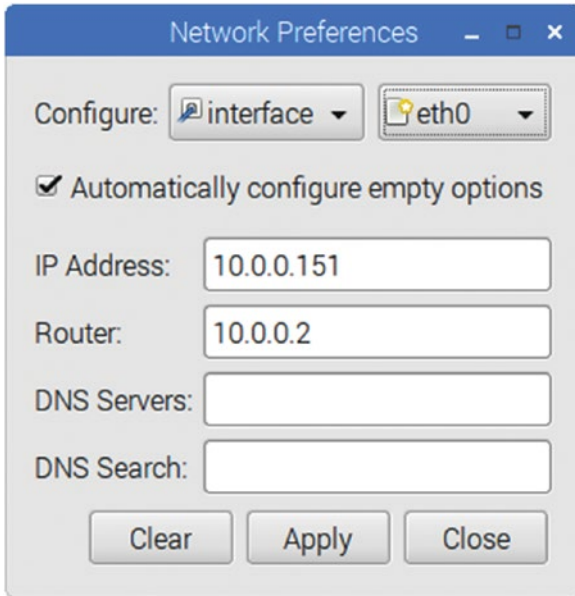
Figure 4-10. *Use the Network Preferences dialog box to set a static IP address for a Raspberry Pi computer. You can specify the router address and DNS (domain name system) server addresses, plus any DNS search domains needed. Select the "Automatically configure empty options" check box to have Raspbian detect settings for any fields you leave blank.*

3. On the Configure row, make sure the left pop-up menu shows Interface rather than SSID (Service Set Identifier).

4. Still on the Configure row, click the right pop-up menu and choose the interface you want to configure. Choose eth0 for Ethernet; choose wlan0 for Wi-Fi.

5. If necessary, click the Clear button to clear the current configuration details.

6. Check the "Automatically configure empty options" check box if you want Raspbian to automatically detect values for network parameters you don't specify.

7. In the IP Address box, type the static IP address you want to assign the computer. Leave this box blank if you want the computer to get an IP address via DHCP.

8. In the Router box, type the IP address for the router. Leave this box blank if you want the computer to get the router's address via DHCP.

9. In the DNS Servers box, type the list of DNS servers the computer is to use. Put the primary server's address first and the secondary server's address second, separated by a comma. Here, too, you can leave the box blank if you want the computer to get this information via DHCP.

10. In the DNS Search box, type any search domain you want to have automatically appended for DNS lookups. For example, you might enter your school's domain here to cause any unqualified searches to be run using that domain.

11. Click the Apply button to apply your changes.

12. Click the Close button to close the Network Preferences dialog box.

To make your changes take effect, you need to restart the Raspberry Pi computer. To do so, choose Menu ➤ Shutdown to display the Shutdown Options dialog box, and then click the Reboot button.

To specify a static IP address for a Raspberry Pi computer by editing the DHCP configuration file, follow these steps:

1. Get to a command prompt on the Raspberry Pi computer. For example

    • Click the Terminal button on the panel at the top of the screen to open a new Terminal window.

    • Boot the Raspberry Pi computer to a command line.

    • Connect to the Raspberry Pi computer via SSH. See the section "Setting Up Remote Access" in Chapter 7 for information on connecting via SSH.

2. Type the following command and press the Enter key:

```
sudo nano /etc/dhcpcd.conf
```

■ **Note**   This example uses the nano text editor, but you can use a different text editor if you want. For example, if you prefer the vi editor, give the `vi` command instead in the Terminal window: `sudo vi /etc/dhcpcd.conf`.

---

3. In the GNU nano window that opens, press the Page Down key a couple of times to scroll to the end of the file.

4. For good form, add a comment line explaining the change you're making:

```
# Set a static IP address for this Raspberry Pi
```

■ **Note**   A pound sign (#) followed by a space at the beginning of a line makes the line a comment.

---

5.   Add an `interface` line specifying the Ethernet network interface:

```
 interface eth0
```

■ **Note**   To set a static IP address for Wi-Fi, use `interface wlan0` instead of `interface eth0`.

---

6.   Add a `static ip_address` line specifying the IP address:

```
static ip_address=10.0.0.99/24
```

■ **Note**   The `/24` parameter specifies that the first three octets of the IP address (such as `10.0.0` or `192.168.1`) are common to the IP addresses on the network. This has the same effect as setting a subnet mask of `255.255.255.0`. This is the most widely used subnet mask, but you may need a different one. Use `/16` for the subnet mask `255.255.0.0`; use `/8` for the subnet mask `255.0.0.0`; for other subnet masks, use a subnet mask converter such as the one at www.subnetmask.info.

---

7.   Add a `static routers` line giving the router's IP address:

```
static routers=10.0.0.2
```

8.   Add a `static domain_name_servers` line giving the DNS server's IP address:

```
static domain_name_servers=10.0.0.2
```

9.   Press Ctrl+O to give the command to "write out" the file. The nano editor prompts you for the name.

10.   Press the Enter key to accept the existing name.

11.   Press Ctrl+X to exit from the nano editor.

Now restart the Raspberry Pi computer in one of these ways:

- *GUI*: Click the Menu button, click Shutdown on the main menu, and then click the Reboot button in the Shutdown Options dialog box.

- *Command line or SSH*: Give the `shutdown -r now` command.

After the Raspberry Pi computer restarts, verify the IP address by holding the pointer over the Wi-Fi Networks icon on the panel and looking at the information in the pop-up balloon (see Figure 4-11).
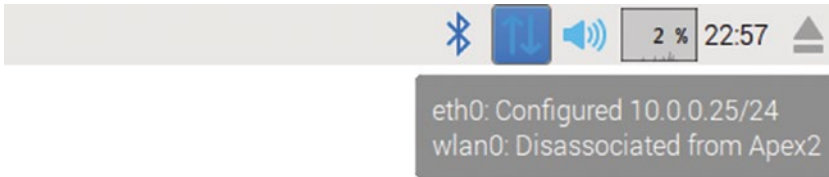
Figure 4-11. *Hold the pointer over the Wi-Fi Networks icon on the panel to display the IP addresses and subnet masks for the Ethernet (eth0) and Wi-Fi (wlan0) interfaces.*

Configuring a Raspberry Pi Computer

Raspbian includes a graphical tool called Raspberry Pi Configuration for changing key settings including boot options, interface settings, and performance settings.

To open the Raspberry Pi Configuration tool, follow these steps:

1. Click the Menu button to display the menu.

2. Click or highlight Preferences to open the submenu.

3. Click the Raspberry Pi Configuration item. The Raspberry Pi Configuration dialog box opens.

■ **Note** The Raspberry Pi Configuration tool supersedes the `raspi-config` script, which enables you to make the same suite of changes. If you want to look at `raspi-config`, click the Terminal button on the Application Launch Bar to open a Terminal window, type the command `sudo raspi-config`, and then press the Enter key.

Choosing Settings on the System Tab

On the System tab of the Raspberry Pi Configuration dialog box (see Figure 4-12), you can choose the following settings:

- *Expand Filesystem*: If this button is available, you can click it to expand the file system to occupy as much of the SD card as possible. If the file system is already expanded, as will be the case if you've used the NOOBS installer, this button will be dimmed and unavailable.
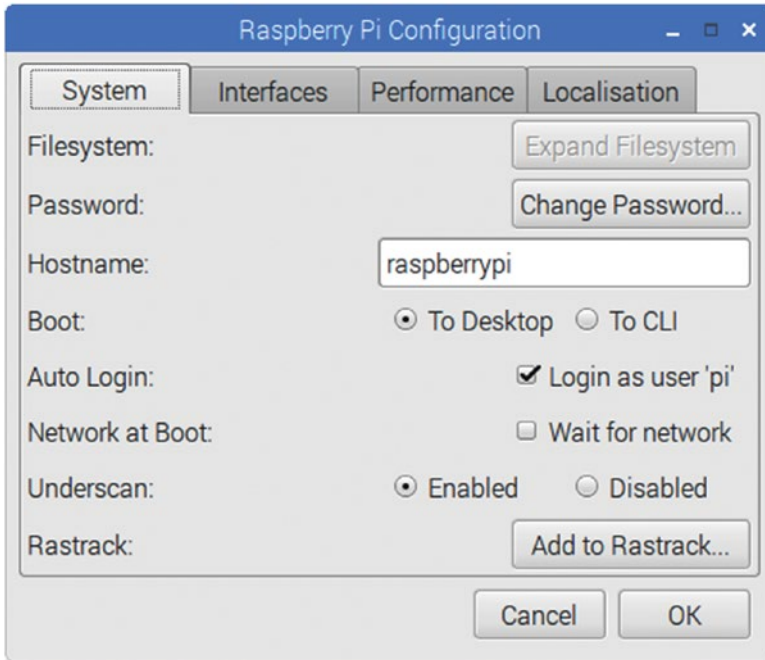
Figure 4-12. *On the System tab of the Raspberry Pi Configuration dialog box, you can take various actions including changing your password, setting the Raspberry Pi computer's hostname, and configuring boot options.*

- *Change Password*: Click this button to change the login password for the account you're logged into.

- *Hostname.* To change the hostname, type the new name in this box.

- *Boot.* Select the To Desktop option button if you want the Raspberry Pi computer to boot to the graphical interface. Select the To CLI (command-line interface) option button if you want the computer to boot to the CLI instead.

- *Auto Login*: Select the "Login as user 'pi'" check box if you want the Raspberry Pi computer to automatically log you in using the pi account. Logging in automatically works with either the graphical interface or the CLI.

- *Network at Boot*: Select the "Wait for network" check box if you want the Raspberry Pi computer to wait until it detects a network connection before it boots. Clear the check box to have the computer go ahead and boot even if a network connection isn't available.

- *Underscan*: Select the Enable option button if you want to use the underscan feature; otherwise, select the Disable feature. If your display doesn't fit exactly on the screen, try enabling underscan to see if it solves the problem.

- *Rastrack.* If you want to add this Raspberry Pi computer to the list at the Rastrack web site (www.rastrack.co.uk), which maintains a map of where Raspberry Pi computers are being used around the world. This isn't a formal registration process. As of this writing, Rastrack is no longer running.

Choosing Settings on the Interfaces Tab

On the Interfaces tab of the Raspberry Pi Configuration dialog box (see Figure 4-13), you can enable or disable the following interfaces by selecting the Enable option button or the Disable option button:

- *Camera*: This is the interface to which you can connect a Raspberry Pi Camera module for graphical input.
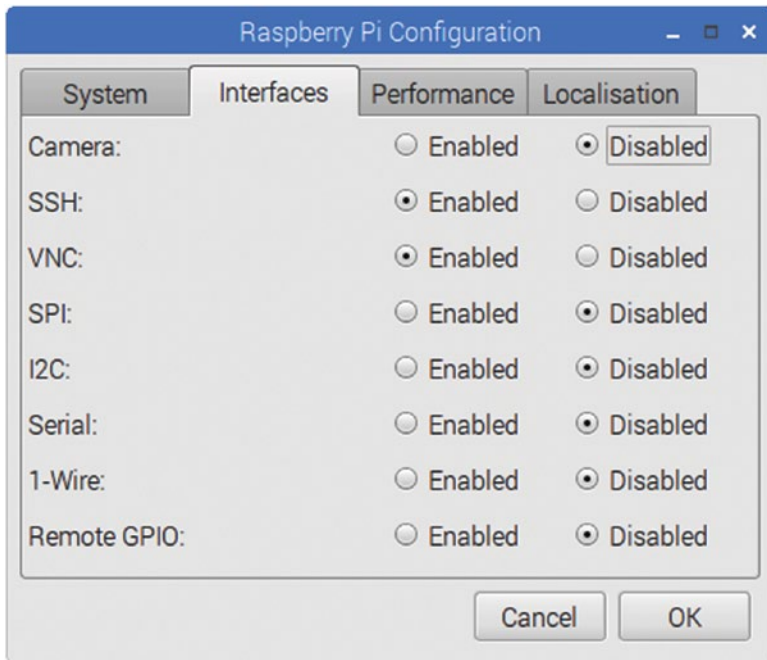
Figure 4-13. *On the Interfaces tab of the Raspberry Pi Configuration dialog box, you can enable or disable interfaces such as the Camera, the Serial interface, and the Remote GPIO.*

- *SSH*: This interface enables you to connect remotely to a Raspberry Pi via the Secure Shell (SSH) protocol.

- *VNC*: This interface enables you to connect remotely to a Raspberry Pi computer via the built-in VNC server.

- *SPI*: The Serial Peripheral Interface (SPI) is one of the three serial interfaces on the GPIO pins.

- *I2C*: The Inter-Integrated-Circuit (I2C) bus is another of the three serial interfaces on the GPIO pins.

- *Serial*: The serial port is the third of the three serial interfaces on the GPIO pins.

- *1-Wire*: The 1-Wire is another interface on the GPIO pins. As its name suggests, it receives input along a single wire.

- *Remote GPIO*: This interface enables you to access the GPIO remotely.

Choosing Settings on the Performance Tab

On the Performance tab of the Raspberry Pi Configuration dialog box (see Figure 4-14), you can adjust the amount of memory assigned to the graphics processing unit by changing the value in the GPU Memory box. The default setting is 64 MB, but you may be able to improve graphics performance by increasing the amount of memory. Assigning more memory to the GPU reduces the amount of memory available for other tasks by the same amount.

On some Raspberry Pi models, you can overclock the processor by changing the setting in the Overclock pop-up menu. On other Raspberry Pi models, such as the one posing for this screenshot, you cannot overclock the processor.

◼ **Note** The maximum amount of GPU memory for a Raspberry Pi model with 1 GB of RAM is 944 MB; for a Raspberry Pi model with 512 MB of RAM, the GPU maximum is 448; and for a Raspberry Pi model with 256 MB of RAM, the GPU maximum is 192 MB.
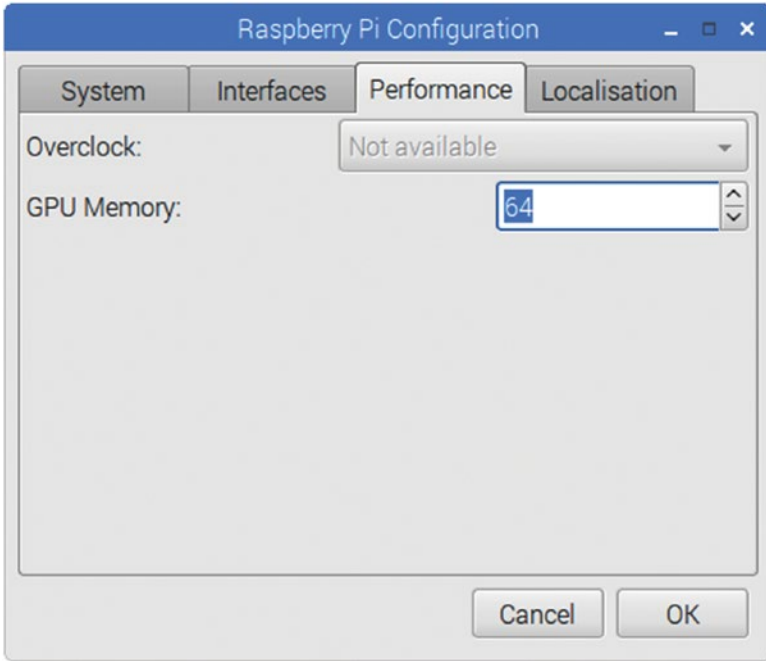
Figure 4-14. *On the Performance tab of the Raspberry Pi Configuration dialog box, you can adjust the amount of graphics memory. You can also overclock some Raspberry Pi models.*

Choosing Settings on the Localisation Tab

From the Localisation tab of the Raspberry Pi Configuration dialog box (see Figure 4-15), you can change the Locale, the Timezone, and the WiFi Country.
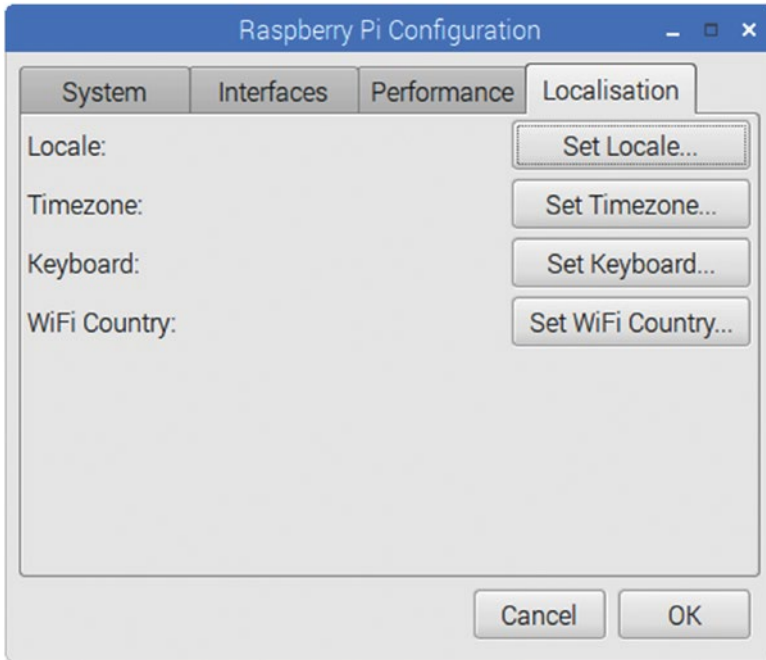
Figure 4-15. *From the Localisation tab of the Raspberry Pi Configuration dialog box, you can set the Locale, the Timezone, the Keyboard layout, and the WiFi Country.*

Changing the Locale

You can change the locale, which controls language and country settings, by clicking the Locale button on the Localisation tab of the Raspberry Pi Configuration dialog box and then working in the Locale dialog box (see Figure 4-16). Here, you can change three settings:

- *Language*: Choose the language, such as en (English) or es (Spanish).

- *Country*: Choose the country, such as US (USA).

- *Character Set*: Choose the character set, such as UTF-8 (Unicode Transformation Format in 8-bit blocks).

When you finish, click the OK button to close the Locale dialog box.
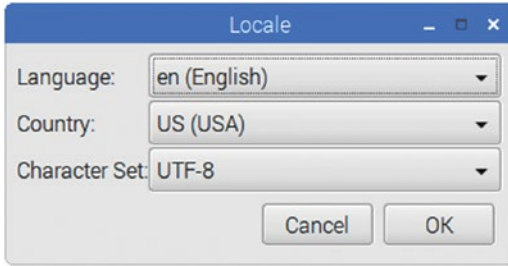
Figure 4-16. *In the Locale dialog box, select the Language, Country, and Character Set for the Raspberry Pi computer to use.*

Changing the Time Zone

You can change the time zone by clicking the Set Timezone button on the Localisation tab of the Raspberry Pi Configuration dialog box, choosing the area and location in the Timezone dialog box (see Figure 4-17), and then clicking the OK button.
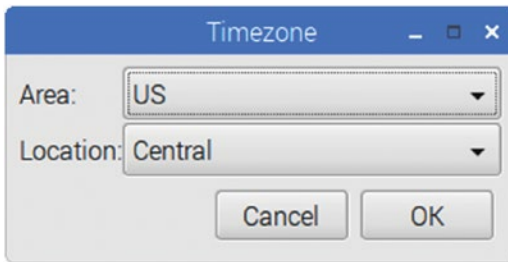
Figure 4-17. *In the Timezone dialog box, select the area (such as US) and location (such as Pacific).*

Changing the Keyboard Layout

You can change the keyboard layout by clicking the Set Keyboard button on the Localisation tab of the Raspberry Pi Configuration dialog box and then working in the Keyboard Layout dialog box.

As you saw in the section "Configuring the Keyboard," earlier in this chapter, you can also reach the Keyboard Layout dialog box from the Mouse and Keyboard Settings dialog box.

Changing the Wi-Fi Country

You can change the Wi-Fi country by clicking the WiFi Country button on the Localisation tab of the Raspberry Pi Configuration dialog box, selecting the country in the Country pop-up menu in the WiFi Country Code dialog box (see Figure 4-18), and then clicking the OK button.

Figure 4-18. *Use the WiFi Country Code dialog box to set the Wi-Fi standard that the Raspberry Pi is using.*

■ **Note** Different countries have different standards for Wi-Fi hardware. For example, some countries allow higher transmitting power than others do.

Configuring and Navigating the Desktop

In this section, we'll look at how to configure and navigate the Raspberry Pi desktop and the file system. This includes how to run apps, how to manage windows, and how to extend your desktop beyond your physical screen space by using multiple desktops.

Configuring Desktop Preferences

To make the desktop look and work the way you prefer, you can set desktop preferences. The desktop preferences available range from appearance preferences, such as the background color and wallpaper, to advanced preferences that control the way folders open and the location of the desktop folder.

Opening the Desktop Preferences Dialog Box

To start configuring desktop preferences, open the Desktop Preferences dialog box in one of these ways:

- Right-click the desktop and click the Desktop Preferences item on the shortcut menu (see Figure 4-19).
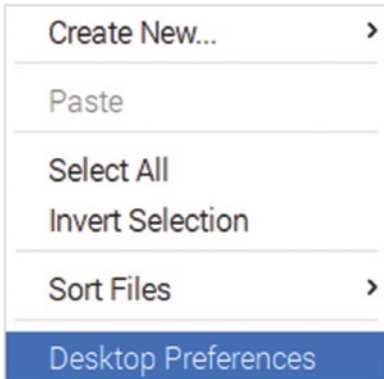
Figure 4-19. *Display the desktop shortcut menu and click the Desktop Preferences item to open the Desktop Preferences dialog box.*

- Click the Menu button to open the main menu, click or highlight the Preferences item, and then click the Desktop Preferences item on the submenu.

■ **Note**   The first method of opening the Desktop Preferences dialog box is available only if you have not selected the Show menus provided by window managers when the desktop is clicked check box. The second method is available only if you have added Desktop Preferences to the Preferences submenu.

Choosing Appearance Preferences

As you can see in Figure 4-20, the Desktop Preferences dialog box has three tabs, of which the first is Appearance. Here you can configure the following settings:

- *Wallpaper mode*: Choose whether to use wallpaper and (if so) how to display it. Your choices are the following:

  - *Fill with background color only:* Use the Background color control to pick the color you want.

  - *Stretch to fill the entire monitor area*: This setting distorts the image so as to fill the screen. This can work well for images that show patterns.

  - *Stretch to fill the monitor area*: This setting enlarges the image so that it takes up the full height or width of the screen (depending on which dimension is closer to the screen size).

  - *Center unscaled image on the monitor*: This setting displays the image at its full size in the middle of the monitor.

- *Tile the image to fill the entire monitor area*: This setting displays as many instances of the image as are needed to fill the entire monitor area.

- *Stretch and crop to fill the monitor area*: This setting stretches the image by the amount needed to make the dimension that is further from the screen's size match the screen's size and then crops off the excess parts in the other dimension.

- *Stretch to fill the entire screen*: This setting has the same effect as the Stretch to fill the entire monitor area setting, distorting the image so that both its dimensions fit the screen.

- *Wallpaper*: Click this button to display the Please Select an Image File dialog box, select the image file, and click the Open button.

- *Use the same wallpaper on all desktops*: Select this check box to make the Raspberry Pi display the same wallpaper on each desktop. Clear this check box if you want to be able to configure each desktop differently—for example, to make the desktops easier to recognize.

- *Background color*: Click this control to display the Pick a Color dialog box, use the controls to select the background color, and then click the OK button.
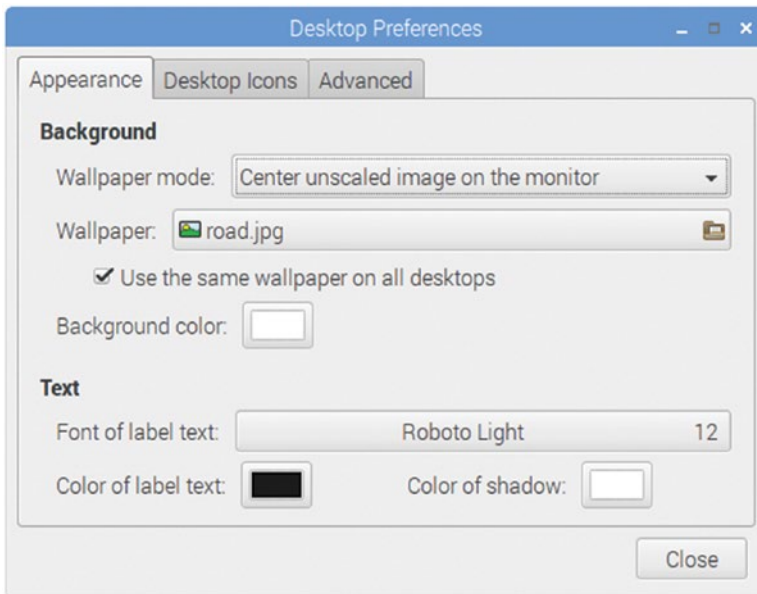
Figure 4-20. *On the Appearance tab of the Desktop Preferences dialog box, you can configure the desktop background and choose the font, its color, and its shadow color.*

- *Label text Font*: Click this button to display the Pick a Font dialog box; select the font family, font style, and font size; and then click the OK button.

- *Label text Color*: Click this control to display the Pick a Color dialog box, use the controls to select the text color, and then click the OK button.

- *Shadow Color*: Click this control to display the Pick a Color dialog box, use the controls to select the shadow color, and then click the OK button.

Choosing Desktop Icons Preferences

On the Desktop Icons tab in the Desktop Preferences, you can choose whether to display icons on the desktop for key system folders and volumes. Figure 4-21 shows the Desktop Icons tab with its three check boxes selected, together with the desktop icons that appear as a result. (The number and names of icons displayed for connected volumes depends on the configuration of the Raspberry Pi's SD card.)
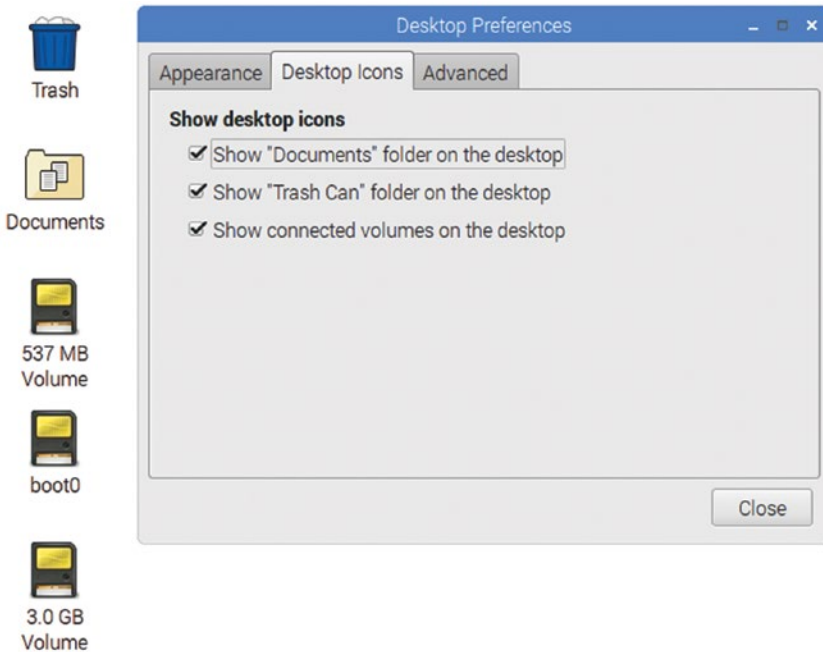
Figure 4-21. *On the Desktop Icons tab of the Desktop Preferences dialog box, select the check boxes for the icons you want to show. The icons for connected volumes include the volumes on the Raspberry Pi's SD card.*

These are the three check boxes:

- *Show "Documents" folder on the desktop*: The Documents icon gives you quick access to the Documents folder in your user account, the folder in which many apps are set by default to save files you create.

- *Show "Trash Can" folder on the desktop*: The Trash icon (the name varies depending on the localization) gives you direct access to the trash folder, which contains files that you've deleted but that the operating system hasn't yet removed from the file system. You can recover files from the trash folder if necessary.

■ **Tip**   If you display the Trash icon on the desktop, you can drag files to the Trash icon to put them in the trash.

- *Show connected volumes on the desktop*: Connected volumes include the volume or volumes on the Raspberry Pi's SD card, any drives connected directly to the computer (such as USB drives or DVD drives), and network drives.

Choosing Advanced Preferences

The Advanced tab of the Desktop Preferences dialog box (see Figure 4-22) contains only a few options, but they're ones that can make a big difference. These are the options:

- *Show menus provided by window managers when desktop is clicked*: Select this check box to make right-clicking the desktop display shortcut menus provided by window managers rather than the default shortcut menus. This check box is cleared by default, but you may want to select it so that you can use multiple desktops. See the section "Understanding and Using Multiple Desktops," later in this chapter, for more information.
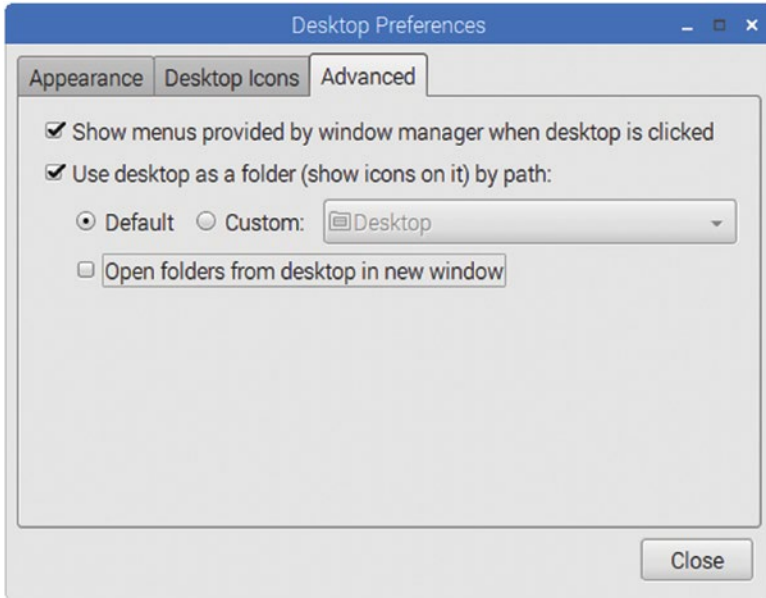
Figure 4-22. *On the Advanced tab of the Desktop Preferences dialog box, choose whether to make the desktop show menus provided by window manager and whether to use the desktop as a folder.*

- *Use desktop as a folder (show icons on it) by path*: Select this check box if you want to be able to display icons on the desktop. Displaying icons on the desktop is the default setting, and many people find it useful. Assuming you select this check box (or leave it selected), you can use the two rows of controls below it to make further desktop choices; if you clear this check box, the two rows of controls are dimmed and unavailable.

- *Default*: Select this option button to use the default location for the desktop folder. This is the Desktop folder in your user account.

- *Custom*: Select this option button if you want to use a different folder for the desktop folder. Click the pop-up menu and select the folder.

- *Open folders from desktop in new window*: Select this check box if you want folders you open from the desktop to open in new File Manager windows rather than in a File Manager window that is already open.

Configuring the Panel

You can configure the panel to make it appear the way you want and display the items you need in the arrangement you prefer.

To start configuring the panel, right-click the Menu button to display the shortcut menu, and then click the Panel Settings item to open the Panel Preferences dialog box. This dialog box has four tabs: Geometry, Appearance, Panel Applets, and Advanced.

Configuring Geometry Preferences

The controls on the Geometry tab of the Panel Preferences dialog box (see Figure 4-23) enable you to control where the panel appears and how big it is.

These are the preferences you can choose in the Position area:

- *Edge*. Select the Bottom option button, the Top option button (the default), the Left option button, or the Right option button to specify which edge of the screen the panel appears on.

- *Alignment*. If you positioned the panel at the top or bottom of the screen, select the Left option button, the Center option button, or the Right option button to set the alignment. If you positioned the panel at the left side or right side of the screen, select the Top option button, the Center option button, or the Bottom option button to set the alignment.

- *Margin*: If you want a margin between the panel and the edge of the screen, set the number of pixels for the margin in this box.

- *Monitor*: If you have multiple monitors (which is difficult with a Raspberry Pi computer), you can choose the monitor on which the panel appears.
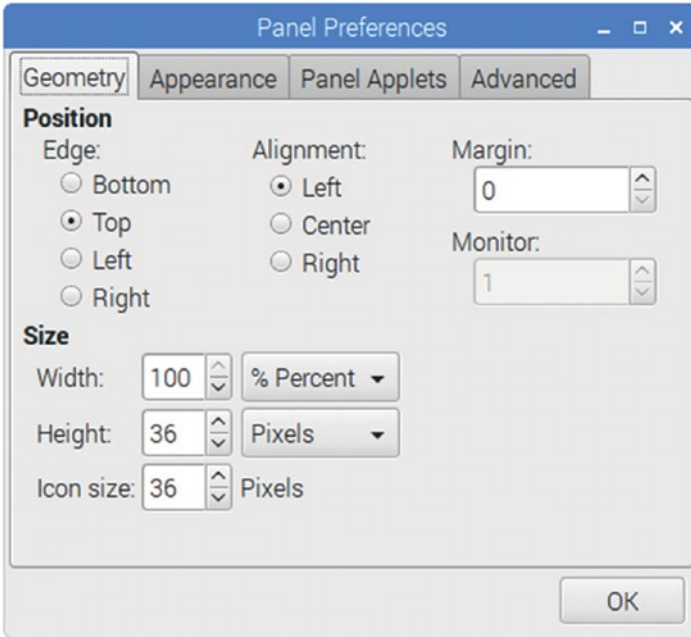
Figure 4-23. *On the Geometry tab of the Panel Preferences dialog box, you can control the position and size of the panel.*

These are the preferences you can choose in the Size area of the Geometry tab:

- *Width*: If you positioned the panel at the top or bottom of the screen, use the spin box and pop-up menu to set the width of the panel. Choosing 100 in the spin box and % Percent in the pop-up menu makes the panel take up the full width of the screen, which is usually the most efficient arrangement. You can choose Pixels or Dynamic in the pop-up menu instead of % Percent. If you positioned the panel at the left side or right side of the screen, set the width in pixels.

- *Height*: If you positioned the panel at the left side or right side of the screen, use the spin box and pop-up menu to set the height of the panel. Here, too, you may find it most efficient to choose 100 in the spin box and % Percent in the pop-up menu. You can choose Pixels or Dynamic in the pop-up menu instead of % Percent. If you positioned the panel at the top or bottom of the screen, set the height in pixels.

- *Icon size*: Set the Icon size in pixels.

Configuring Appearance Preferences

The preferences on the Appearance tab of the Panel Preferences dialog box (see Figure 4-24) allow you to configure the panel background and font.

In the Background area, select the System theme option button if you want to go with the theme settings. Otherwise, you can select the Solid color (with opacity) option button and click the color swatch to choose the color; or select the Image option button and click the button to select the image to use.
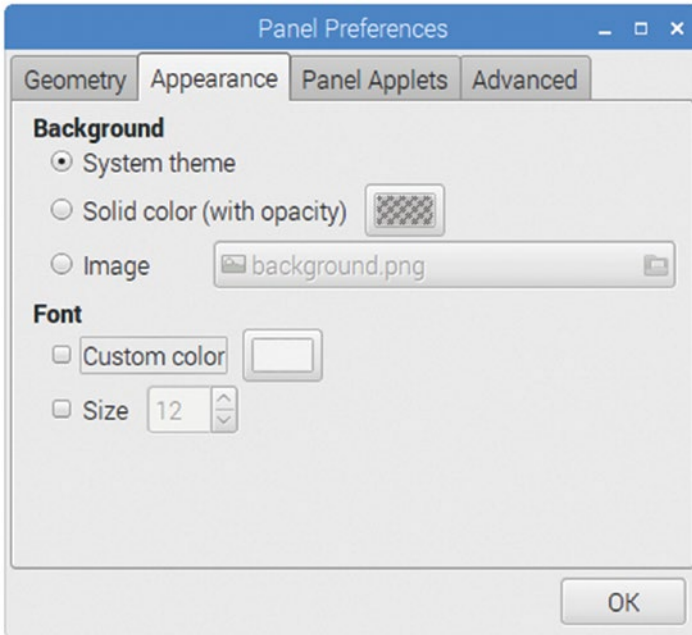
Figure 4-24. *On the Appearance tab of the Panel Preferences dialog box, you can configure the panel Background and Font.*

In the Font area, you can change the font color from the default by selecting the Custom color check box, clicking the color swatch, and then choosing the color. Similarly, you can override the default font size by selecting the Size check box and then setting the font size you want in the spin box.

Configuring Panel Applets Preferences

The Panel Applets tab of the Panel Preferences dialog box (see Figure 4-25) enables you to control which applets appear on the panel. The "Currently loaded plugins" list shows the plug-ins you're currently using; you can click a plug-in and click the Up button or the Down button to move it to a different place on the panel.
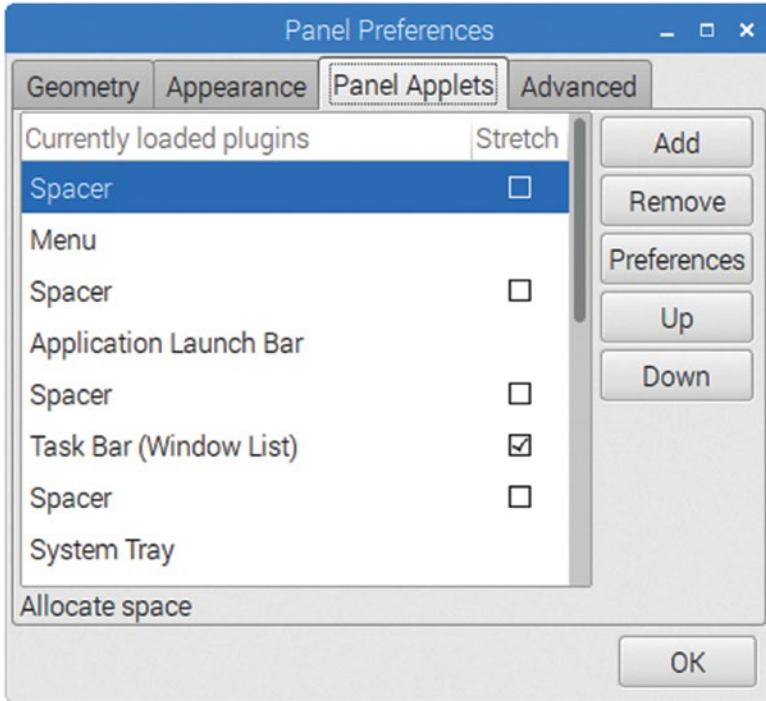
Figure 4-25. *On the Panel Applets tab of the Panel Preferences dialog box, load the plug-ins you want to use and rearrange them into your preferred order.*

To add a plug-in, follow these steps:

1. Click the Add button on the Panel Applets tab of the Panel Preferences dialog box to open the "Add plugin to panel" dialog box (see Figure 4-26).
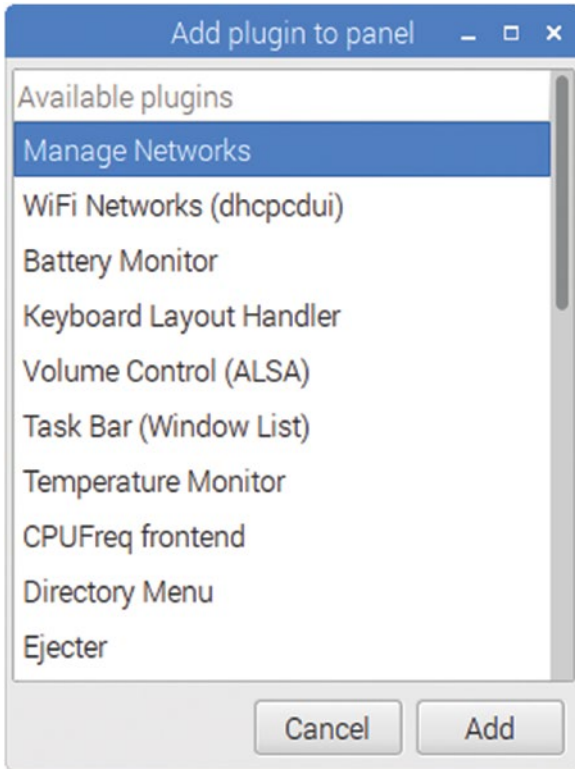
Figure 4-26. *Use the "Add plugin to panel" dialog box to add a plug-in to the panel.*

2. In the "Available plugins" list, select the plug-in you want to add to the panel.

3. Click the Add button. The plug-in appears in the "Currently loaded plugins" list on the Panel Applets tab, and you can move it up or down as needed.

Configuring Advanced Preferences

On the Advanced tab of the Panel Preferences dialog box (see Figure 4-27), you can configure the following settings:

- *File Manager*: You can click this pop-up menu and then click the Customize button to choose a different file manager than the default one.

- *Terminal Emulator*: You can type the terminal emulator you want to use.
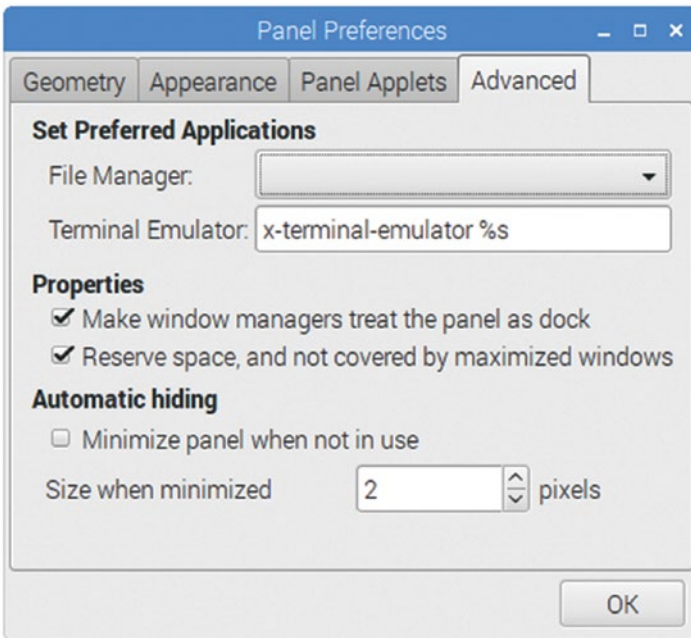
Figure 4-27. *On the Advanced tab of the Panel Preferences dialog box, you can set your preferred file manager and terminal emulator, set advanced properties, and make the panel hide itself when you're not using it.*

- *Make window managers treat the panel as dock*: Select this check box (as it is by default) to make window-management apps use the panel as a dock for storing app buttons.

- *Reserve space, and not covered by maximized windows*: Select this check box to prevent maximized windows from overlapping and hiding the panel.

- *Minimize panel when not in use*: Select this check box if you want the panel to hide itself when you're not using it. Move the pointer to the side of the screen where the panel is hiding when you want to display it.

- *Size when minimized*: In this spin box, set the number of pixels you want the panel to occupy when it is minimized.

Configuring the Task Bar

You can configure the task bar to make it look and behave the way you prefer. Right-click open space in the task bar and then click the Task Bar (Window List) settings item to display the Task Bar (Window List) dialog box (see Figure 4-28). You can then configure the following settings:

- *Show tooltips*: Select this check box to make the task bar display tooltips (little pop-up balloons) when you hold the pointer over items on it.

- *Icons only*: Select this check box to make the task bar display only an icon for each window, without any text. This setting can be handy when you're short of space onscreen, but it makes the window icons inscrutable.
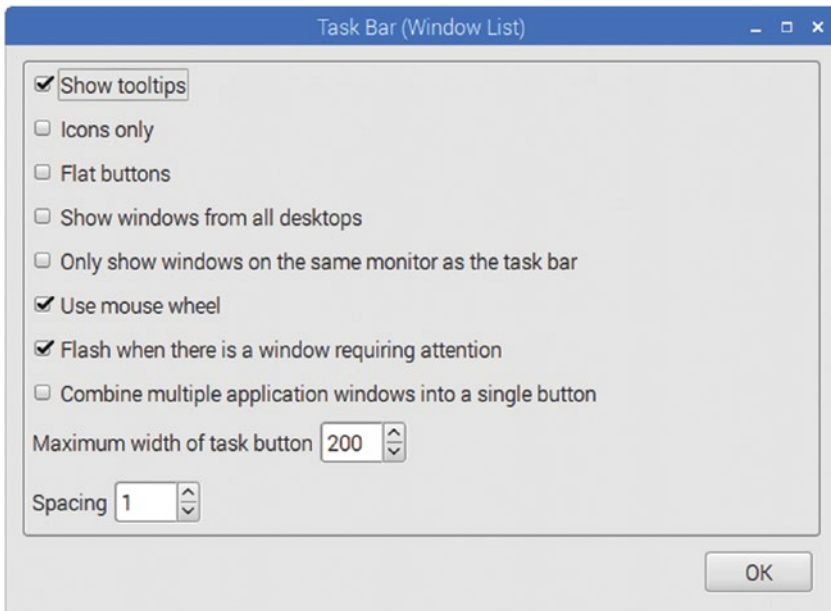
Figure 4-28. *The Task Bar (Windows List) dialog box enables you to control how the task bar looks and behaves.*

- *Flat buttons*: Select this check box if you want the task bar to display buttons with a flat look rather than a raised look.

- *Show windows from all desktops*: Select this check box if you want the task bar to display windows from all your desktops instead of just windows from the current desktop. This setting can make navigation quicker, but the task bar becomes busier as a result.

- *Only show windows on the same monitor as the task bar*: In a multimonitor configuration, you can select this check box to make the task bar show only the windows that are on the same monitor as the task bar is on. If your Raspberry Pi computer has only one monitor attached, this setting is moot.

- *Use mouse wheel*: Select this check box if you are using a mouse that has a wheel.

- *Flash when there is any window requiring attention*: Select this check box if you want the task bar to flash to draw your attention to a window that needs input.

- *Combine multiple application windows into a single button*: Select this check box if you want the task bar to display a single button for an app that has multiple windows open; you can then click that single button to display a list of the windows, and then click the window you need. This option is good for saving space on small displays.

- *Maximum width of task button*: In this spin box, set the maximum width in pixels for a button on the task bar.

- *Spacing*: In this spin box, set the spacing you want between the buttons. The default spacing is 1.

Running Apps

Once you're at the desktop, you can run apps. You can quickly launch an app in either of these ways:

- *Application Launch Bar*: If the app's icon appears on the Application Launch Bar, click the icon to launch the app.

