**Dire-Dawa University**

**College of Natural and Computational Science**

**Department of Physics**

**Curriculum for MSc program in Medical Physics**

**February, 2016**

**Dire-Dawa**

**List of Courses**

**Compulsory Courses**

**Course code Course Title ECTS**

Phys 601 Mathematical Methods 7

Phys 602 Computational Physics 7

Phys 621 Statistical Physics 7

Phys 681 Electromagnetic Theory 7

Phys 683 Anatomy and physiology for medical physics 7

Phys 685 Introduction to Radiation Protection 7

Phys 684 Basic Medical Electronics and Instrumentation 7

Phys 686 Physics and radiotherapy 7

Phys 688 Radiobiology 7

Phys 789 Field Practical Assignment 12

Phys 791 Seminar 3

Phys 603 Research development and writing 3 Phys 799 Thesis 30

**Elective Courses**

**Course code Course Title ECTS**

Phys 781 Health Physics 7

Phys 782 Radiation physics and dosimetry 7

Phys 783 Radio diagnostics 7

Phys 784 Physics of Nuclear Medicine I 7

Phys 785 Physics of Nuclear medicine II 7 Phys 786 Physics of Medical Imaging I 7

Phys 787 Physics of Medical Imaging II 7

**Course Syllabi**

**Course Descriptions**

**Phys 601: Mathematical Methods for Physics**

**Course Description**

Vector Calculus, Eigen value problems and orthogonal functions, matrix theory, tensor analysis, Laplace and Fourier transformations, partial differential equations, integral equations, special functions, complex analysis (residue calculus, method of steepest descent), and advanced topics (Grassman variables, path integrals, super symmetry).

**Objective:** The objective of this course is to enable students to acquire a working knowledge of several mathematical methods, which they can apply to solve a variety of scientific problems.

**Learning Outcomes**

Upon successful completion of this course, the student:

 will be familiar with some of the fundamentals of mathematical methods useful for solving various physical problems and apply the acquired mathematical skills to solve scientific problems.

 Will be able to calculate partial and total derivatives of functions of more than one variable

 Will be able to evaluate single, double and triple integrals using commonly occurring coordinate systems

 Will be able to use vector calculus operators & theorems to solve physical problems

 Will be able to apply techniques of ODE, Fourier series & integral transform to solve physical problems

**Text:** G. Arfken and H.J Weber, Mathematical Methods for Physicists, Academic press Inc., London, sixth edition

**References**

 Sadri Hassani, Foundations of Mathematical Physics, Allyn and Bacon Press.

 P. Dennery and A. Kryzwicki, Mathematics for physicists, Indian Edition 2005

 K. F. Riley, M. P. Hobson and S.J. Bence, Mathematical Methods for Physics, Engineering, Cambridge University Press, 1999..

 Roel Snider, Mathematical Methods for the Physical Sciences.

**Phys 602: Computational Physics**

**Course Description**

Introduction, Roots finding methods: Bisection, Newton-Raphson, secant method. System of Nonlinear equations, Newton's method for Nonlinear systems, Interpolation and Curve fitting: Lagrange approximation, Newton and Chebyshev polynomials. Least square fitting, advanced numerical methods to solve problems in algebra and differential equations, the application of numerical methods to physical problem from different subfields of physics, Matrix methods.

**Notice:** This course has intensive practical sessions. The 7 ECTS course load of this course is distributed as 4 ECTS + 3 ECTS; where 4 ECTS is for lecture session and 3 ECTS is for practical session.

**Objective:** The aim of this course is to enable students to acquire a computational skills and working knowledge of several numerical methods, which they can apply to solve a variety of scientific problems.

**Learning Outcomes**

Upon successful completion of this course, the student should:

 be familiar with some of the numerical techniques and programming language useful for solving various physical problems.

 know how to structure physics problems and their computational solutions.

 be able to develop algorithms and use programming language to write efficient codes.

 be able to use free-open packages & tools for writing graphical interference and plotting.

**Text:** Tao Pang, An Introduction to Computational Physics (Cambridge University Press)

**References**

 S. S. M. Wong, Computational Methods in Physics, World Scientific (1992).

 K. E. Atkinson, Numerical Analysis, John Wiley (