- *Main menu*: Click the Menu button to open the menu, click or highlight the appropriate submenu, and then click the app's item. For example, click the Menu button, click or highlight the Office item to display the Office submenu, and then click the LibreOffice Writer item to open the Writer app. As you can see in Figure 4-29, when you hold the pointer over an app's item on the menu, a tooltip appears explaining the app's purpose.
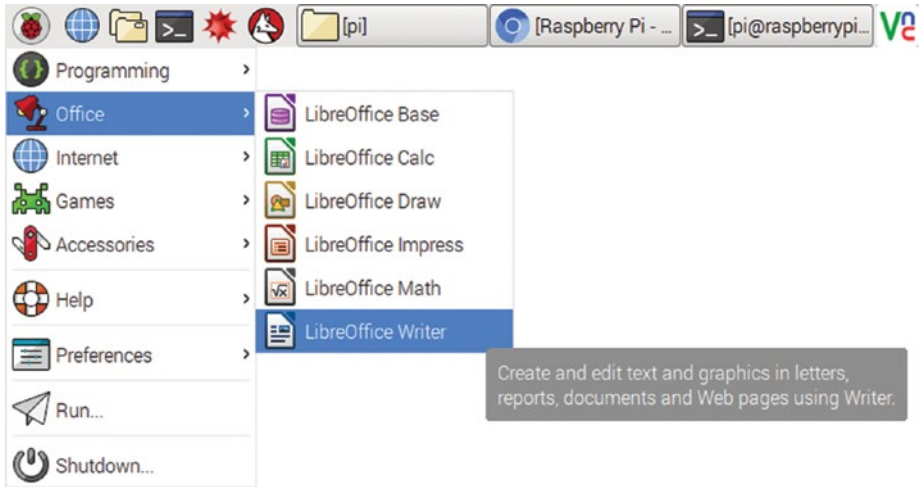
Figure 4-29. *You can run an app by clicking the Menu button, opening the submenu, and then clicking the app's item. Hold the pointer over the app's item to display an explanatory tooltip.*

If the app doesn't appear on the Application Launch Bar or the main menu, you can use the Run dialog box to run the app. Click the Menu button to open the menu, click the Run item to open the Run dialog box (see Figure 4-30), type the app's path and name, and then click the OK button.
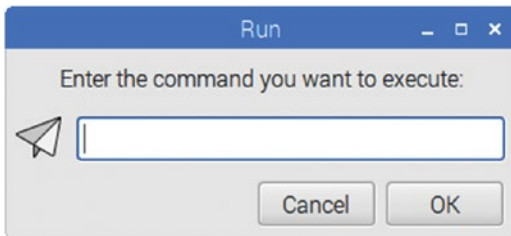
Figure 4-30. *You can use the Run dialog box to run an app that doesn't appear on the Application Launch Bar or the main menu.*

Once the app is open, it typically appears in a window. For example, Figure 4-31 shows an untitled document open in a LibreOffice Writer window.
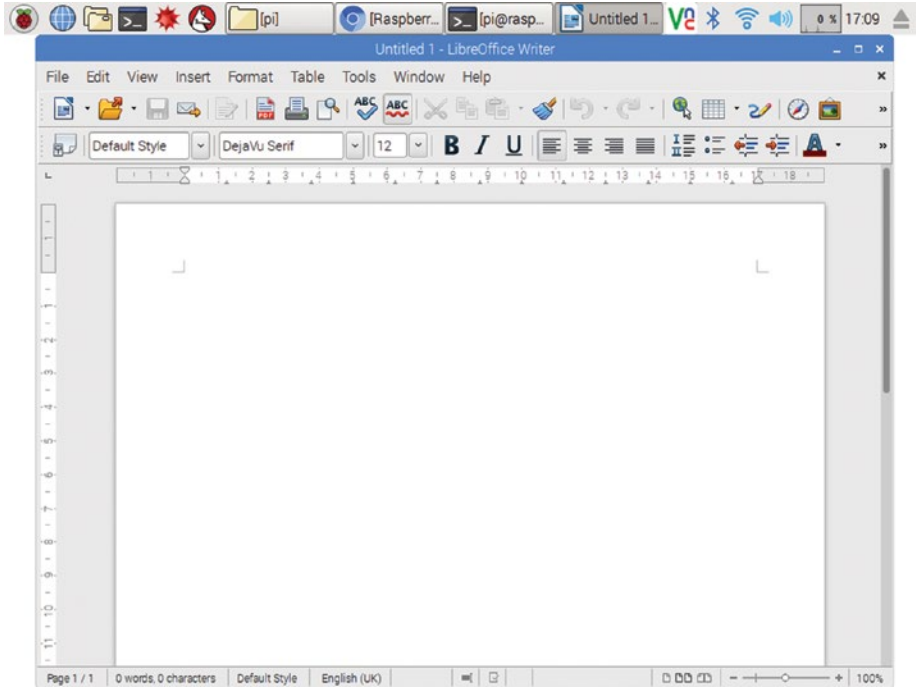
Figure 4-31. *An open app typically appears in a window.*

Managing Windows

On Raspbian, you can manage windows by using techniques that will likely be familiar from Windows and the Mac, plus several other handy techniques.

Resizing and Positioning Windows with the Pointing Device

You can quickly resize and position windows by using your mouse or other pointing device:

- *Resize a window*: Move the pointer over the window's border and drag the border to where you want it. You can drag a corner to resize the window both horizontally and vertically in one move.

- *Position a window*: Drag the window by the title bar.

Using the Window Control Buttons

You can use the three control buttons at the right end of a window's title bar to take actions with the window. The left screen in Figure 4-32 shows the buttons for a nonmaximized window; the right screen in Figure 4-32 shows the buttons for a maximized window.

- *Iconify*: Click this button to minimize the window to an icon.

- *Maximize*: Click this button on a nonmaximized window to make the window take up all the space onscreen not occupied by the panel.

- *Restore*: Click this button on a maximized window to restore the window to its previous, nonmaximized size and position.

- *Close*: Click this button to close the window. If the window contains unsaved content, the app may prompt you to save it.
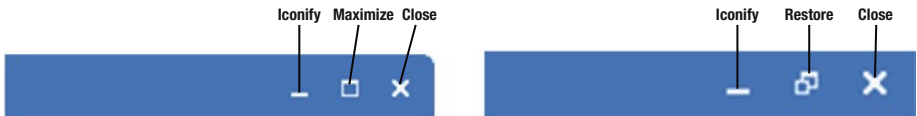
Figure 4-32. *Use the Iconify, Maximize, Restore, and Close buttons to quickly manipulate open windows.*

Using the Shortcut Menu

You can also manipulate windows by using the shortcut menu (see Figure 4-33). This is the menu that you can open in any of the following three ways:

- Click the control menu box at the left end of the title bar.

- Right-clicking open space in the title bar.

- Press Alt+Spacebar.

Control menu box   Shortcut menu
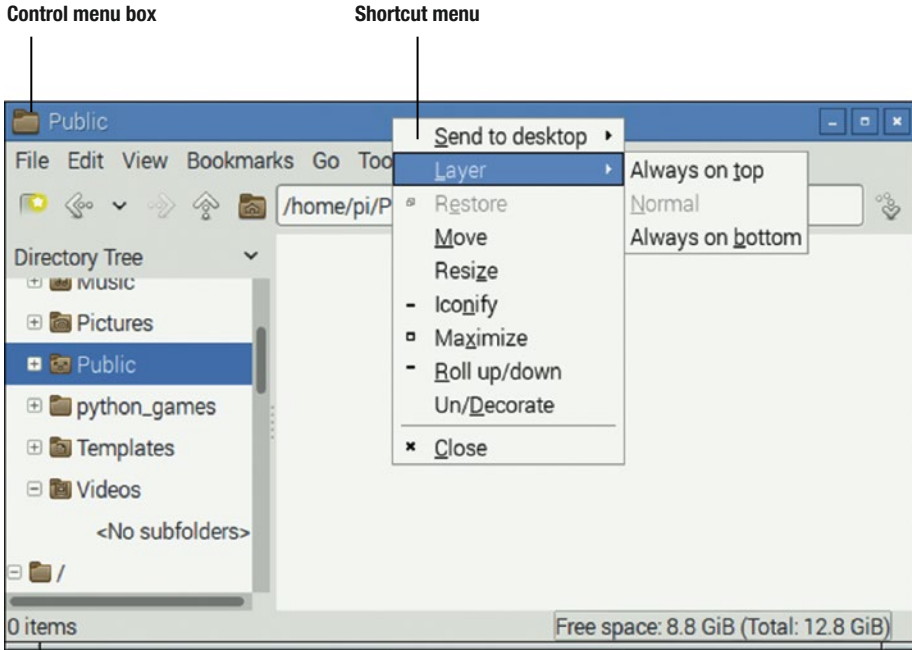
Figure 4-33. *The shortcut menu, which you can open by clicking the control menu box or (as here) right-clicking the title bar, gives quick access to a range of window commands.*

These are the actions you can take from the shortcut menu for a window:

- *Send to desktop*: Click this item to display the submenu of available desktops, and then click the desktop to which you want to send the window.

- *Layer*: Click this item to display the Layer submenu, which enables you to specify where in the stack of windows you want to position this window. Your choices are Always on top, Normal, and Always on Bottom.

- *Restore*: Give this command to restore the window to its previous size and position.

- *Move*: Give this command to activate Move mode in which you can move the window by pressing the Up arrow, Down arrow, Left arrow, and Right arrow. Press Shift and an arrow key to move the window in larger steps. When you've moved the window to where you want it, press the Enter key to turn off Move mode.

- *Resize*: Give this command to activate Resize mode in which you can resize the window by pressing the Up arrow, Down arrow, Left arrow, and Right arrow. Here, too, you can press Shift and an arrow key to resize the window in larger increments. When the window is the size you need, press the Enter key to turn off Resize mode.

- *Iconify*: Give this command to minimize the window to an icon.

- *Maximize*: Give this command to make the window take up the full space onscreen.

- *Roll up/down*: Give this command to roll the window up so that only its title bar is visible. Give this command again to roll the window back down again.

- *Un/Decorate*: Give this command to "undecorate" the window by removing its title bar. Press Alt+Spacebar and click Un/Decorate when you want to restore the window's title bar.

- *Close*: Click this item to close the window. As usual, if the window contains unsaved content, the app may prompt you to save it.

Using the Shortcut Menus on the Task Bar

Right-click an app's button on the Task Bar to display the shortcut menu (see Figure 4-34). You can then take the following actions:

- *Close Window*: Give this command to close the window. Again, if the window contains unsaved content, the app may prompt you to save it.

- *Raise*: Give this command to bring the window in front of other windows.

- *Restore*: Give this command to restore the window to its previous size and position.

- *Maximize*: Give this command to make the window take up the full space onscreen.

- *Minimize*: Give this command to minimize the window to an icon.
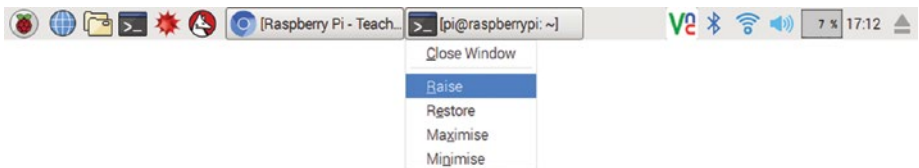
Figure 4-34. *From the shortcut menu for a button on the Task Bar, you can close, raise, restore, maximize, or minimize a window.*

Understanding and Using Multiple Desktops

Like most modern operating systems, Raspbian enables you to extend your desktop space by configuring and using multiple desktops. For example, you might want to have one desktop for programming, one for web browsing and e-mail, one for LibreOffice apps, and one for music.

Having multiple desktops can be a great productivity boost, so you'll likely want to enable this feature, which is disabled by default. You might also want to add the desktop pager applet to the panel to help you navigate your desktops.

Enabling Multiple Desktops

Follow the following steps to enable multiple desktops on Raspbian:

1. Right-click open space on the desktop to display the shortcut menu (shown in Figure 4-19 earlier in this chapter).

2. Click the Desktop Preferences item to display the Desktop Preferences dialog box.

3. Click the Advanced tab to display its contents (see Figure 4-22, earlier in this chapter).

4. Select the Show menus provided by window managers when the desktop is clicked check box.

5. Click the Close button.

Now right-click open space on the desktop, and you'll get a different shortcut menu. As you can see in Figure 4-35, this shortcut menu includes commands for adding, removing, and navigating among desktops.
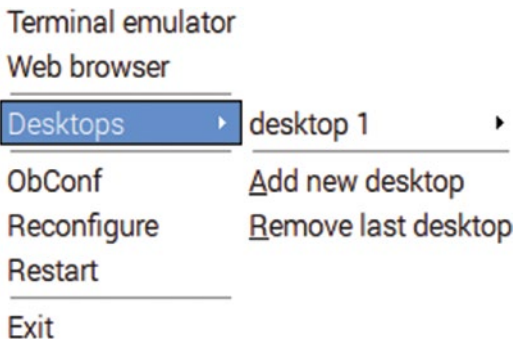
Figure 4-35. *After you select the Show menus provided by window managers when the desktop is clicked check box, the desktop shortcut menu includes commands for adding and removing desktops and navigating among them.*

Adding Desktop Preferences to the Preferences Submenu

Now that you've selected the Show menus provided by window managers when the desktop is clicked check box on the Advanced tab in the Desktop Preferences dialog box, you can no longer access Desktop Preferences by right-clicking the desktop. To give yourself another way to access Desktop Preferences, add Desktop Preferences to the Preferences submenu on the main menu by following the following steps:

1. Click the Menu button to display the main menu.

2. Click the Preferences item to display the Preferences submenu.

3. Click the Main Menu Editor item to open the Main Menu Editor dialog box.

4. In the left pane, if the Applications item is collapsed, click the arrow to its left to expand it.

5. Still in the left pane, click the Preferences item. The list of Preferences applets appears in the second pane (see Figure 4-36).
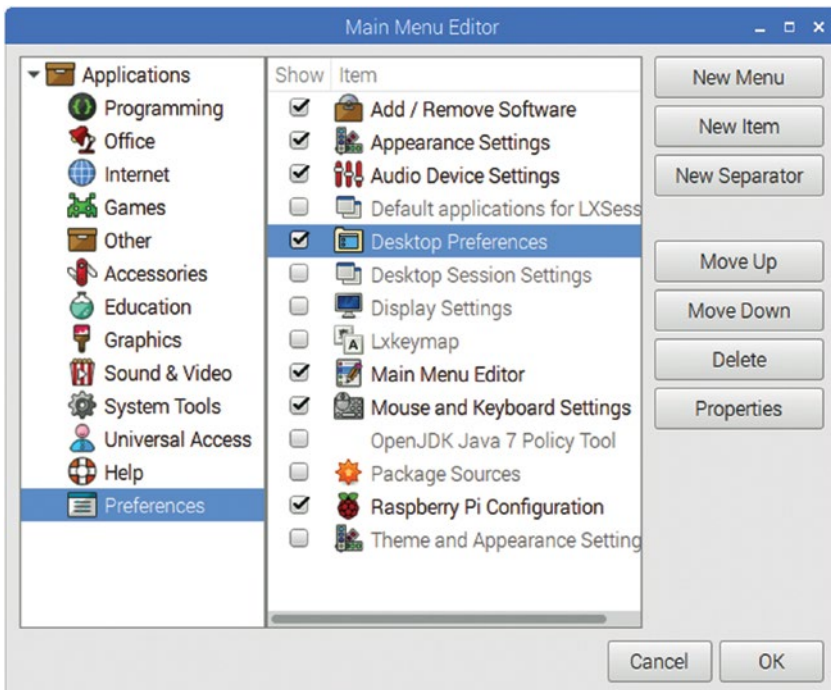
Figure 4-36. *In the Main Menu Editor dialog box, expand the Applications list in the left pane, click Preferences in it, and then select the Desktop Preferences check box.*

6. Select the check box to the left of the Desktop Preferences item.

7. Click the OK button to close the Main Menu Editor dialog box.

Now that you've done this, you can click the Menu button, click or highlight the Preferences item, and then click the Desktop Preferences item to display the Desktop Preferences dialog box.

Adding, Removing, and Navigating Among Desktops

Now that you've changed the desktop shortcut menu, you can quickly add desktops, remove them, and navigate among them as needed.

- *Add a desktop*: Right-click open space on the desktop, click or highlight the Desktops item on the shortcut menu, and then click Add new desktop on the submenu.

- *Remove the last desktop*: Right-click open space on the desktop, click or highlight the Desktops item on the shortcut menu, and then click Remove last desktop on the submenu.

- *Navigate to a desktop*: Right-click open space on the desktop, click or highlight the Desktops item on the shortcut menu, click or highlight the desktop's number, and then click the Go there item.

- *Navigate to a window on a desktop*: Right-click open space on the desktop, click or highlight the Desktops item on the shortcut menu, click or highlight the desktop's number, and then click the item with the window's name (see Figure 4-37).
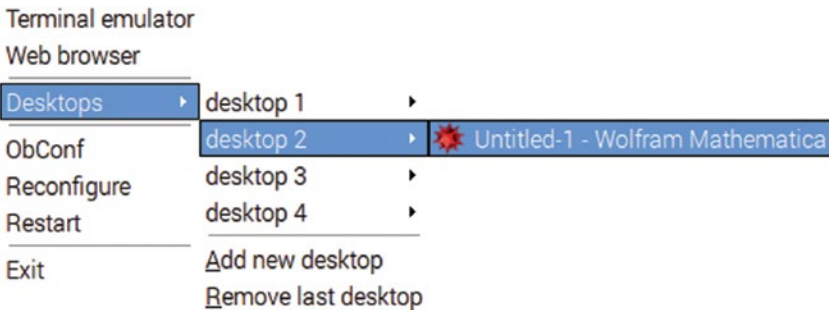
Figure 4-37. *You can go to a particular window on a desktop by clicking or highlighting the desktop's number and then clicking the item with the window's name. Click the Go there item to go to the desktop without picking a window.*

- *Move a window to a desktop*: Right-click the window's title bar, click or highlight the Send to desktop item, and then click the item with the desktop's number.

- *Make a window available on all desktops*: Right-click the window's title bar, click or highlight the Send to desktop item, and then click the All desktops item.

■ **Tip**   Raspbian arranges your desktop spaces in a logical line from left (desktop 1) to right (the highest-numbered desktop). You can move from one desktop to the next by pressing Ctrl+Alt+Right arrow and move from one desktop to the previous desktop by pressing Ctrl+Alt+Left arrow.

Adding the Desktop Pager Applet to the Panel for Easy Navigation

Moving from one desktop to another by using the desktop shortcut menu is convenient only when the desktop isn't fully covered with windows. To give yourself another graphical way to switch among your desktops, you can add the Desktop Page applet to the panel. Follow the following steps:

1. Right-click open space on the Task Bar to display the shortcut menu.

2. Click the Add/Remove Panel Items item to display the Panel Applets tab of the Panel Preferences dialog box (see Figure 4-25 earlier in this chapter).

3. Click the Add button to display the "Add plugin to panel" dialog box (see Figure 4-26, also earlier in this chapter).

4. Select the Desktop Pager add-in.

5. Click the Add button. The "Add plugin to panel" dialog box closes, and the Desktop Pager plug-in appears at the bottom of the list on the Panel Applets tab.

6. If you want to move the Desktop Pager plug-in to a different point in the list, click the Up button or the Down button to move the plug-in.

7. Click the OK button to close the Panel Preferences dialog box.

The Desktop Pager applet appears on the panel, showing thumbnails of your desktops and the windows open on them (see Figure 4-38). The thumbnail for the current desktop appears with a blue background, whereas the thumbnails for the other desktops have gray backgrounds. You can click the thumbnail for the desktop you want to display.
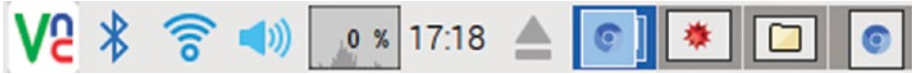
Figure 4-38. *The Desktop Pager applet, shown here at the right end of the panel, enables you to navigate easily among your desktops.*

■ **Tip** You can click the front window on a desktop thumbnail and drag it to another desktop thumbnail to move that window to that desktop.

Exploring the File System with File Manager

Raspbian comes with a file manager that goes by the name of "File Manager," although its more formal name is "PCManFM." File Manager works in a similar way to mainstream file managers such as File Explorer (on Windows) and the Finder (on the Mac). You'll find File Manager also has various thoughtful features that can speed up your work in the app.

Launching File Manager and Navigating Its Interface

To start exploring the file system, click the File Manager icon on the Application Launch Bar section of the panel. File Manager opens a window showing your Home folder—by default, the /home/pi folder, as shown in Figure 4-39.

New Tab   Back   History   Forward   Up   Home   Path Bar   Go

Side Pane   Status bar
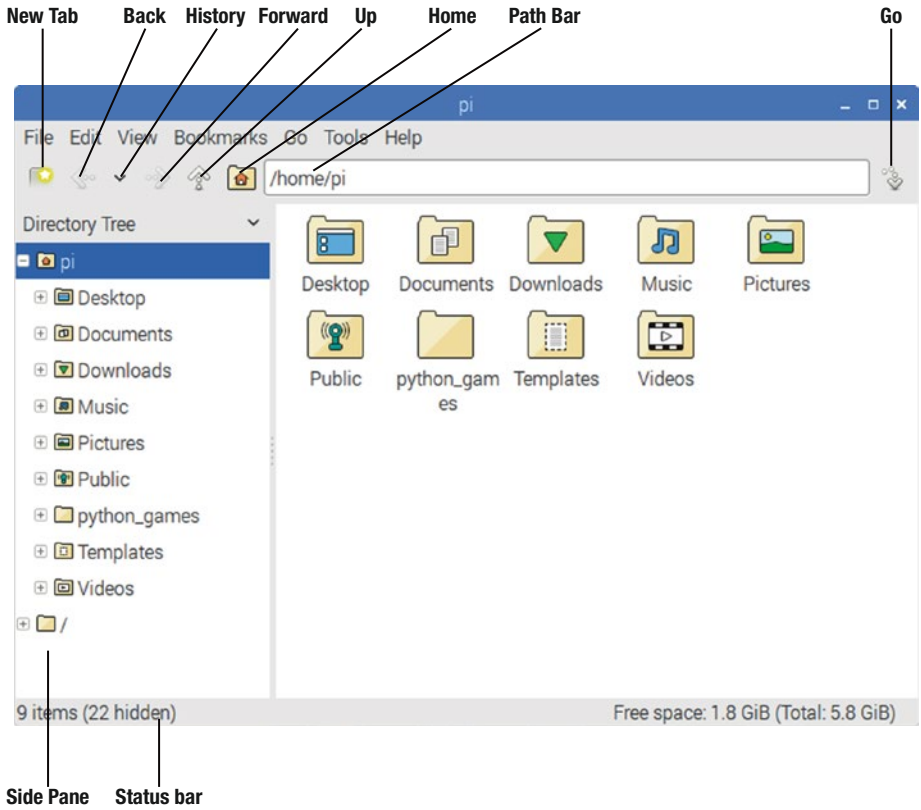
Figure 4-39. *The File Manager app has an easy-to-navigate interface.*

These are the key interface elements in File Manager:

- *New Tab*: Click this button to create a new tab in the same window.

- *Back*: Click this button to go back to the previous folder.

- *History*: Click this button to display a pop-up menu of the folders you've worked in recently. You can click a folder to go back to it quickly.

- *Forward*: Click this button to go forward again after using the Back button to go back.

- *Up*: Click this button to go to the parent folder of the active folder.

- *Home*: Click this button to go to your Home folder.

- *Path Bar*: This bar shows the current location, either as text (as shown in Figure 4-39) or as clickable buttons. You can switch between the two by opening the View menu, clicking or highlighting the Path Bar item, and then clicking the Location item or the Buttons item on the Path Bar submenu.

- *Go*: Click this button to go to the folder whose name you've typed or pasted in the Path Bar.

- *Side Pane*: This pane enables you to navigate quickly around the file system. You can display either the Directory Tree or the Places list by clicking the pop-up button at the top and then clicking Directory Tree or Places.

- *Status bar*: This bar displays information about the currently selected item and the volume on which you're working.

Meeting the File System

If you're already familiar with Linux (or Unix), you probably know your way around the file system. But if you've mostly used Windows or the Mac until now, you might benefit from a short introduction to the main folders.

As you can see in Figure 4-39, File Manager places your Home folder at the top of the Directory Tree in the Side Pane, on the assumption that this folder is where you'll most likely be working. The Home folder contains a default selection of folders whose names are self-explanatory:

- Desktop

- Documents

- Downloads

- Music

- Pictures

- Public

- python_games

- Templates

- Videos

You can expand a collapsed folder by double-clicking its name or by clicking the +
(plus) sign to the left of the name. You can collapse an expanded folder also by double-
clicking its name or by clicking the – (minus) sign to the left of the name.

Below the home folder in the Directory Tree is the root folder, represented by /
(forward slash). The root folder is the base of the file system—hence its name. Table 4-1
illustrates the folders you'll see if you expand the root folder.

Table 4-1. *Folders in the Root Folder*

Folder Name	Contains
Bin	Binary executable files available to all users
boot	Boot loader and boot files
Dev	Files for working with hardware devices
Etc	System configuration files
home	Users' Home folders; for example, this is where the pi account's Home folder is located
Lib	Software library files and kernel modules
lost+found	Files and fragments located during a file system check
media	Mount points for removable media
mnt	Mount points for devices mounted in the file system
Opt	Optional application software packages
proc	Files for recording process status
root	Configuration files for the root account
Run	Files containing runtime variables
sbin	Software support tools for administrators
Srv	Files containing data on system services
Sys	System information
tmp	Temporary files
Usr	Program support files and libraries
Var	Various other files, including the storage of current settings, unread mail, and system events

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■ **Tip**   Encourage the users of your Raspberry Pi computers to store their files in their Home folders or on network folders. Discourage the users from digging into the system folders, let alone from making changes to them.

Exploiting File Manager's Time-Saving Features

Apart from standard features such as tabbed windows and drag and drop, File Manager also has several handy features that can speed up your work. These include bookmarks, Dual Pane Mode, the ability to preserve a folder's settings, the Search Files feature, and keyboard shortcuts.

Using Bookmarks for Quick Access to Key Folders

Bookmarks enable you to return quickly to the folders you find most useful. Here's how to add a bookmark to the list:

1. Select the folder for which you want to create a bookmark.

2. Press Ctrl+D or open the Bookmarks menu and click Add to Bookmarks on it. The Add to Bookmarks dialog box opens (see Figure 4-40).

3. If necessary, edit the suggested name (the folder's name). For example, you might want to type a more descriptive name.

4. Click the OK button.
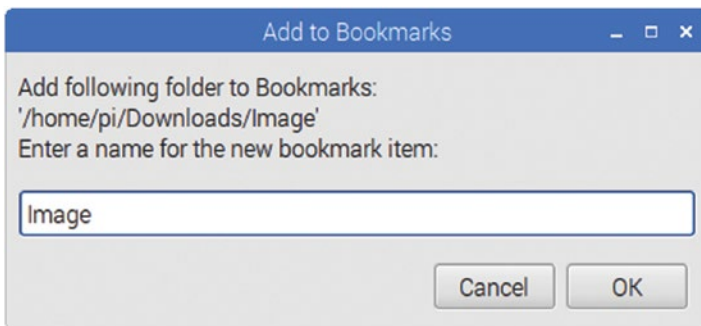
Figure 4-40. *Use the Add to Bookmarks dialog box to create a bookmark for a folder you want to be able to access easily.*

To go to a bookmark, open the Bookmarks menu, and then click the bookmark you want.

Using Dual Pane Mode to Manage Files Quickly

File Manager's Dual Pane Mode enables you to manage files quickly without having to arrange multiple windows. Open the View menu and click the Dual Pane Mode item, or simply press the F3 key, to toggle Dual Pane Mode on; you may also want to press the F9 key to toggle off the display of the Side Pane to give yourself more space if you're using a small screen. Figure 4-41 shows a File Manager window in Dual Pane Mode.
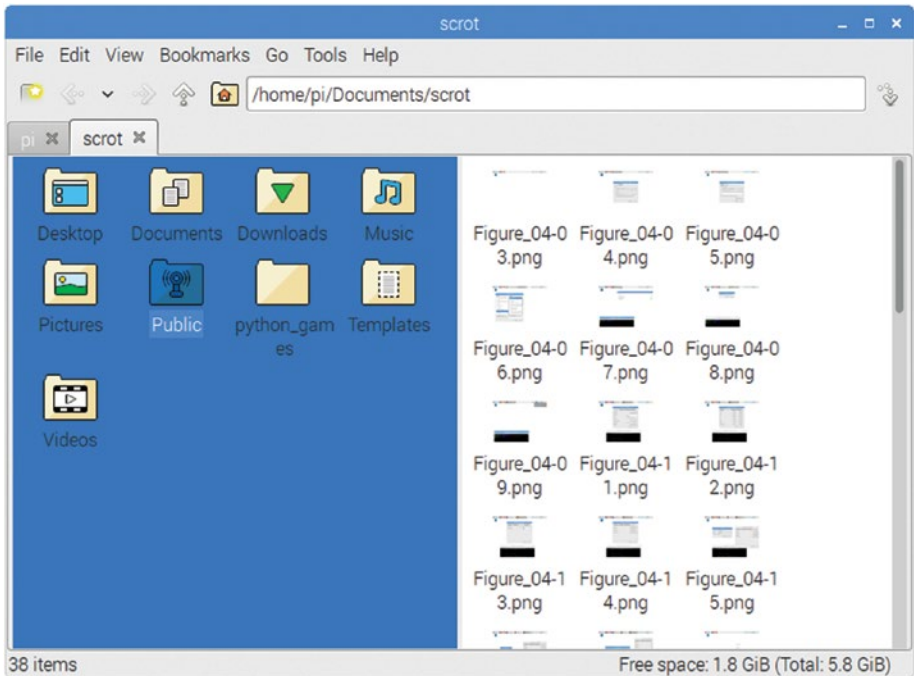
Figure 4-41. Dual Pane Mode gives you an easy way to display two folders in the same window, which makes for faster file management.

Preserving a Folder's Settings

Once you've chosen settings for a folder, you can keep them by choosing View > Preserve This Folder's Settings. A check mark appears to the left of the menu item. Give the command again if you want to stop preserving the settings.

Finding the Files You Need with the Search Files Feature

File Manager's Search Files feature gives you an effective way of locating the files you need. Open the Tools menu and click the Find Files item, or press Ctrl+Shift+F, to display the Search Files window (see Figure 4-42). You can then choose settings on the following four tabs:

- *Name/Location*: You can specify the name or name pattern to search for, choose the places to search, and decide whether to search in subfolders and search for hidden files.

- *File Type*: You can limit the search to specific file types, such as text files, image files, or video files.

- *Content*: You can specify a text string or a regular expression to search for within the file's contents.

- *Properties*: You can specify the approximate file size, such as Bigger than 1,024 KB, or the last modified time.
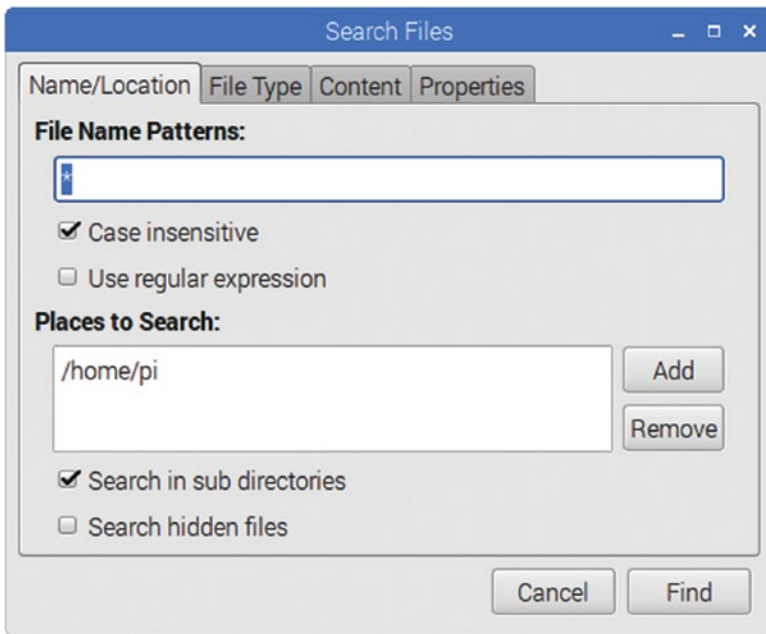
Figure 4-42. *The four tabs of the Search Files dialog box give you power and flexibility in searching for the files you need.*

Navigating and Working with Keyboard Shortcuts in File Manager

You can navigate and work quickly in File Manager windows by using the keyboard shortcuts listed in Table 4-2.

Table 4-2. *Keyboard Shortcuts for Navigating and Working in File Manager*

Keyboard Shortcut	What It Does
Tab	Cycles forward through Folder View, the Side Pane, and the Tools Bar.
Shift+Tab	Cycles backward through Folder View, the Tools Bar, and the Side Pane.
F2	Opens the Rename File dialog box.
F3	Toggles Dual Pane Mode on or off.
F4	Opens a Terminal window to the active folder.
F5	Reloads the active folder.
F6	Moves the focus between the Side Pane and Folder View.
F8	Puts the focus on the divider bar between the Side Pane and Folder View. You can then press Left arrow or Up arrow to move the divider to the left or press Right arrow or Down arrow to move the divider to the right. Press F8 again when you finish moving the divider bar.
F10	Moves the focus to the menu bar and opens the File menu. You can then press Left arrow or Right arrow to navigate to the other menus.
F11	Toggles Full Screen Mode on or off.
Ctrl+A	Select all the files in the current folder.
Ctrl+I	Invert the selection, deselecting the items that were selected and selecting the items that were not selected.
Ctrl+B	Toggles the display of the status bar.
Ctrl+C	Copies the selected item or items.
Ctrl+V	Pastes the copied item or items.
Ctrl+X	Cuts the selected item or items.
Ctrl+D	Opens the Add to Bookmarks dialog box.
Ctrl+E	Opens the Select Filter dialog box.
Ctrl+Shift+F	Opens the Search Files dialog box.
Ctrl+H	Toggles the display of hidden items on and off.
Ctrl+L or Alt+D	Moves the focus to the Address bar and selects its current contents.
Ctrl+N	Opens a new window.
Ctrl+T	Opens a new tab in the active window.
Ctrl+W	Closes the active tab.
Ctrl+Q	Closes the active window.

(*continued*)

Table 4-2. (*continued*)

Keyboard Shortcut	What It Does
Alt+Enter	Opens the File Properties dialog box for the active file or folder.
Alt+Home	Displays the Home folder.
Alt+Left arrow	Select the previous folder.
Alt+Right arrow	Select the next folder.
Alt+Up arrow	Select the parent folder of the active folder.
Ctrl++	Zooms in.
Ctrl+−	Zooms out.

Configuring File Manager Preferences

You'll likely spend a fair amount of time using File Manager, so it's worth investing a few minutes in choosing preferences to make File Manager look and work the way you prefer.

Open the Edit menu and click the Preferences item to open the Preferences dialog box. You can then click the appropriate item in the left pane—General, Display, Layout, Volume Management, Advanced, or Modules—to display the corresponding pane in the main section of the dialog box.

Choosing General Preferences for File Manager

The General pane in the Preferences dialog box for File Manager (see Figure 4-43) has two sections: the Behavior section and the Default View section. Both contain preferences you'll likely want to set.
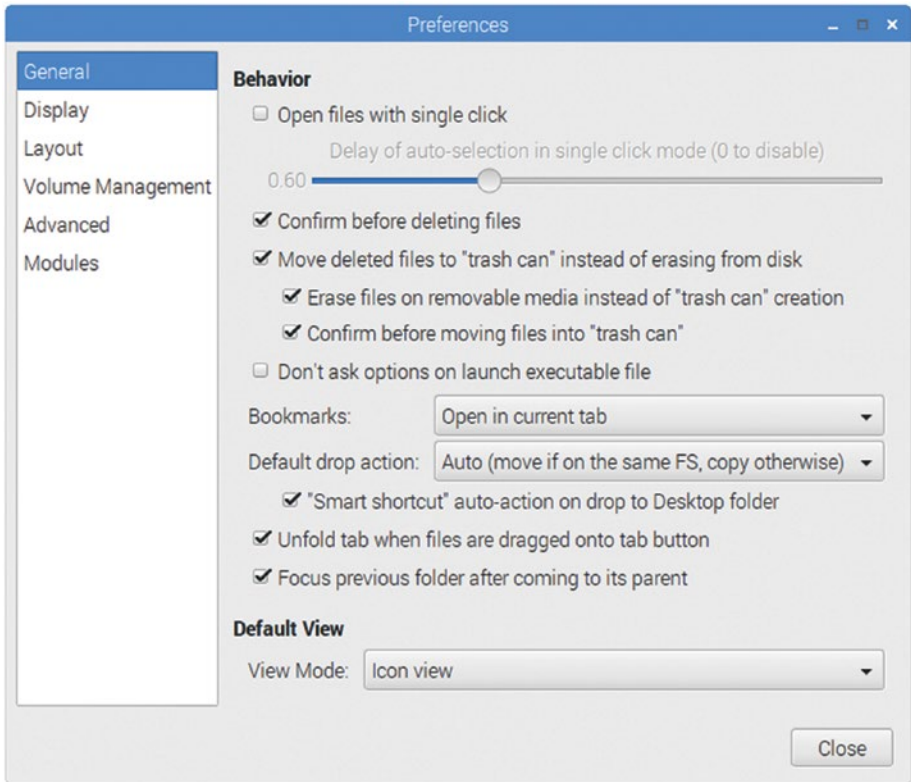
Figure 4-43. *In the General pane of the Preferences dialog box for File Manager, you can set your default view and configure essential behavior, such as opening and deleting files.*

The following are the preferences you can set in the Behavior section:

- *Open files with single click*: Select this check box if you want to be able to open files by clicking them once rather than double-clicking them. Some people like this setting, but most people find it awkward, and it's off by default. If you select the check box, you can drag the "Delay of auto-selection in single click mode" slider to set the delay before File Manager selects the item over which you hold the mouse. Drag the slider all the way to the left, setting 0.0 seconds, to turn off the delay.

- *Confirm before deleting files*: Select this check box (which is selected by default) to have File Manager display a confirmation dialog box when you give the command for deleting a file. This is usually helpful.

- *Move deleted files to "trash can" instead of erasing from disk.* Select this check box (which is also selected by default) to have File Manager put files you delete in the Trash folder instead of deleting them immediately. Having the Trash folder acting as a safety net for accidental deletions is usually helpful. If you select this check box, you can set the following two preferences; if not, they are dimmed and unavailable.

■ **Note**   Depending on the localization, you may see a different term than "trash can," such as "Wastebasket."

- *Erase files on removable media instead of "trash can" creation.* Select this check box if you want File Manager to delete files on removable media (such as USB drives) rather than placing them in the trash can.

- *Confirm before moving files into "trash can"*: Select this check box if you want File Manager confirming moving files to the Trash. You may find this confirmation dialog box to be overkill, but it can be helpful when you are working with files on various drives and it's not necessarily clear which operations involve the files going into the Trash and which operations involve the files being erased immediately.

- *Don't ask options on launch executable file*: Select this check box if you want to suppress any available options when you open an executable file.

- *Bookmarks*: Click this pop-up menu and then click the action you want to take for bookmarks: "Open in current tab," "Open in new tab," or "Open in new window." Which action you choose will depend on how you prefer to work with File Manager windows.

- *Default drop action*: Click this pop-up menu and then click the default action you want to use for drag-and-drop operations. You have four choices:

  - *Auto (move if on the same file system, copy otherwise)*: Choose this action if you want drag-and-drop operations to move files whose source folder is on the same volume as the destination folder but copy files when the source folder and destination folder are on different volumes.

  - *Copy*: Choose this action to make drag-and-drop operations always copy files.

  - *Move*: Choose this action to make drag-and-drop operations always move files.

  - *Ask*: Choose this action to make File Manager display a pop-up menu when you drop files at the end of a drag-and-drop operation. The pop-up menu gives you four choices: Copy Here, Move Here, Link Here, and Cancel.

- *"Smart shortcut" auto-action on drop to Desktop folder*: Select this check box, which is available only if you choose Auto in the Default drop action pop-up menu, to make File Manager create a shortcut on the desktop when you drop a file there instead of moving or copying the file.

- *Unfold tab when files are dragged onto tab button*: Select this check box if you want File Manager to display a tab's contents when you drag files onto the tab button.

- *Focus previous folder after coming to its parent*: Select this check box if you want File Manager to automatically put the focus on the last subfolder you used when you select the subfolder's parent. That sounds like gibberish, but look at Figure 4-44 for an example. Here, the Evaluate subfolder is selected in the Downloads folder. With the "Focus previous folder after coming to its parent" setting enabled, the next time you select the Downloads folder, File Manager will automatically put the focus on the Evaluate subfolder. This helps you identify the last subfolder you used when you return to the parent folder.
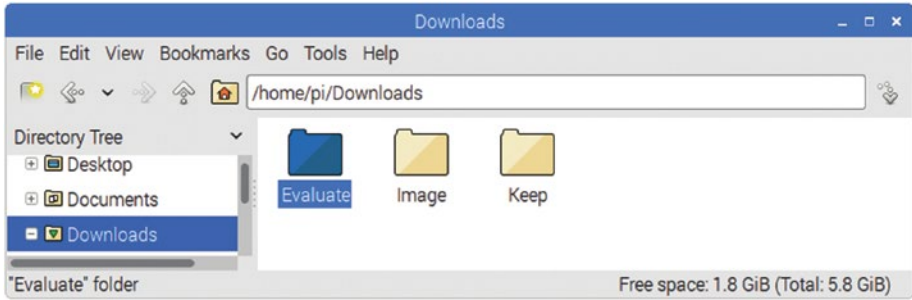
Figure 4-44. *After you enable the "Focus previous folder after coming to its parent" setting, File Manager will automatically put the focus on the previous folder (such as the Evaluate folder here) when you select its parent folder (such as the Downloads folder here).*

■ **Note**   A folder stored within another folder is a *subfolder* or *child folder*. The *parent folder* is the folder that contains a subfolder.

The Default View section of the General pane has only one preference:

- *View Mode*: Click this pop-up menu and then click the view you want to use as the default: Icon view, Compact view, Thumbnail view, or Detailed list view.

Choosing Display Preferences for File Manager

The Display pane in the Preferences dialog box for File Manager (see Figure 4-45) has two sections: the Icons section and the User Interface section.
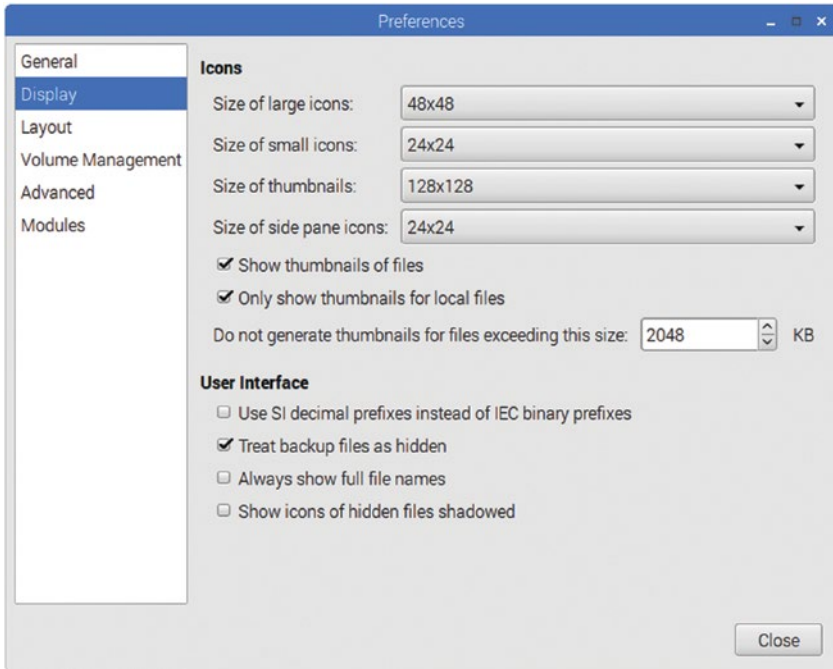
Figure 4-45. *In the Display pane of the Preferences dialog box for File Manager, you can set the size of icons and thumbnails, choose which thumbnails to generate, and set user interface preferences.*

These are the preferences you can set in the Icons section:

- *Size of large icons*: Click this pop-up menu and then click the size you want to use for big icons: 20x20, 24x24, 32x32, 36x36, 48x48, 64x64, 72x72, or 96x96 pixels.

- *Size of small icons*: Click this pop-up menu and then click the size you want to use for small icons: 12x12, 16x16, 20x20, 24x24, 32x32, 36x36, or 48x48 pixels.

- *Size of thumbnails*: Click this pop-up menu and then click the size you want to use for thumbnails: 64x64, 96x96,128x128, 160x160, 192x192, 224x224, or 256x256 pixels.

- *Size of side pane icons*: Click this pop-up menu and then click the size you want to use for icons in the side pane: 12x12, 16x16, 20x20, 24x24, 32x32, 36x36, or 48x48 pixels.

- *Show thumbnails of files*: Select this check box if you want to display thumbnails of files. Thumbnails are useful for files that you can differentiate visually, but they take some processor power to generate, so you may want to clear this check box if your Raspberry Pi computer is laboring.

- *Only show thumbnails for local files*: Select this check box if you want to use thumbnails only for files stored on local volumes and not on remote volumes. This is usually a good idea.

- *Do not generate thumbnails for files exceeding this size*: In the spin box, set the size in KB above which you don't want File Manager to generate thumbnails.

The following are the preferences you can set in the User Interface section of the Display pane:

- *Use SI (International System of Units) decimal prefixes instead of IEC (International Electrotechnical Commission) binary prefixes*: Select this check box if you want File Manager to display decimal prefixes (powers of 10) rather than binary units (powers of 2). For most purposes, you'll likely want to leave this check box cleared (as it is by default) and use binary prefixes.

- *Treat backup files as hidden*: Select this check box if you want File Manager to treat backup files as hidden files. Hiding the backup files unless you choose to display them helps you avoid working with the files inadvertently.

- *Always show full file names*: Select this check box if you want File Manager to always display complete file names.

- *Show icons of hidden files shadowed*: Select this check box if you want File Manager to apply shadows to the icons of hidden files when you choose to display hidden files.

Choosing Layout Preferences for File Manager

The Layout pane in the Preferences dialog box for File Manager (see Figure 4-46) enables you to choose preferences for the User Interface, the Directories Tree, and the Show in Places list.

The following are the preferences you can set in the User Interface section:

- *Always show the tab bar*: Select this check box to have the tab bar appear even when only one tab is open.

- *Maximum width of tab label*: In this spin box, set the maximum number of characters to display on a tab label.
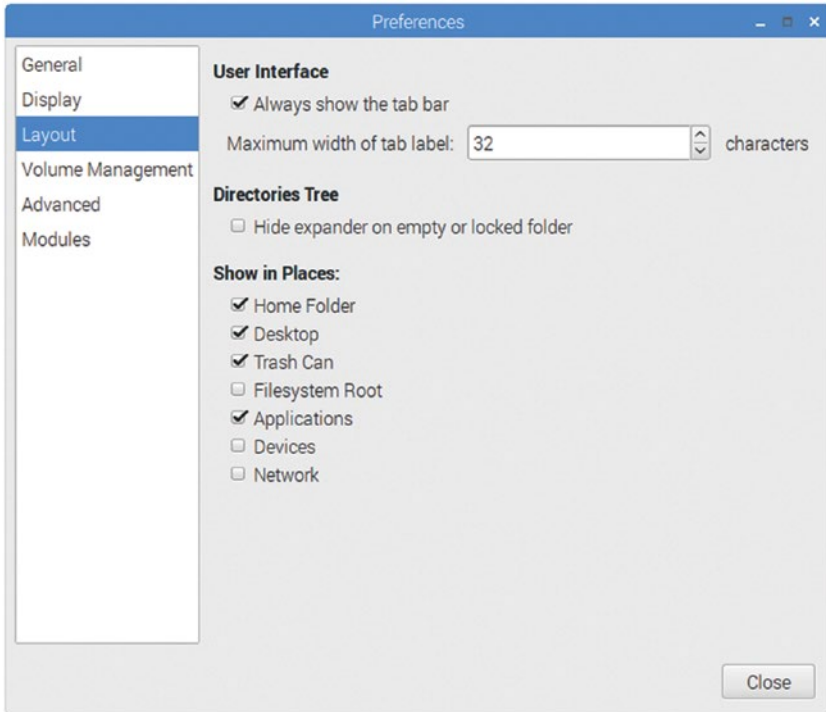
Figure 4-46. *In the Layout pane of the Preferences dialog box for File Manager, you can choose whether to always display the tab bar and select which items to show in the Places list.*

This is the preference you can set in the Directories Tree section:

- *Hide expander on empty or locked folder*: Select this check box if you want File Manager to hide the expansion triangle for a folder that is empty or locked.

In the Show in Places list, select the check box for each item—Home Folder, Desktop, Trash Can/Wastebasket, Filesystem Root, Applications, Devices, and Network—that you want to include in the Places list. Clear the other check boxes.

Choosing Volume Management Preferences for File Manager

The Volume Management pane in the Preferences dialog box for File Manager (see Figure 4-47) lets you specify which volumes to mount automatically and how to handle the unmounting of removable media.

The following are the preferences you can set:

- *Mount mountable volumes automatically on program start-up*: Select this check box to have File Manager automatically mount each mountable volume when the app starts. This feature is usually helpful.

- *Mount removable media automatically when they are inserted*: Select this check box to have File Manager automatically mount removable media when you connect them to the Raspberry Pi computer. This feature is usually helpful too.

- *Show available options for removable media when they are inserted*: Select this check box to have File Manager display options for removable media you connect.

- *Open mounted removable media in new tab instead of new window*: Select this check box if you want File Manager to use a new tab in an existing window rather than a new window to display the contents of removable media you connect.

- *When removable medium unmounted*: To specify what happens when you unmount a removable medium, select the "Close tab containing removable medium" option button or the "Change folder in the tab to Home folder" option button. For most purposes, the former option is more helpful.
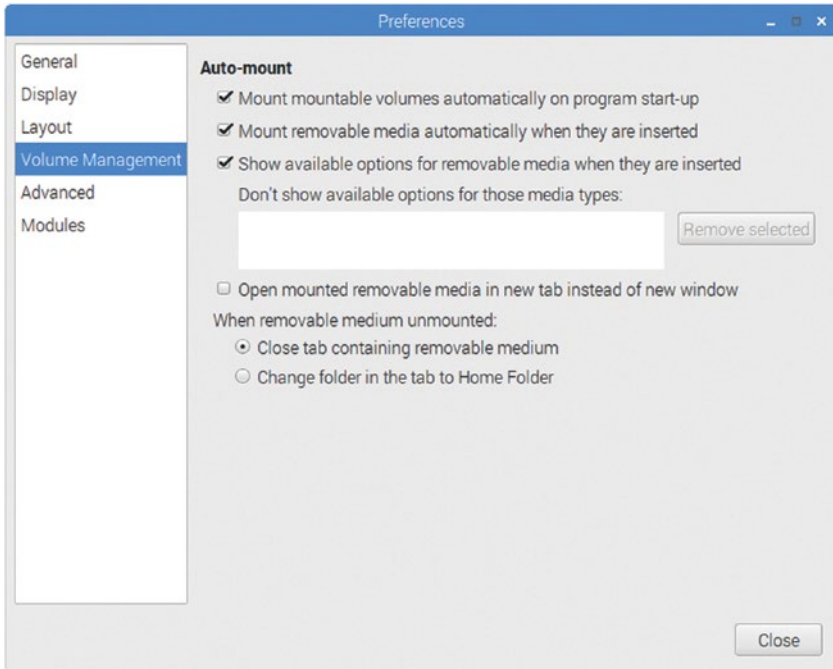
Figure 4-47. *In the Volume Management pane in the Preferences dialog box for File Manager, you can choose which volumes to mount automatically and what to do when you unmount a removable medium.*

Choosing Advanced Preferences for File Manager

The Advanced pane in the Preferences dialog box for File Manager (see Figure 4-48) contains preferences for configuring programs, templates, and several other features.
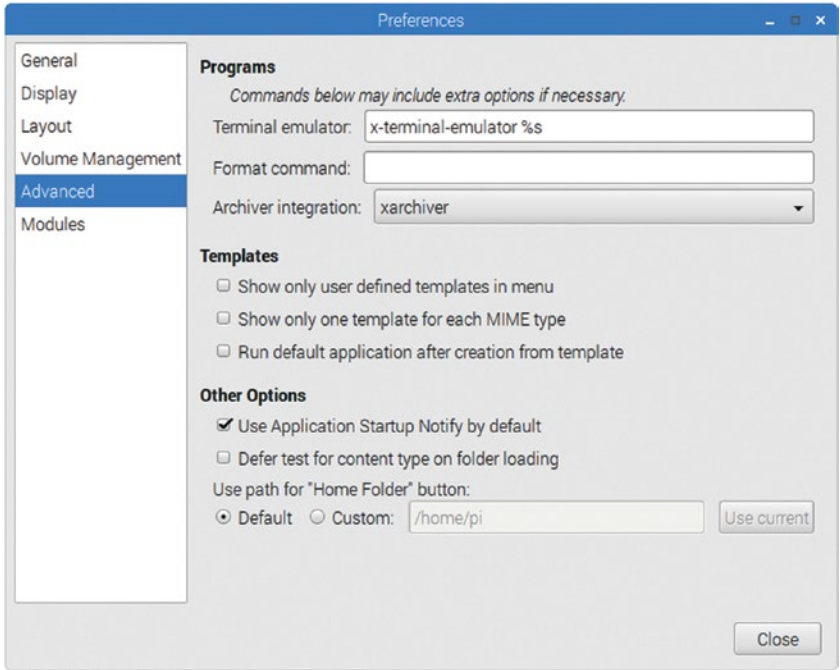
Figure 4-48. *The Advanced pane in the Preferences dialog box for File Manager lets you configure programs, templates, and several other features.*

The following are the preferences you can configure in the Programs section:

- *Terminal emulator*: In this box, enter the command for terminal sessions you launch from File Manager.

- *Format command*: In this box, you can enter the command you want to use for formatting.

- *Archiver integration*: In this pop-up menu, select the archiver you want to use for archiving operations you start from File Manager.

The following are the preferences you can configure in the Templates section:

- *Show only user defined templates in menu*: Select this check box if you want the menus to show only your custom templates.

- *Show only one template for each MIME (Multipurpose Internet Mail Extensions) type*: Select this check box if you want File Manager to display only one template for each file type.

WHAT IS A MIME TYPE?

MIME is the acronym for Multipurpose Internet Mail Extensions, ways of encoding different types of content originally so that they could be sent via e-mail. The MIME type is information written into the beginning of the file.

Operating systems such as Linux and macOS read the MIME type to establish what type of file a file is. By contrast, Windows uses the file extension to determine the file type.

Most people now use the term "Internet Media Types" instead of "MIME types."

- *Run default application after creation from template*: Select this check box if you want File Manager to automatically run the default application for an item you create from a template.

The following are the preferences you can configure in the Other Options section:

- *Use Application Startup Notify by default*: Select this check box if you want the cursor and the panel to display the normal visual cues when you launch an application from File Manager.

- *Defer test for content type on folder loading*: Select this check box if you want File Manager to open folders and display the files they contain before determining the content type of those files. This check box is cleared by default, but you may want to try selecting it if you find File Manager is slow to open folders, especially folders that contain many files.

- *Use path for "Home Folder" button*: In this area, select the Default option button if you want to use the default Home folder. If not, select the Custom option button and either enter the path in the text box or—if you've already navigated to the folder you want to use—click the "Use current" button.

Choosing Modules Preferences for File Manager

The Modules pane in the Preferences dialog box for File Manager (see Figure 4-49) enables you to specify which modules to load and not to load. Use the upper Add button and Remove button to build the list of modules in the "Do not load modules matching box"; use the lower Add button and Remove button to build the list of modules in the "Load these modules anyway" box.
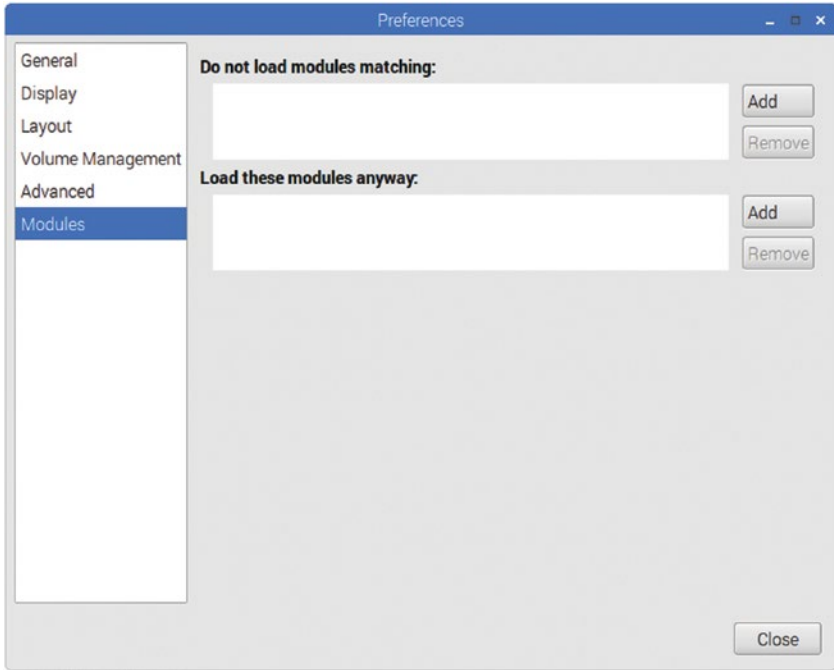
Figure 4-49. *In the Modules pane in the Preferences dialog box for File Manager, you can set up lists of modules you don't want to load and modules you do want to load.*

Summary

In this chapter, you have learned the essentials of using and configuring a Raspberry Pi computer. You know how to startup, shutdown, and restart the computer; how to take other actions from the login screen; and how to identify the component parts of the desktop. You have configured your pointing device, keyboard, and network connection as needed; examined the options offered by the Raspberry Pi Configuration tool; and grasped the key facts about configuring and navigating the desktop.

You've also learned how to use File Manager to look at the Raspbian file system, how to make the most of several time-saving features it offers, and how to configure its preferences to make it work the way you prefer.

In Chapter 5, we'll look at how to set up the hardware for your Raspberry Pi deployment.

CHAPTER 5

■ ■ ■

Building the Raspberry Pi Computers and Installing Software

Now that you've picked your Raspberry Pi models and chosen the software for them, it's time to start putting everything together. In this chapter, we'll look at how to build the Raspberry Pi computers and install software on them. In Chapter 6, we'll go through setting up the network of Raspberry Pi computers.

Building the Raspberry Pi Computers

At this point, you should be all set to start building the Raspberry Pi computers—in other words, putting the Raspberry Pi boards in their cases and adding any other internally connected components you will use, such as the Raspberry Pi camera module.

The specifics of assembling the cases will depend on the type or types of cases you have chosen, so I can't offer you much helpful advice. Most cases are straightforward to put together, with many of the plastic cases simply snapping together. The official Raspberry Pi case for the Raspberry Pi 3 Model B board is an example of such a case. Figure 5-1 shows the six steps required to assemble the case.

Figure 5-1. *The official Raspberry Pi case for the Raspberry Pi 3 Model B clips together in six easy steps.*

INVOLVE YOUR STUDENTS: BUILDING THE RASPBERRY PI COMPUTERS

If you're putting together any significant number of Raspberry Pi computers, consider involving your students. Unlike most other desktop computers, where having students assemble the hardware risks expensive disaster, the Raspberry Pi board is easy to handle, and most cases take negligible amounts of skill to assemble.

Also consider having your students connect peripherals and power to the Raspberry Pi computers, as explained in the next section.

Connecting Peripherals and Power

Now that your Raspberry Pi boards are in their cases, you can connect peripherals and power to their ports. Figure 5-2 shows the ports on a Raspberry Pi 3 Model B with labels.
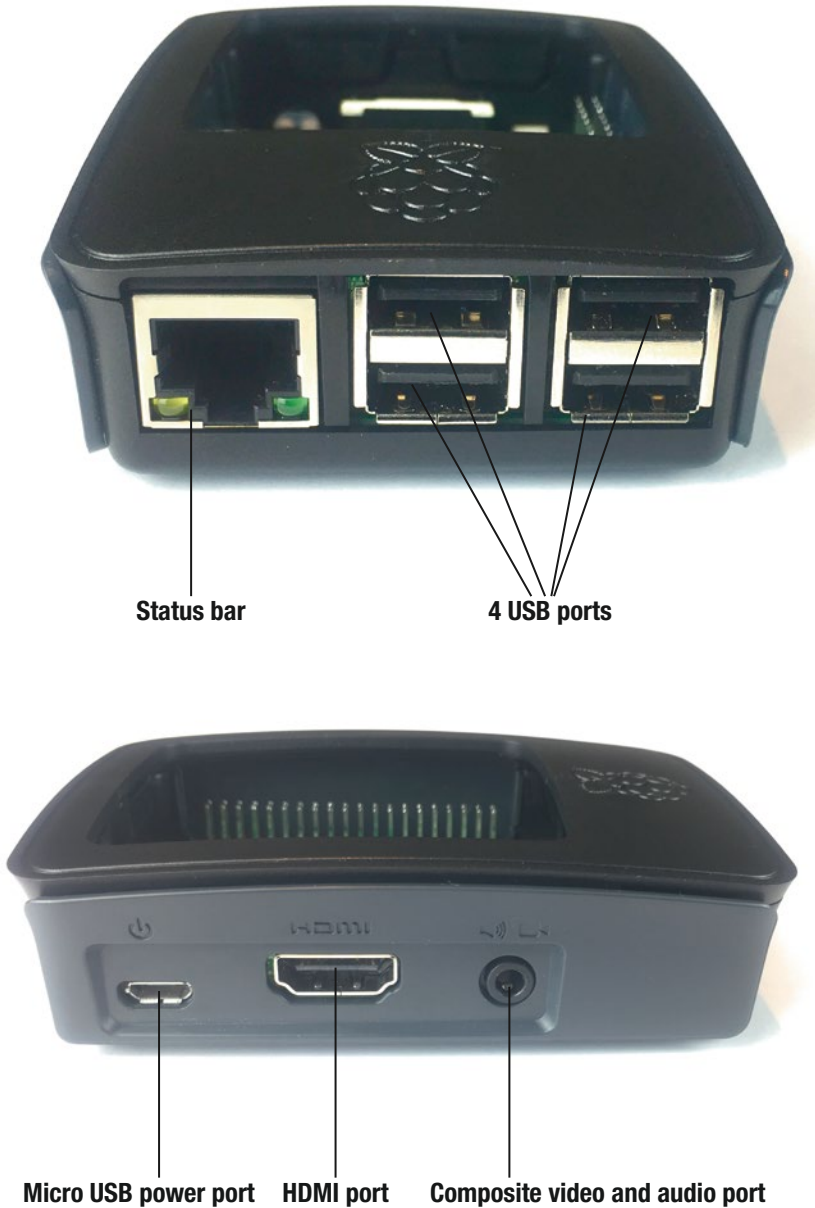
Figure 5-2. *Ports on a Raspberry Pi 3 Model B in a case*

Here's how to connect the peripherals and power:

- *Keyboard*: Connect to a USB port.

- *Pointing device*: Connect to a USB port.

- *Ethernet cable*: Connect to the Ethernet port.

- *Display*: Connect to the HDMI port, using an adapter if necessary. If you will use composite video, connect the cable to the composite video and audio port.

- *Audio*: If you're using an HDMI display, the HDMI cable carries audio as well as video to the display, so you can play audio through the display's built-in speakers or connect speakers or headphones to its audio output port. If you're not using an HDMI display, you can connect an audio cable to the composite video and audio port.

- *Power*: Connect the micro USB connector to the power port.

Downloading the NOOBS Installer

Next, you need the software for the Raspberry Pi computers—unless you have it already. This section shows you how to use the NOOBS installer to install the Raspbian operating system provided by the Raspberry Pi Foundation and (optionally) other supported operating systems.

■ **Note** The Raspberry Pi 1 models use a full-sized SD card. All later models of Raspberry Pi, including the Raspberry Pi Zero, use a micro SD card. Most micro SD cards include an SD card adapter that enables you to use them with full-size SD card slots; if you have a micro SD card without an adapter, you can buy one from any electronics retailer.

If your Raspberry Pi computers came with the NOOBS (New Out Of Box Software) installation manager on a micro SD card, you're all set to get started. If not, you can either buy an SD card containing NOOBS from a Raspberry Pi retailer or simply download NOOBS from the Raspberry Pi Foundation web site (`http://downloads.raspberrypi.org/ NOOBS_latest`) and then burn it to an SD card.

■ **Tip** Usually, it's best to get the latest version of the NOOBS installer because it will contain the latest updates, features, and bug fixes. But you can also download older versions of the NOOBS installer if necessary by going to the Downloads area on the Raspberry Pi web site and navigating to the NOOBS/images/ folder: `http://downloads.raspberrypi.org/ NOOBS/images/`.

SHOULD YOU GET NOOBS OR NOOBS LITE?

As well as the NOOBS installer, which includes the full Raspbian operating system image, the Raspberry Pi Foundation provides a stripped down version of NOOBS called NOOBS Lite. NOOBS Lite is simply NOOBS without the Raspbian operating system image. If you choose to install Raspbian, NOOBS Lite downloads the Raspbian image in the same way that NOOBS downloads the other supported operating systems if you choose to install them.

If you're planning to install Raspbian, either as the only operating system or as one of many, you'll normally do best to download the full version of NOOBS because it will save you from having to download the Raspbian image for each install.

But if you're not planning to install Raspbian, NOOBS Lite is the better choice, as it is a far smaller download.

Formatting an SD Card for Use with the NOOBS Installer

If you've downloaded NOOBS and need to put it on an SD card, work through this section and the next. But if you've got NOOBS on an SD card, skip ahead to the section titled "Installing Operating Systems with the NOOBS Installer" later in this chapter.

Before writing the operating system to the SD card, you normally need to format the card. This section shows you how to format an SD card on Windows and on the Mac by using the SD Formatter app and on Linux by using other tools.

■ **Caution** Before formatting the card, check to make sure it doesn't contain any files you want to keep. If it does, copy the files to a safe location before formatting the card or use a different card instead.

■ **Note** Windows and the Mac both include formatting tools that can format an SD card or a micro SD card with the FAT32 file system. But because none of these formatting tools fully uses the SD card's features, you'll do better to use the free SD Formatter app, which you can download for free from the SD Association's web site.

Installing and using the SD Formatter app is a little different on Windows than on the Mac, so the following subsections cover the two platforms separately.

Installing the SD Formatter App on Windows

To install the SD Formatter app on Windows, follow these steps:

1. Open your browser if it's not running or switch to it if it is running.

2. Go to https://www.sdcard.org/downloads/formatter_4/ and download the SD Formatter for Windows. This is a zip file that Windows may unzip automatically when the download finishes. If Windows displays the "How Do You Want to Open This File?" dialog box, select the File Explorer app, click the OK button, and then extract the setup.exe file manually.

3. Double-click the setup.exe file to run it, and then follow through the steps of the InstallShield Wizard for SDFormatter.

4. When the InstallShield Wizard finishes, click the Finish button to close it.

You can then run the SDFormatter app either from the desktop shortcut that the InstallShield Wizard normally creates without consulting you or from the Start menu.

Formatting an SD Card with the SD Formatter App on Windows

Once you've installed the SD app on your Windows PC or your Mac, you can format the SD card with it. To format the SD card, follow these steps:

1. Launch the app. The SDFormatter window opens (see Figure 5-3).
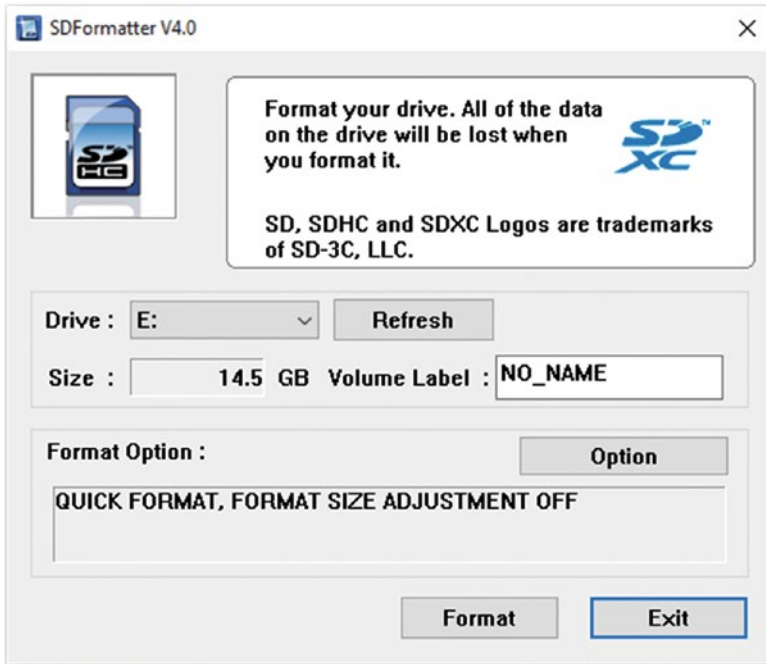
Figure 5-3. *Using the SDFormatter app on Windows*

2. Look at the Drive drop-down menu to see if it shows the SD card you want to format. If not, open the drop-down menu and select the right SD card. If the right card doesn't appear in the drop-down menu, make sure the card is connected to your PC, and then click the Refresh button to refresh the list of drives.

3. Double-click the Volume Label box and type the name you want to give the SD card—11 characters maximum, using underscores and spaces if you want but not characters such as a colon (:) or backslash (\).

4. In the Format Option area, click the Option button to display the Option Setting dialog box (see Figure 5-4).
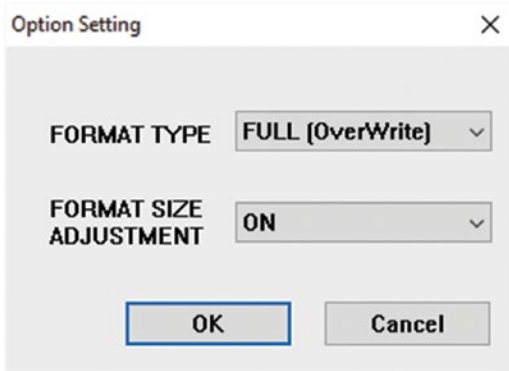
Figure 5-4. *In the Option Setting dialog box for the SDFormatter app, choose the Full (OverWrite) format type and enable Format Size Adjustment.*

5. Open the Format Type drop-down menu and select the Full (OverWrite) item.

6. Open the Format Size Adjustment drop-down menu and select the On item.

7. Click the OK button to close the Option Setting dialog box.

8. Back in the SDFormatter window, click the Format button. An SDFormatter dialog box opens (see Figure 5-5) to warn you not to remove the drive during formatting and to confirm that you want to format it.
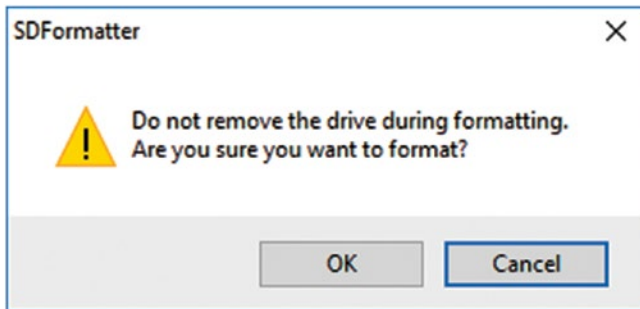
Figure 5-5. *In this SDFormatter dialog box, confirm that you want to format the SD card.*

9. Click the OK button. The Formatting dialog box opens and displays the progress of the format operation.

10. When the Memory Card Format complete! message appears, click the OK button to close the message box.

11. Click the Exit button to close the SD Formatter app.

Installing the SD Formatter Tool on the Mac

To install the SD Formatter app on the Mac, follow these steps:

1. Open your browser if it's not running, or switch to it if it's already running.

2. Go to https://www.sdcard.org/downloads/formatter_4/ and download the SD Formatter for Mac package.

3. Click the Downloads icon on the Dock to display the Downloads stack, and then click the SDFormatter package file. The Install SDFormatter installer runs.

4. Click the Continue button and follow through the installation process, entering your password and clicking the Install Software button when prompted to do so. You don't need to make any decisions during the installation.

5. When the screen called "The Installation Was Successful" appears, click the Close button.

You can now launch the SD Formatter app by clicking the Launchpad icon on the Dock and then clicking the SDFormatter icon on the Launchpad screen.

Formatting an SD Card with the SD Formatter App on the Mac

Once you've installed the SD app on your Mac, you can format the SD card with it. To format the SD card, follow these steps:

1. Launch the app. The SDFormatter window opens (see Figure 5-6).
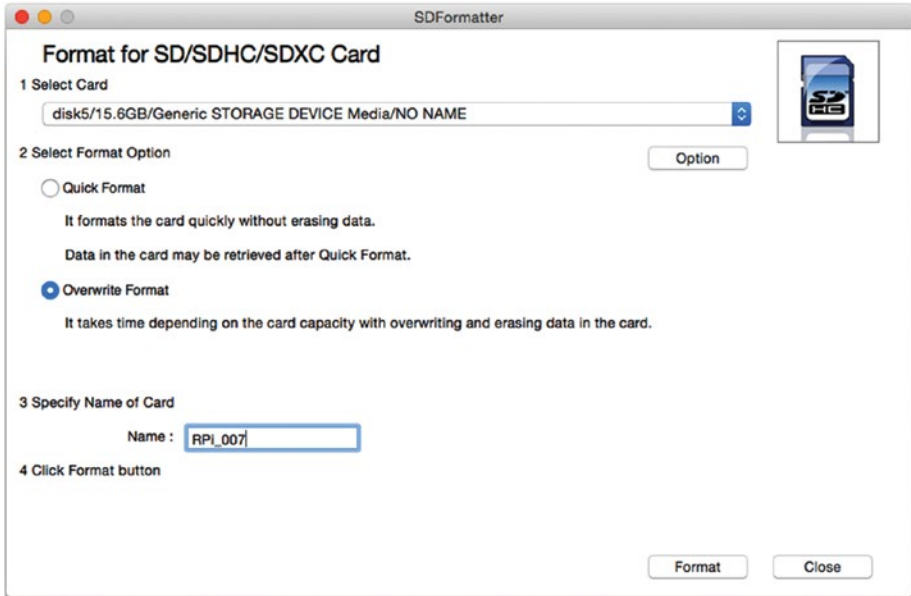
Figure 5-6. *Formatting an SD card with the SDFormatter app on a Mac*

2. Look at the Select Card pop-up menu and see if it shows the SD card you want to format. If not, open the pop-up menu and select the right SD card.

3. In the Select Format Option area, click the Option button to display the Logical Address Adjustment dialog box.

4. Select the Yes option button. (The No option button is the default.)

5. Click the OK button to close the Logical Address Adjustment dialog box.

6. Also in the Select Format Option area, select the Overwrite Format option button instead of the Quick Format option button. Overwriting the data on the SD card makes the formatting operation take longer, but it leaves the SD card in a better state for use with the Raspberry Pi computer.

7. In the Specify Name of Card area, double-click in the Name box and type the name you want to assign to the SD card—11 characters maximum, using underscores and spaces if you want, but none of the characters you can't use in filenames such as colon (:) or forward slash (/).

8. Click the Format button. The SD Formatter app formats the card, displaying a progress readout as it does so.

9. When the "Card Format Complete!" readout appears, click the Close button. The SDFormatter window closes, and the app quits.

Formatting an SD Card on Linux

Linux offers a variety of different tools for formatting disks, including SD cards. Many distributions include a graphical tool for formatting disks as well as command-line tools. As an example, this section uses Ubuntu's Disks app, which puts an easy-to-use graphical interface on the disk-formatting tools.

■ **Caution**   Even if you're experienced with the command line, be especially careful when using command-line tools to format SD cards. It's all too easy to unleash the formatting command on the wrong drive and permanently delete valuable data.

Follow these steps to format an SD card using the Disks app in Ubuntu:

1. Click the Search Your Computer button to open the Search panel.

2. Type *disks* in the Search box. The search results appear.

3. Click the Disks result in the Applications section of the Search panel. The Disks app opens.

4. In the left panel, click the entry for the SD card. You should be able to identify the right entry easily by its size. The details for the SD card appear (see Figure 5-7).
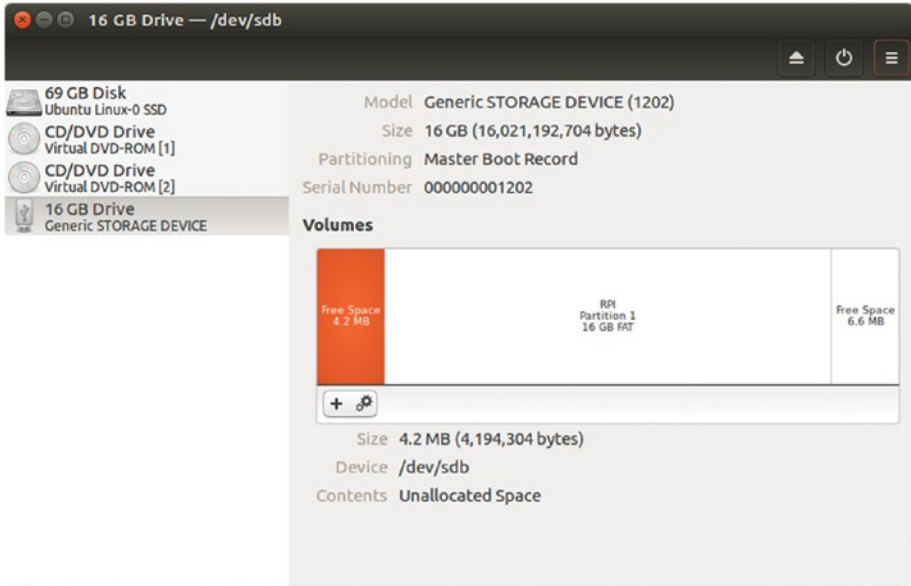
Figure 5-7. *Use the Disks app on Ubuntu to format an SD card.*

5. Click the Menu button in the upper-right corner of the Disks window to open the menu, and then click the Format Disk item. If you prefer keyboard shortcuts, press Ctrl+F. The Format Disk dialog box opens (see Figure 5-8).
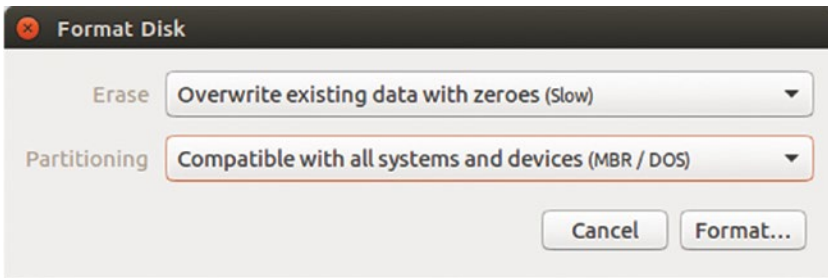
Figure 5-8. *In the Format Disk dialog box, choose whether to overwrite the disk's existing data and which type of Partitioning to use.*

6. Open the Erase pop-up menu and choose Overwrite existing data with zeroes.

7. Open the Partitioning pop-up menu and choose Compatible with all systems and devices.

8. Click the Format button. A confirmation dialog box appears (see Figure 5-9), giving you one last chance to make sure you've chosen the right disk.

Are you sure you want to format the disk?

All data on the disk will be overwritten and will likely not be recoverable by data recovery services

Affected Devices

16 GB Drive — Generic STORAGE DEVICE [1202] (/dev/sdb)

Cancel   Format

Figure 5-9. In the confirmation dialog box, verify that you've selected the right disk, and then click the Format button.

9. Click the Format button. The Disks app formats the disk, displaying a progress readout as it does so.

10. When the Disks app finishes formatting the disk, the SD card appears in the Volumes area marked as Free Space. Click the Create Partition (+) button just above the Size readout to display the Create Partition dialog box (see Figure 5-10).
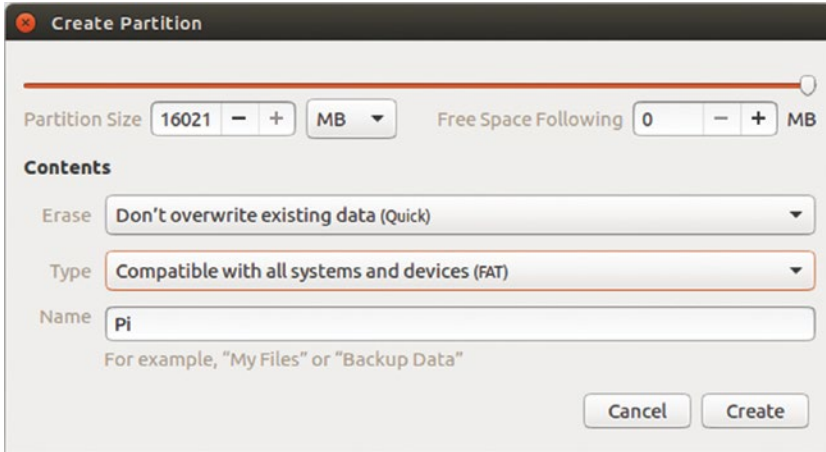
Figure 5-10. *In the Create Partition dialog box, set the partition size and name, and then click the Create button.*

11. In the Partition Size box at the top, set the partition size in megabytes. Normally, the Create Partition dialog box suggests the maximum size possible for the SD card, and you can simply accept this.

12. In the Erase pop-up menu, make sure the "Don't overwrite existing data" item is selected.

13. In the Type pop-up menu, make sure the "Compatible with all systems and devices (FAT)" item is selected.

14. In the Name box, type the name you want to give the SD card.

15. Click the Create button. The Disks app creates the partition, which then appears in the Volumes box.

16. Click the Mount Selected Partition button (the button with the Play icon) to mount the new partition. The Mount Selected Partition button changes to the Unmount Selected Partition button (a Stop icon).

You can now copy files to the SD card, as explained in the section "Putting the NOOBS Installer on an SD Card on Linux" later in this chapter.

■ **Tip**   The Disks app also has a Restore Disk Image command that you can use to restore (in lay terms, "put") an operating system image onto an SD card. If you have downloaded another operating system, such as Xubuntu or Ubuntu Mate (discussed in Chapter 3), you can use this command to put the image on the SD card. You can then boot from the SD card to install the operating system.

Putting the NOOBS Installer on an SD Card

If you've downloaded the NOOBS installer, unzip it and copy the files to the SD card you will use to install the operating system on the Raspberry Pi computer.

Putting the NOOBS Installer on an SD Card on Windows

To put the NOOBS installer on an SD card on Windows, follow these steps:

1. Open a File Explorer window to the folder that contains the NOOBS zip file. For example, if you're using Windows 10 and you've downloaded the NOOBS zip file to your Downloads folder, click the Start button to open the Start menu, click the Show Jump List button to the right of the File Explorer item, and then click the Downloads item to display the Downloads folder.

2. Click the NOOBS zip file to select it. The Compressed Folder Tools tab appears on the Ribbon.

3. Click the Extract button under Compressed Folder Tools to display the Extract controls.

4. Click the Extract All button. The Extract Compressed (Zipped) Folders Wizard runs and displays the Select a Destination and Extract Files screen (see Figure 5-11).
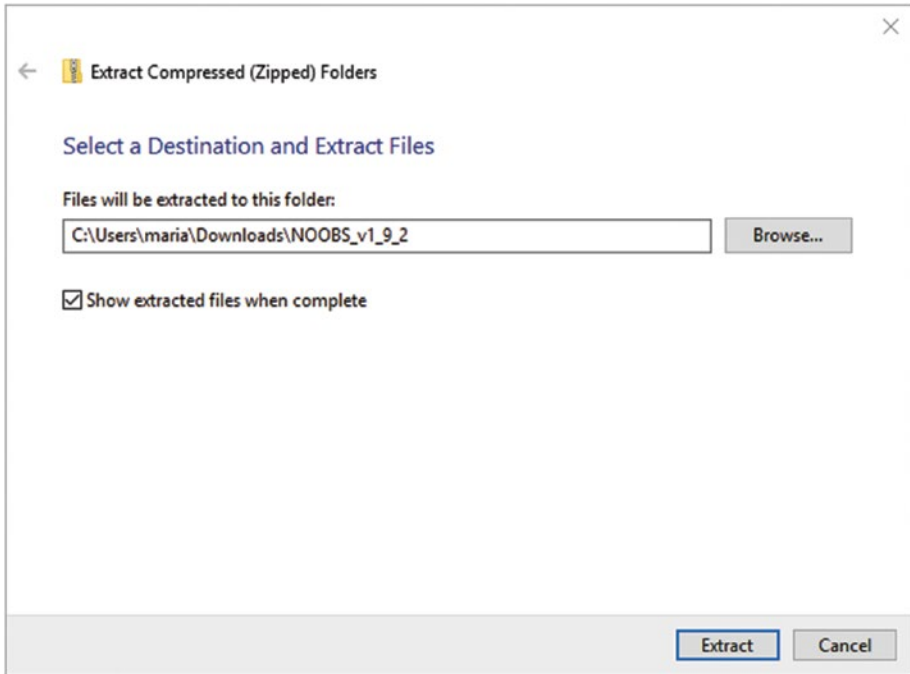
Figure 5-11. *On the Select a Destination and Extract Files screen of the Extract Compressed (Zipped) Folders Wizard, choose the destination folder for the unzipped files and folders, and then click the Extract button.*

5. Look at the "Files will be extracted to this folder" box. If the folder is okay, you're set; if not, click the Browse button to display the Select a Destination dialog box, click the right folder, and then click the Select Folder button.

6. Select the "Show extracted files when complete" check box if you want Windows to display the files after the extraction finishes. If you're planning to copy the files to an SD card, displaying the files is usually handy.

7. Click the Extract button. The Wizard extracts the files and then (assuming you selected that check box) displays them in a File Explorer window.

CAN YOU EXTRACT THE FILES STRAIGHT TO AN SD CARD?

You might be wondering whether you can extract the files directly to an SD card instead of extracting them to a folder on your computer's storage and then copying them to the SD card.

You can certainly do this, but the Extract Compressed (Zipped) Folders Wizard puts the files in a folder that has the same name as the zip file, such as NOOBS_v1_9_2. To make the SD card work, you must move the files from this folder to the root folder of the SD card. This takes only a couple of seconds, so it shouldn't be a problem. You should also delete the NOOBS folder from the SD card once you've moved the files out of it.

So extracting the files directly to the SD card works moderately well if you need to set up only a single SD card. But if you need to copy the files to multiple SD cards, you'll normally do better to extract them to your computer's storage and then copy them across to each SD card in turn.

Putting the NOOBS Installer on an SD Card on the Mac

When the download of the zip file containing the NOOBS installer completes, OS X automatically unzips the zip file, puts its contents in a folder of the same name (minus the .zip file extension), and places the zip file in the Trash.

To put the NOOBS installer on an SD card, follow these steps:

1. Open a Finder window to the NOOBS folder. For example, if OS X unzipped the NOOBS zip file to a NOOBS folder in the Downloads folder, click the Downloads icon on the Dock, click the NOOBS folder, and then click the Open in Finder icon.

2. Insert the SD card in a reader connected to your Mac. The SD card appears in the Devices category in the Finder window. (If the Devices category is collapsed, move the pointer over the Devices heading, and then click the Show button that appears.)

3. Select all the items in the NOOBS folder. For example, with the NOOBS folder selected, press Cmd+A or choose Edit ➤ Select All from the menu bar.

4. Drag the selection to the SD card's entry in the Devices list. Finder copies the items to the SD card.

5. After the copy operation finishes, click the Eject icon to the right of the SD card's entry in the Devices list to eject the SD card.

Putting the NOOBS Installer on an SD Card on Linux

After you download the zip file containing the NOOBS installer, your version of Linux may unzip it automatically for you. If not, unzip it manually.

Once NOOBS is unzipped, open a file-management window to the folder that contains it. You can then select the files and folders within the NOOBS folder and drag them to the SD card to copy them there.

Installing Operating Systems with the NOOBS Installer

By this point, you should have an SD card containing the NOOBS installer. The following subsections show you how to install Raspbian and other operating systems on a Raspberry Pi computer using NOOBS.

Launching the NOOBS Installer

To install Raspbian using the NOOBS installer, follow these steps:

1. Insert the SD card containing the NOOBS installer in the Raspberry Pi computer.

2. Power on the Raspberry Pi computer. For example, connect the power lead to the micro USB power input. The Raspberry Pi computer starts, and after a few moments, the NOOBS screen appears (see Figure 5-12).
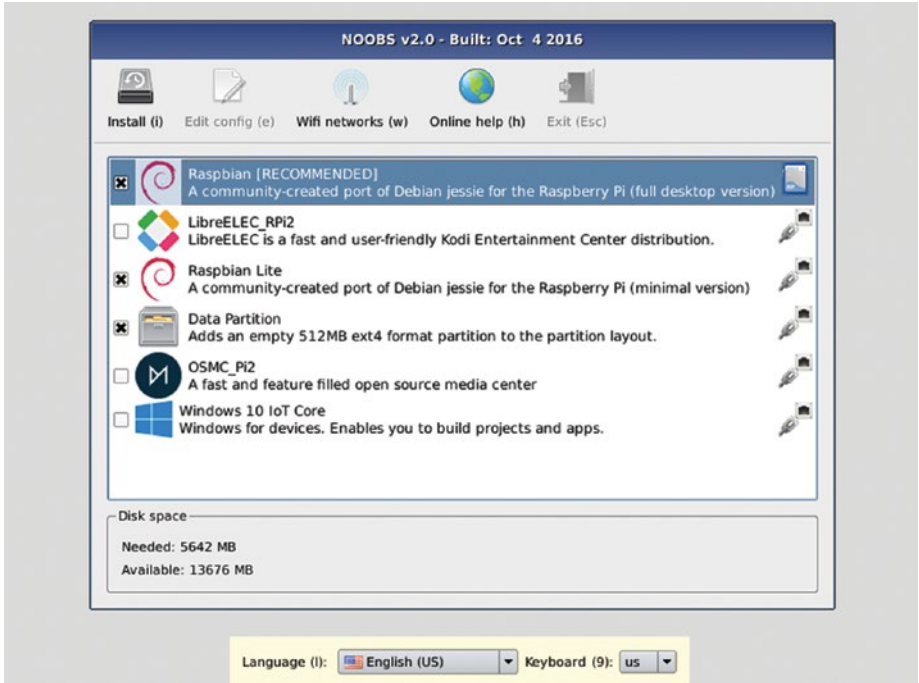
Figure 5-12. *On the NOOBS screen, first check that the right language and keyboard layout are selected. Then choose the operating system you want to install and click the Install button.*

■ **Note**   Normally, NOOBS detects the type of the connected display and produces output suitable for it. If you don't see anything on the display, first check that it is connected firmly with an intact cable; if you're not certain the cable works, replace it with one that you know works. Next, try pressing the keys for switching output modes: Press 1 for the preferred resolution from the HDMI port, press 2 for VGA resolution from the HDMI port, press 3 for PAL (Phase Alternating Line) output from the composite port, or press 4 for NTSC (National Television System Committee) output from the composite port. If your display still has no output, see the section "Editing the config.txt File" later in this chapter for information on editing the config.txt file to change the output.

You'll notice that in Figure 5-12, the Edit Config (e) button and the Exit (Esc) button on the toolbar of the NOOBS window are dimmed and unavailable. These buttons become available when you are using NOOBS to change the existing configuration on a Raspberry Pi computer. See the section "Using Recovery Mode," later in this chapter, for details on using NOOBS this way.

NAVIGATING THE NOOBS WINDOW WITH THE KEYBOARD

If you've plugged a compatible mouse into the Raspberry Pi computer, you should be able to navigate the NOOBS screen using the mouse.

If your mouse isn't operational, use the keyboard instead. Press the down-arrow key and up-arrow key to move the highlight down or up the list of operating systems, and then press the spacebar to check the box for the operating system you want to install.

Press a letter shown in parentheses to use the toolbar buttons and the pop-up menus. For example, press the "L" key to open the Language pop-up menu, or press the "I" key to "click" the Install button.

3. In the bar at the bottom of the screen (see Figure 5-12), verify that the Language pop-up menu shows the language you want to use. If not, open the pop-up menu and click the appropriate language.

4. Also in the bar at the bottom of the screen, verify that the Keyboard pop-up menu shows the keyboard layout you need. If not, open the pop-up menu and click the appropriate keyboard.

Connecting the Raspberry Pi computer to a Wi-Fi Network

After launching the NOOBS installer, you can connect the Raspberry Pi computer to a Wi-Fi network. You'd normally need to connect to a Wi-fi network only if

- This is a Raspberry Pi computer with built-in Wi-Fi, such as the Raspberry Pi 3, or another Raspberry Pi model with the Raspberry Pi USB Wi-Fi Dongle.

- You need to download an operating system.

- The Raspberry Pi computer doesn't have an Ethernet connection available.

To connect the Raspberry Pi computer to a Wi-Fi network, follow these steps:

1. Click the Wi-Fi Networks button on the toolbar or press the W key to display the "Wifi network selection" dialog box (see Figure 5-13).
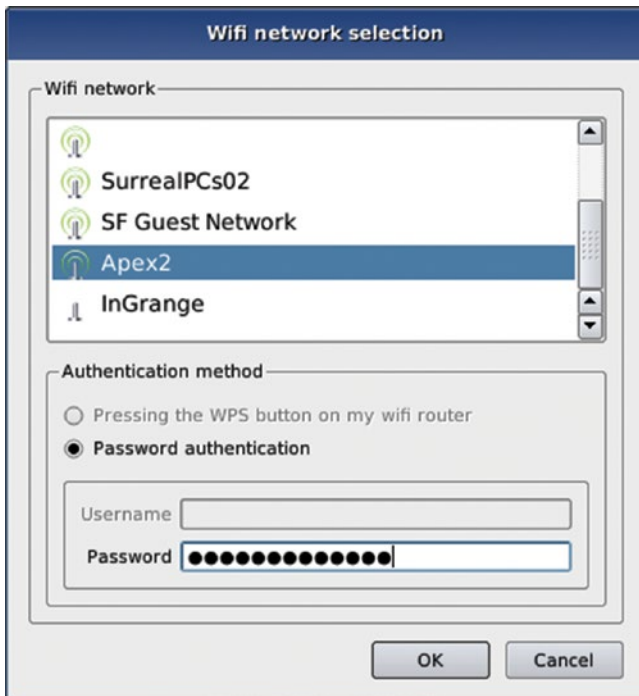
Figure 5-13. *In the Wifi network selection dialog box, click the appropriate Wi-Fi network, choose and provide the authentication method, and then click the OK button.*

2. In the "Wifi network" list box, click the Wi-Fi network to which you want to connect the Raspberry Pi computer.

3. In the Authentication method box, select the "Pressing the WPS button on my wifi router" option button or the "Password authentication" option button, as appropriate.

4. If you selected the Password authentication option button, click in the Password box and type the password for the Wi-Fi network.

5. Click the OK button. The Raspberry Pi computer connects to the network.

Choosing Whether to Create a Data Partition

Apart from installing an operating system, the NOOBS installer enables you to create a data partition on the SD card in the Raspberry Pi computer. The data partition is 512 MB in size and is formatted with the ext4 file system (fourth extended filesystem).

The data partition is an area in which you can safely save files that you want to keep even if you have to reinstall your operating systems. NOOBS keeps the data partition safe during reinstallation rather than overwriting it like the other partitions.

■ **Caution**　　The data partition is a great idea, and in general it works well, but you'd be wise not to rely on it too much. First, you should be prepared for some of your SD cards to fail, particularly if used heavily or vigorously. And second, if you sometimes need to remove the SD cards from your Raspberry Pi computers, you may find it difficult to keep clear which card is which, because they're almost impossible to label. In this case, you may be better off storing any important data on a server.

Selecting the Operating System and Performing the Installation

At this point, you should be ready to select and install one or more operating systems. In the NOOBS installer, follow these steps:

1. Select the check box for each operating system you want to install. For example, select the Raspbian check box to install the Raspbian operating system.

■ **Note** The icon on the right of each operating system's button in the NOOBS window shows an SD card icon if the operating system is on the SD card and a chain icon if the operating system needs to be downloaded. Downloading one or more operating systems may take a while, depending on the speed of your Internet connection. As of this writing, the LibreELEC operating system is about 1 GB; the OSMC operating system is about 1.5 GB; and Windows 10 IoT Core is about 7.8 GB.

2. Click the Install button or press the I key. The Confirm dialog box opens (see Figure 5-14), making sure you want to overwrite all the existing data on the SD card.

Figure 5-14. *In the Confirm dialog box, click the Yes button to confirm that you're prepared to overwrite all the existing data on the SD card.*

3. Click the Yes button if you're ready to go ahead. The installer runs, displaying a series of decorative and information screens and progress readouts as it does so. Figure 5-15 shows an example.

■ **Note** You can install multiple operating systems on an Raspberry Pi computer if the SD card has enough free space.
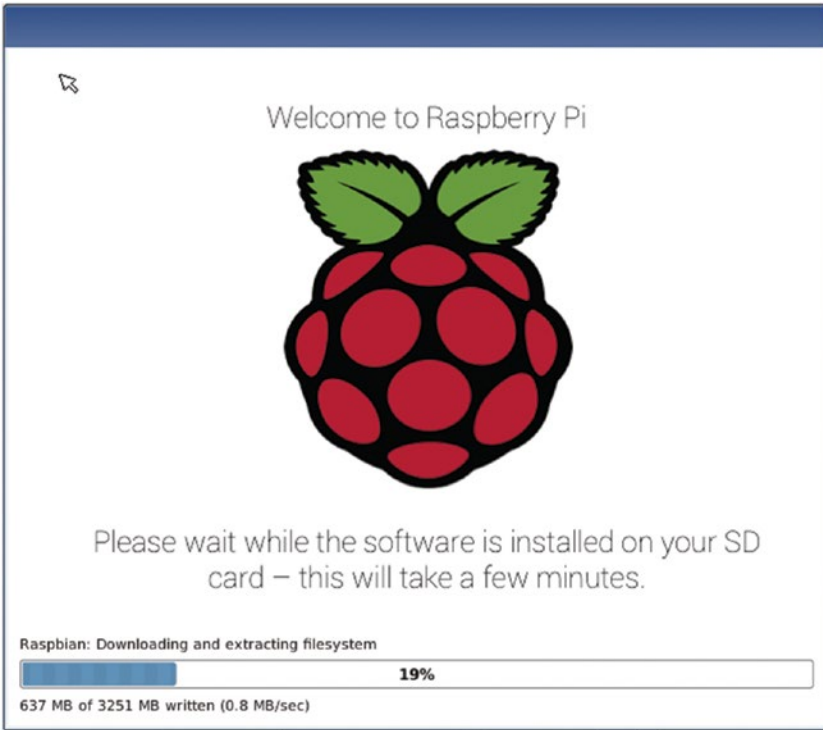
Figure 5-15. *The NOOBS installer displays information and progress readouts as it works.*

When the installation finishes, the OS(es) installed dialog box appears (see Figure 5-16). Click the OK button to close the dialog box.

Figure 5-16. *The NOOBS installer displays information and progress readouts as it works.*

The Raspberry Pi computer then reboots. During the boot process, the Recovery splash screen appears for a couple of seconds. This is a gray screen with the Raspberry Pi logo in the middle and the prompt *For Recovery Mode, hold Shift here*. As the message says, you can press the Shift key to access Recovery mode. We'll look at this in the section "Using Recovery Mode" later in this chapter.

If you installed multiple operating systems on the Raspberry Pi computer, the Select OS to Boot dialog box then appears for a few seconds (see Figure 5-17). Double-click the operating system you want to boot, or press the up-arrow key or down-arrow key to move the highlight to the operating system, and then press the Enter key. If the operating system you want is selected, you can also simply wait until the countdown completes and the Raspberry Pi computer boots that operating system.
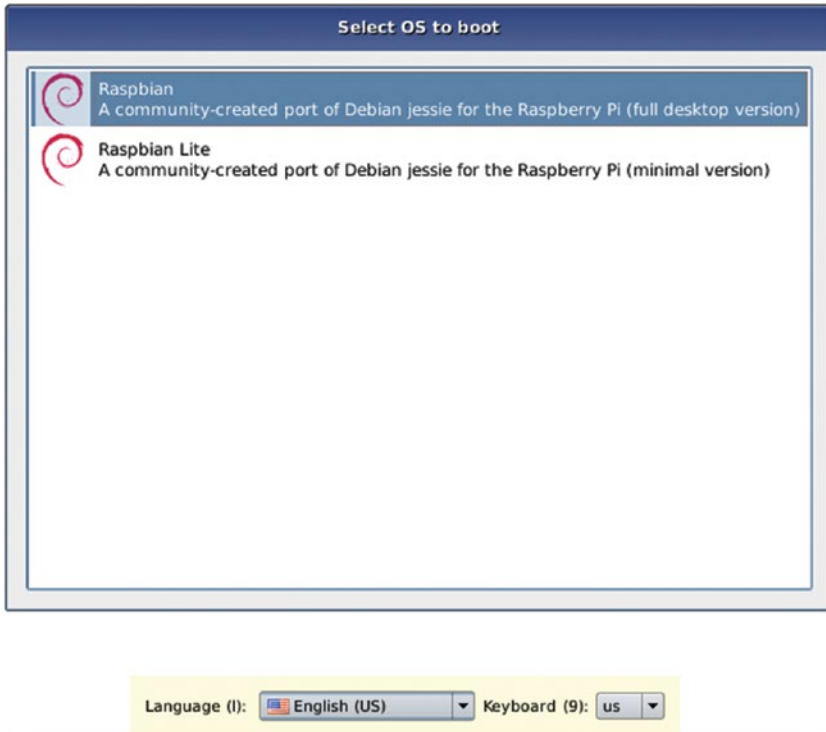
Figure 5-17. *In the Select OS to boot dialog box, select the operating system by double-clicking or by pressing down arrow or up arrow and then pressing the Enter key.*

■ **Note**   Below the Select OS to boot dialog box, you can also change the language and the keyboard if necessary.

Performing a Headless Install via VNC

As you've seen, booting the NOOBS installer and installing Raspbian or another operating system on a Raspberry Pi computer is straightforward, but you need to give commands directly on the computer. If you find it more convenient to work remotely, you can use Virtual Network Computing (VNC) to run the installation from another computer instead—or from another device, such as a tablet or a phone, if you prefer. This section shows you how to do so.

Getting a VNC Client if Necessary

If you don't yet have a VNC client, you'll need to get one. The following list gives examples of VNC clients that are known to work for headless installs:

- *Windows*: TightVNC, which you can download for free from the TightVNC web site (http://www.tightvnc.com/download.php).

- *Mac*: Chicken of the VNC, which you can download for free from the Chicken web site on SourceForge (https://sourceforge.net/projects/chicken/).

■ **Note**   OS X and macOS include a built-in VNC client, Screen Sharing.app; but as of this writing, it doesn't work for connecting to the NOOBS installer.

- *Linux*: Many Linux distributions include a VNC app that will work for connecting to NOOBS. For example, the Ubuntu distribution includes the Remmina Remote Desktop Client app, which enables you to connect via VNC as well as via other protocols, such as RDP (Remote Desktop Protocol) and SSH.

- *iPhone or iPad*: Mocha VNC Lite, which you can download for free from the App Store, can connect to NOOBS.

- *Android*: VNC Viewer, which you can download for free from the Play Store, can connect to NOOBS.

Adding the `vncinstall` Command to the `recovery.cmdline` File

Your next move is to add the `vncinstall` command to the `recovery.cmdline` file. As its name suggests, the `vncinstall` command causes the NOOBS installer to install VNC.

Follow these steps to add the `vncinstall` command to `recovery.cmdline`:

1. Put the SD card you'll use for this Raspberry Pi computer in an SD card reader connected to another computer.

2. Open the file called `recovery.cmdline` in a text editor, such as Notepad on Windows or TextEdit on the Mac. The file usually looks something like this:

```
runinstaller quiet ramdisk_size=32768 root=/dev/ram0 init=/init vt.cur_
default=1 elevator=deadline
```

3. Add the `vncinstall` command to the end after a space:

```
runinstaller quiet ramdisk_size=32768 root=/dev/ram0 init=/init vt.cur_
default=1 elevator=deadline vncinstall
```

4. Save the file.

5. Close the file.

■ **Note**   If you use TextEdit on the Mac to edit `recovery.cmdline`, an alert dialog box may open to warn you that the file is on a volume that does not support permanent version storage, which means that you won't be able to access older versions of the file after you close it. This is fine because you don't need the extra versions of the file that TextEdit can maintain on a fixed drive. So just click the OK button to dismiss the alert.

DEALING WITH THE "UNIDENTIFIED DEVELOPER" WARNING ON THE MAC

When you try to open the `recovery.cmdline` file for editing on a Mac, you may see an alert dialog box warning you that `recovery.cmdline` can't be opened because it is from an unidentified developer. This alert appears because macOS reads the `recovery.cmdline` file as being a UNIX executable file rather than a configuration file, which makes the developer's lack of Apple accreditation register as a security threat.

Follow these steps to deal with this problem:

1. Click the OK button to dismiss the alert dialog box.

2. Open the Security & Privacy pane in System Preferences. For example, Ctrl+click or right-click the System Preferences icon on the Dock and then click the Security & Privacy item on the context menu.

3. If the General tab isn't displayed, click the General tab button to display it.

4. Go to the Allow Apps Downloaded From area and click the Open Anyway button.

The file opens in the app you tried to use (such as TextEdit), and you can edit it.

Replacing the SD Card and Booting the Raspberry Pi Computer

Now that you've added the `vncinstall` command to the `recovery.cmdline` file, eject the SD card from the computer you used for editing the file, and then replace it in the Raspberry Pi computer.

Make sure the Raspberry Pi computer is connected to your network via an Ethernet cable, and then power on the computer. You'll see a short screen of status information, which may include several errors. No graphical interface appears, because VNC is now getting that information.

Finding the IP Address for the Raspberry Pi Computer

To connect via VNC to the Raspberry Pi computer, you need to know the IP address assigned to it. The following subsections give examples of tools you can use to find the Raspberry Pi computer's IP address.

Windows, Mac, or Linux: Nmap

Nmap is a free network-scanning tool that you can download from the Nmap web site (`www.nmap.org/download`). Nmap is a command-line tool but includes a graphical front end called *Zenmap.*

■ **Caution**   Avoid the development releases of Nmap because these are not yet proven stable.

Normally, you'll want to download the latest stable release self-installer file for your operating system. Run the self-installer file and follow through the installation. On the Choose Components screen, you'll normally want to check all of the boxes to install all the components. On the WinPcap Options screen, check the Start the WinPcap Service "NPF" Now check box if you plan to use Zenmap right away. Check the Start the WinPcap Service "NPF" at Startup check box if you plan to use Zenmap regularly.

Once you've installed Nmap and Zenmap, run Nmap–Zenmap GUI from the Start menu (in Windows), from Launchpad (on the Mac), or in the normal way for the Linux distribution you're using.

In the Target box, specify the IP address range you want to search. For a network that uses the 192.168 private range, you would normally use a target such as `192.168.0.0/24`, where "`/24`" specifies the network mask; for a network that uses the 10.0 private range, you would normally use a target such as `10.0.0.0/24`.

Next, open the Profile pop-up menu and choose Ping Scan, then click the Scan button. After a little while, the Nmap Output tab displays a list of the hosts found in that address range (see Figure 5-18), and you can identify the Raspberry Pi computer to which you want to connect.
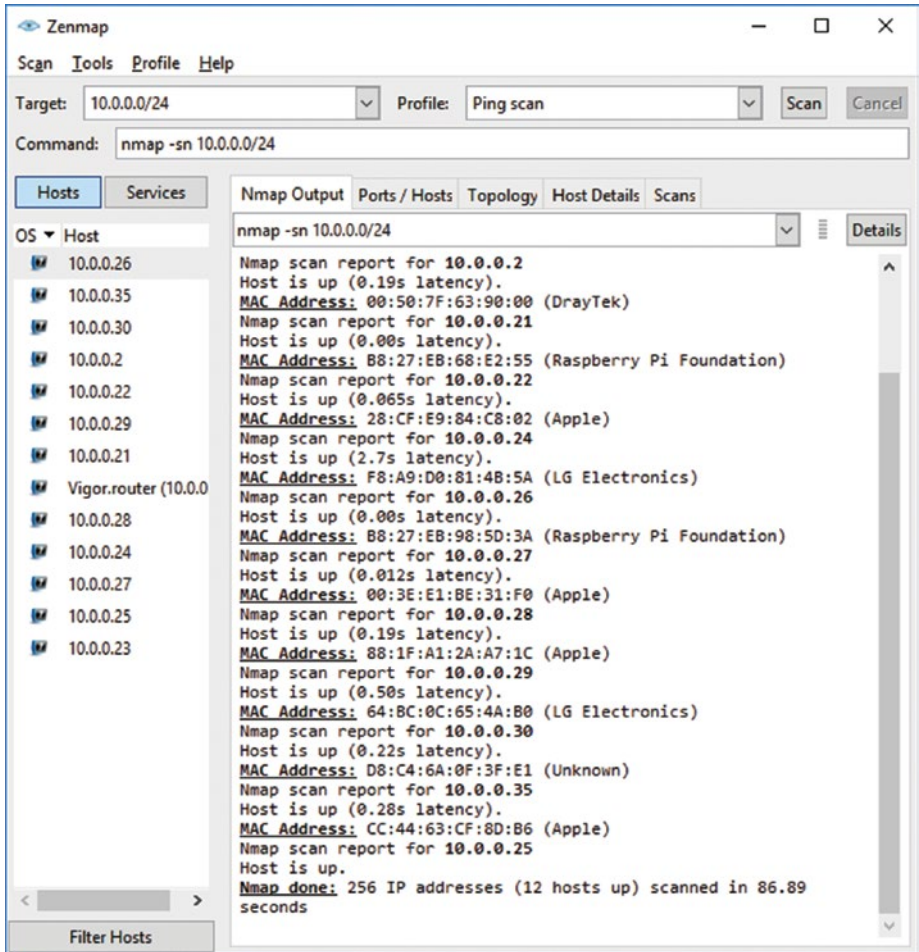
Figure 5-18. *Nmap, shown here with the Zenmap graphical interface, is a network scanner you can use to determine the IP address of a Raspberry Pi computer on the network.*

SCANNING FOR OPEN PORT 5900 WITH NMAP

If you're looking for a single Raspberry Pi computer on your network, a straightforward host scan using Nmap may give you all the information you need. But if you must distinguish a Raspberry Pi computer that's listening for VNC connections from other Raspberry Pi computers that aren't listening for VNC connections, run a port scan for computers and devices that have port 5900 open. Port 5900 is the TCP (Transmission Control Protocol) port used for VNC.

To do this, add the `-p 5900 --open` parameter to the nmap command in the Command box in Zenmap. For example

```
nmap -p 5900 --open 10.0.0.0/24
```

This makes Nmap return a list of only those computers and devices with port 5900 open.

---

iPhone or iPad: Fing

Fing is a free network-scanning app that gives you a straightforward list of the computers and devices it finds on the network. The list shows each item's IP address, MAC (Media Access Control) address, hostname (if available), and manufacturer. To identify the Raspberry Pi computer, look for the entry with Raspberry Pi Foundation listed as the manufacturer.

■ **Tip**   Fing displays the hostname for a Raspberry Pi computer that has one or more operating systems installed. If you're about to set up a Raspberry Pi computer for the first time, look for the entry without a hostname. You can also tap the entry for a device to display a screen with more information about the device. From there, tap the Scan Services button to display the Services screen, where you can see whether the VNC service is running.

Android: IP Tools

IP Tools is a network-scanner app for Android that enables you to find out a wide range of information about the computers and devices on a network. The basic version of IP Tools is free and includes the functionality needed to determine IP addresses; you must pay if you want to upgrade to the Pro version of IP Tools.

After installing IP Tools via the Play Store app, follow these steps to find out the Raspberry Pi computer's IP address:

1. Launch IP Tools either by tapping the Open button on the app's screen in the Play Store app (if you still have it open) or by tapping the app's icon on the Apps screen.

2. Swipe in from the right side of the screen to open the Navigation panel.

3. Tap the LAN (local area network) Scanner button to display the LAN Scanner screen.

4. Leave the default entry (`127.0.0.1`) in the box at the top of the screen.

5. Make sure the Show Manufacturer check box is checked.

6. Tap the right-arrow button to run the scan.

7. In the list of computers and devices that the LAN Scanner screen displays, look for the one with `Manufacturer: RASPBERR` (longer names are truncated to eight characters).

FINDING THE RASPBERRY PI COMPUTER'S IP ADDRESS ON YOUR ROUTER

If you have access to your network's router, you can look up the Raspberry Pi computer's entry in the DHCP table. Router manufacturers use a wide variety of layouts for the control screens on their routers, so you may need to browse through the router's interface or even read its manual to find the DHCP table.

IDENTIFYING RASPBERRY PI COMPUTERS BY MAC ADDRESS

Another way to identify Raspberry Pi computers on a network is by their MAC addresses. MAC is the acronym for Media Access Control and is a unique hardware address assigned to a network interface, such as an Ethernet or a Wi-Fi adapter. A MAC address has six hexadecimal pairs separated by colons, such as `00:50:7F:63:90:01` or `B8:27:EB:98:3C:BB`, or by hyphens.

Each Raspberry Pi computer has a MAC address whose first three pairs are `B8:27:EB`. You can use these pairs to identify Raspberry Pi computers on your network by MAC address alone. This is occasionally useful, but it's normally easier to use network-scanning tools that can also tell you the hostnames and IP addresses.

Distinguishing one Raspberry Pi computer from another by MAC address is trickier. The MAC address doesn't appear on the Raspberry Pi board itself. You can easily get the MAC address by using a command such as `ifconfig eth0`, but you must install an operating system first. So MAC addresses as identifiers are more useful for managing the network, as discussed in Chapter 7, than during setup.

Connecting and Working via VNC

Now that you know the IP address of the Raspberry Pi computer, open the VNC client and connect to that IP address. Usually, the IP address is all you need to specify; the port number is 5900, but because this is the default VNC port, most VNC clients establish the connection without you specifying it. There's no password for connecting to the NOOBS installer via VNC.

Once you've connected to the Raspberry Pi computer via VNC, you can use your computer's keyboard and pointing device to control the Raspberry Pi computer much as if you were sitting at it. Figure 5-19 shows a Chicken of the VNC window connected to NOOBS for remote installation.
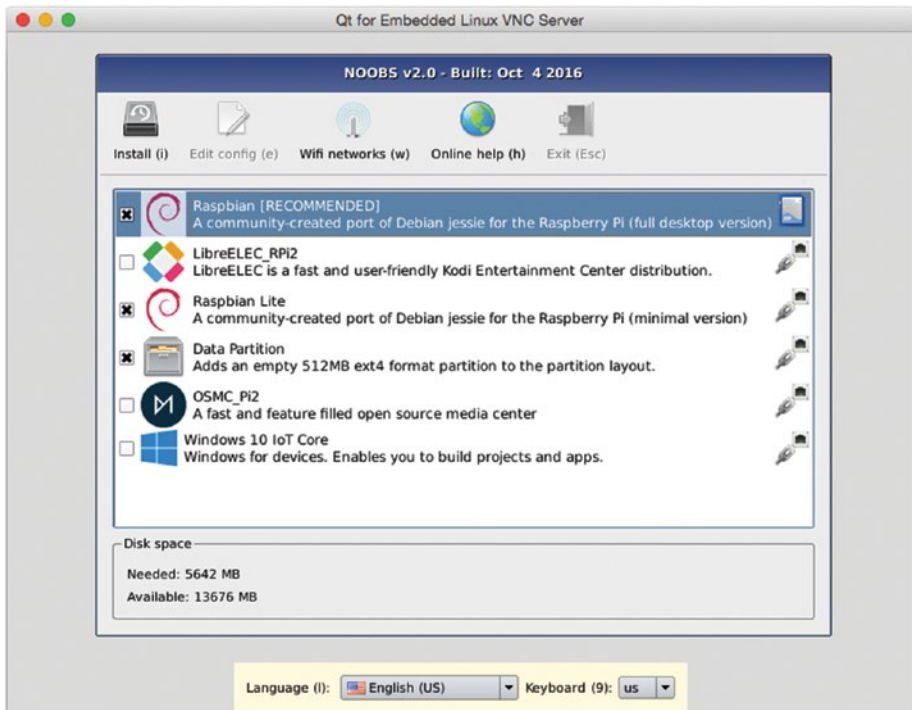
Figure 5-19. *You can use a VNC client, such as Chicken of the VNC on the Mac, to control the NOOBS installer remotely.*

Using Recovery Mode

The NOOBS installer provides a recovery and management feature called Recovery mode. You access Recovery mode by pressing the Shift key during startup. Recovery mode enables you to change the selection of operating systems installed on a Raspberry Pi computer.

■ **Caution**   Changing the operating systems on the Raspberry Pi wipes out the existing operating systems on the SD card. However, if you have created a data partition, NOOBS preserves it.

Recovery mode also enables you to edit the configuration files used to boot the Raspberry Pi computer. For example, you may need to change the display mode to use a different type of monitor or to remove a black border around the edge of the display.

Booting into Recovery Mode

To boot into Recovery mode, power the Raspberry Pi computer on and wait for the Recovery splash screen, a gray screen with the Raspberry Pi logo in the middle and a prompt to press Shift to enter Recovery mode, to appear. When you see the Recovery splash screen, press and hold the Shift key for a couple of seconds.

The NOOBS screen then appears (see Figure 5-20), looking much the same as for initial setup but now with the Edit Config button and the Exit button on the toolbar enabled.
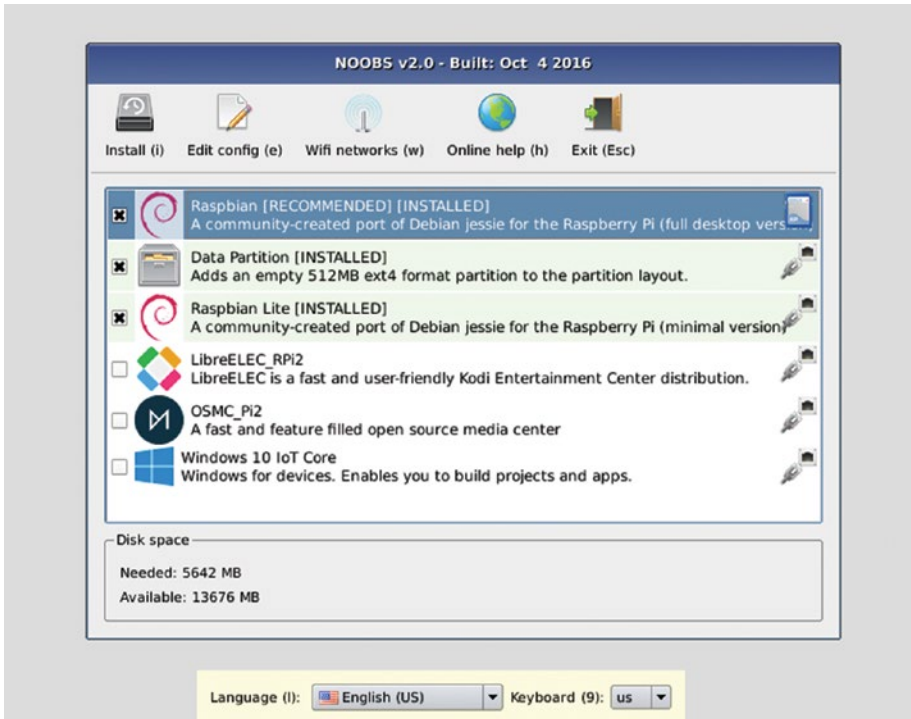
Figure 5-20. *When you boot into Recovery mode, the NOOBS installer appears with the Edit Config button and the Exit button enabled.*

FORCING RECOVERY MODE—OR PREVENTING IT

If you're having trouble triggering Recovery mode by pressing Shift at the right time, edit the `recovery.cmdline` file as explained earlier in this chapter and add the `forcetrigger` parameter to the end of the file. This parameter causes the Raspberry Pi computer to boot into Recovery mode every time, so you'll want to edit `recovery.cmdline` again and remove the parameter as soon as you no longer need it.

The `forcetrigger` parameter is easy to use; but for flexibility, the Raspberry Pi also lets you force Recovery mode by using the GPIO pins. To do this, first add the `gpiotriggerenable` parameter to `recovery.cmdline`. Once you've done that, you can connect GPIO pin 3 on header P1 to the GND (ground) pin (pin 25) to force Recovery mode.

While we're talking about triggering Recovery mode, there's also a `keyboardtriggerdisable` parameter that you can add to `recovery.cmdline` to prevent a press on the Shift key from triggering Recovery mode. You might want to use `keyboardtriggerdisable` if you need to prevent students from accessing

Recovery mode or if you find a Raspberry Pi computer reads phantom Shift keypresses from a particular keyboard during startup and so triggers Recovery mode when you don't need it.

Opening the Config Editor

In Recovery mode, you can edit the `config.txt` file and the `cmdline.txt` file by clicking the Edit Config button on the toolbar (or pressing the E key) and working in the Config Editor dialog box that opens. As you can see in Figure 5-21, the Config Editor dialog box has two tabs, one for `config.txt` and one for `cmdline.txt`.
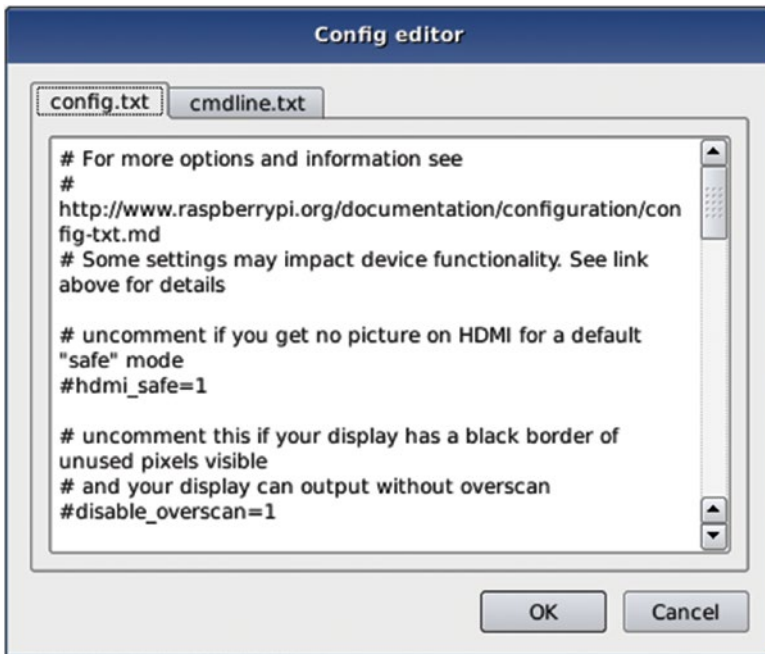
Figure 5-21. *You can edit the config.txt file by clicking the config.txt tab in the Config Editor.*

Recovery mode is usually the most convenient way to edit `config.txt` and `cmdline. txt` because you're working directly on the Raspberry Pi computer and need only restart it to apply the changes. But you may sometimes need to remove the SD card from the Raspberry Pi computer and use another computer to edit the files. You might have to do this to solve problems that are preventing the Raspberry Pi computer from booting or to remove the `keyboardtriggerdisable` parameter from the `recovery.cmdline` file.

■ **Note**   You can also edit the `config.txt` file indirectly by using the Raspberry Pi Configuration tool while the Raspberry Pi computer is running. The Raspberry Pi Configuration tool prompts to restart the computer when you have made a change that requires a restart.

Editing the config.txt File

The `config.txt` file is a text file that contains configuration information for the Raspberry Pi computer. The `config.txt` file on the Raspberry Pi plays a similar role to the BIOS (Basic Input/Output System) on a normal PC, storing details of the system configuration required to start the computer.

The `config.txt` file is stored on the boot partition of the SD card. The Raspberry Pi computer's GPU reads `config.txt` before the computer initializes the CPU and the Linux operating system.

The `config.txt` file can contain a wide variety of parameters. In this section, we'll look at a sample `config.txt` file and discuss some of the changes you're most likely to need to make. I'll point you to where you can find a full reference to the parameters you can use in `config.txt`.

Meeting a Sample `config.txt` File

The following code listing shows a sample `config.txt` file from a Raspberry Pi 3 Model B running Raspbian Jessie. Here's a quick word of explanation to start with:

- Any line that starts with a # and a space is a comment.

- Some of the comment lines are text that explain the options that follow and suggest when to use those options.

- Most of the options are "commented out" by a # placed before them. You can "uncomment" an option by deleting the # before it. The option then takes effect when you restart the Raspberry Pi computer.

```
# For more options and information see
# http://www.raspberrypi.org/documentation/configuration/config-txt.md
# Some settings may impact device functionality. See link above for details

# uncomment if you get no picture on HDMI for a default "safe" mode
#hdmi_safe=1

# uncomment this if your display has a black border of unused pixels visible
# and your display can output without overscan
#disable_overscan=1

# uncomment the following to adjust overscan. Use positive numbers if
console
```

```
# goes off screen, and negative if there is too much border
#overscan_left=16
#overscan_right=16
#overscan_top=16
#overscan_bottom=16

# uncomment to force a console size. By default it will be display's size
minus
# overscan.
#framebuffer_width=1280
#framebuffer_height=720

# uncomment if hdmi display is not detected and composite is being output
#hdmi_force_hotplug=1

# uncomment to force a specific HDMI mode (this will force VGA)
#hdmi_group=1
#hdmi_mode=1

# uncomment to force a HDMI mode rather than DVI. This can make audio work
in
# DMT (computer monitor) modes
#hdmi_drive=2

# uncomment to increase signal to HDMI, if you have interference, blanking,
or
# no display
#config_hdmi_boost=4

# uncomment for composite PAL
#sdtv_mode=2

#uncomment to overclock the arm. 700 MHz is the default.
#arm_freq=800

# Uncomment some or all of these to enable the optional hardware interfaces
#dtparam=i2c_arm=on
#dtparam=i2s=on
#dtparam=spi=on

# Uncomment this to enable the lirc-rpi module
#dtoverlay=lirc-rpi

# Additional overlays and parameters are documented /boot/overlays/README

# Enable audio (loads snd_bcm2835)
dtparam=audio=on

# NOOBS Auto-generated Settings:
hdmi_force_hotplug=1
```

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The following sections discuss the parts of the config.txt file and some changes you may want to make.

Getting Full Information on the config.txt File

At the top of the config.txt file is a URL you can visit to get full information on the configuration file:

http://www.raspberrypi.org/documentation/configuration/config-txt.md

On this page, you'll find information about the many parameters you can configure in config.txt to change the configuration of a Raspberry Pi computer.

Resolving HDMI Display Issues

The Raspberry Pi boards use HDMI as the primary output for audio and video.

If you're using an HDMI display but not getting output, or the output drops out, try using the hdmi_safe=1 option. This option applies the Safe mode for HDMI to increase compatibility. Safe mode has the effect of choosing the following options:

```
hdmi_force_hotplug=1
hdmi_ignore_edid=0xa5000080
config_hdmi_boost=4
hdmi_group=2
hdmi_mode=4
disable_overscan=0
overscan_left=24
overscan_right=24
overscan_top=24
overscan_bottom=24
```

Alternatively, you can use the individual options:

- hdmi_force_hotplug=1: Use this option if the HDMI display is not getting any output because the Raspberry Pi computer is directing output to the composite port.

- hdmi_ignore_edid=0xa5000080: Use this option if the display is not providing accurate Extended Display Identification Data (EDID). EDID is the information that enables the graphics card to know what resolutions, refresh rates, and so on the display can manage.

- config_hdmi_boost=4: Use this option to increase the strength of the signal the Raspberry Pi computer outputs on the HDMI port. You'd do this if the HDMI display is getting no signal or shows interference or blanking. You can use values from 0 (the default) to 7, but try 4 first.

- hdmi_group=2: Use this option to specify that the display is a
  monitor rather than a TV; if you're using a TV, use hdmi_group=1.
  (The option hdmi_group=0 causes the Raspberry Pi computer to
  autodetect the monitor type from the EDID.) You use the hdmi_
  group option with the hdmi_mode setting (see the next paragraph).

- hdmi_mode=1: Use this option to force VGA output (640 pixels
  × 480 pixels). You can also use a wide range of other settings.
  Table 5-1 shows the ones that are normally most useful; see
  http://www.raspberrypi.org/documentation/configuration/
  config-txt.md for the full list. There are settings for both the
  hdmi_group=1 option (TVs) and the hdmi_group=2 option
  (monitors).

Table 5-1. *Settings for the hdmi_mode Option*

hdmi_mode	hdmi_group	Resolution	Frequency	Other
1	1	640 × 480	60 Hz	VGA
4	1	720 p	60 Hz	
5	1	1080 i	60 Hz	
16	1	1080 p	60 Hz	
19	1	720 p	50 Hz	
20	1	1080 i	50 Hz	
31	1	1080 p	50 Hz	
40	1	1080 i	100 Hz	
41	1	720 p	100 Hz	
1	2	640 × 350	85 Hz	
4	2	640 × 480	60 Hz	
5	2	640 × 480	72 Hz	
6	2	640 × 480	75 Hz	
7	2	640 × 480	85 Hz	
16	2	1024 × 768	60 Hz	
17	2	1024 × 768	70 Hz	
18	2	1024 × 768	75 Hz	
69	2	1920 × 1200	60 Hz	
70	2	1920 × 1200	75 Hz	
71	2	1920 × 1200	85 Hz	
72	2	1920 × 1200	120 Hz	

Adjusting Overscan Settings

You may also need to edit the `config.txt` file to adjust overscan settings on the display you're using with an Raspberry Pi computer. These are the settings you're most likely to need to adjust:

- `disable_overscan=1`: Use this option to turn off overscan. You'd do this if the display shows a black border of pixels around the output.

- `overscan_left`, `overscan_right`, `overscan_top`, `overscan_bottom`: Use these options to adjust the position of the left border, right border, top border, and bottom border of the output. Use a positive value (the `config.txt` file suggests starting with 16) to move the image toward the middle of the screen; use a negative value (such as –16) to move the image toward the edge of the screen.

Forcing HDMI Mode or Composite PAL

You can also edit the `config.txt` file to force the Raspberry Pi computer to use HDMI mode or composite PAL. These are the options:

- `hdmi_drive=2`: Use this option to force HDMI mode instead of DVI.

- `sdtv_mode=2`: Use this option to force composite PAL output.

Enabling Optional Hardware Interfaces and Modules

Another reason for editing the `config.txt` file is to enable optional hardware interfaces and modules. These are the options you're most likely to find useful:

- `dtparam=audio=on`: This option is set to On by default, enabling audio. If you want to disable audio, comment out the line by placing # and a space at its beginning.

- `dtparam=i2c_arm=on`: Use this option to enable I2C on the GPIO pins.

- `dtparam=i2s=on`: Use this option to enable I2S audio hardware.

- `dtparam=spi=on`: Use this option to enable the SPI driver.

- `dtoverlay=lirc-rpi`: Use this option to enable the Linux Remote Control overlay.

Editing the `cmdline.txt` File

The `cmdline.txt` file passes arguments to the Linux kernel during startup. You can edit `cmdline.txt` by entering Recovery mode and working on the cmdline.txt tab of the Config Editor dialog box or by removing the SD card from the Raspberry Pi computer, connecting it to another computer, and opening it in a text editor (for example, Notepad on Windows or TextEdit on the Mac).

You may not need to edit `cmdline.txt` at all—but in case you do, Table 5-2 provides a quick reference to the default options the file contains. Table 5-3 also lists some options that you may want to use.

■ **Note**   All the options in the `cmdline.txt` file appear on a single line, delimited by spaces. The line appears wrapped in the Config Editor (see Figure 5-22), but it doesn't contain any carriage returns; if you include a carriage return, options after that point are ignored.
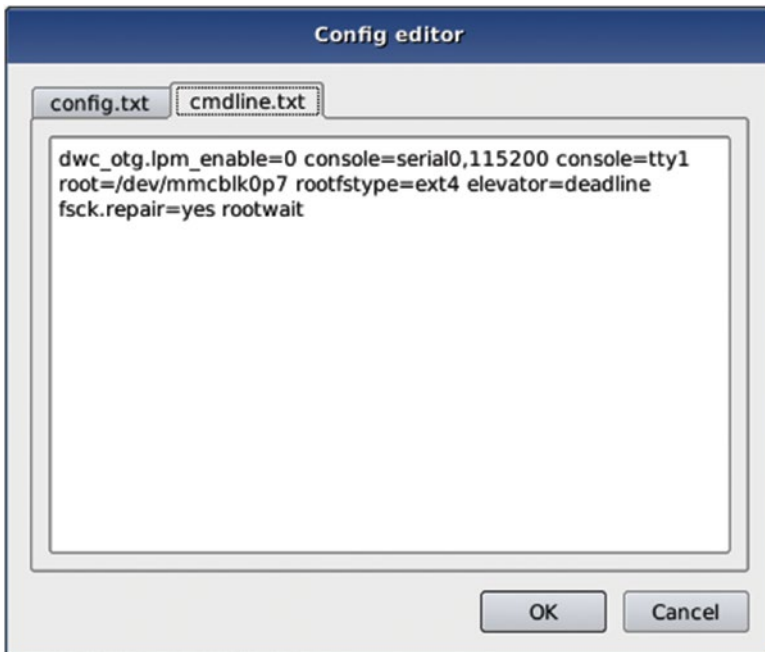
Figure 5-22. *The cmdline.txt tab of the Config Editor dialog box enables you to edit the cmdline.txt file, which passes arguments to the operating system's kernel during startup.*

Table 5-2. *Default Options for the* `cmdline.txt` *File*

Option	Explanation
`dwc_otg.lpm_enable=0`	Disables low-power mode for USB.
`console=serial0,115200`	Sets the serial console number and the speed (115200 bps).
`console=tty1`	Sets the console to use TTY1 for input.
`root=dev/mmcblk0p7`	Specifies the boot partition to use.
`rootfstype=ext4`	Sets the root file system type to ext4.
`elevator=deadline`	Sets the kernel to use the deadline method of processing input/output (I/O) requests. Some Raspberry Pi enthusiasts recommend changing to `elevator=noop` to improve performance.
`fsck.repair=yes`	Automatically repairs errors detected during the file-system check.
`rootwait`	Sets the computer to wait until a root device becomes available before continuing to boot.

Table 5-3. *Other Options for the* `cmdline.txt` *File*

Option	Explanation
ip=*address*	Sets a static IP address; for example, `ip=192.168.1.100`.
smsc95xx.macaddr=*address*	Sets the specified MAC address to override the built-in MAC address; for example, `smsc95xx.macaddr=B8:27:EB:60:00:BA`.
`dwc_otg.speed=1`	Limits the speed of the USB bus to USB 1.1 (12 Mbps) instead of USB 2.0 (480 Mbps).
`dwc_otg.fiq_fix_enable=1`	When USB is not busy, reduces the number of USB interrupts to improve the CPU's performance.
`dwc_otg.microframe_schedule=1`	Schedules periodic endpoints to avoid USB errors.
`dwc_otg.nak_holdoff_enable=1`	Enables the use of a hold-off time before retrying a USB transaction.
dwc_otg.nak.holdoff=*value*	Specifies the hold-off time in microframes before retrying a USB transaction. The default is 8; you can set it to 0 to disable the hold-off time.

Learning Advanced Moves with NOOBS

In this section, we'll look at three advanced moves you can perform with NOOBS. First, you can set NOOBS to install an operating system automatically. Second, you can set NOOBS to boot directly to a particular operating system. Third, you can create a custom version of Raspbian—or another operating system—to speed up configuration and deployment.

Setting NOOBS to Install an Operating System Automatically

You can set the NOOBS installer to install your chosen operating system automatically when you run NOOBS. This can be a great way of setting up Raspberry Pi computers quickly. Follow these steps:

1. Download NOOBS if you haven't already done so. Unzip NOOBS if your computer's operating system doesn't do so automatically.

2. If the operating system you want to install automatically isn't Raspbian, download the operating system. Unzip it, placing it in the os folder in NOOBS.

3. Remove any other operating systems from the os folder in NOOBS.

■ **Note**　If you're installing an operating system that includes multiple flavors (versions), open the flavours.json file in a text editor and remove the entries for all the flavors except the one you want to install.

---

4. Open the recovery.cmdline file, add the silentinstall parameter at the end, and then save the file.

5. Prepare an SD card and put your customized version of NOOBS on it as explained earlier in this chapter.

6. Put the SD card in a Raspberry Pi computer and power it on.

Booting Directly to a Particular Operating System

If you need to limit the actions your students can take with your Raspberry Pi computers, you may want to set the computers to boot directly to a particular operating system. Doing this prevents access to the NOOBS installer and to any other operating systems you have installed on the computers.

To boot directly to a particular operating system, you create a file named `autoboot.txt` in the NOOBS root folder. This file contains the number of the partition to boot.

The following subsections show you how to enable autobooting to a particular operating system.

Determining the Partition to Boot

After setting up the Raspberry Pi computer with all the operating systems you want it to have, open a Terminal window on the computer, type the following command, and press the Enter key:

```
sudo fdisk -l
```

You'll see details such as these:

```
Device          Boot    Start      End  Sectors  Size Id Type
/dev/mmcblk0p1           8192  2341796  2333605  1.1G  e W95 FAT16 (LBA)
/dev/mmcblk0p2        2341797 15663103 13321307  6.4G  5 Extended
/dev/mmcblk0p5        2342912  2408445    65534   32M 83 Linux
/dev/mmcblk0p6        2408448  2537471   129024   63M  c W95 FAT32 (LBA)
/dev/mmcblk0p7        2539520 11165693  8626174  4.1G 83 Linux
/dev/mmcblk0p8       11165696 12214269  1048574  512M  c W95 FAT32 (LBA)
/dev/mmcblk0p9       12214272 14614525  2400254  1.1G 83 Linux
/dev/mmcblk0p10      14614528 15663103  1048576  512M 83 Linux
```

Look at the Type column on the right and identify the partitions whose type is `W95 FAT 32 (LBA)`—in this case, `/dev/mmcblk0p6` (partition 6) and `/dev/mmcblk0p8` (partition 8). Then look at the Size column for those partitions to establish which is the right one. In this case, `/dev/mmcblk0p6` is 63 megabytes—too small—whereas `/dev/mmcblk0p8` is 512 megabytes and is the partition we need.

Creating the autoboot.txt File

Now use a text editor to create a text file named `autoboot.txt` in the root folder on the NOOBS SD card. Enter a `boot_partition=` statement specifying the partition number you have identified. For example

```
boot_partition=8
```

Save the file, and then boot the Raspberry Pi computer from the SD card.

Creating a Custom Version of Raspbian

One of the best aspects of NOOBS for teachers and educators is that you can use it to install a custom version of Raspbian—or of another standard Raspberry Pi operating system—including the packages and files you need. Installing a custom version enables

you to set up and configure your Raspberry Pi computers quickly and efficiently. And when the settings on a Raspberry Pi computer get messed up, you can reinstall the custom version to reset the computer to your preferred settings quickly.

The following sections outline how to create a custom version of Raspbian that you can install on your Raspberry Pi computers.

Creating Your Custom Version

To create your custom version, install Raspbian on a Raspberry Pi computer as explained earlier in this chapter and then customize it as needed. For example

- Choose the settings to use as the defaults for new installations.

- Remove any included apps that you do not need in your custom version.

- Install any other apps that you do need.

Once you've set up Raspbian the way you want it, shut down the Raspberry Pi computer, remove the SD card, and connect the SD card to a reader on the computer you'll use for the rest of the process.

Creating the Root and Boot Filesystem Tarballs

The next step is to create two compressed tarball files, one called `root.tar.xz` containing the root filesystem and the other called `boot.tar.xz` containing the boot filesystem.

Open a Terminal window and navigate to the root folder on the SD card. Then use these commands to create the root tarball:

```
tar -cvpf root.tar /* --exclude=proc/* --exclude=sys/* --exclude=dev/pts/*
xz -9 -e root.tar
```

Once you've done that, navigate to the root folder in the boot partition of the SD card. Then use these commands to create the boot tarball:

```
tar –cvpf boot.tar
xz -9 –e boot.tar
```

Putting Your Custom Tarballs into NOOBS

Next, grab your copy of the NOOBS installer. If you already have the latest version, or an older version that you prefer to use, you're all set. If not, download the latest version from http://downloads.raspberrypi.org/NOOBS_latest.

NOOBS comes as a zip file, which your computer's operating system may unzip automatically for you. If not, unzip the file yourself to a convenient folder, and then open a window in your file-management app to that folder.

Inside the NOOBS folder, click or double-click (depending on your computer's operating system) the os folder to display its contents: a folder for each operating system included for installation. Figure 5-23 shows the NOOBS folder structure in a Finder window on the Mac. The only operating system is Raspbian, as is standard for the full NOOBS installer.
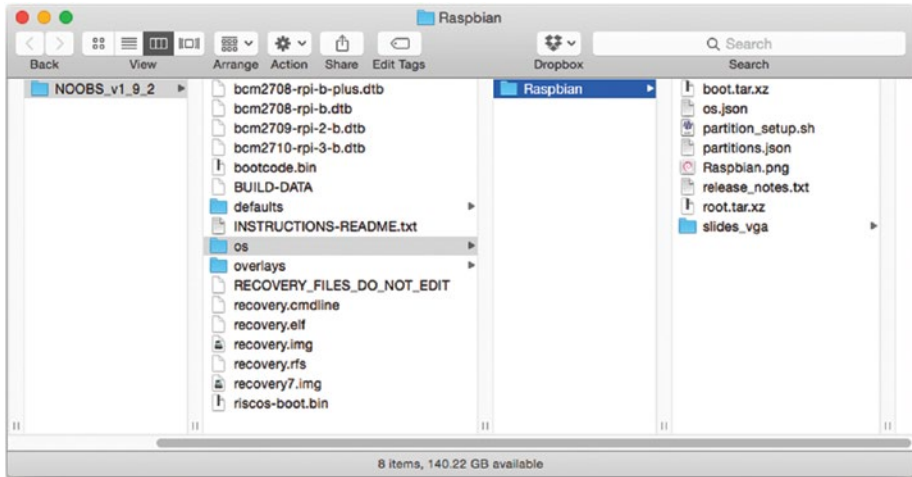
Figure 5-23. *In the* NOOBS *folder, the* os *folder contains a folder for each operating systems included for installation—in this case, only Raspbian.*

Create a copy or duplicate of the Raspbian folder within the os folder. For example, on the Mac, you might select the Raspbian folder and press Cmd+D or choose File ➤ Duplicate to duplicate the folder.

Whichever way you create the copy or duplicate, select its default name (such as Raspbian copy) and change it to the descriptive name you want to use. In this example, we use the name Schoolbian.

Now replace the root.tar.xz file and the boot.tar.xz file with the root tarball and boot tarball you created in the previous section.

■ **Tip**   If you want to emphasize the customizations to the operating system, you can replace its icon and the slides that appear during installation. The icon is the .png file, such as Raspbian.png. The slides are .png files in the slides_vga folder.

Editing the os.json File

Next, using a text editor, open the os.json file from the folder you've just created. You'll see a text file that looks something like the next listing. Each line contains a field name in double quotes (such as "description"), followed by a colon and a space, and then the value for the field—again in double quotes.

■ **Note**   JSON is the acronym for JavaScript Object Notation, an open file format for exchanging data between systems or people.

```json
{
    "description": "A community-created port of Debian jessie for the
Raspberry Pi",
    "kernel": "4.4",
    "name": "Raspbian",
    "password": "raspberry",
    "release_date": "2016-05-27",
    "supported_models": [
        "Pi Model",
        "Pi 2",
        "Pi Zero",
        "Pi 3"
    ],
    "url": "http://www.raspbian.org/",
    "username": "pi",
    "version": "jessie"
}
```

Go to the `"description"` field and enter the description you want NOOBS to display for the customized operating system—for example, a `customized version of Raspbian for our school's Raspberry Pi fleet`. Then go to the `"name"` field and replace Raspbian with the name you gave your folder, such as `Schoolbian`.

Save the changes to the `os.json` file and then close the file.

Editing the partitions.json File

Finally, you need to edit the `partitions.json` file to set the partition size and to specify the size of the uncompressed tarball files.

Open `partitions.json` in a text editor, and you'll see something like the following listing:

```json
{
    "partitions": [
        {
            "filesystem_type": "FAT",
            "label": "boot",
            "partition_size_nominal": 63,
            "uncompressed_tarball_size": 21,
            "want_maximised": false
        },
        {
```

```
        "filesystem_type": "ext4",
        "label": "root",
        "mkfs_options": "-O ^huge_file",
        "partition_size_nominal": 3552,
        "uncompressed_tarball_size": 3152,
        "want_maximised": true
    }
  ]
}
```

For the boot partition and the root partition, enter the appropriate partition size in the `partition_size_nominal` pair and the size of the uncompressed boot tarball in the `uncompressed_tarball_size` pair.

Save and close `partitions.json`, and you'll be ready to try your custom operating system.

Summary

In this chapter, you have learned how to build the Raspberry Pi computers and connect them to peripherals and power, perhaps with the help of your students. You know how to download the NOOBS installer; how to format an SD card for use with NOOBS; how to put NOOBS on the SD card; and how to install operating systems using NOOBS. You also know how to perform a headless install via VNC, use Recovery mode, and perform advanced moves with NOOBS.

In Chapter 6, we'll examine how to connect the Raspberry Pi computers to a network.

■ ■ ■

Connecting the Raspberry Pi Computers to the Network

In this chapter, we'll look at how to set up your Raspberry Pi computers in your classroom or lab, connect them to your establishment's network, and verify that the computers and the network are working to your satisfaction.

This chapter assumes that you have built the Raspberry Pi computers and installed operating systems on them as discussed in Chapter 5.

INVOLVE YOUR STUDENTS: CONNECTING THE RASPBERRY PI COMPUTERS TO THE NETWORK

Connecting the Raspberry Pi computers to the network offers several activities in which you may want to involve students, both to develop their skills and simply to get the task finished sooner.

For best results, choose a handful of responsible students with a good grounding in IT skills. The first task is to move the equipment into place, so make sure they know how to carry displays safely—safely both for themselves and for the displays. Moving the keyboards, the pointing devices, and the Raspberry Pi computers themselves should pose little physical challenge by comparison.

The second task is connecting the devices and cables: HDMI, USB, power, audio, and Ethernet. This should be straightforward, but you'll do well to bear Murphy's Law in mind. Most students will likely be able to identify the ports on the Raspberry Pi computer from their use of their computers, consoles, TVs, and smart phones. Even so, consider making available a reference on a handout or whiteboard to remove any doubt. Plugging a USB device into an Ethernet port seldom turns out well for either the device or the port.

The third task is testing that the computers are working correctly.

Setting Up the Raspberry Pi Computers with Peripherals and Power

At this point, you should be ready to set up the Raspberry Pi computers in your classroom, perhaps with the help of your students.

Setup is likely to be more of a logistical challenge than a technical challenge. The following subsections give brief notes on connecting keyboards and pointing devices, displays, audio, power, and Ethernet cables.

CONTROLLING MULTIPLE RASPBERRY PI COMPUTERS WITH A KVM SWITCH

This section assumes that you're setting up the Raspberry Pi computers as individual workstations. Another possibility is to set up a group of Raspberry Pi computers using a single keyboard, pointing device, and monitor using a keyboard-video-mouse (KVM) switch that enables you to switch quickly from one computer to another. You might want to use a KVM when setting up the Raspberry Pi computers or when testing software configurations on them.

Connecting Keyboards and Pointing Devices

For input, each Raspberry Pi computer will need a keyboard and a pointing device.

In most cases, USB keyboards and pointing devices are the best choice. You can connect them in moments by plugging them into the USB ports on the Raspberry Pi computer; they work during setup, enabling you to give commands; and you may not even need to configure them afterward.

■ **Note** If you're using PS/2 keyboards or pointing devices, connect them using PS/2-to-USB adapters. See the section "Choosing Keyboards and Pointing Devices" in Chapter 2 for more information on selecting keyboards and pointing devices to use with Raspberry Pi computers.

If you need to use Bluetooth keyboards or pointing devices, you'll need to set them up after booting the Raspberry Pi computers. See the section "Connecting a Bluetooth Keyboard or Pointing Device," later in this chapter, for instructions.

■ **Note** If you're using a USB hub to connect devices, make sure that the hub is receiving power, either from its own power supply or from the USB port into which it's plugged on the Raspberry Pi computer.

Connecting Displays

Connect a display to each Raspberry Pi computer using a suitable connection type:

- *HDMI*: This is the Raspberry Pi computer's preferred means of output, so it's the best choice if the display has an HDMI input.

- *DVI*: Connect the display using an HDMI-to-DVI cable.

- *DisplayPort*: Connect the display using an active HDMI-to-DisplayPort adapter.

■ **Caution**   For DisplayPort and VGA, you need active adapters and not passive adapters. Passive DisplayPort-to-HDMI adapters typically work only in one direction—taking DisplayPort output and delivering it to an HDMI input—not taking HDMI output and delivering it to a DisplayPort input. Passive HDMI-to-VGA cables and adapters do not work with Raspberry Pi computers.

- *VGA*: Connect the display using an active HDMI-to-VGA cable.

- *Composite*: For a display with a single composite input, use a composite cable with a single RCA connector at each end. For a display with separate video and audio inputs, use a cable that has a single RCA connector at one end and three RCA connectors at the other end. Plug the single RCA connector into the Raspberry Pi computer's composite port. On the display, connect the yellow RCA connector to the video input, the red RCA connector to the right audio input, and the white or black RCA connector to the left audio input.

■ **Note**   See the section "Choosing Displays" in Chapter 2 for more information on selecting displays and adapters to use with Raspberry Pi computers.

Connecting Audio

If you're using HDMI displays with built-in speakers, the HDMI cable carries the audio output from the Raspberry Pi computer to the display along with the video output, so you don't need to make any further connections. If you're using HDMI displays with audio outputs for external speakers, connect any speakers you'll be using to the audio outputs.

■ **Note**   If you're using active HDMI-to-DVI adapters that separate the audio signal from the video signal, connect an audio cable to the audio output on the adapter and to your display or speakers.

If the connection type for a display doesn't carry audio, connect an audio cable to the Raspberry Pi computer's composite port and to the input on the display or speakers.

Connecting Power

Next, connect a power supply to the micro USB power port on each Raspberry Pi computer. This is straightforward, but here are three quick points to bear in mind:

- *Right type of power supply*: Make sure each power supply is the right kind for the Raspberry Pi model. See the section "Choosing Power Sources for Your Raspberry Pi Computers" in Chapter 2 for more information about power supplies and details of the power requirements of Raspberry Pi boards.

- *Keep the power off for now*: Don't connect the power supply to power yet unless you're using a power socket with a switch that you can keep turned off for now.

- *Secure any extension sockets*: Extension sockets can be a big help for sorting out power, especially ones that have a switch for each socket, enabling you to turn on or off the power to Raspberry Pi computers without unplugging them or their power supplies. If you're using extension sockets to provide power to the computers and their displays, secure the extension sockets in place so that they can't move around and drag the Raspberry Pi computers. For example, some extension sockets include screw holes for securing them to walls or furniture; others have recesses that slide onto two exposed screw-heads for quick mounting.

Connecting Ethernet

If you'll be using Ethernet connections for the Raspberry Pi computers, connect an Ethernet cable to each Raspberry Pi computer's Ethernet port and to the network hardware—for example, to a wall plate, to a switch, or to a router.

Booting and Configuring the Raspberry Pi Computers

Once you've connected all the hardware, it's time to boot the Raspberry Pi computers. You can then perform further essential configuration, such as connecting Bluetooth keyboards and pointing devices, choosing settings to identify the computers, connecting to Wi-Fi networks, and configuring the network connections.

Powering on the Displays

Before you boot the Raspberry Pi computers, make sure that the displays are powered on and that they're set to receive input on the appropriate port, such as HDMI. This is important because if a Raspberry Pi computer doesn't detect a display on the HDMI port, it will output video on the composite port instead.

■ **Note**   If a display is powered on and switched to the correct input, but the Raspberry Pi computer still fails to detect it, you may need to use the `hdmi_safe=1` option or the `hdmi_force_hotplug=1` option in the `config.txt` file. See the section "Resolving HDMI Display Issues" in Chapter 5 for details.

Booting the Raspberry Pi Computers

Boot the Raspberry Pi computers by supplying power to them—for example, by plugging the connected power supply into a power socket or turning on the switch on a switched socket.

If all is well, each Raspberry Pi computer will boot, and you'll see the command-line interface, a login screen, or the desktop, depending on how you configured Raspbian.

If a Raspberry Pi computer doesn't boot, check its connections and try again. If it still doesn't work, turn to Chapter 8 for troubleshooting suggestions.

■ **Note**   See the sections "Resolving HDMI Display Issues," "Adjusting Overscan Settings," and "Forcing HDMI Mode or Composite PAL" in Chapter 5 for information on how to deal with display issues.
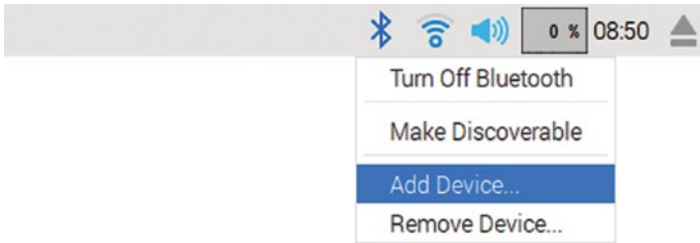

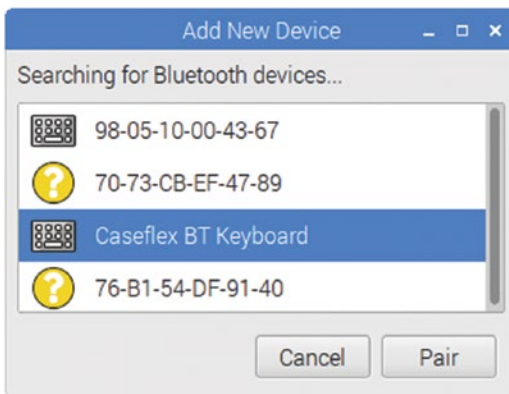# Connecting a Bluetooth Keyboard or Pointing Device

Now that the Raspberry Pi computers are running, you can add Bluetooth keyboards and pointing devices to replace the USB devices where necessary. Follow these steps to add a Bluetooth device:

1. Click the Bluetooth icon on the panel to display the Bluetooth pop-up menu (see Figure 6-1).

*Figure 6-1. To connect a Bluetooth device, click the Bluetooth icon on the panel and then click Add Device on the Bluetooth pop-up menu.*

2. Click the Add Device item to display the Add New Device dialog box (see Figure 6-2).

Figure 6-2. In the Add New Device dialog box, click the Bluetooth keyboard or pointing device, and then click the Pair button.
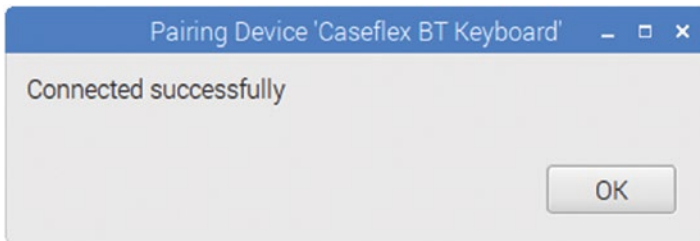
3. Click the entry for the Bluetooth keyboard or pointing device. This example uses a keyboard.

4. Click the Pair button. For some Bluetooth keyboards, the Pairing Device dialog box then opens, prompting you to enter a pairing code (see Figure 6-3). Type the pairing code on the keyboard, confirming that it's the correct device, and then press the Enter key.
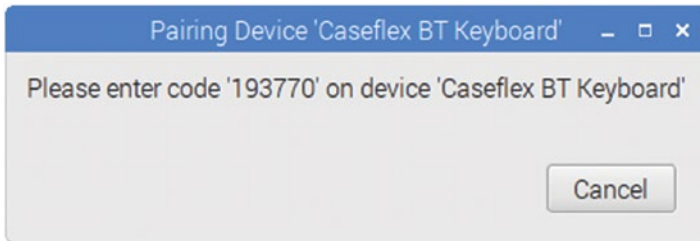
Figure 6-3. *If the Pairing Device dialog box prompts you to enter a pairing code, type it on the keyboard and press the Enter key.*

5. Next, Raspbian displays progress dialog boxes as it establishes the connection. When it has done so, it displays the Connected Successfully message in the Pairing Device dialog box (see Figure 6-4).

Figure 6-4. *When the "Connected successfully" message appears in the Pairing Device dialog box, click the OK button to finish the pairing process.*

6. Click the OK button. You can now start using the Bluetooth keyboard or pointing device.

Identifying Your Raspberry Pi Computers

To keep your classroom running smoothly, you'll likely want to be able to identify your Raspberry Pi computers, both directly—by looking at a Raspberry Pi computer itself—and via the network.

You can give yourself a way to identify the Raspberry Pi computers directly by labelling them, preferably on a part of the case that can't easily be swapped between computers. A tape labeler is easy and gives a neat look; but writing on cloth tape—or even directly on the cases—can work just fine too.

You can use MAC addresses, hostnames, and static IP addresses to identify your Raspberry Pi computers via the network. The following sections explain how to determine MAC addresses and how to assign hostnames and static IP addresses to your Raspberry Pi computers.

Returning the MAC Address for a Raspberry Pi Computer

As you probably know, "MAC address" is the acronym for "Media Access Control address." A MAC address in a unique identifier assigned to a network interface, such as the Ethernet interface or the Wi-Fi interface on a Raspberry Pi computer. A MAC address consists of six hexadecimal pairs separated by hyphens or colons, such as 18-AF-61-A9-2B-73 or C8:BC:C9:FB:D2:FC.

■ **Note**   A MAC address is stored in the hardware and cannot be changed; it is sometimes referred to as a *hardware address*, a *physical address*, or a *burned-in address*. However, a device can be configured to report a different MAC address than its true address. You can set the MAC address for a Raspberry Pi board by adding the smsc95xx.macaddr parameter to the cmdline.txt file (e.g., smsc95xx.macaddr=b8:28:eb:00:00:07). See the section "Using Recovery Mode" in Chapter 5 for instructions on editing the cmdline.txt file.

■ **Tip**   The MAC address for each network interface on each Raspberry Pi board starts with the same three pairs: b8:28:eb. You can use these standardized MAC addresses to identify your Raspberry Pi computers more easily across the network.

To return the MAC address of the Ethernet interface on a Raspberry Pi computer, open a Terminal window and give the following command:

cat /sys/class/net/eth0/address

To return the MAC address of the Wi-Fi interface, use wlan0 instead of eth0:

cat /sys/class/net/wlan0/address

To return the MAC address of the Bluetooth interface, give the hciconfig command:

hciconfig

In the output (see the following example), look at the BD Address line:

hci0:   Type: BR/EDR   Bus: UART
        BD Address: B8:27:EB:32:F7:90   ACL MTU: 1021:8   SCO MTU: 64:1

```
UP RUNNING
RX bytes:773 ACL:0 sco:0 events:50 errors: 0
TX bytes: 2540 ACL:0 sco:0 commands:50 errors:0
```

Setting a Hostname for a Raspberry Pi Computer

The *hostname* is a text string used to identify a computer or device on a network. Hostnames need to be unique for the network hardware to be able to resolve them. You can set the hostname for each Raspberry Pi computer manually to make the computers easier to identify by name.

Raspbian sets the hostname raspberrypi during installation, so if you install Raspbian on multiple Raspberry Pi computers, they'll all have the same name. This doesn't work well because only the first of those Raspberry Pi computers to join the network will have that hostname registered on the network; the other Raspberry Pi computers will appear not to have hostnames. So normally you'll want to assign hostnames to your Raspberry Pi computers to help you identify them on the network. For example, you might use incrementing numbers (pi001, pi002, and so on); or you might use names for individual Raspberry Pi computers that play particular roles (e.g., musicbox or files).

Whatever naming convention you choose, follow these steps to set the hostname for a Raspberry Pi computer:

1. Choose Menu ➤ Preferences ➤ Raspberry Pi Configuration to open the Raspberry Pi Configuration dialog box.

2. Click the System tab to display its controls.

3. Type the name in the Hostname box.

4. Click the OK button to close the Raspberry Pi Configuration dialog box. The Reboot Needed dialog box opens.

5. Click the Yes button. The Raspberry Pi computer restarts, after which it appears on the network under its new hostname.

Setting Static IP Addresses

Most networks use Dynamic Host Configuration Protocol (DHCP) to assign IP addresses to most clients on the network. When a client joins the network, it requests an IP address from the DHCP server or DHCP allocator, which assigns the client a currently unused IP address from the pool of addresses it manages. After a client leaves the network, the DHCP server or allocator reclaims the IP address, returning it to the pool.

DHCP is an efficient way to manage IP addresses, but it means that you don't know which IP address any particular computer or device has unless you look it up (for example, using its hostname or MAC address). You may prefer to assign static IP addresses to particular Raspberry Pi computers that you want to be able to identify quickly and easily. You might even want to assign static IP addresses to *all* your Raspberry Pi computers for ease of identification.

■ **Caution**   If you assign static IP addresses to your Raspberry Pi computers, make sure you use a range of IP addresses that's not in the DHCP pool. Otherwise, you'll get network conflicts when you start up a Raspberry Pi computer to which you've assigned a static IP address that the DHCP server has allocated to another computer or device

Configuring Network Connections

Your Raspberry Pi computers can connect to the network via either Ethernet or Wi-Fi:

- *Ethernet*: If you plugged in the Ethernet cables before booting the Raspberry Pi computers, chances are that the computers have connected to the network. You may need to configure the network connection; see the section "Configuring the Network Connection for a Raspberry Pi Computer," later in this chapter.

- *Wi-Fi*: Unless you already set up a Wi-Fi network connection on the Raspberry Pi computers, you'll need to connect them to the Wi-Fi network now. See the next section for details.

Connecting to a Wi-Fi Network

Follow these steps to connect a Raspberry Pi computer to a Wi-Fi network:

1. If the Raspberry Pi computer doesn't have a built-in Wi-Fi adapter, plug a compatible Wi-Fi adapter into a USB port.

2. Click the Wi-Fi Networks icon at the right end of the Panel to display the list of available Wi-Fi networks (see Figure 6-5).

■ **Note**   The built-in Wi-Fi on the Raspberry Pi 3 Model B is 2.4 GHz only. If your school has Wi-Fi access points providing 5 GHz networks, the Raspberry Pi 3 Model B will not show them.
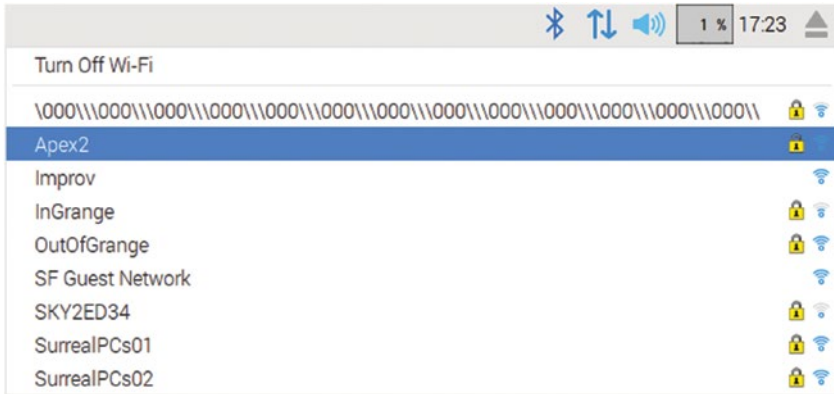
Figure 6-5. *Open the Wi-Fi Networks pop-up menu and click the network to which you want to join the Raspberry Pi computer. At this point, the Wi-Fi Networks icon appears as two blue arrows, one pointing up and the other pointing down.*

3. Click the Wi-Fi network you want the computer to join. If the Wi-Fi network uses security, a dialog box whose title bar shows the network's name (SSID) appears, prompting you for the Pre Shared Key (see Figure 6-6).
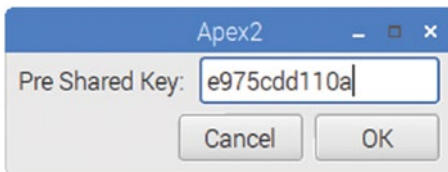
Figure 6-6. *Open the Wi-Fi Networks pop-up menu and click the network to which you want to join the Raspberry Pi computer.*

4. Type the preshared key (the password) for the network and click the OK button. The Raspberry Pi computer connects to the network.

When the Raspberry Pi computer has established the connection to the Wi-Fi network, the Wi-Fi Networks icon appears as a Wi-Fi symbol showing an access point with arc-like waves radiating from it. To see which Wi-Fi network the Raspberry Pi computer has connected to, hold the pointer over the Wi-Fi Networks icon and look at the pop-up balloon, which also shows the IP address and netmask (see Figure 6-7).

Figure 6-7. *Once the Wi-Fi connection is established, the Wi-Fi Networks icon appears as a Wi-Fi symbol. You can hold the pointer over the icon to display a pop-up balloon showing the Wi-Fi network and the IP address.*

FORGETTING A WI-FI NETWORK

When you enter the preshared key for a Wi-Fi network, Raspbian automatically stores it for future use. Storing the key enables the Raspberry Pi computer to connect quickly to the Wi-Fi network when the computer is within range, saving time and effort.

Sometimes, however, you will want to prevent a Raspberry Pi computer from connecting to a particular Wi-Fi network again. Unlike most operating systems, Raspbian doesn't have a graphical tool for "forgetting" (removing) Wi-Fi networks it has used; instead, you need to edit the wpa_supplicant.conf file and remove the network's name and password.

Click the Terminal icon on the Panel to open a Terminal window, and then give the following command:

```
sudo nano /etc/wpa_supplicant/wpa_supplicant.conf
```

Terminal opens the wpa_supplicant.conf file in the nano editor, where you'll see details of the control interface and a list of Wi-Fi networks and preshared keys. Here's an example:

```
ctrl_interface=DIR=/var/run/wpa_supplicant GROUP=netdev
update_config=1
country=US

network={
        ssid="SchoolLab01"
        psk="correcthorse"
        key_mgmt=WPA-PSK
}
```

```
network={
        ssid="SchoolLab02"
        psk="batterystaple"
        key_mgmt=WPA-PSK
}
```

Delete the entry for the network you want to stop using, starting with `network={` and ending with `}`. Press Ctrl+O to give the command to write out the file, and then press the Enter key to accept the existing name. Finally, press Ctrl+X to exit the nano editor.

Disconnecting from a Wi-Fi Network

If you need to disconnect from the current Wi-Fi network, follow these steps:

1. Click the Wi-Fi Networks icon on the Panel to display the Wi-Fi Networks pop-up menu.

2. Click the current network, the one with the green check mark to the left of its name. The Disconnect Wi-Fi Network dialog box opens (see Figure 6-8).

Figure 6-8. *Click the OK button in the Disconnect Wi-Fi Network dialog box to disconnect from the current Wi-Fi network.*

3. Click the OK button.

■ **Note**   You can also disconnect from the current Wi-Fi network by connecting to another Wi-Fi network. A Wi-Fi interface can have only one Wi-Fi network connection at a time, so connecting to a different network disconnects the Raspberry Pi computer from the current network.

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Configuring the Network Connection for a Raspberry Pi Computer

If your network uses a DHCP server, each Raspberry Pi computer automatically requests an IP address and other network settings from the server when it tries to join the network. For some computers, however, you may want to configure the network connections manually. For example, you may need to configure static IP addresses for some Raspberry Pi computers, as discussed earlier in this chapter.

Follow these steps to configure either an Ethernet connection or a Wi-Fi connection:

1. Right-click the Networks icon on the panel to display the shortcut menu.

2. Click the WiFi Networks (dhcpcdui) Settings item to display the Network Preferences dialog box (shown in Figure 6-9 with some settings chosen).
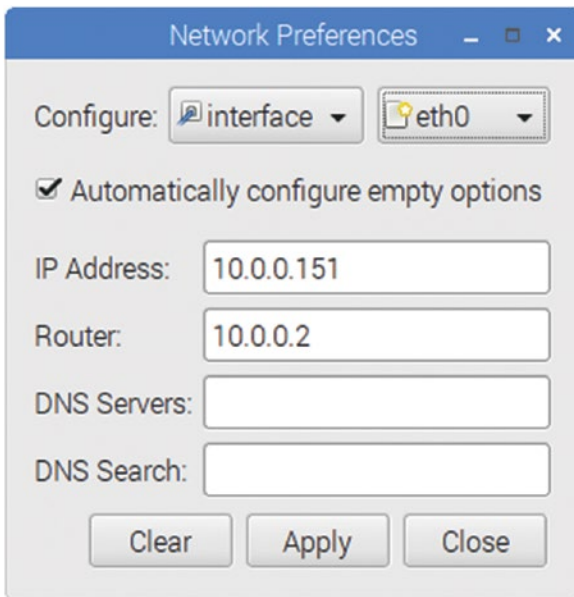
Figure 6-9. *Use the Network Preferences dialog box to set a static IP address for a Raspberry Pi computer. You can also specify the address of the router and the DNS servers and add any DNS search domains needed.*

3. On the Configure row, make sure the left pop-up menu shows Interface rather than SSID.

4. Still on the Configure row, click the right pop-up menu and choose the interface you want to configure. Choose `eth0` for Ethernet; choose `wlan0` for Wi-Fi.

5. If necessary, click the Clear button to clear the current configuration details.

6. Check the Automatically Configure Empty Options check box if you want Raspbian to automatically detect values for network parameters you don't specify.

7. In the IP Address box, type the static IP address you want to assign the computer. Leave this box blank if you want the computer to get an IP address via DHCP.

8. In the Router box, type the IP address for the router. Leave this box blank if you want the computer to get the router's address via DHCP.

9. In the DNS Servers box, type the list of DNS servers the computer is to use. Put the primary server's address first and the secondary server's address second, separated by a comma. Here, too, you can leave the box blank if you want the computer to get this information via DHCP.

10. In the DNS Search box, type any search domain you want to have automatically appended for DNS lookups. For example, you might enter your school's domain here to cause any unqualified searches to be run using that domain.

11. Click the Apply button to apply your changes.

12. Click the Close button to close the Network Preferences dialog box.

To make your changes take effect, you need to restart the Raspberry Pi computer. To do so, choose Menu ➤ Shutdown to display the Shutdown Options dialog box, and then click the Reboot button.

Testing the Computers and the Network

Now that you've set up the workstations, test them and the network. For this, too, you may want to involve a group of your more trustworthy students to save yourself time and effort.

Prepare a checklist of the things you want to check for each Raspberry Pi computer. You could implement the checklist as a paper form or run it on tablets that connect to a database.

Here are examples of the items you may want to check:

•   Verify that each Raspberry Pi computer is running.

•   Log in if the Raspberry Pi computer is not set to log in automatically. See Chapter 7 for information on creating user accounts on Raspberry Pi computers.

•   Open the menu and verify that the apps are present.

•   Open a sample app and verify that it runs.

- Open the Web browser and make sure that the Internet connection is working.

- Shut down the Raspberry Pi computer and then restart it to verify that the SD card and filesystem are in good shape.

- Shut down the Raspberry Pi computer.

Checks such as these will enable you to identify which Raspberry Pi computers—if any—need remedial configuration or other attention.

Summary

In this chapter, you've learned how to set up the Raspberry Pi computers in your classroom or lab, perhaps with the help of some of your more capable and responsible students. You know how to make the physical connections, boot and configure the computers, and how to test the computers and the network.

In Chapter 7, we'll look at how to administer and manage the Raspberry Pi computers on your network.

■ ■ ■

Administering and Managing Your Raspberry Pi Network

In this chapter, we'll look at how to administer and manage your classroom network of Raspberry Pi computers.

If you have just a few Raspberry Pi computers, you may want to manage them individually. We'll look at managing Raspberry Pi computers individually in the first part of the chapter, examining how to create user accounts and how to set up remote access to the computers so that you can administer them remotely.

If you have a full classroom or lab's worth of Raspberry Pi computers, you'll likely want to manage them centrally. The easiest way to do this is by using the free server software called PiNet. PiNet can be a great solution for classroom deployments of Raspberry Pi computers, so we'll dig into it in detail in the second main part of the chapter.

Managing Your Raspberry Pi Computers Individually

If you have only a few Raspberry Pi computers, you may choose to manage them individually. To do so, you should create a separate user account for each user who will log in to a Raspberry Pi computer. You will also likely want to set up remote access to the Raspberry Pi computers so that you can manage them remotely.

■ **Note**   If you need to manage many Raspberry Pi computers, you'll probably be better off using PiNet than managing the computers individually. See the section "Setting Up and Managing a Network with PiNet," later in this chapter, for coverage of PiNet.

Creating and Managing User Accounts

By default, the Raspberry Pi automatically logs in using an account called pi, with the password raspberry. The pi account has administrative permissions, so anyone using the account can execute system-modifying commands by prefacing them with the sudo (do as superuser) command.

Normally, you'll want your students to log in using user-level accounts, which don't have the power of sudo. You can create and manage these accounts by opening a Terminal window and giving the appropriate commands. So to get started, click the Terminal button on the Panel to open a Terminal window.

■ **Tip** You can also create user accounts by connecting via SSH from another computer. See the section "Connecting via SSH," later in this chapter, for instructions on connecting via SSH.

Creating a User Account

To create a user account, you use the adduser command, which takes a single argument, the name to assign the new user. You preface the command with sudo because it's a system change.

For example, the following command creates a user called bill:

```
sudo adduser bill
```

When you give this command and press the Enter key, Raspbian creates the account and prompts you to enter a password, the user's full name, and other identifying information. Raspbian doesn't display the password as you type it. For any information you don't have or don't want to enter, press the Enter key to leave the field blank. Here's an example:

```
Adding user `bill' ...
Adding new group `bill' (1001) ...
Adding new user `bill' (1001) with group `bill' ...
Creating home directory `/home/bill' ...
Copying files from `/etc/skel' ...
Enter new UNIX password:
Retype new UNIX password:
passwd: password updated successfully
Changing the user information for bill
Enter the new value, or press ENTER for the default
        Full Name []: Bill Williams
        Room Number []:
        Work Phone []:
        Home Phone []:
        Other []:
Is the information correct? [Y/n] y
```

Changing a User's Password

To change a user's password, give the `passwd` command followed by the username, again prefacing the command with `sudo`. Here's an example:

```
sudo passwd bill
```

Raspbian prompts you to enter the password twice, and then confirms that the password has been updated successfully:

```
Enter new UNIX password:
Retype new UNIX password:
passwd: password updated successfully
```

Giving a User Access to the `sudo` Command

Normally, you won't want your students to have access to the `sudo` command so as to limit the actions they can take on the Raspberry Pi computers. However, in some cases you may want to allow a student to use the `sudo` command—for example, so that she can help you configure a Raspberry Pi computer or use the GPIO pins (which require `sudo` access).

To give a user access to the `sudo` command, give the following command in a Terminal window:

```
sudo visudo
```

Raspbian opens the file `/etc/sudoers.tmp` in the nano editor. Here is an example of this file:

```
# This file MUST be edited with the 'visudo' command as root.
#
# Please consider adding local content in /etc/sudoers.d/ instead of
# directly modifying this file.
#
# See the man page for details on how to write a sudoers file.
#
Defaults        env_reset
Defaults        mail_badpass
Defaults        secure_path="/usr/local/sbin:/usr/local/bin:/usr/sbin:/usr/
bin:/s$

# Host alias specification

# User alias specification

# Cmnd alias specification

# User privilege specification
root    ALL=(ALL:ALL) ALL
```

```
# Allow members of group sudo to execute any command
%sudo   ALL=(ALL:ALL) ALL

# See sudoers(5) for more information on "#include" directives:

#includedir /etc/sudoers.d

pi ALL=(ALL) NOPASSWD: ALL
```

Go to the section with the heading # User privilege specification (shown in boldface in the previous example). Under the root ALL=(ALL:ALL) ALL line, type a similar line but with the appropriate username in place of root. Here is an example for the user alice:

```
# User privilege specification
root    ALL=(ALL:ALL) ALL
alice   ALL=(ALL:ALL) ALL
```

Now press Ctrl+O to write out the file, and press the Enter key to accept the existing name. Press Ctrl+X to edit nano.

■ **Note**   Raspbian enables you to give a user passwordless root access. This is the kind of access the pi account has in a default installation of Raspbian; the last line in the preceding sudoers.tmp file gives the pi account this access. Giving other users passwordless root access is not usually a good idea—but if you need to do it, enter NOPASSWD: ALL on the user's line in the User privilege specification section of the file. For example, enter alice ALL = NOPASSWD: ALL.

Deleting a User Account

To delete a user account but leave the user's home folder in place, give the userdel command. For example, the following command removes the user bill:

```
sudo userdel bill
```

To delete the user account and the user's home folder, add the -r parameter:

```
sudo userdel -r bill
```

Setting Up Remote Access

Going to each Raspberry Pi computer you want to update or configure gets old fast, so you'll likely want to give yourself remote access to the computers.

You can access the computers remotely in several ways. These are the three most widely useful ways:

- *SSH*: Secure Shell (SSH) enables you to connect securely to a remote computer across a network and issue commands via a command-line interface. You can also forward an X session over SSH, which allows you to display a window on your computer showing the graphical output of an app that's running on the remote computer.

- *VNC*: Virtual Network Computing (VNC) lets you connect to a remote computer and view its screen in a window on your computer. Depending on how you configure VNC, you can also control the remote computer via VNC.

- *xrdp*: xrdp (x Remote Desktop Protocol) enables you to connect to a remote computer, view its screen in a window on your computer, and optionally control the remote computer. xrdp's capabilities are similar to those of VNC, but the underlying technology is different.

The following sections explain the pros and cons of these three approaches and show you how to set them up.

Connecting with Remote Access via SSH

SSH is a handy way to connect remotely to a Raspberry Pi computer. Connecting via SSH gives you a command-line connection that you can use to issue commands on the Raspberry Pi computer. Using the command line, SSH sends only text between the computers, so it works well even over a slow connection.

You can also forward an X session over SSH, directing the graphical output of an app that's running on the remote computer (e.g., a Raspberry Pi computer) to a window on the computer you're using. Because graphical output is involved, this works better over a fast connection than a slow connection.

To connect via SSH, you need to enable SSH on the Raspberry Pi computer by using the Raspberry Pi Configuration tool. You then need an SSH client app on your computer. OS X and macOS includes an SSH client, as do almost all distributions of Linux. Windows doesn't include an SSH client, but there are plenty of choices, some that are free and others that you must pay for. Neither iOS nor Android includes an SSH client, but you can add one easily and inexpensively.

Enabling SSH in Raspberry Pi Configuration

You can quickly enable SSH by using the Raspberry Pi Configuration tool. Follow these steps:

1. Choose Menu ➤ Preferences ➤ Raspberry Pi Configuration to open the Raspberry Pi Configuration dialog box.

2. Click the Interfaces tab to display its contents.

3. Click the Enable option button on the SSH line.

4. Click the OK button to close the Raspberry Pi Configuration dialog box.

■ **Note** You can also enable SSH in the `raspi-config` file: Open `raspi-config` by using the `sudo raspi-config` command in a Terminal window, select the Advanced Options item, select the SSH item, and then select the Yes button or the No button at the *Would you like the SSH server to be enabled?* prompt. Normally, you'd want to do this only if the Raspberry Pi computer is running an older version of the operating system that doesn't have the Raspberry Pi Configuration tool.

Getting an SSH Client for Windows, iOS, or Android

If you're using Windows, iOS, or Android, you'll need to add an SSH client to your computer or device unless you've already done so.

Many SSH clients are available, but here are three recommendations:

- *Windows:* Download PuTTY from the PuTTY web site (http://www.chiark.greenend.org.uk/~sgtatham/putty/). If you're wondering about the name, the TTY is a play on the abbreviation for *teletypewriter*, TTY.

- *iOS*: Cathode ($4.99 from the App Store) is an effective SSH client for iOS.

- *Android*: JuiceSSH (free from the Play Store) is a full-featured SSH client for Android.

Connecting via SSH

To connect via SSH, you'll need to know the IP address or hostname of the Raspberry Pi computer. Usually, it's easier to use the IP address, which you can determine in either of these ways:

- *On the Raspberry Pi computer*: Hold the pointer over the Network icon on the right side of the panel, and then look at the IP address for `eth0` (the Ethernet interface) or `wlan0` (the Wi-Fi interface) in the pop-up balloon.

- *Using a network scanner*: Use a network-scanning app on another computer or on a device to display the list of computers and devices on the network and their IP addresses.

To connect via SSH, give the `ssh` command followed by a space, the account name, the @ sign, and the IP address. For example, the following command connects to the computer using the IP address `10.0.0.25` using the `pi` account:

```
ssh pi@10.0.0.25
```

When prompted, enter the account password. You'll then be connected via SSH and able to give commands via the command line.

When you are ready to close the connection, give the `logout` command to close the connection:

```
logout
```

Forwarding an X Session over SSH

Running commands at the command line via SSH is handy, but you may also want to open graphical windows that display on your computer but are running on the remote Raspberry Pi computer. You can do this by forwarding your X session over SSH.

To forward your X session, use the –Y parameter when establishing your SSH connection:

```
ssh -Y pi@10.0.0.25
```

■ **Note**   After connecting via SSH, you can use tools such as SFTP (Secure File Transfer Protocol), SCP (Secure Copy Protocol), and SSHFS (Secure Shell Filesystem) to copy files between the computer you're using and the remote computer.

Controlling a Raspberry Pi Computer Remotely via VNC

Virtual Network Computing (VNC) is a technology for remotely viewing and controlling computers. You can use VNC on pretty much any computer or device to view the contents of a Raspberry Pi computer's screen remotely or to take control of it.

■ **Note**   You can use VNC when installing operating systems on your Raspberry Pi computers. See the section "Performing a Headless Install via VNC" in Chapter 5 for details.

Understanding Your Choices for VNC

Versions of Raspbian that have the Pixel interface include a built-in VNC server, so if the Raspberry Pi computer is running such a version of Raspbian, you need only enable the server and configure it. For earlier versions of Raspbian, you need to install a VNC server and set it running.

Enabling the Built-In VNC Server on Pixel Versions of Raspbian

Follow these steps to enable the built-in VNC server on Pixel versions of Raspbian:

1. Choose Menu ➤ Preferences ➤ Raspberry Pi Configuration to display the Raspberry Pi Configuration dialog box.

2. Click the Interfaces tab to display its controls.

3. On the VNC row, select the Enable option button.

4. Click the OK button to close the Raspberry Pi Configuration dialog box. This is a change that Raspbian can make without restarting the Raspberry Pi computer. The VNC icon appears in the system tray on the right side of the panel.

Viewing Information About the Built-In VNC Server

To view information about the VNC server, click the VNC icon in the system tray. Normally, when you do this the first time on a Raspberry Pi computer using the default pi account, the "Granted permissions without asking for password" dialog box opens (see Figure 7-1), explaining that the VNC server was started with root privileges without a password. This is as it should be. Check the "Do not display this message again" check box, and then click the Close button to close the dialog box.
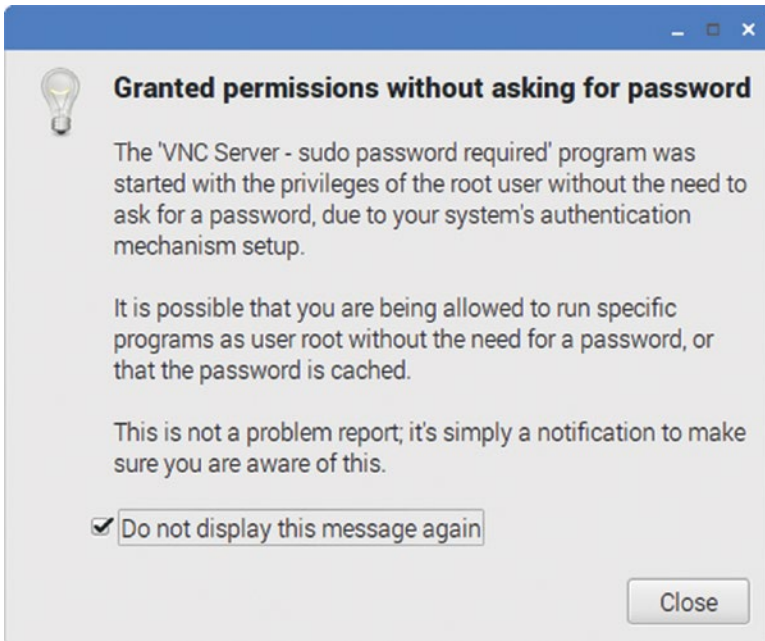
Figure 7-1. *The "Granted permissions without asking for password" dialog box may open the first time you go to view information about the VNC server.*

The VNC Server dialog box then opens (see Figure 7-2), displaying the server's status and providing information. Make sure the Ready for connections bar appears, then look at the IP address shown in the Get Started section. To see the name under which the VNC connection appears on the network, look at the Connectivity section.
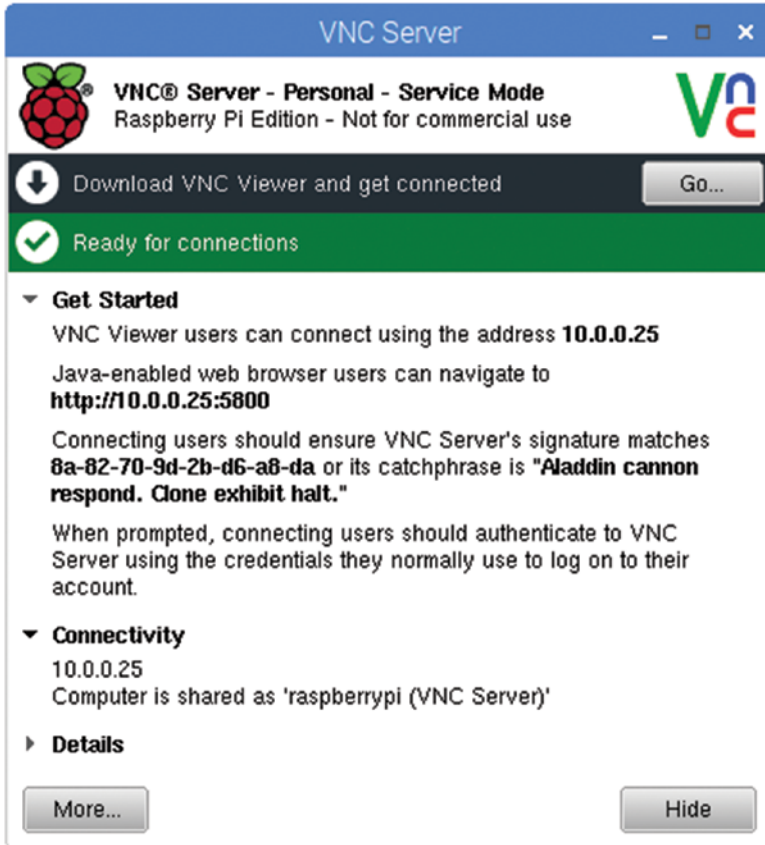
Figure 7-2. *The VNC Server dialog box shows whether the server is ready for connections and displays the IP address. Look at the Connectivity section to see the name under which the server appears on the network.*

Configuring the Built-In VNC Server

At this point, you can try connecting to the server at the IP address shown in the VNC Server dialog box. The server is using its default configuration, which should work fine. But if you want to configure the server, follow these steps:

1. Right-click the VNC icon in the system tray, and then click Options on the shortcut menu that appears. The VNC Server – Options dialog box opens, showing the Security pane at first (see Figure 7-3).
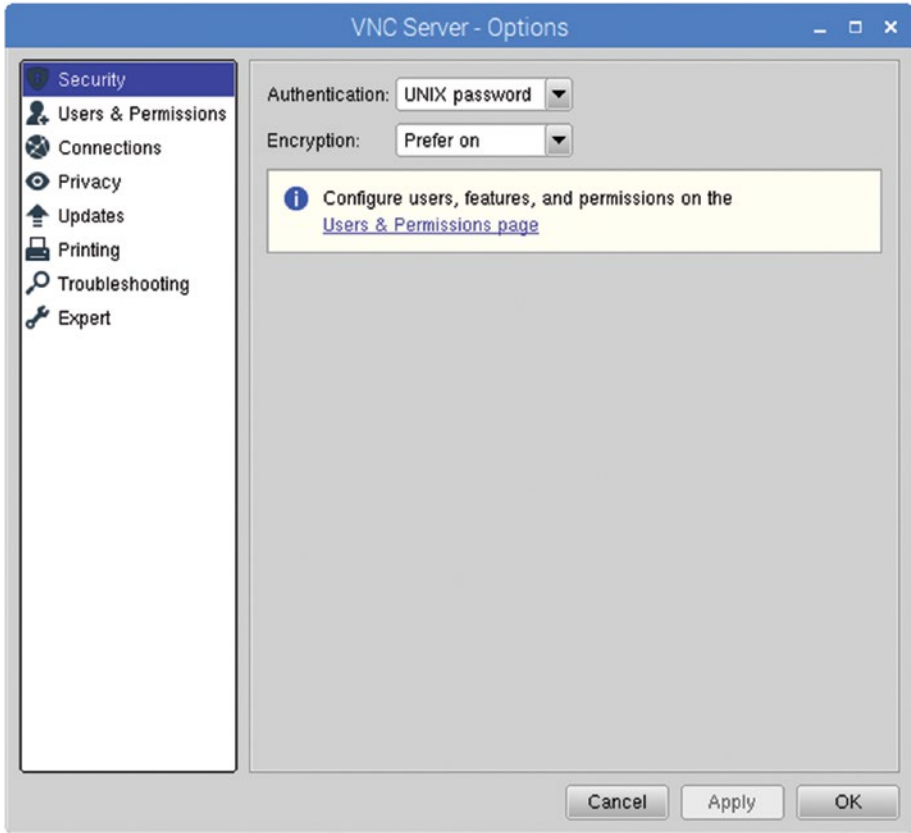
Figure 7-3. *In the Security pane of the VNC Server – Options dialog box, choose the Authentication method and Encryption setting for the VNC server.*

2. In the Authentication drop-down menu, choose UNIX password if you want to use the passwords for user accounts for incoming VNC connections. Choose VNC password if you want to set a different password for VNC connections.

3. In the Encryption drop-down menu, choose Always On to require encryption always, Prefer on to prefer encryption but not require it, or Prefer off.

4. Click the Users & Permissions item in the left box. The Users & Permissions pane appears (see Figure 7-4).
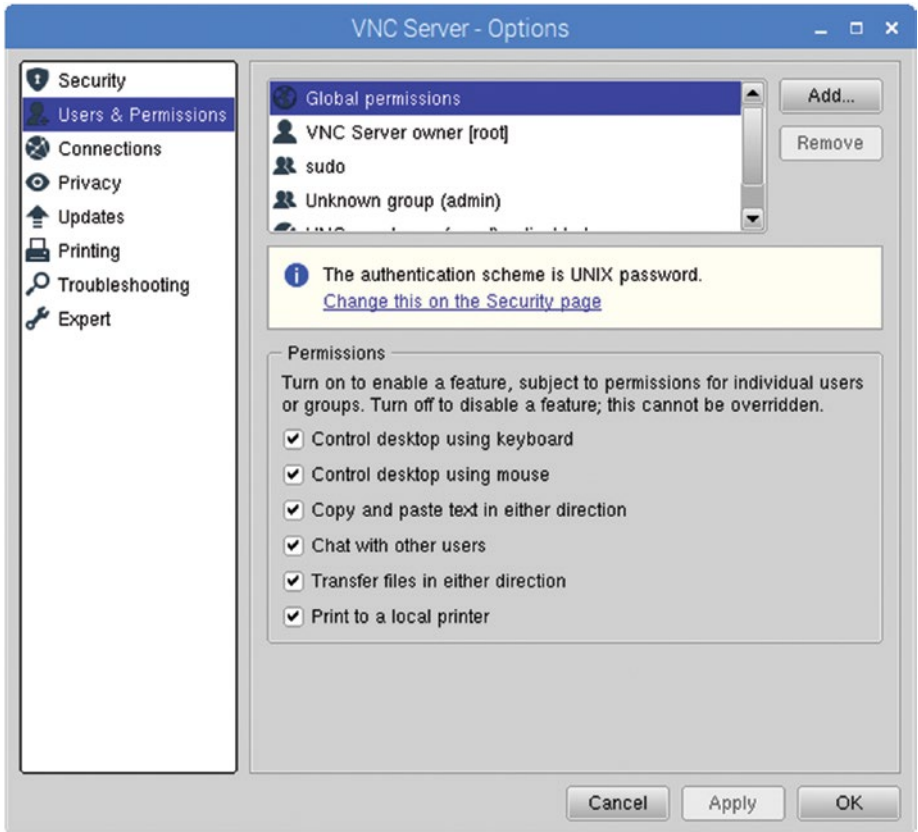
Figure 7-4. *In the Users & Permissions pane of the VNC Server – Options dialog box, select the user or group you want to affect, and then check or uncheck the appropriate check boxes in the Permissions box.*

5. In the box at the top, click the user or group you want to affect.

■ **Note** If you selected VNC password in the Authentication drop-down menu, click the Password button to open the Specify VNC Password dialog box, type the password in the Password box and the Confirm Password box, and then click the OK button.

---

6. Use the controls in the Permissions box to set permissions for the user or group. This works differently depending on whether you selected UNIX Password or VNC Password in the Authentication drop-down menu:

- *UNIX Password*: Check or uncheck the check boxes for the permissions: Control desktop using keyboard, Control desktop using mouse, Copy and paste text in either direction, Chat with other users, Transfer files in either direction, and Print to a local printer.

- *VNC Password*: Check or uncheck the check boxes in the Allow column and the Deny column for each permission: View the desktop, Control desktop using keyboard, Control desktop using mouse, Copy and paste text in either direction, Chat with other users, Transfer files in either direction, Print to a local printer, and Bypass accept/reject prompts.

7. Click the Connections item in the left box to display the Connections pane (see Figure 7-5).
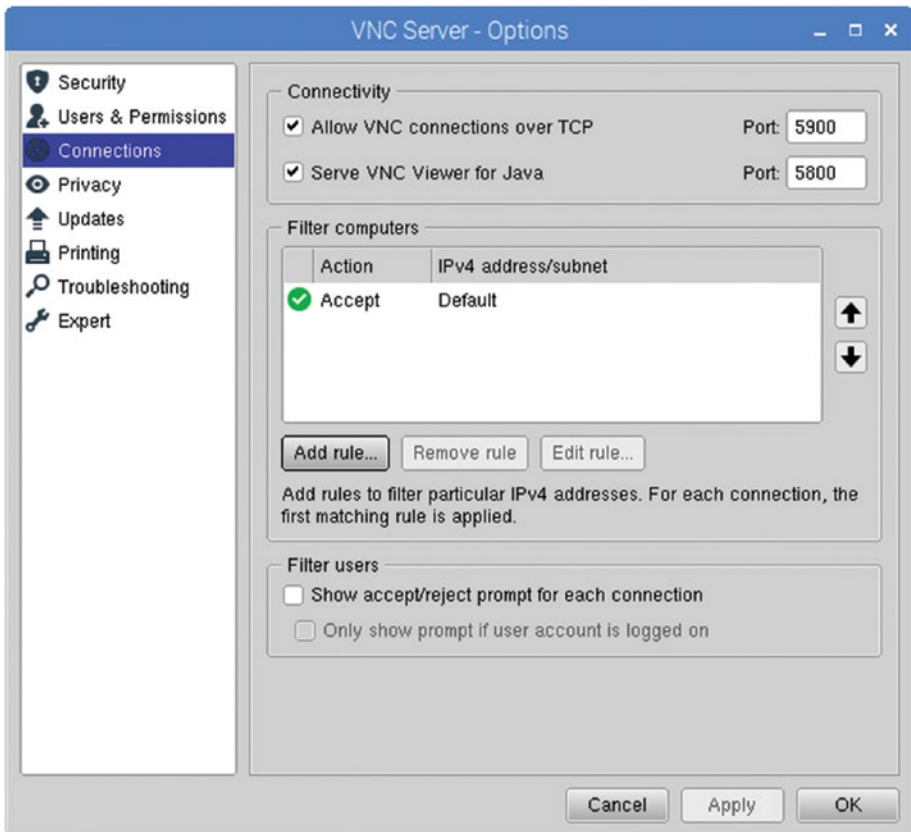
Figure 7-5. *In the Connections pane of the VNC Server – Options dialog box, choose which types of connections to allow. You can also create rules to filter computers by IP address.*

8. In the Connectivity box, check or uncheck the Allow VNC connections over TCP check box as needed. If you check this check box, as you normally would, make sure the Port box on that row shows the correct port. The default port is 5900.

9. Also in the Connectivity box, check or uncheck the Serve VNC Viewer for Java check box, as needed. Normally, you'd check this check box only if you're using VNC Viewer for Java; if so, make sure the Port box on that row shows the correct port. The default port is 5800.

10. Use the controls in the Filter computers dialog box to create any rules needed to control VNC connections to this computer. For example, to allow a particular computer to connect, follow these substeps:

   a. Click the Add rule button to open the Add IP filter rule dialog box (see Figure 7-6).
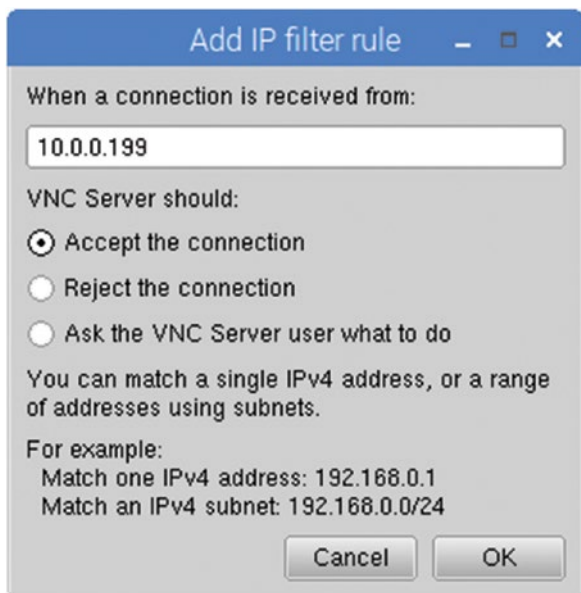
Figure 7-6. *In the Add IP filter rule dialog box, set up a rule to accept or reject VNC connection requests from either a specific IP address or a range of IP addresses.*

   b. In the "When a connection is received from" box, type the IP address of an individual computer (such as `10.0.0.199`) or the address range (such as `10.0.0.0/24`) that you want the rule to affect.

    c.   In the VNC Server should area, select the Accept the connection option button, the Reject the connection option button, or the Ask the VNC Server user what to do option button, as appropriate.

    d.   Click the OK button. The Add IP filter rule dialog box closes, and the rule appears in the Filter Computers box.

  11.   When you finish working in the Connections pane, click the Privacy item in the left box to display the Privacy pane (see Figure 7-7).
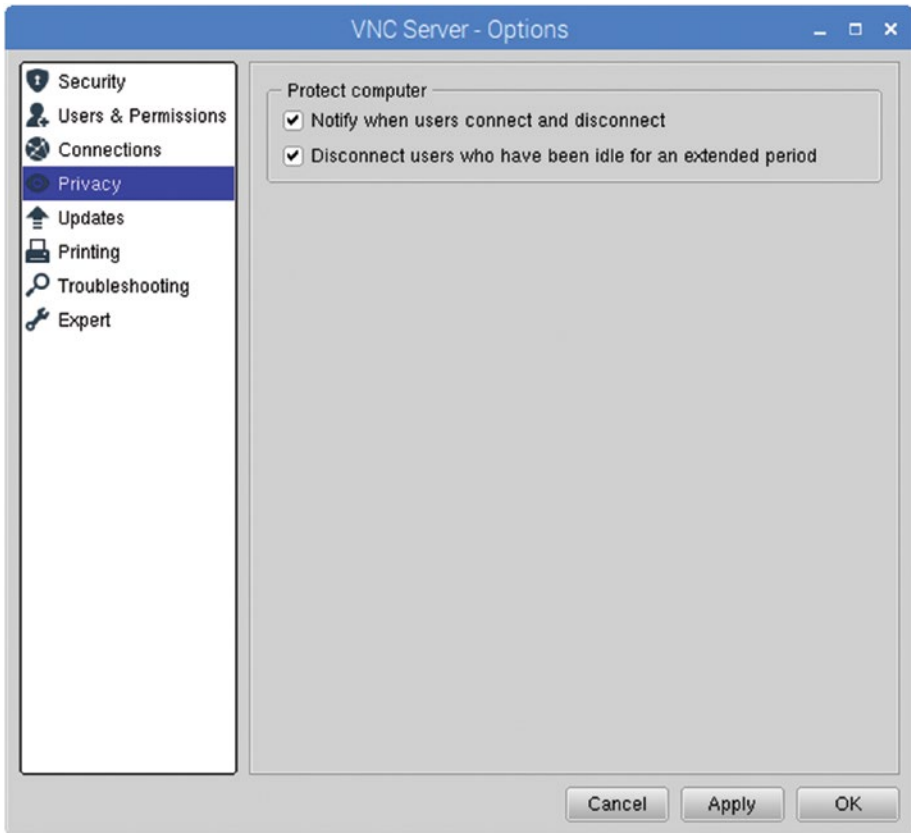
Figure 7-7. *In the Privacy pane of the VNC Server – Options dialog box, choose whether to receive notifications when users connect to and disconnect from the VNC server and whether to disconnect users who remain idle for an extended period.*

12. In the Protect computer box, check the "Notify when users connect and disconnect" check box if you want the VNC server to display alerts when users connect and disconnect.

13. Also in the Protect computer dialog box, check the "Disconnect users who have been idle for an extended period" check box if you want the server to automatically disconnect users who have left the connection idle for a while. This is normally a good idea.

14. When you finish choosing options in the VNC Server – Options dialog box, click the OK button to close it.

Installing a VNC Server on Earlier Versions of Raspbian

On versions of Raspbian that don't include a built-in VNC server, you need to install a VNC server on the Raspberry Pi computer and set it running. You can install and configure the VNC server either working directly on the Raspberry Pi computer or via SSH.

To install the VNC server, open a Terminal window and give the following command:

```
sudo apt-get install tightvncserver
```

You may get a warning that extra disk space is required. If so, type **y** and press the Enter key.

After the install completes, type the command to launch TightVNC Server and press the Enter key:

```
tightvncserver
```

Connecting to the VNC Server

You can now connect to the Raspberry Pi computer by opening a VNC client and specifying the IP address. Figure 7-8 shows a VNC connect to a Raspberry Pi computer using the Chicken of the VNC client on a Mac.
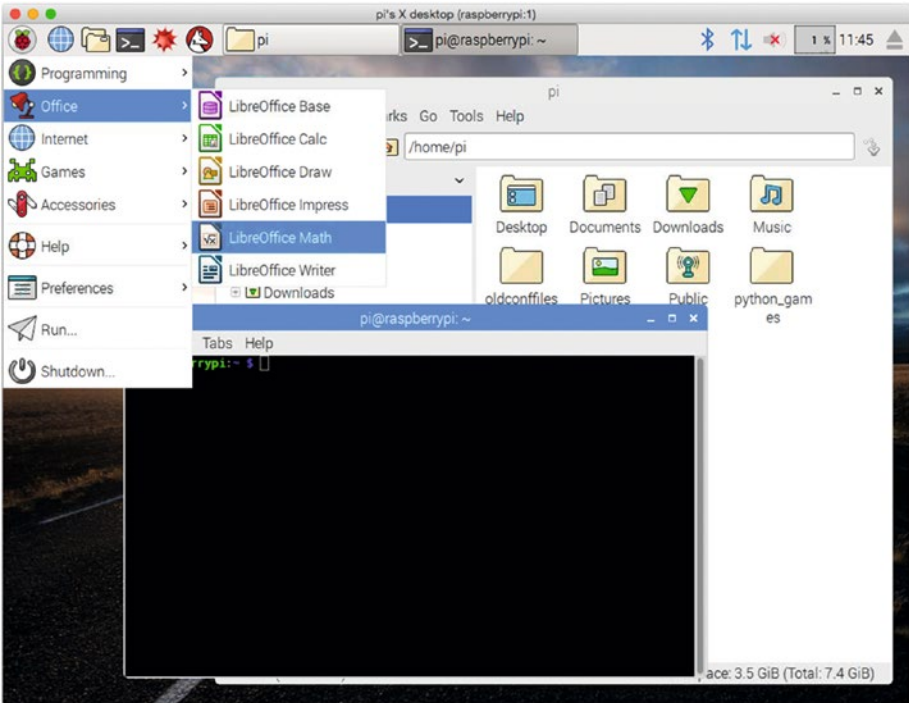
Figure 7-8. *A VNC connection on a Mac to a Raspberry Pi computer*

Controlling a Raspberry Pi Computer Remotely via RDP

If you want to work from a Windows PC, you can choose from a wide variety of VNC clients to take control of Raspberry Pi computers on your network. But Windows offers an alternative that frequently works better: Remote Desktop Protocol, or RDP for short.

What Is RDP?

RDP is Microsoft's protocol for Windows' Remote Desktop feature. As you'll probably know if you've used Windows extensively, Remote Desktop is the feature that enables you to connect one Windows computer (which we'll call the "client computer" here) remotely to another one (which we'll call the "remote computer"). After connecting with the Remote Desktop Connection app on the client computer, you run apps on the remote computer, with the output appearing on the client computer's monitor.

RDP, Remote Desktop, and Remote Desktop Connection enable you to configure the screen size, color depth, and other features on the client computer so you can control the amount of data that needs to be transferred between the remote computer and the client computer. For example, if you have only a slow connection between the computers, you can choose settings that require as little data transfer as possible so that performance remains tolerable.

The disadvantage to RDP is that only the "business" versions of Windows include the Remote Desktop feature that runs on the remote computer, whereas all versions of Windows include the Remote Desktop Connection app. So you can connect using Remote Desktop Connection on a "home" version of Windows to Remote Desktop on a "business" version of Windows, but not vice versa.

Things are better on Linux machines, including the Raspberry Pi: you can run the free xrdp app to enable remote access via RDP. The xrdp app is an RDP server that displays an X Window desktop on the client computer.

Downloading and Installing xrdp

The xrdp app may be included in your installation of Raspbian. To find out, open a Terminal window and give the following command:

```
xrdp
```

If the Terminal gives the message `xrdp: command not found`, give the following command to download and install xrdp:

```
sudo apt-get install xrdp
```

When the installation finishes, type `xrdp` and press the Enter key to run the server.

Connecting to xrdp with Remote Desktop Connection

To connect to xrdp with Remote Desktop Connection, follow these steps:

1. Launch Remote Desktop Connection on Windows. Usually the easiest way is to click the Search box, type **remote**, and then click the Remote Desktop Connection search result. The Remote Desktop Connection window opens.

2. If the Remote Desktop Connection window is at its small size, click the Show Options button to expand it to its full size (see Figure 7-9).
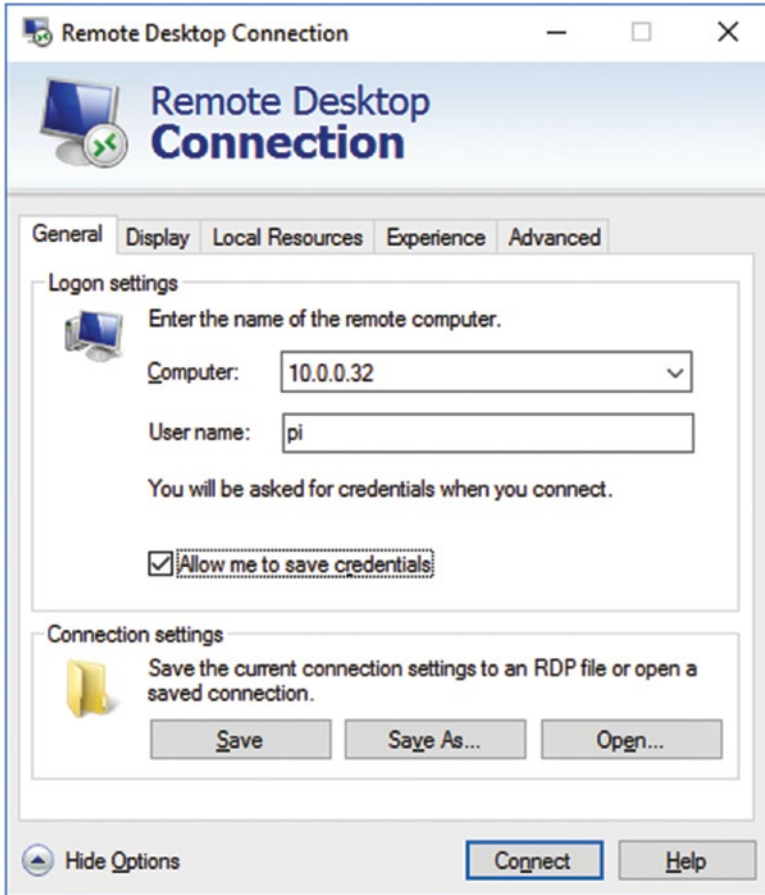
Figure 7-9. *Enter the details for the connection on the General tab of the Remote Desktop Connection dialog box, select the "Allow me to save credentials" check box, and then click the Connect button.*

3. Click the Computer box and type the Raspberry Pi computer's IP address.

4. Click the User name box and type the user name for the account on the Raspberry Pi computer.

5. Select the "Allow me to save credentials" check box if you want Remote Desktop Connection to save these credentials for future use.

6. Click the Connect button. Usually, when you're connecting to a Raspberry Pi computer, the Remote Desktop Connection dialog box shown in Figure 7-10 opens, warning you that the identity of the remote computer can't be verified.
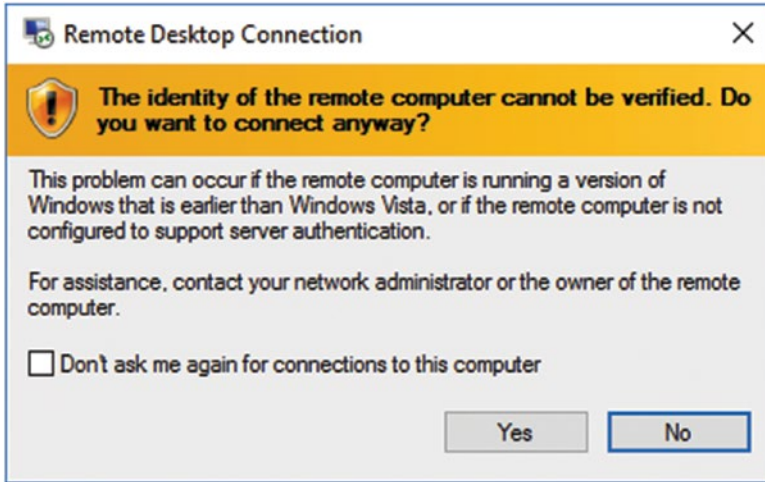
Figure 7-10. *In this Remote Desktop Connection dialog box, select the "Don't ask me again for connections to this computer" check box, and then click the Yes button.*

7. Select the "Don't ask me again for connections to this computer" check box.

8. Click the Yes button. The Windows Security dialog box opens (see Figure 7-11).
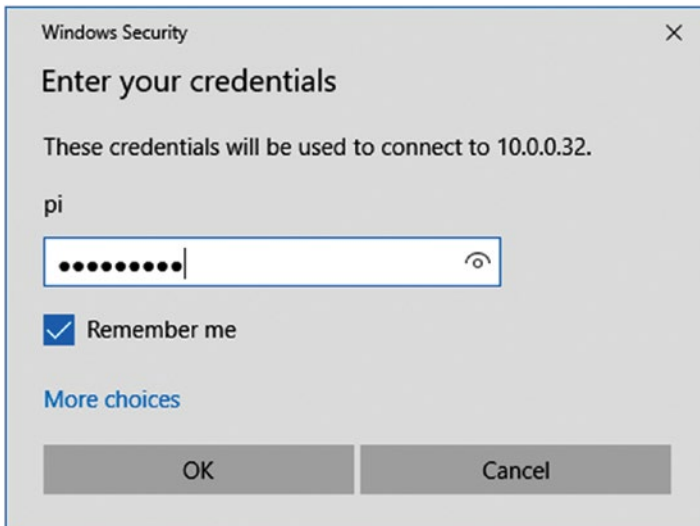
Figure 7-11. *In the Windows Security dialog box, type your password, select the Remember me check box if appropriate, and then click the OK button.*

9. Type your password for the Raspberry Pi computer account.

10. Select the "Remember me" check box if you want Remote Desktop Connection to store the credentials. This saves you time in the future.

11. Click the OK button. Remote Desktop Connection establishes the connection and displays the Raspberry Pi computer's desktop, with the Remote Desktop Connection control bar superimposed on the middle of the top edge (see Figure 7-12).
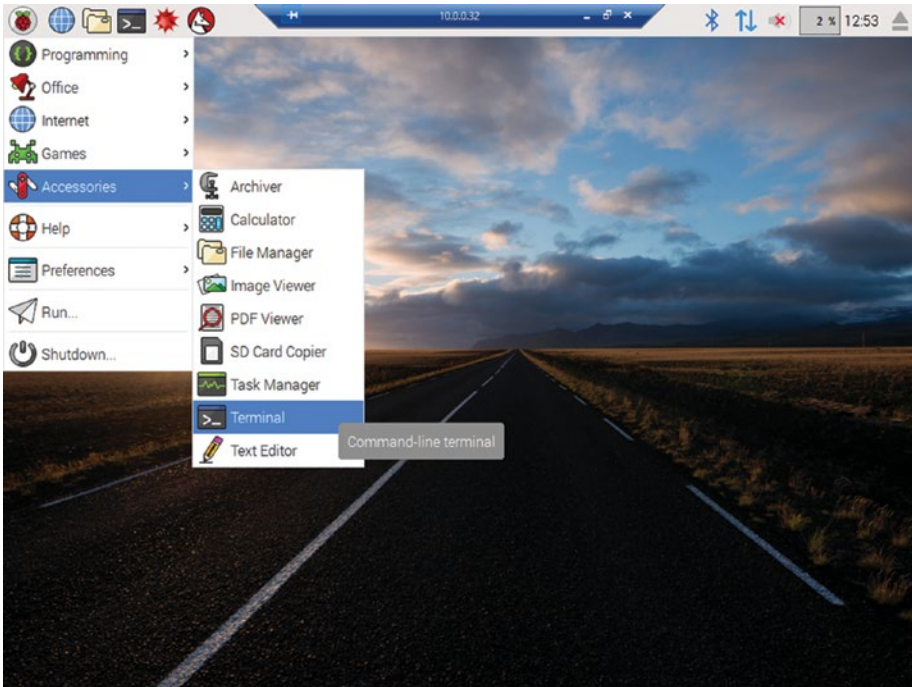
Figure 7-12. *The Remote Desktop Connection control bar appears superimposed on the middle of the top edge of the Raspberry Pi computer's desktop.*

You can now work on the Raspberry Pi computer much as if you were sitting in front of it. When you are ready to end the connection, click the Close (x) button at the right end of the Remote Desktop Connection control bar, and then click the OK button in the Remote Desktop Connection dialog box that opens (see Figure 7-13).
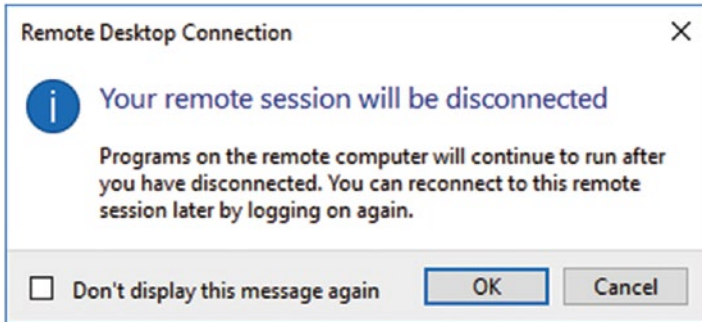
Figure 7-13. *Click the OK button in this Remote Desktop Connection dialog box to end the Remote Desktop Connection session.*

Setting Up and Managing a Network with PiNet

In this section, we'll look at how to set up and manage a network of Raspberry Pi computers using the PiNet server. We'll start by installing PiNet on a suitable PC. We'll then move along to creating and managing user accounts, setting up the Raspberry Pi computers to work with PiNet, and booting the Raspberry Pi computers. After that we'll go through how to set up shared folders for users, how to install programs and keep the Raspberry Pi computers and PiNet itself up to date, and how to use features such as collecting work from students and updating SD card images. Finally, I'll show you how to use the Epoptes classroom-management software to work remotely with your classroom's computers.

What Is PiNet?

PiNet is a free server operating system for managing networks of Raspberry Pi computers. PiNet is designed for classroom use and runs on the free Ubuntu operating system.

What Are the Advantages of PiNet?

PiNet has several advantages for classroom deployments of Raspberry Pi computers:

- *You can create user accounts for students*: Using the accounts, a student can log in on any Raspberry Pi computer in the classroom and can access his or her files and settings on the server.

- *You can share folders easily from a central location*: PiNet enables you to keep files on the server easily instead of putting them on the individual Raspberry Pi computers. You can back up the files easily from the server.

- *There's a work-collection system*: This system gives you an easy way for students to submit work to you.

- *Raspberry Pi computers boot from the server*: Instead of having to install Raspbian on the Raspberry Pi computers individually, you configure the copy of Raspbian on the server the way you want it. The Raspberry Pi computers then boot from the server and install that copy of Raspbian across the network.

- *You can use Epoptes to manage your classroom's computers*: PiNet makes it easy to install and use the Epoptes classroom-management software, which includes features such as monitoring what students are doing on the Raspberry Pi computers; taking control of their screens remotely to help them; sharing your screen to demonstrate techniques; and locking, restarting, or shutting down the Raspberry Pi computers.

What Are the Disadvantages of PiNet?

PiNet has two main disadvantages that you need to balance against its advantages:

- *PiNet may use an older version of Raspbian*: For the Raspberry Pi computers, PiNet uses a customized version of the Raspbian operating system, including extensive modifications. As a result, the version of Raspbian is usually one or two versions behind the latest Raspbian release, so it doesn't have all the latest features.

- *PiNet requires Ethernet rather than Wi-Fi*: You need to use Ethernet connections for the Raspberry Pi computers rather than Wi-Fi to get adequate performance.

Getting a Suitable PC for Running PiNet

To run PiNet, you need a PC with the Ubuntu Server operating system installed. You can download Ubuntu for free from the Ubuntu web site (`www.ubuntu.com/download`). Normally, you'll want to get the latest long-term support (LTS) release; as of this writing, that's Ubuntu Server 16.04.1 LTS, which has support guaranteed until April 2021.

The PC doesn't have to be new or particularly powerful, but it's a good idea to have at least 4 GB of RAM (as usual, more is better) and plenty of disk space for storing files.

The PC also needs a Gigabit Ethernet port to make the PiNet network run at a good speed. Don't try to run a PiNet network on Fast Ethernet—performance will be disappointing because PiNet needs to transfer large amounts of data when the Raspberry Pi computers boot from the server.

Before installing PiNet, configure Ubuntu to use the IP address that the server will have on the network. To do so, follow these steps:

1. Click the System Settings button on the launcher to display the System Settings window.

2. In the Hardware row, click the Network icon to display the Network pane (see Figure 7-14).
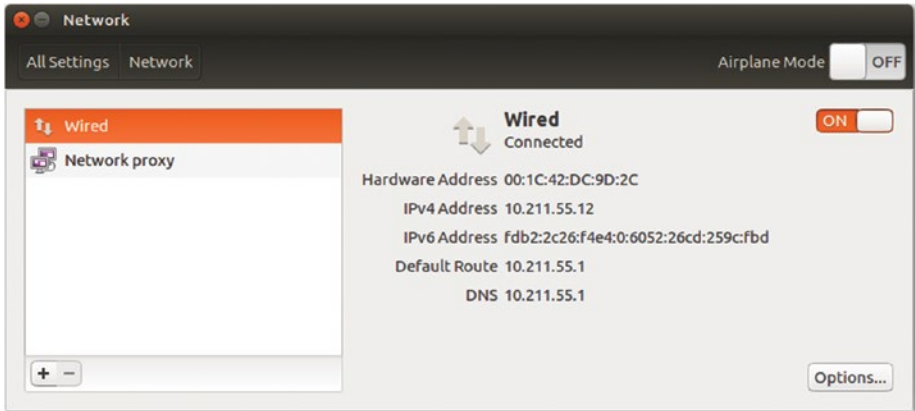
Figure 7-14. *In the Network pane of System Settings, click the network connection you want to use for PiNet, and then click the Options button.*

3. In the left pane, click the network you want to use for PiNet. Normally, this will be the Wired connection.

4. Click the Options button to open the Editing dialog box for the connection. This dialog box's title shows the connection's name, such as Editing Wired connection 1 as in Figure 7-15.
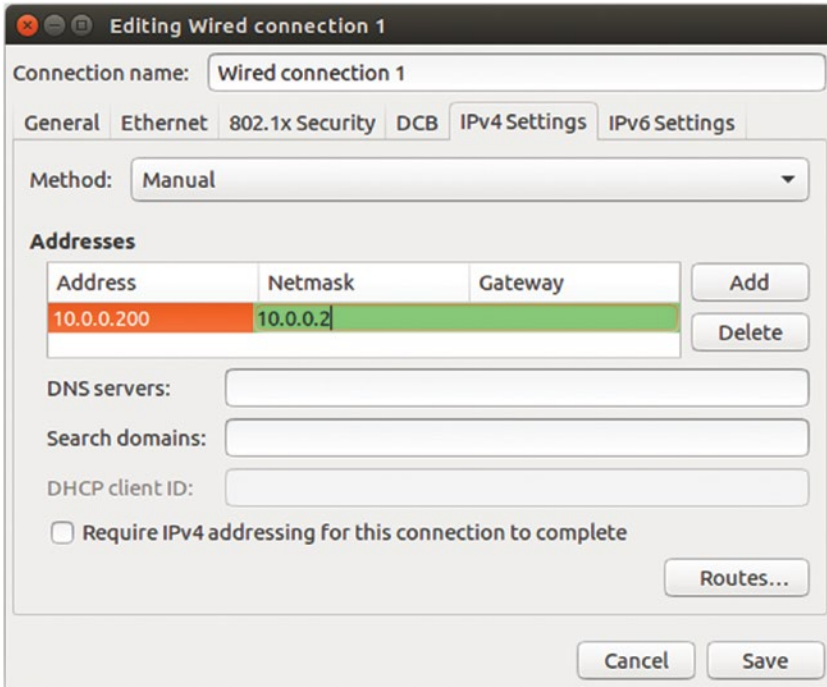
Figure 7-15. In the Editing dialog box for the network connection, click the IPv4 Settings tab and select Manual in the Method pop-up menu. Click the Add button to activate a line in the Addresses box, and then type the IP address, netmask, and gateway address.

5. Click the IPv4 Settings tab to display its controls.

6. Click the Method pop-up menu, and then click the Manual item.

7. Click the Add button to activate a line in the Addresses box.

8. Click the Address column on the new line and type the IP address, such as `10.0.0.200` or `192.168.1.200` (depending on the private address block your network uses).

9. Click the Netmask column and type the netmask, such as 24.

■ **Note** As you enter data in the Addresses box, the active box (the green box) on the address line may overlap the adjacent box and may hide its contents. This is why Figure 7-15 appears to show the gateway address being entered in the Netmask column.

---

10. Click the Gateway column and type the IP address of the gateway, such as 10.0.0.1 or 192.168.1.1 (again, depending on the network's address block).

11. Click the DNS servers box and type the IP addresses of the primary and secondary DNS servers, separating them with a comma.

12. Click the Search domains box and type any search domain you want to have automatically appended for DNS lookups, such as your school's domain.

13. Click the Save button to save the changes. The Editing dialog box closes.

14. Close the Network window by clicking the Close button (the red x button at the left end of the title bar).

Now restart your computer to make the network changes take effect.

TESTING PINET ON A VIRTUAL MACHINE

If you want to try PiNet but don't have a PC you can dedicate to it, try running PiNet on a virtual machine. You can use pretty much any virtual-machine software, such as VirtualBox, VMWare, or (on the Mac) Parallels Desktop.

Downloading and Installing PiNet

To get started with PiNet, log into your Ubuntu box and take the following steps:

1. Press Ctrl+Alt+T to open a Terminal window. You can also click the Terminal icon if it's handy.

2. Give the following command to download the PiNet script:

```
wget --content-disposition http://bit.ly/pinetbeta
```

3. Wait while Ubuntu downloads the script called pinetbeta. The script is a small file, so this shouldn't take more than a few seconds. After the download completes, you'll see brief details of the file transfer, and the prompt appears again.

4. Give the following command to launch PiNet:

```
sudo bash pinet
```

■ **Tip**　The script for installing PiNet is complex and sometimes throws errors, especially if it temporarily can't access Internet repositories from which it needs to download files. If PiNet stops with an error, try giving the `sudo bash pinet` command—several times if necessary.

5. In the Welcome dialog box (see Figure 7-16), select the Yes button and press the Enter key.

Figure 7-16. *Select the Yes button and press the Enter key in the Welcome dialog box to start installing PiNet.*

6. In the Importing users dialog box (see Figure 7-17), select the No button and press the Enter key.
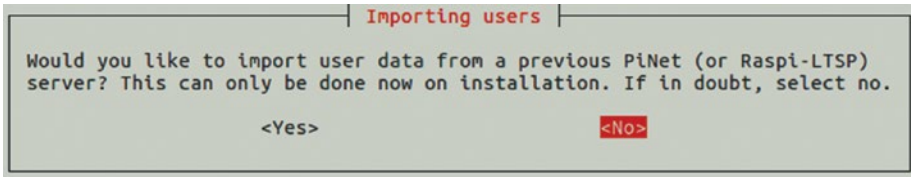
Figure 7-17. *Select the No button and press the Enter key in the Importing Users dialog box.*

7. In the Release channels dialog box (see Figure 7-18), select the Stable button and press the Enter key.
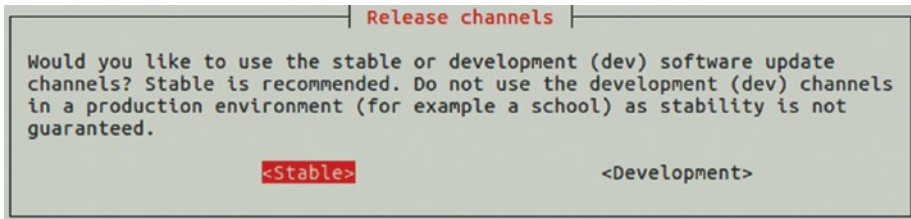
Figure 7-18. *Select the Stable button and press the Enter key in the Release channels dialog box.*

8. In the Additional Software dialog box (see Figure 7-19), press the Enter key to accept the OK button.
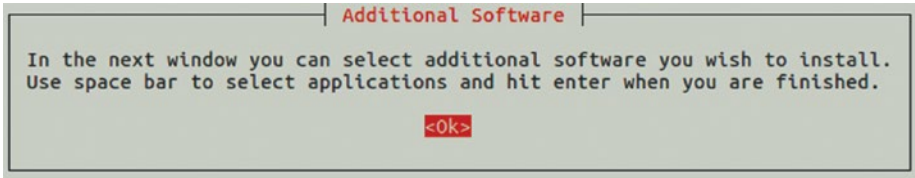
Figure 7-19. In the Additional Software dialog, press the Enter key.

9. In the Extra Software Submenu dialog box (see Figure 7-20), select the extra software packages you want to install. To select a package, press Down arrow or Up arrow to move the highlight to its line, and then press Spacebar to place an asterisk (*) between the brackets.
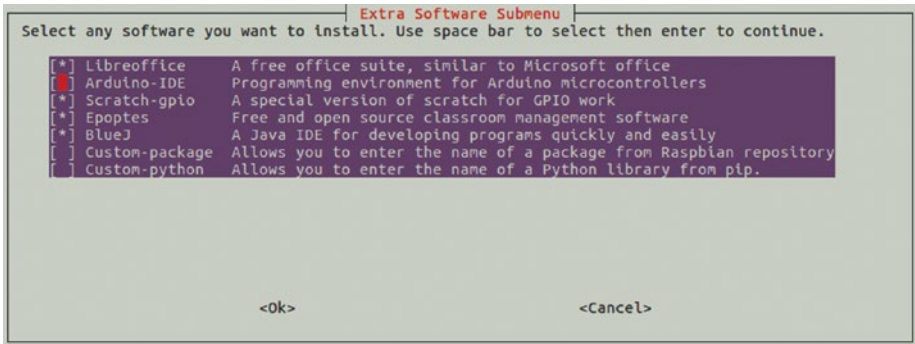
Figure 7-20. In the Extra Software Submenu dialog box, choose the extra software packages you want to install.

10. Select the OK button and then press the Enter key to proceed.

■ **Note** In the Extra Software Submenu dialog box, you'll likely want to install LibreOffice, the office software suite. You may also want to install Epoptes, classroom-management software that we'll show you how to use later in this chapter to control the network's computers.

---

11. In the Are you sure? dialog box (see Figure 7-21), verify your choices before selecting the Yes button and pressing the Enter key.
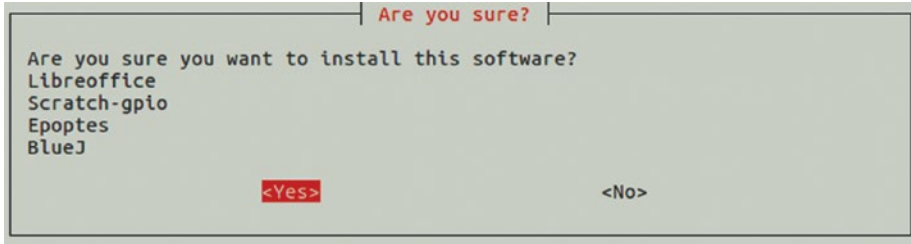
Figure 7-21. *In the Are you sure? dialog box, select the Yes button and press the Enter key to proceed.*

12. In the Full Install dialog box (see Figure 7-22), read the information shown—briefly, downloading the files will take a while, during which you must leave the Terminal window open—and then press the Enter key to accept the OK button.
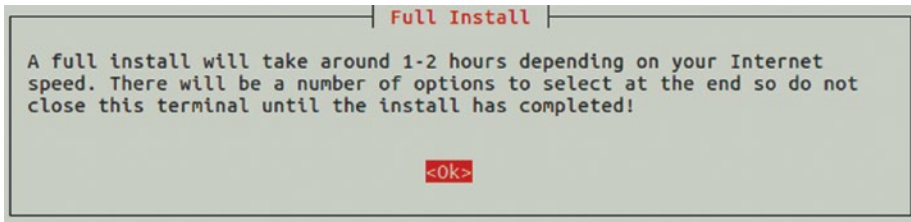
Figure 7-22. *In the Full Install dialog box, read the information and then press the Enter key to accept the OK button.*

13. The script then downloads the files required for the installation. This may take an hour or two. After that, the Warning dialog box opens (see Figure 7-23), asking whether you want to give the students access to the sudo command.

■ **Tip** Give your students access to the sudo command only if they will be doing projects that use the GPIO pins on the Raspberry Pi computers. Otherwise, for security, don't give students access to the sudo command.

```
┤ WARNING ├
Would you like to give students access to the sudo command? Sudo access is
vital for use with GPIO, but in theory introduces the possibility of
students bypassing built in PiNet tampering safeguards. You can change
your mind later the in Manage-Users submenu.

                    <Yes>                          <No>
```
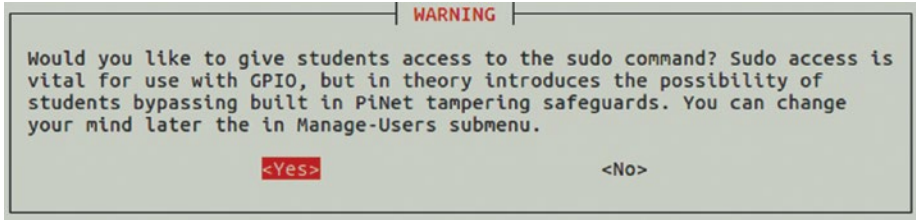
Figure 7-23. *In the Warning dialog box, choose the Yes button or the No button to control whether PiNet gives students access to the sudo command.*

14. Select the Yes button or the No button, as needed, and then press the Enter key. The script then compresses the operating system, which takes several minutes. When that process finishes, the IP address dialog box opens (see Figure 7-24).

```
┤ IP address ├
I have detected your current IP address is 10.0.0.200. Would you like to
setup the SD card image with it? (Recommended)
                    <Yes>                          <No>
```
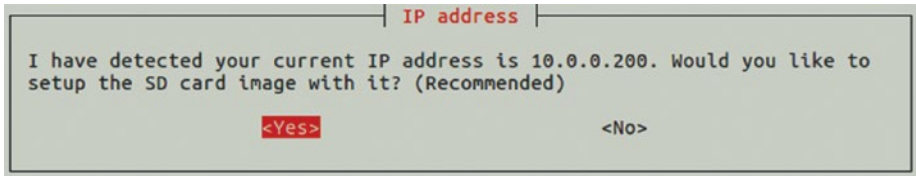
Figure 7-24. *In the IP address dialog box, verify that the IP address the script has detected is the one you want to use for PiNet. Then select the Yes button and press the Enter key.*

15. Make sure that the IP address shown is the one you want to use for PiNet. If you set the Ubuntu box's IP address, as explained in the previous section, the IP address should be right; but if the computer has two or more network interfaces, you may need to pick the right one.

■ **Note**   If the IP address dialog box shows the wrong address, select the No button and press the Enter key. In the second IP address dialog box that opens, type the correct IP address, select the OK button, and then press the Enter key.

16. Select the Yes button and press the Enter key. The Stats dialog box then opens, letting you know that PiNet will automatically collect usage statistics (see Figure 7-25).
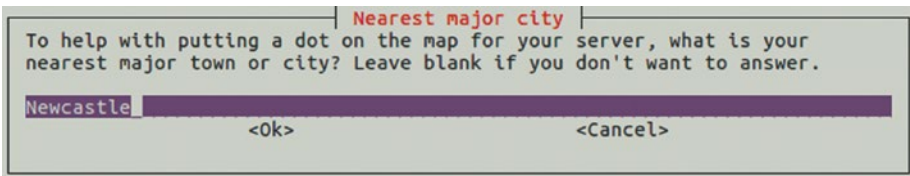
```
┤ Stats ├

Please be aware PiNet now collects very basic usage stats. These stats are
uploaded to the secure PiNet metrics server over an encrypted 2048 bit
SSL/TLS connection. The stats logged are PiNet version, Raspbian kernel
version, number of users, development channel (stable or dev), external IP
address, a randomly generated unique ID and any additional information you
choose to add. These stats are uploaded in the background when PiNet
checks for updates. Should you wish to disable the stats, see -
http://pinet.org.uk/articles/advanced/metrics.html

                              <Ok>
```

Figure 7-25. *The Stats dialog box explains PiNet's collection of usage statistics. Press the Enter key to proceed.*

17. Press the Enter key to accept the OK button. The Additional information dialog box then appears (see Figure 7-26), inviting you to add extra information to your server in the dialog boxes that follow. This information is to help the PiNet team understand PiNet usage; if you don't want to provide it, leave the fields blank in the dialog boxes.

```
┤ Additional information ├

It is really awesome to see and hear from users across the world using
PiNet. So we can start plotting schools/organisations using PiNet on a
map, feel free to add any extra information to your PiNet server. It
hugely helps us out also for internationalisation/localisation of PiNet.
If you do not want to attach any extra information, please simply leave
the following prompts blank.

                              <Ok>
```

Figure 7-26. *In the Additional information dialog box, read the instructions and press the Enter key.*

18. Press the Enter key to accept the OK button. The "Nearest major city" dialog box then appears, prompting you to enter your nearest major city (see Figure 7-27).

```
┤ Nearest major city ├
To help with putting a dot on the map for your server, what is your
nearest major town or city? Leave blank if you don't want to answer.

Newcastle
                    <Ok>                          <Cancel>
```

Figure 7-27. *You can enter your nearest city in the Nearest major city dialog box.*

19. Enter the city (or leave the field blank), select the OK button, and then press the Enter key. The Organisation type dialog box then opens (see Figure 7-28).
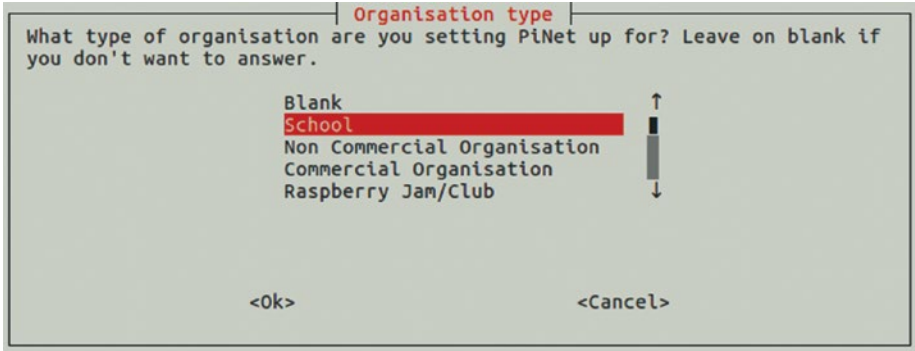
Figure 7-28. *In the Organisation type dialog box, select your organization type, such as School; choose the Blank item if you don't want to answer.*

20. In the list, select the organization type, such as School or Non Commercial Organisation. Then select the OK button and press the Enter key. The School/organisation name dialog box then opens (see Figure 7-29).
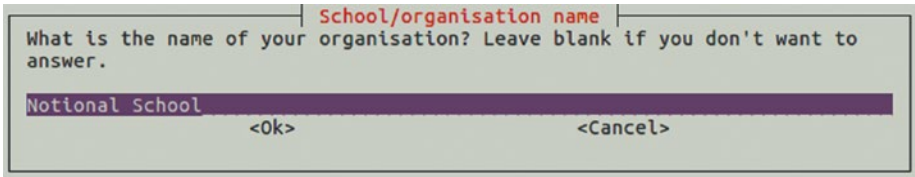
Figure 7-29. *You can enter the name of your school or organization in the School/ organisation name dialog box.*

21. Type the name of your school or organization (or leave the field blank), then select the OK button and press the Enter key. The Additional information dialog box then opens, telling you how to edit the information later if needed (see Figure 7-30).

```
┤ Additional information ├

Thanks for taking the time to read through (and if possible fill in)
additional information. If you ever want to edit your information
supplied, you can do so by selecting the "Other" menu and selecting
"Edit-Information".

                              <Ok>
```
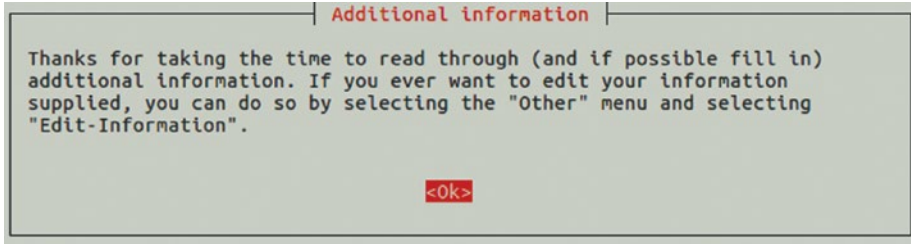
Figure 7–30. *The Additional information dialog tells you how to edit the additional information later if you need to.*

22. Press the Enter key to accept the OK button. The Compression dialog box then opens (see Figure 7-31).

```
┤ Compression ├

The operating system will now be compressed. This normally takes around 5
minutes.

                              <Ok>
```
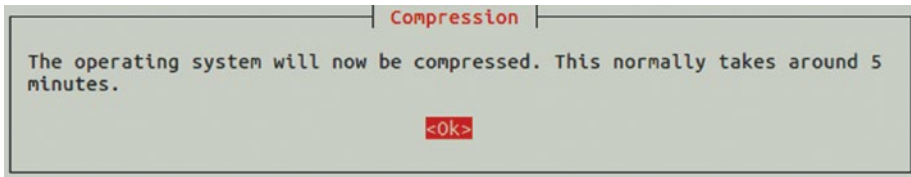
Figure 7-31. *In the Compression dialog box, press the Enter key to accept the OK button.*

23. Press the Enter key to proceed. After the compression completes, the Main installation complete dialog opens (see Figure 7-32), telling you to copy the files found in the /home/ YourUser/PiBoot folder to the root of an SD card and use the SD card to boot a Raspberry Pi computer on the network.

```
┤ Main installation complete ├

PiNet main installation is now complete. There may be a few other minor
updates that will be applied now. Please copy the files found in
/home/YourUser/PiBoot to the root of an SD card. Then plug the Raspberry
Pi into the network and boot it up.

                              <Ok>
```
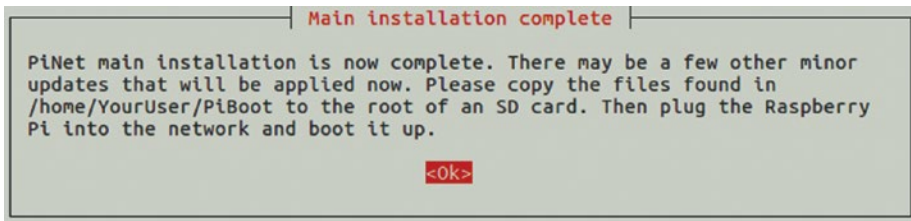
Figure 7-32. *In the Main installation complete dialog box, read the instructions for copying the boot files to an SD card and using it to boot a Raspberry Pi computer. Then press the Enter key.*

24. Press the Enter key. The script looks for updates and applies any it finds. The PiNet Main Menu dialog box then opens (see Figure 7-33), and you can start administering the PiNet server. See the next sections for details.

```
┌──────────────┤ PiNet 1.1.8 Main Menu - 10.0.0.200 ├──────────────┐
│ What would you like to do?                                        │
│                                                                   │
│  System-Status    Display status of key parts of your PiNet server│
│  Install-Program  Install a new program on the Raspberry Pi's     │
│  Manage-Users     Add new users, change passwords and delete users│
│  Update-All       Run an automatic update on server and Raspbian  │
│  Backup-Menu      User files backup submenu                       │
│  Shared-Folders   Manage and create shared folders                │
│  Collect-work     Collects students work in a single folder       │
│  Update-SD        Update the SD card image. This includes IP address changes│
│  Rebuild-OS       Rebuilds the LTSP Raspberry Pi image from scratch again│
│  Epoptes-Menu     Epoptes classroom management submenu            │
│  Troubleshooter   Having issues? Try running the troubleshooter   │
│  Other            Other options and utilities for management      │
│  Update-PiNet     Forces PiNet to update itself                   │
│                                                                   │
│                                                                   │
│                                                                   │
│              <Select>                         <Quit>              │
│                                                                   │
└───────────────────────────────────────────────────────────────────┘
```

Figure 7-33. From the PiNet Main Menu dialog box, you can configure the PiNet server, manage users, back up user files, and more.

Creating and Managing User Accounts

Normally, you'll want to create a user account for each student who will use the Raspberry Pi computers. The user accounts enable students to log in to the network on any of the Raspberry Pi computers and see their own files and settings.

You'll also usually want to create a user account for each teacher who will use the system. PiNet automatically creates an account for you during setup, giving it your Ubuntu username and password.

■ **Note** PiNet assigns students to a group called `pupil` and teachers to a group called `teacher`. The `pupil` group has limited permissions, whereas the `teacher` group has administrative permission for PiNet.


Creating User Accounts

To create a user account, follow these steps:

1. In the PiNet Main Menu dialog box, select the Manage-Users item and press the Enter key. The Manage-users Submenu screen appears (see Figure 7-34).


```
                               ┤ Manage-users Submenu ├
   What would you like to do?

     Add-user           Add a new Linux user
     Remove-user        Remove a Linux user
     Change-password    Change password of a user
     Display-users      List all the users on the system
     Add-teacher        Add user to the staff permission group
     Import-Users       Import usernames and passwords from a CSV file
     Enable-Sudo        Enables the use of sudo for pupils. Used for GPIO access
     Disable-Sudo       Disables the use of sudo for pupils
     Group-check        Checks all users are in the correct system groups
     Export-users       Export all user data for migrating to new PiNet server




                   <Select>                        <Main Menu>
```

Figure 7-34. *The Manage-users Submenu dialog box includes commands for adding and removing users, adding teachers, changing passwords, and enabling and disabling the sudo command.*

2. Select the Add-user item and press the Enter key. The Username dialog box opens.

3. Type the name for the user, select the OK button, and press the Enter key. The Password dialog box opens.

4. Type the password for the user, select the OK button, and then press the Enter key. The Permission Level dialog box opens, asking whether the user is a pupil or a teacher.

5. Select the Pupil button or the Teacher button, as appropriate, and then press the Enter key. The Success dialog box opens, confirming that the new student user (or teacher user) has been added to the system.

6. Press the Enter key to accept the OK button. The Another User dialog box opens, prompting you to add another user.

7. Select the Yes button or the No button, as appropriate, and then press the Enter key. If you select the Yes button, the Username dialog box opens, and you can repeat steps 3–6 to create the user account. If you select the No button, the PiNet Main Menu dialog box opens again.

Removing User Accounts

You can quickly remove a user account from the PiNet system. Follow these steps:

1. In the PiNet Main Menu dialog box, select the Manage-Users item and press the Enter key. The Manage-users Submenu dialog box appears.

2. Select the Remove-user item and press the Enter key. The Users dialog box appears (see Figure 7-35), showing all the user accounts. This dialog box doesn't indicate which of the accounts are teacher accounts.
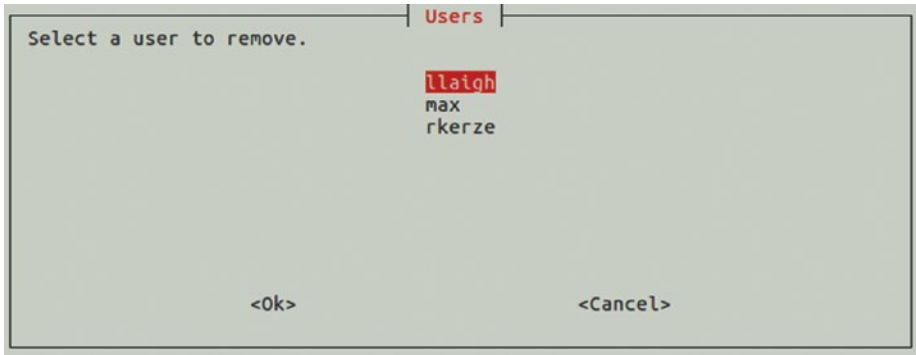
Figure 7-35. *In the Users dialog box, select the user account you want to remove, select the OK button, and then press the Enter key.*

3. Select the user account you want to remove.

4. Select the OK button, and then press the Enter key.

Displaying the List of Users

To see the list of users, and to see which of them are teachers, go to the Manage-users Submenu screen, select the Display-users item, and press the Enter key. You'll see a readout something like this:

```
------------------
Current Linux users
------------------
jmatrix
hhughes
llaigh
rkerze
------------------
Current Linux users in the teacher group
```

```
jmatrix
rkerze
-------------------
Press enter to continue
```

Press the Enter key when you want to return to the PiNet Main Menu dialog box.

Promoting a Pupil Account to a Teacher Account

You can promote a pupil account to a teacher account if you want the pupil to be able to help administer the PiNet system. To promote the account, follow these steps:

1. In the PiNet Main Menu dialog box, select the Manage-Users item and press the Enter key. The Manage-users Submenu screen appears.

■ **Note**   You can also give the Add-teacher command from the Shared Folders submenu.

---

2. Select the Add-teacher command and press the Enter key. The Teacher dialog box opens (see Figure 7-36), explaining which access teachers have.
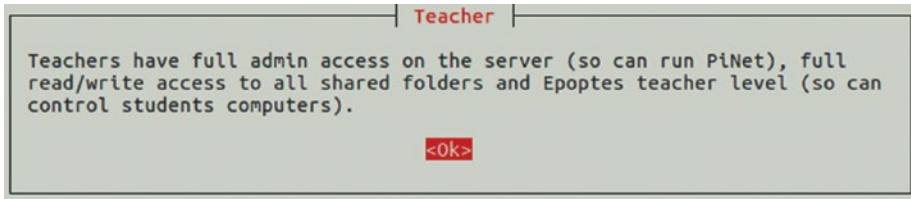
Figure 7-36. *The Teacher dialog box explains the access that teachers have in PiNet.*

3. Press the Enter key. The Users dialog box opens, showing a list of all accounts but not indicating which are students and which are teachers. (To find out which accounts are teachers, see the previous section.)

4. Select the user you want to add to the teacher group.

5. Select the OK button and press the Enter key. The Success dialog box opens, confirming that the user has been added to the teacher group.

6. Press the Enter key to accept the OK button. The PiNet Main Menu dialog box opens again.

Enabling and Disabling the sudo Command

From the Manage-users Submenu dialog box, you can also give the Enable-Sudo and Disable-Sudo commands. These commands enable or disable the `sudo` command on the Raspberry Pi computers that connect to the PiNet system.

■ **Note**   Normally, you'll want to prevent students from giving the `sudo` command to prevent them from taking administrative actions. The exception is if the students will be working with the GPIO pins on the Raspberry Pi computers, because controlling the GPIO pins requires the `sudo` command.

After you give one of these commands, PiNet creates a new system image that includes the change. Compressing the new system image takes several minutes. After that, you need to restart each Raspberry Pi computer to make the change take effect.

Importing and Exporting Users

If you are moving from one PiNet server to another, you can use the Export-users command on the old server to export the list of users to a CSV (comma-separated values) file. You can then use the Import-users command on the new server to import the list of users.

Both these commands are in the Manage-users Submenu dialog box.

Setting Up a Raspberry Pi Computer with the PiBoot Files

To set up a Raspberry Pi computer to connect to the PiNet server, you copy the files from the PiBoot folder in your Home folder on the Ubuntu box to an SD card that you then insert in a Raspberry Pi computer. Follow these steps:

1. Open a Files window and navigate to the `PiBoot` folder in your Home folder.

2. Connect an SD card or micro SD card to your Ubuntu box. For example, insert a micro SD card in a card reader attached to the computer.

3. Use the Files app to copy the files from the PiBoot folder to the root folder on the SD card.

4. Eject the SD card from the Ubuntu box's filesystem.

5. Insert the SD card in a Raspberry Pi computer that's connected to the network via Ethernet.

You can then boot the Raspberry Pi computer as discussed in the following section.

Booting a Raspberry Pi Computer with PiNet

After you insert the SD card containing the PiBoot files in a Raspberry Pi computer, you can boot the computer much as normal. Startup takes somewhat longer than usual because the Raspberry Pi computer copies the operating system across the network from the PiNet server rather than getting it from the SD card, but it's pretty quick on a Gigabit Ethernet connection.

To boot a Raspberry Pi computer, follow these steps:

1. Power on the Raspberry Pi computer. You'll see several screens full of information, and then the login screen appears.

2. Type your username and press the Enter key. The Password field appears.

3. Type your password and press the Enter key. The PiNet server verifies your credentials, and the Raspberry Pi computer then logs you in.

Once you've logged in, the desktop appears, and you can start using Raspbian as normal.

Setting Up Shared Folders for Users

PiNet makes it easy to provide shared folders for the system's users. Shared folders are accessible on each Raspberry Pi computer that connects to the PiNet system. They appear in the left pane of File Manager.

Opening the Shared-Folders Dialog Box

To work with shared folders, select the Shared-Folders command in the PiNet Main Menu dialog box and press the Enter key. The Shared folders dialog box appears (see Figure 7-37).
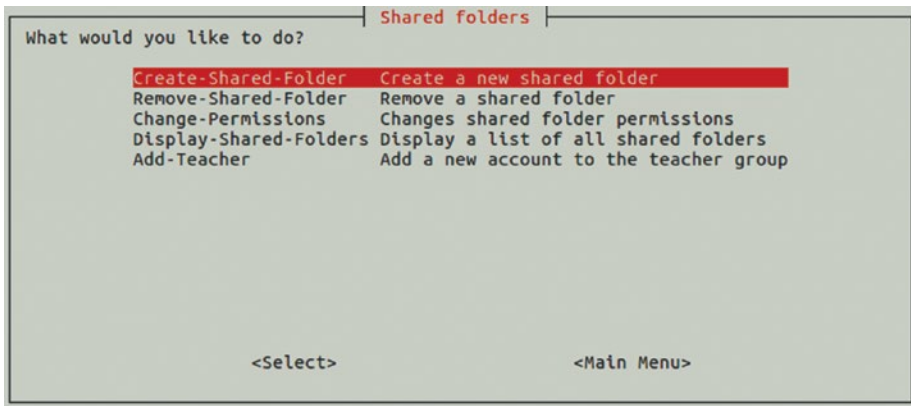
Figure 7-37. *The Shared folders dialog box gives you access to the commands for creating and removing shared folders, changing permissions on shared folders, displaying shared folders, and adding accounts to the teacher group.*

<div style="border:1px solid #000; text-align:center;">

ESSENTIALS OF SHARED FOLDERS

</div>

PiNet creates shared folders in the `/home/shared` folder. For each folder, you can choose whether students have read access or read/write access.

Read/write access enables the user not only to create new files in the folder but also to change and delete existing files. Normally, you'll want to give students only read access to folders in which you provide files to the students, give them read/write access only to folders in which they may create files, and keep the two firmly separate.

Creating a Shared Folder

Follow these steps to create a shared folder:

1. In the Shared folders dialog box, select the Create-Shared-Folder command and press the Enter key. The Create shared folder dialog box opens (see Figure 7-38).


Figure 7-38. *In the Create Shared Folder dialog box, select the Yes button and press the Enter key.*

2. Select the Yes button and press the Enter key. The Current Shared Folders list appears, showing a text list of shared folders. Here's an example, showing only a folder called `Resources`:

```
---------------------
Current shared folders
---------------------

Resources

Hit enter to continue
```

3. Press the Enter key. The Shared folder dialog box opens (see Figure 7-39).

```
┌─────────────────────┤ Shared folder ├─────────────────────┐
│ Enter the name of the new shared folder                    │
│                                                            │
│ Demos▌                                                     │
│                                                            │
│            <Ok>                        <Cancel>            │
│                                                            │
└────────────────────────────────────────────────────────────┘
```
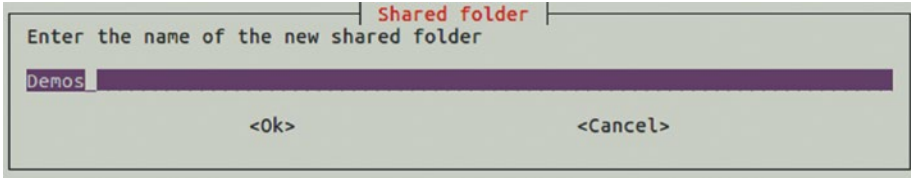
Figure 7-39. *In the Shared folder dialog box, type the name for the new shared folder, select the OK button, and then press the Enter key.*

4. Type the name for the new shared folder.

5. Select the OK button, and then press the Enter key. The Pupil write access dialog box opens, with the Read button selected by default (see Figure 7-40).

```
┌─────────────────────┤ Pupil write access ├─────────────────────┐
│ Should pupils have read/write access to this shared folder or just read │
│ access? (Default read only)                                            │
│              <Read>                        <Read/Write>                 │
│                                                                        │
└──────────────────────────────────────────────────────────────────────┘
```
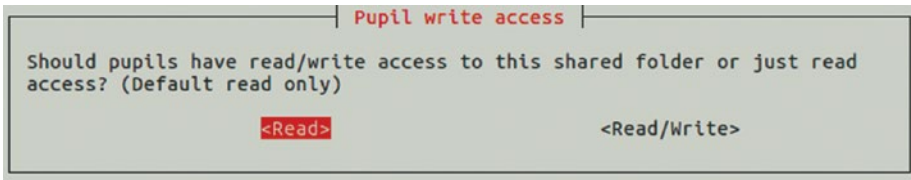
Figure 7-40. *In the Pupil write access dialog box, specify whether pupils should have read/ write access or only read access to the folder.*

6. Select the Read/Write button if you want students to be able to have read/write access to the folder. Otherwise, leave the Read button selected.

7. Press the Enter key. The Complete dialog box opens (see Figure 7-41), confirming that the folder has been created and telling you that you will need to reboot the Raspberry Pi computers to access the folder.

```
┌─────────────────────┤ Complete ├─────────────────────┐
│ The shared folder at /home/shared/Demos has been created! To access it │
│ reboot your Raspberry Pis.                                             │
│                          <Ok>                                          │
│                                                                        │
└────────────────────────────────────────────────────────────────────────┘
```

Figure 7-41. *The Complete dialog box confirms that you have created the folder and reminds you to reboot the Raspberry Pi computers to access it.*

8. Press the Enter key to accept the OK button. The PiNet Main Menu dialog box then opens again.

When you've finished creating shared folders, restart each Raspberry Pi computer to force it to update the list of shared folders.

Removing a Shared Folder

PiNet enables you to remove a shared folder almost as easily as you can create one.

■ **Caution**   Before you remove a shared folder, open a Files window to the folder and make sure you know what it contains. Move any files that you need to keep to another folder, or back up all the files in the folder to a medium from which you can easily recover them.

To remove a shared folder, follow these steps:

1. In the Shared folders dialog box, select the Remove-Shared-Folder command and press the Enter key. The Warning! dialog box opens (see Figure 7-42), letting you know that you will need to reboot all running Raspberry Pi computers after deleting a shared folder.
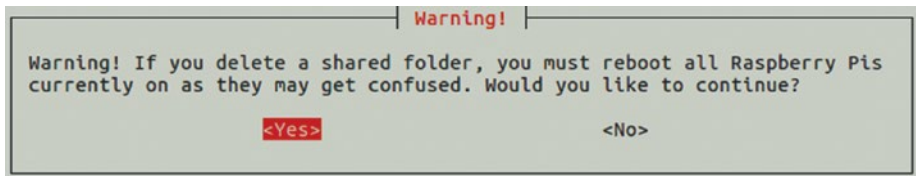
Figure 7-42. *In the Warning! dialog box, read the warning about having to reboot all running Raspberry Pi computers after deleting a shared folder. Then press the Enter key.*

2. With the Yes button selected (as it is by default), press the Enter key. The Shared-folders dialog box opens, showing the list of shared folders on the system (see Figure 7-43).
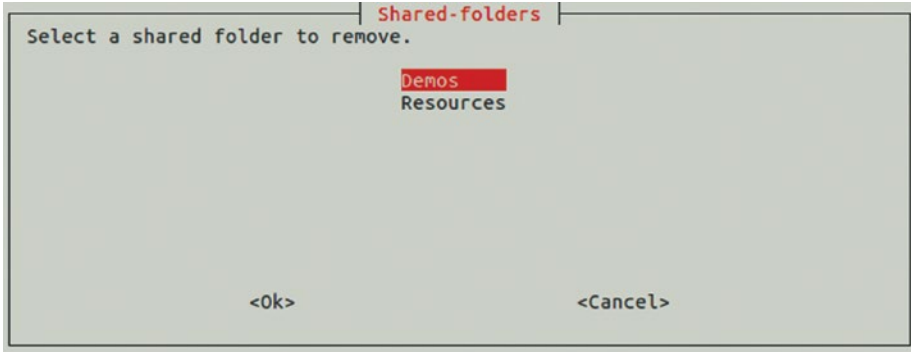
Figure 7-43. *In the Shared-folders dialog box, select the shared folder you want to remove, select the OK button, and then press the Enter key.*

3. In the "Select a shared folder to remove" list, select the shared folder you want to remove.

4. Select the OK button and press the Enter key. The "Are you sure?" dialog box opens (see Figure 7-44).
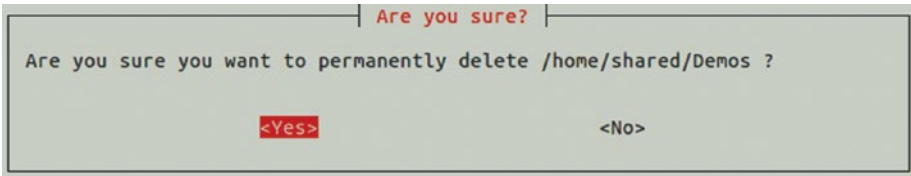
Figure 7-44. *In the Are you sure? dialog box, double-check the name of the shared folder you're about to delete before pressing the Enter key to accept the Yes button.*

5. Look at the name and double-check the name of the shared folder you're about to delete.

6. Press the Enter key to accept the Yes button. The Success dialog box opens (see Figure 7-45), confirming that the folder has been deleted.
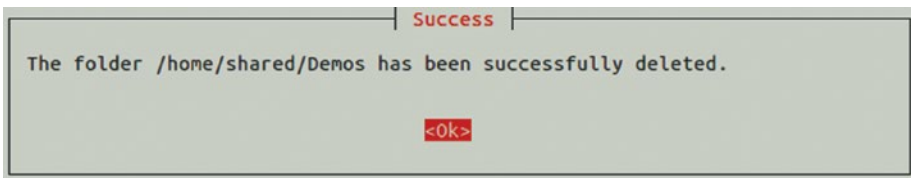
Figure 7-45. *The Success dialog box confirms that PiNet has deleted the shared folder.*

7. Press the Enter key. The PiNet Main Menu dialog box opens again.

After deleting one or more shared folders, restart all the running Raspberry Pi computers to force them to update the list of shared folders.

Switching a Shared Folder Between Read and Read/Write

After creating your shared folders, you may sometimes need to change a folder's access permission from read to read/write or vice versa.

■ **Caution**   When you change a shared folder from read/write to read, students will be unable to change or delete any files they have already created in that folder.

To change the access permission for a shared folder, follow these steps:

1. In the Shared folders dialog box, select the Change-Permissions command and press the Enter key. The Shared-folders dialog box opens (see Figure 7-46).
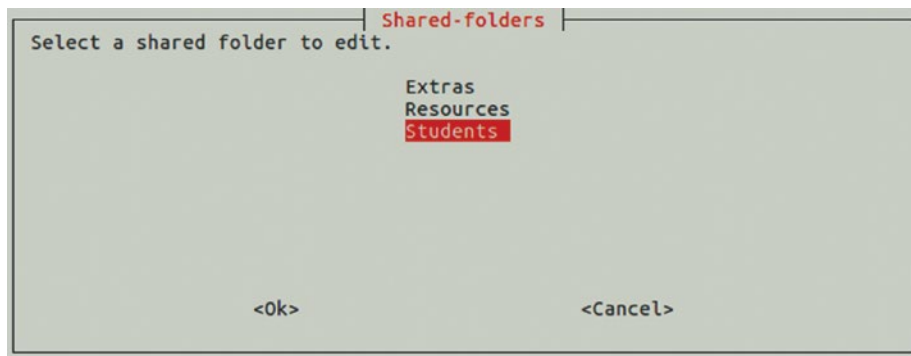
Figure 7-46. *In the Shared-folders dialog box, select the shared folder whose permissions you want to change.*

2. In the "Select a shared folder to edit" list, select the shared folder you want to change.

3. Select the OK button and press the Enter key. The Pupil write access dialog box opens (see Figure 7-47).
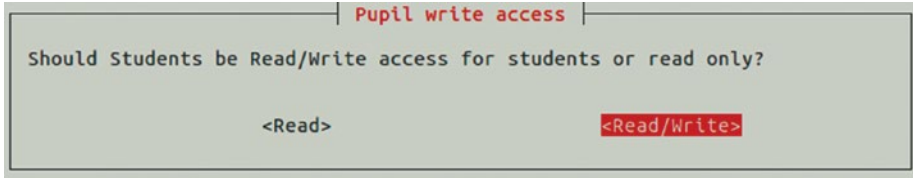
Figure 7-47. *In the Pupil write access dialog box, select the Read button or the Read/Write button, as needed, and then press the Enter key.*

4.   Select the Read button or the Read/Write button, as needed, and then press the Enter key. The Complete dialog box opens, confirming the change (see Figure 7-48).
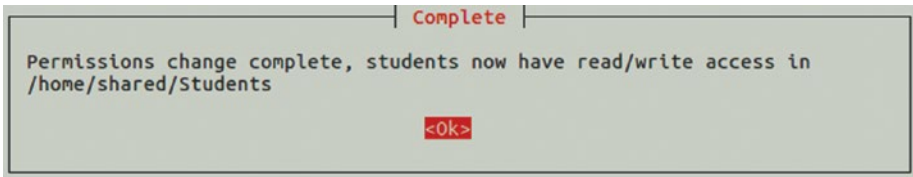
Figure 7-48. *The Complete dialog box confirms the permissions change to the shared folder.*

5.   Press the Enter key. The PiNet Main Menu dialog box opens again.

Viewing the List of Shared Folders

When you want to see a list of all the shared folders on the PiNet system, go to the Shared folders dialog box, select the Display-Shared-Folders command, and press the Enter key. You'll see a list such as this:

```
----------------------
Current shared folders
----------------------

Extras
Resources
Students

Hit enter to continue
```

As you can see, the list doesn't show which folders have read access and which have read/write access for students.

Press the Enter key to return to the PiNet Main Menu dialog box.

Viewing the PiNet System Status

To see the status of the PiNet system, select the System-Status command in the PiNet Main Menu dialog box and press the Enter key. You'll see text output giving various statistics about the system. Here is an example:

```
        PiNet System Status
-------------------------------------------------------
Current version                    - 1.1.8
Server IP address                  - 10.0.0.200
-------------------------------------------------------
Been running version 1.1.8 since   - 2016-09-01
PiBoot folder last updated         - 2016-10-05
Last system-wide update (update-all) - 2016-10-05
----------------
Hard Drive Usage
----------------
Total space                        - 7.9G
Used space                         - 2.4G
Free space                         - 5.5G
-----
Other
-----
CPU usage                          - 8%
Epoptes installed                  - True
Teacher members                    - max, rkerze, llaigh
--------------------
Current active users
--------------------
10.0.0.201:41837 - max
10.0.0.202:41837 - hhughes
...
10.0.0.225:41837 - dweir

Hit enter to return to the main menu
```

Here's what you can see on the PiNet System Status screen:

- *PiNet version*: You can see the PiNet version, which you may need to know when checking for support. This too appears in the title bar of the PiNet Main Menu dialog box.

- *Server IP address*: You can see the server's IP address, but you can see it more easily anytime in the title bar of the PiNet Main Menu dialog box.

- *Running and updates statistics*: You can see how long the server has been running, when the PiBoot folder was last updated, and when the last system-wide update was run.

- *Hard drive usage*: You can see the total amount of space, how much has been used, and how much remains free.

- *CPU usage*: You can see the CPU usage percentage when you gave the System-Status command.

- *Epoptes installed*: You can see whether the Epoptes classroom-management system is installed (`True`) or not (`False`).

- *Teacher members*: You can see which users are members of the `teacher` group.

- *Current active users*: You can see which users are logged in and which IP addresses their computers are using.

Press the Enter key when you finish viewing the system status information.

Installing Programs on the Raspberry Pi Computers

PiNet enables you to install programs easily on all the Raspberry Pi computers on the network by adding them to the Raspbian image that the computers copy from the server during startup. After you add a program, PiNet needs to compress a new Raspbian image, which takes a few minutes. After that, you must restart any running Raspberry Pi computers to get them to pick up the new image.

To install a program, select the Install-Program command in the PiNet Main Menu dialog box and press the Enter key. The Additional Software dialog box opens, and you can follow through the same procedure as when choosing which additional software to install while installing PiNet itself. See the section "Downloading and Installing PiNet," earlier in this chapter, for details.

Updating PiNet and the Raspberry Pi Computers

The PiNet Main Menu dialog box includes the Update-All command for updating its own software and that of the Raspberry Pi computers. When you give this command, PiNet checks and displays the system status, then automatically downloads and installs any updated packages that are available. This may take a while, depending on how many packages there are, what their file size is, and the speed of the Internet connection.

When the update is finished, the Update Complete dialog box opens. Press the Enter key to accept the OK button. The PiNet Main Menu dialog box then appears.

Collecting Work from Students

Pinet gives you an easy means to collect work from students. Each student saves the work they want to submit in his or her `handin` folder. You then give the Collect-Work command and specify the account in which you want PiNet to save the collected work.

To collect work from each student's `handin` folder, follow these steps:

1. In the PiNet Main Menu dialog box, select the Collect-Work command and press the Enter key. The User selection dialog box opens (see Figure 7-49).
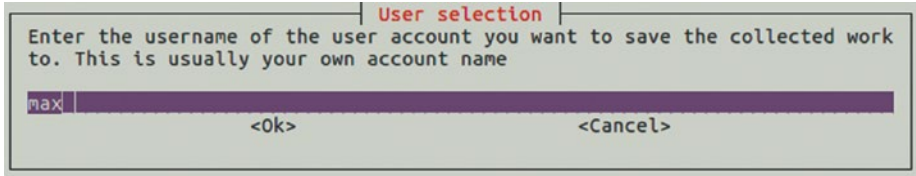
Figure 7-49. *In the User selection dialog box, type the name of the user account in which you want to save the collected work.*

2. Type the name of the user account in which you want to save the collected work. PiNet suggests the username under which you're currently logged in.

3. Select the OK button and press the Enter key. The Warning dialog box opens (see Figure 7-50), telling you that the current submitted folder will be deleted.
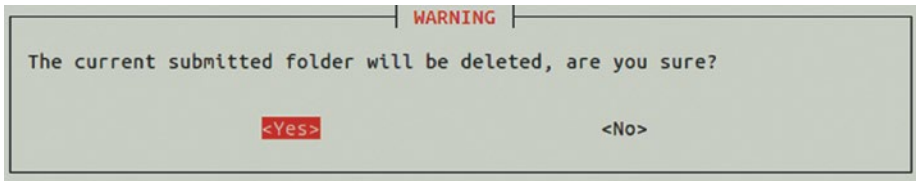
Figure 7-50. *In the Warning dialog box, select the Yes button and press the Enter key to agree that PiNet may delete the current folder used for work submissions.*

4. Select the Yes button and press the Enter key. The Complete dialog box opens (see Figure 7-51), telling you that the students' work has been collected and shows the folder in which it is stored.
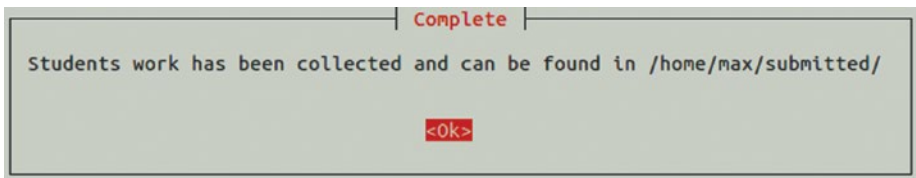
Figure 7-51. *The Complete dialog box tells you that the students' work has been collected and the folder in which to find it.*

5. Press the Enter key to accept the OK button. The PiNet Main Menu dialog box opens again.

Updating the SD Card Image

If you make changes to your PiNet server's configuration, such as changing its IP address, you can use the Update-SD command to update the image that you burn to the SD cards you install in the Raspberry Pi computers.

Updating the SD card image takes a few minutes, during which PiNet prompts you to make sure that the IP address that PiNet is using is correct. When the SD card image is ready, the SD image updated dialog box opens to let you know the names of the files and where to find them (see Figure 7-52).
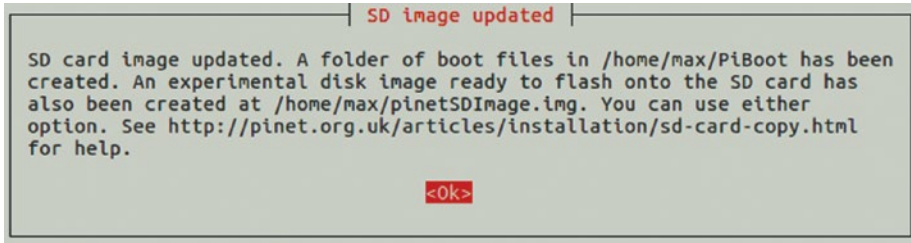
Figure 7-52. *The SD image updated dialog box notifies you that the SD card image files are ready and tells you where to find them.*

Updating the PiNet System

PiNet checks for updates automatically unless you prevent it from doing so (see the sidebar titled "Turning Off Uploading of PiNet Statistics"). You can also check for updates manually by giving the Update-PiNet command from the PiNet Main Menu dialog box.

TURNING OFF UPLOADING OF PINET STATISTICS

By default, PiNet uploads some usage statistics to the PiNet team when it checks for updates. These statistics include the version of PiNet, whether it's the Stable release or the Development release of PiNet, the version of the Raspbian kernel, the number of users on the system, a randomly generated ID number for your PiNet server, and the server's external IP address (the IP address on the Internet). The PiNet team uses these statistics to determine where PiNet is being used and to establish development priorities.

Normally, these statistics present no privacy worries. But you can set PiNet to not upload the statistics by adding the `DisableMetrics=true` parameter to the PiNet configuration file. If you do this, PiNet still uploads the server ID, the external IP address, and the PiNet version when you check for updates.

If you want to disable all uploading of data, you need to turn off automatic update checking. To do so, add the `DisableUpdateChecking=true` parameter to the PiNet configuration file.

You'll find the PiNet configuration file at `/etc/pinet`. To open the file for editing, give the following command:

```
sudo nano /etc/pinet
```

After adding the `DisableMetrics=true` parameter or the `DisableUpdateChecking=true` parameter on a new line at the end of the file, press Ctrl+O to write out the file, and then press the Enter key to accept the existing name.

Taking Remote Control with Epoptes

To keep an eye on what your students are doing during lessons, and to manage your Raspberry Pi computers remotely, you can use Epoptes, a free computer lab management and monitoring app. Epoptes is a Greek word that means "overseer" or "one who has the vision sublime"—a fair description of you in your classroom—rather than a complex acronym.

EXPLAINING EPOPTES' FEATURES TO YOUR STUDENTS

Before you use Epoptes to manage the Raspberry Pi computers in your classroom, spend a few minutes making sure the students understand the app's capabilities. The following are the key points:

- You can see what's happening on any of the computers in the classroom at any time.

- The students receive no indications when you're viewing their screens.

- You can take control of any computer.

- You can lock the screens, log students out, or reboot or shut down the computers remotely.

Installing Epoptes

Epoptes is one of the apps you can install from the Extra Software Submenu dialog box while setting up PiNet itself. You can also install it afterward by using either the Install-Program command from the PiNet Main Menu dialog box or the Install-Epoptes command from the Epoptes Submenu dialog box. If you prefer to work from the command line, the command `apt-cache search epoptes` will do the trick.

The Epoptes Submenu dialog box (see Figure 7-53), which you open by giving the Epoptes-Menu command in the PiNet Main Menu dialog box, contains commands for installing Epoptes, launching Epoptes, adding accounts to the teacher group, and uninstalling Epoptes.
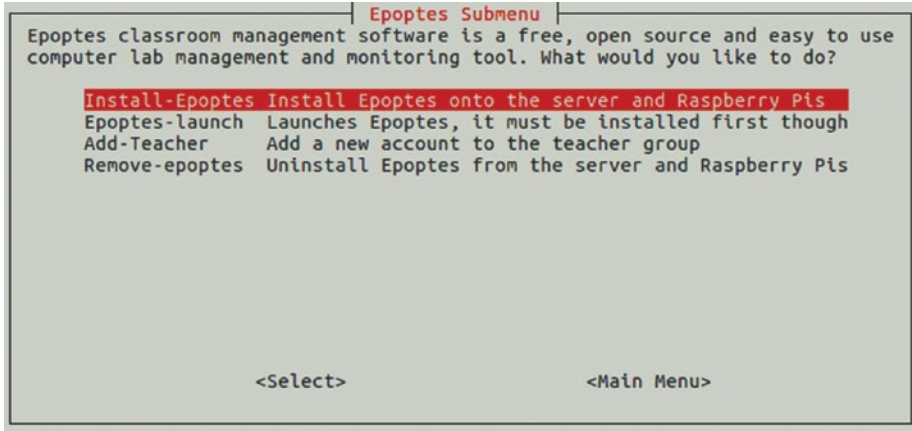
Figure 7-53. *From the Epoptes Submenu dialog box, you can install or uninstall Epoptes, launch Epoptes, and add accounts to the teacher group.*

Launching Epoptes

Once you've installed Epoptes, you can launch it by selecting the Epoptes-launch command in the Epoptes Submenu dialog box and pressing the Enter key.

Epoptes opens in a separate window, showing an overview with a thumbnail for each client (see Figure 7-54). You can zoom the thumbnails larger or smaller by using the controls on the right side of the status bar. Click the – button to zoom out by increments; click the + button to zoom by increments; or drag the slider to zoom in or out freely.
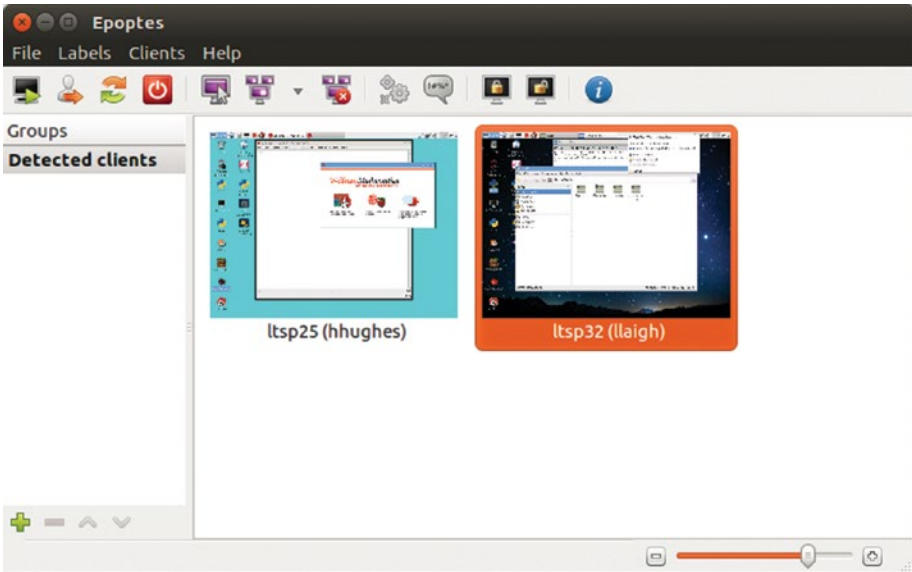
Figure 7-54. *Epoptes displays a thumbnail for each client connected to the network. Use the controls on the right side of the status bar to increase or decrease the thumbnail size as needed.*

■ **Tip** You can choose which information appears under each client thumbnail by opening the Labels menu and then clicking the readout you want: Computer (User), Computer, User (Computer), User, or Show Real Names.

DEALING WITH "MUST BE A MEMBER OF GROUP TEACHER" ERRORS WHEN LAUNCHING EPOPTES

If, when you try to launch Epoptes, the app quits with an error message saying that your user account must be a teacher account, try using the Add-Teacher command in the Epoptes Submenu dialog box to add your account to the `teacher` group again.

If that doesn't work, open a Terminal window and give the following command to add your user account to the `epoptes` group, substituting your username for `username`:

```
sudo gpasswd –a username epoptes
```

Enter your password when Ubuntu demands it, and then give the Epoptes-launch command again.

Working with Your Class's Computers in Epoptes

Once you've launched Epoptes, you can use it to take a wide variety of actions with the client computers on your network. In this section, we'll cover briefly the main actions, most of which you can take from the toolbar, leaving you to explore other capabilities if you need them.

Figure 7-55 shows the toolbar with the buttons labeled.
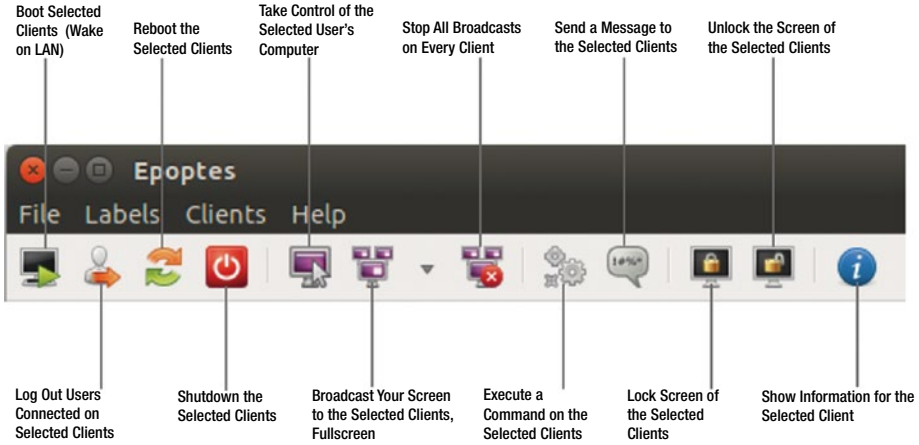
Figure 7-55. *You can give the most widely used commands in Epoptes from the toolbar.*

These are the main actions you can take:

- *Select the client or clients you want to affect*: Click the first (or only) client. After that, you can select a range of contiguous clients by Shift+clicking the one at the far end of the range, or add noncontiguous clients by Ctrl+clicking them.

■ **Note**   The Boot Selected Clients (Wake On LAN) feature of Epoptes doesn't work on Raspberry Pi computers as of this writing, but the Raspberry Pi Foundation is working on Wake On LAN booting.

- *Log out users*: Click the Log Out Users Connected on Selected Clients button to log the users out.

■ **Note**   Epoptes gives the clients no alert or warning about actions you're taking on the clients. If students are using the computers, you might want to use the Send a Message to the Selected Clients command before taking actions such as rebooting the computers, logging the users out, or taking control of the screen.

- *Reboot a Raspberry Pi computer*: Click the Reboot the Selected Clients button to reboot each Raspberry Pi computer you have selected.

- *Shut down a Raspberry Pi computer*: Click the Shutdown the Selected Clients button to shut down each of the Raspberry Pi computers.

- *Take control of a Raspberry Pi computer*: Click the Take Control of the Selected User's Computer button, or simply double-click the computer's thumbnail, to open a VNC window showing the computer's screen (see Figure 7-56). You can then take actions as needed to help the user or to manage the computer. Close the VNC window when you want to end your control of the computer.
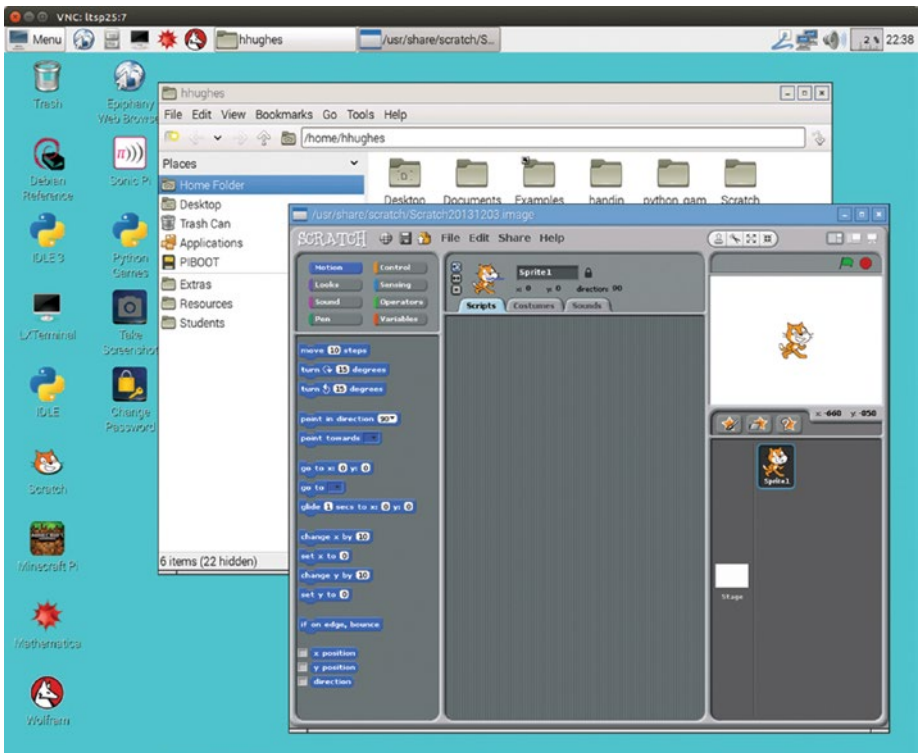
Figure 7-56. *Open a VNC window showing a client's desktop when you want to view what the user is doing, help the user, or control the computer remotely.*

■ **Note** You can take control of multiple computers at the same time. Each computer's desktop appears in a separate VNC window, and you can take actions separately in each window.

- *Broadcast your screen to one or more clients*: Select the clients, and then click the Broadcast Your Screen to the Selected Clients, Fullscreen button to send your computer's screen so that it appears full screen on the client's screen. To send your computer's screen so that it appears in a window on the client's screen, click the pop-up arrow to the right of the Broadcast Your Screen to the Selected Clients, Fullscreen button and then click Broadcast Screen (Windowed) on the pop-up menu.

■ **Caution**   Before broadcasting your screen, make sure it is displaying only what you want the students to see. Normally, you'll want to close any VNC windows you're using to monitor or help students before starting broadcasting. Epoptes will happily broadcast to students the VNC windows in which you're monitoring clients; but network performance tends to suffer, and students will likely find the display visually confusing.

- *Stop broadcasting your screen*: Click the Stop All Broadcasts on Every Client button.

- *Open a URL, open a file, or give a command*: Click the Execute a Command on the Selected Clients button to open the Execute command dialog box (see Figure 7-57). Type the URL, the filename, or the command, and then click the Execute button.
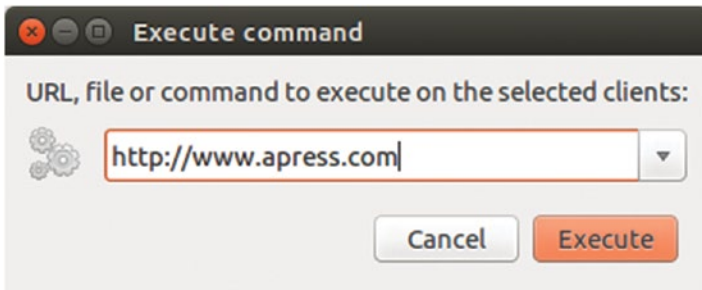
Figure 7-57. *Use the Execute command dialog box to open a web page, open a file, or run a command on the selected clients.*

- *Send a message*: Click the Send a Message to the Selected Clients button to display the Send message dialog box (see Figure 7-58). If necessary, change the default text (*Message from administrator*) in the Message title box. Type your message in the Message text box, and then click the Send button.

■ **Note** Select the Use Pango markup check box in the Send Message dialog box if you want to use the Pango markup language to format your message text.
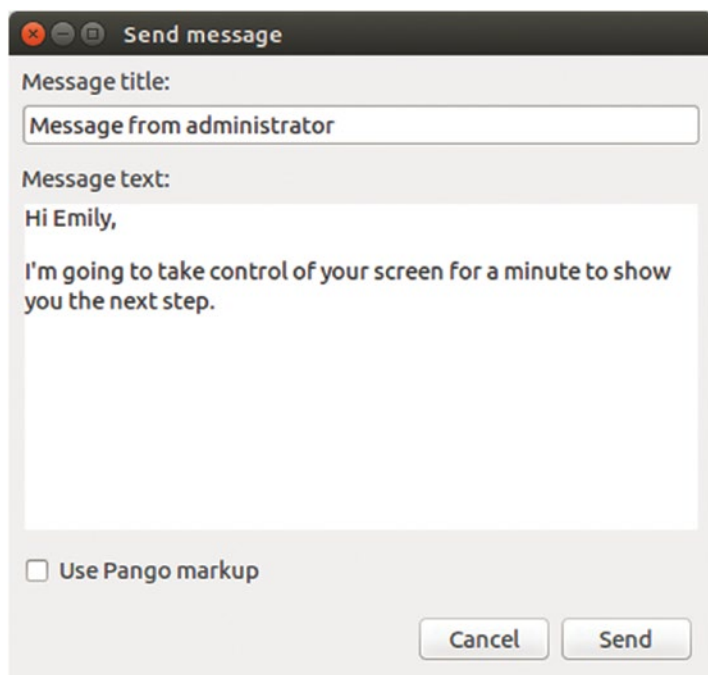
Figure 7-58. Use the Send message box to send a message to one or more clients.

- *Lock the client's screen*: Click the Lock the Screen of Selected Clients button to lock the screen. The client displays a lock screen containing a padlock symbol and the message *The screen is locked by a system administrator*.

- *Unlock a locked client's screen*: Click the Unlock the Screen of the Selected Clients button to unlock a client you've locked.

■ **Note** If the Unlock the Screen of the Selected Clients command fails to unlock a client's screen, reboot the client to get it working again.

- • *View information about a client*: Click the Show Information for the Selected Client button to open the Properties dialog box (see Figure 7-59) in which you can see the client type (fat or thin), the hostname, the MAC address, the IP address, the username, the processor type, and the amount of RAM.

Figure 7-59. *The Properties dialog box lets you see a client's type, MAC address, processor type, and other details.*

■ **Note**   Epoptes is extremely useful software and usually works very well—but as of this writing, it sometimes crashes. If this happens, there's no indication to the clients unless you're broadcasting your screen to them. Restart Epoptes without fanfare, and you'll be able to resume your instruction without the students noticing the crash.

Summary

In this chapter, you've learned how to administer and manage your classroom network of Raspberry Pi computers. You now know how to create user accounts on individual Raspberry Pi computers and how to connect to them using SSH, VNC, and RDP. You also know how to install, configure, and use the PiNet server software to manage your Raspberry Pi computers centrally, and how to use the Epoptes software to control your classroom computers remotely.

In Chapter 8, we'll look at how to troubleshoot your classroom deployment of Raspberry Pi computers.

■ ■ ■

Troubleshooting Raspberry Pi Computers

Raspberry Pi computers are generally pretty sturdy and reliable, and Raspbian is a mature and stable operating system. That said, sooner or later you're almost certain to experience problems with some of your Raspberry Pi computers. This chapter shows you how to troubleshoot the problems you're most likely to encounter.

As you know from your experience with computers, many different things can go wrong with hardware, software, or both. Some problems have quick and easy fixes, whereas other problems—even if they initially appear trivial—can require involved steps and plenty of time to troubleshoot.

In this chapter, I'll assume that you'll be troubleshooting Raspberry Pi computers deployed in your classroom and that your priority is to keep the computers running and your classroom functioning smoothly. This means that you likely won't have time to dig into the specifics of each problem the moment it occurs; instead, you will want to work around problems as far as possible. To this end, the chapter begins by suggesting a troubleshooting approach that assumes you have multiple Raspberry Pi computers—preferably more than you need running at any one point—and extra peripherals.

After that, we'll cover how to keep the system software on your Raspberry Pi computers up to date. We'll then move along to troubleshooting specific things that often go wrong, examining issues with startup, SD cards, network connections, displays, keyboards and pointing devices, and audio output.

How to Approach Troubleshooting Your Raspberry Pi Computers

When something goes wrong with a desktop computer in the classroom, you'll normally need to troubleshoot it soon—if not immediately—to keep the classroom functioning usefully. But the nature, design, and low cost of Raspberry Pi computers mean that, in the classroom, you're often better off using a restart-and-replace approach to troubleshooting instead of dealing with problems in situ.

Restarting as a Troubleshooting Move

As you'll read repeatedly in this chapter, you can clear up many problems with Raspberry Pi computers simply by restarting them. The speed and simplicity of restarting an Raspberry Pi computer means that a restart is often a sensible place to start troubleshooting. A restart usually takes less than a minute, and any student can perform it—unless you've configured the Raspberry Pi computers to prevent restarts.

Replacing the SD Card

Your second major troubleshooting move for Raspberry Pi computers is to replace the SD card. This is a move that can clear up various kinds of problems ranging from the Raspberry Pi computer refusing to boot to the computer running unstably.

Sometimes you'll want to take a known good SD card from another Raspberry Pi computer that's working well and insert it in the problem Raspberry Pi computer to see if doing so solves the problems. Other times, you'll want to replace the SD card either to perform a fresh installation of the operating system or to change the operating systems available. Either way, you'll likely want to have a good supply of SD cards available, preferably in a waterproof storage box divided into compartments that you can label to indicate what's on the SD cards in each compartment.

Replacing the SD card to solve apparently minor problems can feel like overkill, but it's quick, effective, and inexpensive. Depending on the cases you've chosen for your Raspberry Pi computers, you often don't even need to open the computer's case to replace the SD card, so it's far easier than physically replacing the hard drive or SSD in a regular desktop. If you've chosen cases to make sure your students don't remove SD cards from the Raspberry Pi computers, you'll need to do a bit more work—or have competent students do it for you.

■ **Caution**   To give yourself flexibility in troubleshooting your Raspberry Pi computers, avoid storing data files on the SD cards in the Raspberry Pi computers. Instead, keep all data files on the network or on other removable storage, such as USB sticks.

Replacing Peripherals

Your third major troubleshooting move is to replace peripherals that are causing problems. For input/output peripherals—such as the keyboard, the pointing device, and (in some cases) the display—replacement tends to be the only practical means as well as the easiest means for resolving problems. But even for other peripherals, replacing the peripheral that's causing problems is often the fastest and easiest way of getting the Raspberry Pi computer working properly again.

This assumes that you'll be able to put your hands on extra peripherals of the right kind. But in a classroom situation, you likely have extra peripherals available as replacements. If not, you can borrow peripherals from a Raspberry Pi computer on which they're working correctly to troubleshoot the problem computer.

Replacing the Raspberry Pi Computer

Your fourth major troubleshooting move is to replace the Raspberry Pi computer itself. If you suspect the problem is only minor, this move too may feel like overkill—but your priority should be to keep your classroom fleet in full working order. To that end, replacing a problem Raspberry Pi computer with a known good one or a freshly configured one is as practical and sensible as it is effective.

A replacement strategy assumes that you have enough surplus Raspberry Pi computers to be able to swap them in and out as necessary. If you weren't able to get the budget for extra computers in your initial deployment, try to work toward it as a long-term goal.

Keeping Raspbian Up to Date

To keep your Raspberry Pi computers running well, you should periodically update Raspbian to the latest version available so as to take advantage of any bug fixes, new features, or other improvements the Raspberry Pi Foundation has implemented.

■ **Note**   In this section, I assume your Raspberry Pi computers are running Raspbian, but the same principles—and in many cases, the same commands—apply to other operating systems you can run on the Raspberry Pi as well.

■ **Note**   You can also use the PiNet server to update Raspbian on Raspberry Pi clients. See Chapter 7 for details.

Getting to a Command Prompt

To update Raspbian, first get to a command prompt on the Raspberry Pi computer. These are the three most convenient ways to do this:

- *Connect via SSH*: When you need to work from another computer, connect via SSH, specifying the username and Raspberry Pi computer's IP address (for example, `ssh pi@10.0.0.55`) and then entering your password when prompted. This is a convenient way to work from your main computer—or from another Raspberry Pi computer, from a tablet, from a smart phone, or whatever you're using.

- *Open a Terminal window*: If the Raspberry Pi computer is set to boot to the GUI, click the Terminal button on the Panel to open a Terminal window. You can do this either working directly on the Raspberry Pi computer or working remotely via VNC or xrdp.

- • *Use the command line*: If you've set the Raspberry Pi computer to boot to the command line rather than to the GUI, simply give the commands at the command line.

Updating the System's Package List

Once you're at a command prompt on the Raspberry Pi computer, give the following command to update the system's package list:

```
sudo apt-get update
```

This may take a few minutes to execute, but usually not much more than that—it's downloading the list of packages, not the packages themselves.

Checking How Much Space Is Available on the SD Card

Next, it's a good idea to make sure that the SD card has enough space available for any packages the computer needs to download. You ought to do this because the apt command doesn't check that there's enough free space and will happily run the root partition out of free space by downloading packages.

To see how much space is available, give the following command:

```
df –h
```

You'll see output such as this:

```
Filesystem      Size  Used Avail Use% Mounted on
/dev/root       7.4G  3.5G  3.5G  50% /
devtmpfs        459M     0  459M   0% /dev
tmpfs           463M     0  463M   0% /dev/shm
tmpfs           463M   13M  451M   3% /run
tmpfs           5.0M  4.0K  5.0M   1% /run/lock
tmpfs           463M     0  463M   0% /sys/fs/cgroup
/dev/mmcblk0p6   63M   20M   43M  32% /boot
tmpfs            93M     0   93M   0% /run/user/1000
/dev/mmcblk0p9  4.5G  9.4M  4.2G   1% /media/pi/41fd8903-2ed9-4fe5-a742-
76c36aa1aacc
/dev/mmcblk0p8  512M  129M  384M  26% /media/pi/9791-7D8E
/dev/mmcblk0p5   30M  2.5M   26M   9% /media/pi/SETTINGS
/dev/mmcblk0p10 488M  408K  452M   1% /media/pi/data
```

Locate the /dev/root entry in the Filesystem column, and then look across the row to see the partition size, amount of space used and available, and the percentage used. Usually, as in this case, there'll be plenty of space—but it's wise to make sure. See the sidebar "Getting Rid of Downloaded Package Files" for an easy way to make space on the root partition if it's nearly full.

GETTING RID OF DOWNLOADED PACKAGE FILES

If the `df -h` command shows that the root partition on the SD card is nearly full, you may need to free up space before running or updating your installed packages. You can get rid of any files you don't need, but one easy way to free up space is to delete downloaded package files that are no longer needed.

Raspbian stores these files in the `/var/cache/apt/archives` folder. You can delete these files manually if you want (e.g., by using the File Manager app), but it's quicker and easier to use this command if you want to delete all of them:

```
sudo apt-get clean
```

After giving this command, run the `df -h` command again to see how space is now available.

Upgrading the System's Installed Packages

Once you've checked the amount of free space, give the following command to upgrade all the Raspberry Pi computer's installed packages to the latest versions available:

```
sudo apt-get dist-upgrade
```

If there are packages to install, you'll see a prompt telling you how much additional disk space will be used. Make sure that this is less than the amount of space you've just established is available, and then type **y** and press the Enter key.

The Raspberry Pi downloads and installs the updates. This may take many minutes, depending as usual on how much data there is to download and the speed of the Internet connection.

Troubleshooting Startup

In this section, we'll look at how to troubleshoot startup problems. The Raspberry Pi uses a different architecture than standard computers, so we'll start by going through what happens during startup so that you know what's happening. We'll then use that knowledge to identify and deal with common startup problems, such as the SD card being missing, damaged, or configured incorrectly; the Raspberry Pi signaling an error code; and the display receiving no video output even though the Raspberry Pi has actually booted.

Understanding What Happens During Startup

To troubleshoot startup problems, it's helpful to know what happens while the Raspberry Pi is booting. Each Raspberry Pi board has two light-emitting diodes (LEDs) near the upper-left corner (looking with the SD slot at the top and the USB ports at the bottom) that help you to determine what's happening. The LED on the left is the Power LED and is red. The LED on the right is the ACT LED and shows different colors depending on what's happening. Figure 8-1 shows the Power LED and the ACT LED on a Raspberry Pi 3 Model B board. Figure 8-2 shows the Power LED and the ACT LED as you'll see them through a case.

ACT LED   Power LED   Micro USB power port   HDMI port   Composite video and audio output port
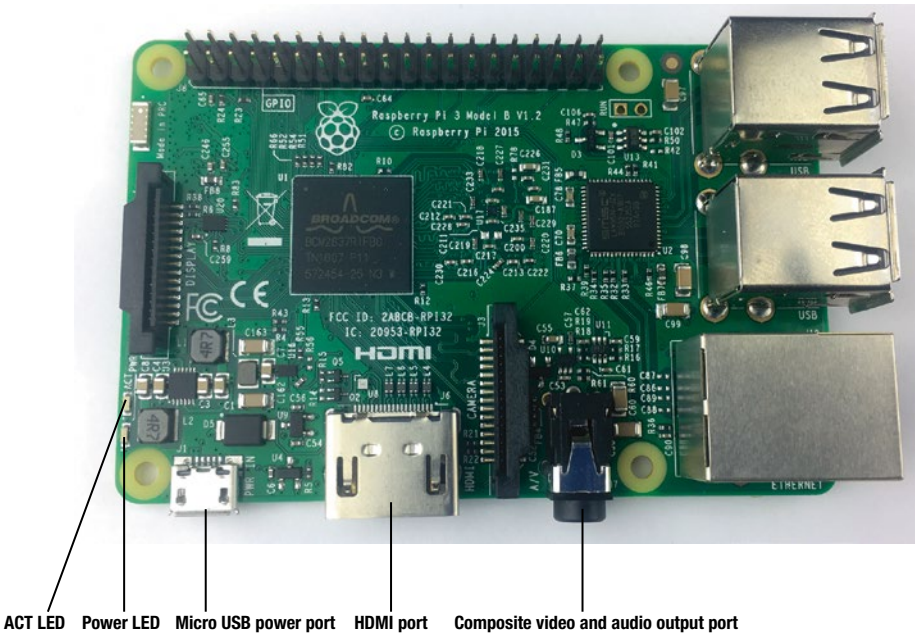
Figure 8-1. *The Power LED and the ACT LED enable you to ensure that the Raspberry Pi board is getting power and is able to read the SD card.*

SD card slot   **ACT LED**   **Power LED**
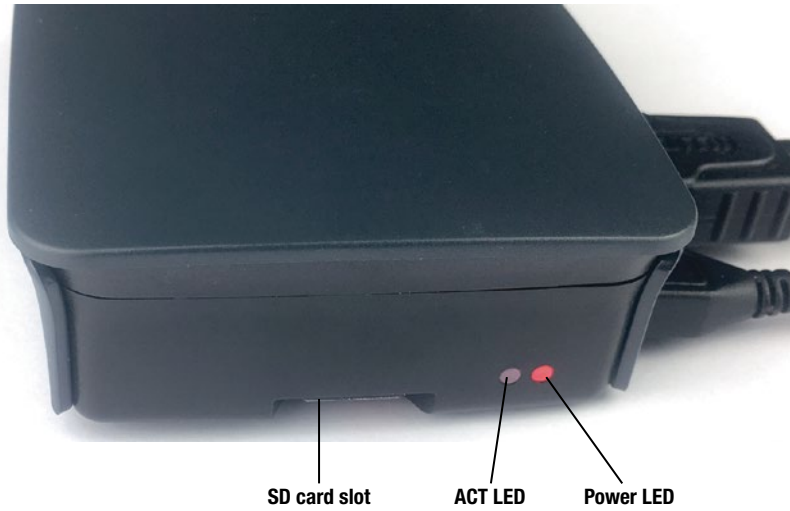
Figure 8-2. *The Power LED and the ACT LED during bootup with the Raspberry Pi board in a case.*

Here's the brief version of the startup sequence:

- *Power on*: When you connect a Raspberry Pi board to power (and switch on the power supply if necessary), the Power LED lights up and stays illuminated. Use the Power LED to determine whether the Raspberry Pi board is getting power.

HOW THE RASPBERRY PI BOOTS WITHOUT A BIOS

Unlike most desktop and laptop computers, Raspberry Pi boards have no BIOS, the Basic Input/Output System used to store firmware (built-in software). Instead, all the software is on the SD card—and if the SD card is not usable, the Raspberry Pi will not boot. There will be no video output, because there is no BIOS to produce any.

When you power on an Raspberry Pi board, a small central processing unit (CPU) located inside the graphical processing unit (GPU) looks for code to boot the Raspberry Pi. It first looks for a file via USB, and then uses its MMC hardware to search the SD card for a file called `bootcode.bin`. The CPU in the GPU executes `bootcode.bin` and the reads the `start.elf` file.

The `start.elf` file gives the CPU in the GPU the information it needs to read the `config.txt` file and use the instructions it contains to configure memory, video modes, and other essential settings. The CPU in the GPU then loads and configure the Linux kernel. At this point, the system starts the ARM CPU, the Raspberry Pi's main CPU, which executes the kernel code and handles the rest of the startup process.

- *Raspberry Pi reads the configuration and software from the SD card*: The Raspberry Pi loads all its software from the SD card, including the configuration files. This normally takes around 20–30 seconds, depending on the model of the Raspberry Pi board. As the Raspberry Pi reads data from the SD card, the ACT LED flickers intermittently; the ACT LED lights up when the Raspberry Pi is reading data from the SD card, so the pattern of flickering varies. If the ACT LED blinks in a regular pattern, it's indicating that something is wrong. See the section "Identifying Startup Errors from ACT LED Flashing Patterns," later in this chapter, for information about interpreting the patterns.

- *The Raspberry Pi outputs video*: Assuming the Raspberry Pi can read the SD card just fine, the Raspberry Pi starts outputting video. The Raspberry Pi outputs the video on the HDMI port as long as it detects a device connected to that port; if not, it outputs composite video on the composite video and audio port.

- *The Raspberry Pi boots to a command-line interface or a graphical interface, depending on how it is configured*: With output on the display you're using, you can watch the rest of the boot process. Once booting finishes, you can log in and start using the Raspberry Pi computer.

Generally speaking, if a Raspberry Pi computer fails to boot, and there's no obvious damage to the computer (such as being physically smashed or doused in liquid), your first suspect should be the SD card—because if the SD card is damaged, or even if it's configured incorrectly, that will prevent the Raspberry Pi computer from booting.

Solving Typical Boot Problems

Now that you know the essentials of what happens in the boot process, let's look at how to solve typical boot problems that your Raspberry Pi computers may manifest. We'll start with the most obvious—and easiest to fix—problems and work our way up from there.

Power LED Shows No Light

If the Power LED on the Raspberry Pi computer shows no light, the power supply either isn't delivering enough power or isn't delivering any power at all.

■ **Note**   If the Power LED illuminates briefly and then goes dark, the problem is usually that the power supply is delivering some power but not enough for this Raspberry Pi model. Try replacing the power supply with one designed for this Raspberry Pi model.

The first question is whether this power supply used to work with this Raspberry Pi computer. If you know it did, check for anything obvious that has changed. The most straightforward problem is that there are now more USB devices plugged into the Raspberry Pi computer, drawing too much power. In this case, disconnect all the devices except the keyboard and pointing device and try starting the Raspberry Pi computer again. If it now works, use a powered USB hub to connect the extra devices if you still need them.

■ **Tip**   If the number of USB devices plugged into the Raspberry Pi computer hasn't changed, check also whether their power configuration has. For example, if the USB devices are connected to a powered USB hub, make sure that the hub's power supply is working; if not, it will significantly increase the load on the Raspberry Pi's USB ports. Similarly, make sure that any other USB device that has its own power supply is receiving power from it.

■ **Caution**   Raspberry Pi power requirements vary by model. Look back to the section "Choosing Power Sources for Your Raspberry Pi Computers" in Chapter 2 for advice on choosing suitable power supplies. See Table 2-2 in Chapter 2 for the specific power requirements.

If the Raspberry Pi computer has only a modest number of USB devices, the problem is more likely that the power supply has failed or is not suitable for this model of Raspberry Pi. Try connecting a power supply that you know to be good. For example, connect the power supply that has been powering another Raspberry Pi computer of the same type as the one that's having the problem. If the problem Raspberry Pi computer works after you switch power supplies, your simplest solution is to replace the power supply with one of your surplus ones and put the power supply that may be bad into your To Check box; when you have time, try connecting it to a known good Raspberry Pi computer or to your multimeter.

Power LED Shows Light But ACT LED Shows No Light

If the Power LED on the Raspberry Pi computer shows a steady light but the ACT LED shows no light, you'll know that the computer is getting power but no activity is happening on the SD card.

Power down the Raspberry Pi computer and make sure that the SD card is in the SD slot—someone might have removed the card, even if you didn't yourself—and that the card is the right way up and the right way around. Inserting an SD card the wrong way up or backward (or both—bonus points) requires effort and determination, so if you find that your students or colleagues have demonstrated these usually admirable qualities, check both the SD card and the SD card slot for damage.

If there is an SD card in the slot, make sure that it's fully inserted. Some Raspberry Pi models have a click-in micro SD slot that gives tactile feedback when the card is fully inserted, but more recent Raspberry Pi models (such as the Raspberry Pi 3 Model B) have a micro SD slot without the click-in component. As a result, it's easy to insert the micro SD card most of the way, so that it looks as though it's in properly but isn't fully engaged with the contacts.

When you're sure the Raspberry Pi computer has an SD card correctly and fully inserted, try booting it again.

If the Power LED illuminates but the ACT LED does not, the SD card is most likely the problem. Replace the SD card with a known good one that contains the NOOBS installer or a configured operating system and try booting again. If the Raspberry Pi computer boots correctly, put the SD card you've removed in your To Check box for testing or reconfiguration.

Power LED and ACT LED Both Illuminate Constantly

If the Power LED and the ACT LED on the Raspberry Pi computer both show a steady light, rather than the ACT LED flickering as it normally does, the problem is that the Raspberry Pi computer can't read properly from the SD card. This may indicate either a physical problem with the connection between the SD card and the reader, a formatting problem with the SD card, or a problem that's intermittent and more mysterious.

When this happens, try the following moves to get the Raspberry Pi computer working:

- *Restart the Raspberry Pi computer*: Sometimes this is all that's required to enable the system to read the SD card properly. But it's not clear why, so you should note that this Raspberry Pi computer has suffered this problem and see if it recurs.

- *Remove the SD card and reinsert it*: The problem may be that the SD card isn't quite making full contact with the SD card slot. Remove the SD card, wipe off any dust or smears of chewing gum, and then reinsert the card, making sure you push it all the way into the slot.

- *Replace the SD card with a known good one*: If the Raspberry Pi computer was working before but won't work now, chances are that someone or something has managed to hose the partitions on the SD card, leaving the system unable to find a suitable partition to boot from. If this is the case, you'll need to reformat the card and reinstall the software on it; in the meantime, replace the card to get the Raspberry Pi computer working again.

Identifying Startup Errors from ACT LED Flashing Patterns

If the Raspberry Pi is unable to boot, its only way of communicating the problem to you—other than total inactivity accompanied by the silence beloved of grumpy teenagers—is by flashing the ACT LED in patterns. Table 8-1 explains the meaning of regular patterns of flashing from the ACT LED and how to respond to them.

Table 8-1. *ACT LED Flashing Patterns and Their Meanings*

Flashes	Meaning	What to Do
1	The Raspberry Pi has Micron SDRAM.	Look to see if the processor has an M logo. If so, download and install the latest version of NOOBS or Raspbian and install it using a 4 GB or larger SD card.
3	The start.elf file is not found.	Insert an SD card that includes start.elf and boot again.
4	The start.elf file is corrupt.	Insert an SD card with an intact start.elf file and boot again.
7	The kernel.img file is not found.	Insert an SD card that includes kernel.img and boot again.
8	The SDRAM is not recognized.	Download the latest version of NOOBS or Raspbian. If the error recurs, the SDRAM is likely damaged; replace the Raspberry Pi board.

ACT LED Flashes Intermittently But There's No Video Output

If the Power LED illuminates and the ACT LED flashes intermittently after you provide power, you'll know that the Raspberry Pi computer is reading from the SD card. If you're not getting any video output on the connected display, chances are that the Raspberry Pi is trying to output video on the wrong port.

■ **Tip**   If the Raspberry Pi computer has an Ethernet cable plugged into its Ethernet port and connected to a working network, you can confirm that the Raspberry Pi has booted by seeing if the Ethernet LEDs are illuminated. If they are, the Raspberry Pi has booted.

Normally, you'll want to start with the basics to solve the lack of video output:

- *Make sure the display is getting power*: For many displays, you can check by glancing at the power light on the front.

- *Make sure the display and its cable are working*: Disconnect the cable from the Raspberry Pi computer and connect it to another computer (Raspberry Pi or other) to make sure. Reconnect the cable to the problem Raspberry Pi.

- *Use HDMI if possible*: Although Raspberry Pi computers can connect to displays via various technologies, HDMI is the easiest to use. See the section "Choosing Displays" in Chapter 2 for more information on displays and connections.

- *Switch the display to HDMI input*: If you're using a display that has multiple inputs, switch the display to HDMI input before starting the Raspberry Pi. This will help the Raspberry Pi's HDMI port to detect the display, causing Raspbian to send the video output via HDMI rather than falling back to the composite port, which Raspbian uses as the default if it doesn't detect an HDMI display.

■ **Note**   As explained in Chapter 5, the NOOBS installer always uses HDMI for video output unless you press 1, 2, 3, or 4 during the 10 seconds after the Raspberry Pi boots the installer. Press 1 to switch to ideal HDMI settings for the monitor that NOOBS has detected, press 2 for safe HDMI settings that should work with most monitors, press 3 to switch to PAL output on the composite port, or press 4 to switch to NTSC output on the composite port.

- *Force HDMI detection if necessary*: If the Raspberry Pi computer isn't detecting a display connected to its HDMI port, add the hdmi_force_hotplug=1 parameter to the config.txt file to force HDMI detection. This problem tends to occur more when you're using an HDMI-to-DVI cable than when you're using an HDMI-to-HDMI cable. See the section "Editing the config.txt File" in Chapter 5 for more information on editing config.txt and adding other parameters for configuring video.

NOOBS Dialog Box Opens But "Wait While NOOBS Initialises" Message Appears

If you're booting a Raspberry Pi computer to the NOOBS installer, and the NOOBS dialog box opens, but the "Please wait while NOOBS initialises" dialog box opens and stays open, try restarting the Raspberry Pi computer by turning off the power, waiting a few seconds, and then turning on the power again. Failure to complete NOOBS initialization may indicate a minor glitch that a reboot will cure.

If the same problem continues, power the Raspberry Pi computer down and replace the SD card with one containing a fresh install of NOOBS.

Troubleshooting SD Card Issues

SD cards are usually pretty reliable, but if you're running a classroom fleet of Raspberry Pi computers, you'll likely run into problems with SD cards sooner or later.

Preparing to Deal with SD Card Issues

To enable yourself to recover quickly and easily from SD card problems, follow these two recommendations:

- *Treat the SD cards as replaceable*: Use the SD cards only for booting the Raspberry Pi computers and running the operating systems you need. Keep all valuable files on the network or on students' personal USB sticks rather than on the SD cards. This way, you can replace a problem SD card and troubleshoot it at your leisure.

- *Keep a stock of replacement SD cards ready for use*: Format the SD cards and load them with the software you need—for example, install the latest version of NOOBS or install your default OS setup—so that you can instantly replace an SD card that has become corrupted or that has failed. Keep the SD cards in a compartmented box with labels indicating the cards' contents—NOOBS, OS, To Check, Failed, and so on.

Identifying SD Card Problems

SD card problems can manifest themselves in various ways, but the following are most typical:

- *File corruption*: If document files on the SD card become mangled or unreadable, the SD card may have suffered corruption.

- *Raspberry Pi computer gives errors*: If the operating system starts displaying error messages, the SD card may have become corrupted.

- *Raspberry Pi computer fails to boot*: As discussed earlier in the "Troubleshooting Startup" section, earlier in this chapter, corruption to the SD card may prevent a Raspberry Pi computer from booting.

Generally speaking, you'll do best to take an aggressive approach to SD card problems: if you believe that an SD card is becoming (or has become) corrupted, deal with the problem immediately rather than waiting for things to get worse and confirm your diagnosis. Dealing with the problem may mean replacing the SD card or trying to repair it.

Avoiding SD Card Problems

If you find that the SD cards on your Raspberry Pi computers are getting corrupted, try the following fixes:

- *Use high-quality, genuine SD cards*: A huge range of SD cards are available, especially at the low-price end. Generally, it's best to stick with major manufacturers, such as (in no particular order) Kingston, SanDisk, Transcend, Integral, PNY, Panasonic, Lexar, Verbatim, Sony, and Samsung.

■ **Caution**   Avoid SD cards from brands with which you are not familiar. Many low-quality SD cards are available, often for tempting prices. Some of these cards are low-capacity cards marked as higher capacities, which is a recipe for problems; other cards are simply not very reliable, which is another recipe for problems. High-quality SD cards in Raspberry Pi–friendly capacities (16 GB and 32 GB) are affordable enough that it's not worth wasting time or money on lower-quality cards.

- *Use high-quality power supplies and USB cables*: As you know, the Raspberry Pi computers use relatively little power overall compared to full-size computers, but they still need the right amount of power. To keep a Raspberry Pi computer running well, use a power supply designed specifically for that Raspberry Pi model. If the power supply uses a separate USB cable rather than a built-in cable, make sure the cable is a high-quality one because a low-quality cable can lose as much as 1 V of potential difference between its ends. Connect the power supply to a reliable AC power source—"grid power" or "mains power"—or to an uninterruptible power supply that itself is connected to an AC power source.

- *Shut down the Raspberry Pi computer before turning off the power*: Simply cutting the power to the Raspberry Pi can cause SD card corruption, so be sure to always shut down the Raspberry Pi computer formally:

- *Shut down from the desktop*: Click the Menu button, click the Shutdown item to display the Shutdown Options dialog box, and then click the Shutdown button. A Raspberry Pi computer usually shuts down pretty quickly, but if you're planning to switch off the power or unplug it, wait for a few seconds after the screen goes blank.

- *Shut down from the command line*: Give the sudo halt command and wait for activity to cease.

■ **Tip**   If you allow students to power the Raspberry Pi computers on and power them off, make sure the students know they should use Shutdown command from the GUI or the sudo halt command from the command line rather than simply turning off the power.

- *Stop overclocking the Raspberry Pi computer*: If you've overclocked the Raspberry Pi computer, try restoring it to its normal clock speed. In some cases, overclocking can cause the SD card to get corrupted, and removing the overclocking will end the problem.

Repairing an SD Card with the fsck Command

If you make sure that your SD cards contain only standard software installations, you may be able to deal with corrupted SD cards by simply reformatting them and reinstalling the software. But it's more than possible that you'll sometimes need to repair corrupted SD cards on which your students or colleagues have saved valuable files.

The easiest way to repair an SD card is by connecting the SD card to a Linux system and using the fsck command; fsck is the abbreviation for File System Consistency Check and does pretty much what its name says. You can run fsck manually from a command line and choose whether to repair problems automatically.

After connecting the SD card to a Linux system (such as one of your Raspberry Pi computers that's working properly), open a Terminal window and give the following command to list the block devices on the system:

```
sudo lsblk -l
```

You'll see a list of devices laid out in a table. The following listing shows just the beginning of the list from a Raspberry Pi computer:

```
NAME       MAJ:MIN RM  SIZE RO TYPE MOUNTPOINT
sda         8:0    1 14.4G  0 disk
sda1        8:1    1 14.4G  0 part /media/pi7
mmcblk0    179:0    0 14.5G  0 disk
mmcblk0p1  179:1    0  1.1G  0 part
```

In the NAME column, look at the devices whose names begin with sda. In the example, there are two: sda and sda1. Because this is a Raspberry Pi computer, each device is removable (1 appears in the RM column), so you can't distinguish them that way; by contrast, on a computer with a fixed disk, you'll see 0 in the RM column for each fixed disk.

You can also see that each device is the same size (14.4 G), which might otherwise help you distinguish the device you want to check and fix. But by looking at the MOUNTPOINT column, you can see that sda1 is mounted in the media folder, which enables you to identify it as the external drive connected to the Raspberry Pi computer.

Now that you know which device you want to check, give the fsck command, using the -f parameter to force checking of parts of the filesystem that are not marked as dirty and the y parameter to attempt to fix any problems detected:

```
sudo fsck -fy /dev/sda1
```

When the command finishes, see if you can recover the important files from the SD card.

Troubleshooting Network Issues

You can connect a Raspberry Pi computer to a network via either Ethernet or Wi-Fi. All Raspberry Pi models except the Raspberry Pi Zero have built-in Ethernet, whereas only the Raspberry Pi 3 Model B has built-in Wi-Fi (and Bluetooth). You can add Wi-Fi (and Bluetooth, if necessary) to other Raspberry Pi models by using a compatible Wi-Fi adapter.

Choosing Ethernet over Wi-Fi Wherever Possible

If you have the choice between connecting your Raspberry Pi computers via Ethernet and connecting them via Wi-Fi, it's best to choose Ethernet.

Raspbian has good support for Wi-Fi; but even so, Wi-Fi tends to cause more problems that Ethernet. And though the Ethernet port built into each full-size Raspberry Pi is only Fast Ethernet (100 Mbps) rather than Gigabit Ethernet (1000 Mbps), Ethernet usually delivers faster speeds as well as greater reliability than Wi-Fi. The Wi-Fi speeds that manufacturers choose to quote are the theoretical maximum transfer rates for the equipment; and real-world speeds are usually much slower, especially when many computers and devices are connecting to the same Wi-Fi networks.

TIMES TO USE WI-FI INSTEAD OF ETHERNET

As you just read in the main text, Ethernet is usually a better bet than Wi-Fi. But there are times and places where Wi-Fi is a better choice than Ethernet. Here are three examples:

- *Handhelds*: Raspberry Pi computers that are built into handheld touch screen devices are far easier to use with Wi-Fi than with Ethernet.

- *Mobile classroom*: Raspberry Pi computers mounted on a cart that travels from one classroom to another may be better off using Wi-Fi.

- *Heavy data transfer via USB*: On the Raspberry Pi boards, the same chip handles both Ethernet and USB connections. In general, this bus-sharing arrangement works well, but you may find that data-transfer rates drop when a Raspberry Pi is trying to transfer a lot of data across the Ethernet connection at the same time as it is transferring data to a USB device. If this limitation becomes a problem, use Wi-Fi instead of Ethernet for networking.

Checking the Connection Status

If you're at the Raspberry Pi computer that's having network problems, look at the Network icon at the right end of the panel to see what network status appears. This icon shows either the WiFi Networks icon or the Network icon:

- *WiFi Networks icon*: The computer is connected to a Wi-Fi network. You can hold the pointer over the icon to display the details (see the left screen in Figure 8-3).

- *Network icon with X*: The computer has neither a Wi-Fi connection nor a working Ethernet connection. Again, you can hold the pointer over the icon to display details of the bad news (see the right screen in Figure 8-3). The interface wlan0 is the first wireless network interface on the computer, such as the built-in wireless network interface on the Raspberry Pi 3 Model B.

- *Network icon without X*: The computer has a working Ethernet connection. Once more, you can view the details by holding the pointer over the icon. The interface eth0 is the first Ethernet interface on the computer; on all Raspberry Pi models except the Raspberry Pi Zero, this should be the built-in Ethernet interface.
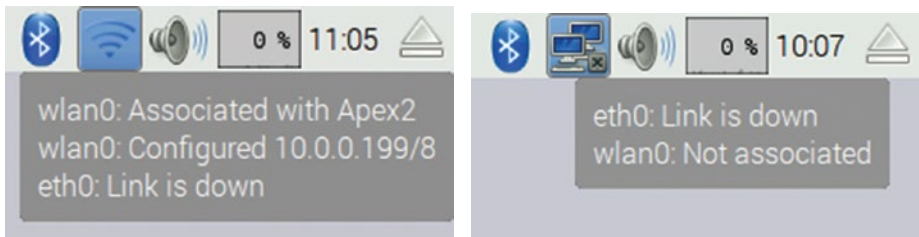
Figure 8-3. *If the Raspberry Pi computer is connected to a Wi-Fi network, the WiFi Networks icon appears in the Panel (left). If not, the Network icon appears, with an X if there is no connection (right). In either case, hold the pointer over the icon to view details.*

Troubleshooting Ethernet Connections

Ethernet connections tend to be reliable—but that's not to say that they can't go wrong. This section explains what to do when a Raspberry Pi computer shows it has no connection.

Making Sure the Ethernet Cable Is Working

First, make sure that the Ethernet cable is connected securely to the Raspberry Pi computer and to the network hardware—a wall Ethernet socket; a patch panel; or a switch, hub, or router—and is not damaged or severed in between.

If you have any doubt about the Ethernet cable, test it using a network cable tester. This is a device into which you plug each end of the cable and press a button to pass a signal through it, verifying whether the cable is transmitting the signal correctly. Most cable testers have a detachable section that you can connect at the far end of the cable, enabling you to test a cable you have deployed. The test is quick to perform and enables you to be confident that the Ethernet cable is working—assuming it is.

If you don't have a network cable tester, replace the suspect Ethernet cable with a known good cable—for example, one that you've disconnected from a Raspberry Pi computer that was connecting just fine to the network.

Interpreting the Ethernet LEDs on the Raspberry Pi Computer

Next, look at the Ethernet LEDs on the Raspberry Pi computer. There are two LEDs (see Figure 8-4):

- *Amber LED*: This LED illuminates and stays illuminated when the Ethernet cable is connected to the Raspberry Pi and to another device, such as a network switch.

- *Green LED*: This LED flickers when the Raspberry Pi is sending or receiving data across the Ethernet connection. It stays illuminated when the Raspberry Pi is not sending or receiving data.

If an Ethernet cable is connected to the Raspberry Pi but neither LED is illuminated, check for damage to the cable or for the cable being disconnected at the other end.

Amber LED   Green LED

Figure 8-4. *You can use the amber LED and the green LED in the Ethernet port to determine whether a Raspberry Pi computer has a working network connection.*

Restarting the Raspberry Pi Computer

If you've verified that the Ethernet cable is connected at both ends and intact in between, but the Ethernet LEDs aren't illuminating, try restarting the Raspberry Pi computer as the next step. Like any computer, a Raspberry Pi computer can suffer any number of software glitches; restarting the Raspberry Pi normally clears up these problems and may restore network connectivity.

Troubleshooting Wi-Fi Connections

Wi-Fi is a wonderful and highly enabling technology, but it can be a source of problems on Raspberry Pi computers, just as it can on other computers.

When a Wi-Fi connection isn't working, first check the connection status. Look at the Network icon on the Panel to see whether Raspbian is detecting a Wi-Fi connection.

If there is a Wi-Fi connection, hold the pointer over the WiFi Networks icon to see which wireless network the Raspberry Pi computer is connected to. If it's the wrong network, click the WiFi Networks icon to display the menu of available networks, and then click the network the Raspberry Pi computer should be using. If a dialog box bearing the network's name opens, enter the preshared key, and click the OK button.

■ **Note**   If the Raspberry Pi computer has a Wi-Fi connection to the right network, but it's unable to access network resources, right-click the WiFi Networks icon, click WiFi Networks (dhcpcdui) Settings on the shortcut menu, and then use the WiFi Networks dialog box to configure the settings for the wireless network. See the section "Connecting to a Wi-Fi Network" in Chapter 6 for more details.

If there is no Wi-Fi connection, and the Raspberry Pi computer is using a USB Wi-Fi adapter, try unplugging the adapter and then plugging it back in. Disconnecting and reconnecting the adapter may force Raspbian to reload the network driver. If so, you can reestablish the connection to the Wi-Fi network manually if Raspbian does not reestablish it automatically. If not, try restarting the Raspberry Pi computer.

If there is no Wi-Fi connection, and the Raspberry Pi computer is a model with a built-in Wi-Fi adapter (such as the Raspberry Pi 3 Model B), restart the Raspberry Pi computer to get the Wi-Fi adapter working again.

Troubleshooting No Output on the Display

If the Raspberry Pi computer has booted successfully, but now the display shows no output, try checking for obvious problems first. If there are none, you may need to connect via SSH to solve the problem.

Checking for Obvious Problems

When the display shows no output, start by checking for obvious problems with the display:

- *Sleep*: Make sure that the display isn't asleep.

- *Power*: Verify that the display is getting power.

- *Cabling*: Check that whatever cable (or adapter or converter) links the Raspberry Pi computer to the monitor is connected at all relevant points and hasn't been savaged by wildlife (or students).

- • *Activity*: Look at the Raspberry Pi computer's LEDs to verify that the computer is powered on. First, check that the Power LED is showing a steady red. Then look at the ACT LED to see if it's displaying an intermittent pattern of flashes (which indicates that it's reading the SD card) or if it's signaling a boot problem with a repeated pattern of flashes. If there's no activity from the ACT LED, and the Raspberry Pi computer is connected to the network via Ethernet, look at the Ethernet LEDs to make sure that they're illuminated; if so, you'll know that the Raspberry Pi computer is running.

Troubleshooting Display Issues via SSH

If you've enabled SSH on the Raspberry Pi computer whose display is blank, try connecting via SSH. If you can establish an SSH connection, you can try editing the `config.txt` file and then restarting the Raspberry Pi computer; or you can shut down the Raspberry Pi computer properly (rather than simply cutting the power, which might cause corruption) so that you can take out the SD card and edit the `config.txt` file using another computer.

■ **Note**   See the section "Connecting via SSH" in Chapter 7 for instructions on connecting via SSH to a Raspberry Pi computer.

To edit the `config.txt` file via SSH, connect via SSH as usual, and then give the command for opening the file in an editor—for example, use the following:

```
sudo nano /boot/config.txt
```

Edit the file as needed to fix the problem. For example, comment out or uncomment any lines as needed, or type new lines. Press Ctrl+O to write out (save) the file, and press the Enter key to accept its existing name as the file name. Then press Ctrl+X to exit the editor.

Once you've done that, you can give the `shutdown` command with the `-r` parameter to restart the Raspberry Pi computer:

```
sudo shutdown -r now
```

■ **Note**   If you don't specify the `now` parameter for the `shutdown -r` command or the `shutdown` command, the Raspberry Pi computer will reboot or shut down one minute after you give the command. During that time, you can use the `shutdown -c` command to cancel shutdown if necessary.

If you prefer to shut down the Raspberry Pi computer so that you can remove the SD card safely, give the `shutdown` command without the `-r` parameter:

```
sudo shutdown now
```

Troubleshooting USB Keyboards and Pointing Devices

If a USB keyboard or pointing device stops working, first try unplugging it and then plugging it back in. If that doesn't make the device work, or if you suspect the device is broken, try plugging in a known good device and seeing if that works.

At this point, it's usually best to restart the Raspberry Pi computer to get the input devices working again. If you've still got either the keyboard or the pointing device working, use it to open the main menu and give the Shutdown command, and then select the Reboot button in the Shutdown Options dialog box.

■ **Note**   If both the keyboard and pointing device seem to have stopped working, but the display is still getting output, make sure the Raspberry Pi computer hasn't hung. Look at CPU Usage Monitor on the Panel to see if it's still moving; if you've removed the CPU Usage Monitor, look at the clock readout instead and give it a minute to change.

If neither the keyboard nor the pointing device is working, connect to the Raspberry Pi computer via SSH if possible and restart it. See the section "Troubleshooting Display Issues via SSH," earlier in this chapter, for information on connecting via SSH.

If you can't connect via SSH, power down the Raspberry Pi computer by switching off or unplugging the power supply, and then switch it back on or plug it back in to restart it. As you know, shutting down the Raspberry Pi computer this way may cause corruption to the SD card, so do this only as a last resort.

Troubleshooting Audio Issues

As you know, a Raspberry Pi computer has two built-in interfaces for outputting audio:

- *HDMI*: The HDMI port outputs digital audio along with digital video. If you're using an HDMI display, getting audio out of the display's speakers or headphone port is usually your best option.

- *Composite video and audio port*: You can set the Raspberry Pi computer to output analog audio from the composite video and audio port.

If you're not getting audio, first make sure that the volume isn't muted or set to 0. In the Raspbian GUI, click the Volume Control icon on the Panel to display the Volume Control pop-up menu. Make sure the Mute check box at the bottom isn't checked, and make sure the slider is not set right at the bottom.

Next, verify that the Raspberry Pi computer is set to use the right port. Right-click the Volume Control icon on the Panel to display the pop-up menu, and then click the Analog item or the HDMI item, as needed.

If you're still not getting audio, make sure the HDMI cable or composite cable is securely connected at each end and not severed between them. Also check that your speakers have power (if they need it) and that their volume isn't set to the minimum.

SWITCHING AUDIO OUTPUT USING THE COMMAND LINE

You can also switch the audio output between the HDMI port and the composite port from the command line. You may find this capability helpful when working on a Raspberry Pi computer remotely via SSH.

Use the following command to switch audio output to the HDMI port:

```
amixer cset numid=3 2
```

Use the following command to switch audio output to the composite port:

```
amixer cset numid=3 1
```

As you'll no doubt guess, 2 specifies HDMI, whereas 1 specifies composite. You can also use `amixer cset numid=3 0` to use automatic detection.

Summary

In this chapter, you've learned essential moves for troubleshooting your classroom deployment of Raspberry Pi computers. You have an overall strategy for keeping your Raspberry Pi computers running by using the two Rs—restarting and replacing—so that you can deal with difficulties when you have time. You know how to keep the system software up to date, how to deal with startup issues, how to fix problems with SD cards, how to troubleshoot network connections and blank displays, how to get balky keyboards and pointing devices working again, and how to redirect audio output to the port through which you want to output it.

This is the end of the book—apart from the Appendix, which points you to information resources.

■ ■ ■

Raspberry Pi Resources and Training for Educators

In this appendix, I'll provide a short list of resources and training that you may find useful for planning and executing your deployment of Raspberry Pi computers in the classroom.

Where to Get Raspberry Pi Hardware and Accessories

You can buy Raspberry Pi boards and accessories from a wide variety of places, mostly online. In this section, I list some worldwide retailers first; then I list some stores for the United States, for Canada, for the United Kingdom, and for Australia.

Worldwide Retailers

Amazon and eBay both sell Raspberry Pi boards and a wide range of accessories. Go to your local Amazon or eBay site and search for `raspberry pi` plus any other relevant keywords (such as `case`).

Premier Farnell, a global electronics distributor, has the trading brands Newark element14 and Farnell element14. (In case you're wondering about the names, silicon is the 14th element in the periodic table.) Newark element14 (also known as Newark, Newark Electronics, and Newark Corporation) distributes Farnell items in North America and parts of Central America and South America. Farnell element14 handles Europe and Australia.

You'll see the names Newark and Element14 in the country-specific lists following. To see the Element14 list of Raspberry Pi Approved Resellers, go to this address:

http://farnell.com/raspberrypi-consumer/approved-retailers.php

For other retailers worldwide, see the Main Distributors and Subsidiaries/Sister Companies list on the RPi Buying Guide page here:

http://elinux.org/RPi_Buying_Guide#Main_distributors_and_
subsidaries.2Fsister_companies

US Stores

Here is a short list of US-based stores that sell a wide range of Raspberry Pi boards and accessories.

- Adafruit (http://www.adafruit.com)
- Allied Electronics (http://www.alliedelec.com)
- Newark (http://www.newark.com)
- MCM Electronics (http://www.mcmelectronics.com)

Canada Stores

Here are three Canada-based stores for Raspberry Pi boards and accessories:

- Newark (http://canada.newark.com)
- HiPi Industries (http://buyapi.ca)
- Canada Robotix (http://canadarobotix.com)

UK Stores

Here is a short list of UK stores from which you can buy Raspberry Pi boards and accessories:

- RS Components Ltd (http://uk.rs-online.com)
- The Pi Hut (http://www.thepihut.com)
- Element14 (http://www.element14.com)
- ModMyPi (http://www.modmypi.com)

Australia Stores

Here are three stores for buying Raspberry Pi computers and accessories in Australia:

- RS Components (http://au.rs-online.com)
- Element14 (http://au.element14.com)
- GPIO Australia (http://www.buyraspberrypi.com.au)

Where to Get Raspberry Pi Software

This section tells you where to get Raspberry Pi operating systems and key apps.

NOOBS Installer

The NOOBS (New Out Of Box Software) installer enables you to install the Raspbian, Raspbian Lite, LibreELEC, OSMC, and Windows IoT Core operating systems easily.

You can download either the full version of NOOBS, which includes the Raspbian operating system, or the stripped-down NOOBS Lite, which does not include Raspbian, from this page:

https://www.raspberrypi.org/downloads/noobs/

Raspbian and Raspbian Lite Operating Systems

You can download the Raspbian operating system, which includes the Pixel graphical interface, or the Raspbian Lite operating system, which does not include a graphical interface, from this page:

https://www.raspberrypi.org/downloads/raspbian/

Other Operating Systems

The Raspberry Pi Foundation's Downloads page provides links to several other operating systems that you can install on the Raspberry Pi.

https://www.raspberrypi.org/downloads/

As of this writing, these operating systems include:

- Ubuntu MATE
- Snappy Ubuntu Core
- Windows 10 IoT Core
- OSMC
- LibreELEC
- PiNet
- RISC OS
- Weather Station

■ **Note**   You can download and install Windows 10 IoT Core, OSMC, and LibreELEC by using the NOOBS installer.

The Ubuntu Pi Flavour Maker web site provides versions of Ubuntu customized for the Raspberry Pi. As of this writing, these versions include Lubuntu, Xubuntu, Ubuntu MATE, Ubuntu Server Minimal, and Ubuntu Server Standard.

https://ubuntu-pi-flavour-maker.org

You can download RaspBSD from the RaspBSD web site:

http://www.raspbsd.org

You can download FullPageOS from GitHub:

https://github.com/guysoft/FullPageOS

You can download OpenWrt from the OpenWrt web site:

https://openwrt.org

Where to Get Other Useful Software

This section lists other software you may find useful when deploying Raspberry Pi computers.

Ubuntu

Ubuntu is a Linux distribution for both desktop PCs and servers. The PiNet server system runs on Ubuntu.

http://www.ubuntu.com/download

PuTTY

PuTTY is a free SSH client for Windows.

http://www.chiark.greenend.org.uk/~sgtatham/putty/

SD Formatter

SD Formatter is a tool for formatting SD cards and micro SD cards correctly.

https://www.sdcard.org/downloads/formatter_4/

Visual Studio

To work with Windows 10 IoT Core, you need a version of Microsoft's Visual Studio app-development tool. Normally, you'll want to start with Visual Studio Community, which is free from the Visual Studio web site.

http://www.visualstudio.com

Information Resources

This section provides some information resources for working with Raspberry Pi computers.

Raspberry Pi Foundation Documentation

The Raspberry Pi Documentation page on the Raspberry Pi Foundation web site provides links to the official documentation for the Raspberry Pi.

https://www.raspberrypi.org/documentation/

Details on config.txt Settings

For details of all the settings you can use in the config.txt file, visit this page:

http://www.raspberrypi.org/documentation/configuration/config-txt.md

RPi Hub Page on the Embedded Linux Wiki

The RPi Hub page on the Embedded Linux Wiki contains a large amount of information about configuring and using Raspberry Pi computers.

http://elinux.org/RPi_Hub

Phone Chargers That Work with Raspberry Pi

In a pinch, you can run some Raspberry Pi models successfully using phone chargers. See the RPi Verified Peripherals page for details.

http://elinux.org/RPi_VerifiedPeripherals#Power_adapters

Training and Education Resources

This section briefly introduces some key training and education resources.

Picademy

Picademy is a professional development program for teachers. Picademy runs two-day training courses whose graduates have the Raspberry Pi Certified Educator qualification.

https://www.raspberrypi.org/picademy/

Raspberry Pi Education Forum

The Raspberry Pi Education forum provides a forum for discussing topics related to Raspberry Pi in education.

https://www.raspberrypi.org/forums/viewforum.php?f=17

Raspberry Jam

Raspberry Jam sessions are community events at which you can meet other Raspberry Pi enthusiasts in your area. From the main site (URL following), you can find your local Raspberry Jam events.

https://www.raspberrypi.org/jam/

Teaching Resources on the Raspberry Pi Foundation Web Site

The Resources section of the Raspberry Pi Foundation web site includes resources for teaching, learning, and creative projects involving the Raspberry Pi.

https://www.raspberrypi.org/resources/

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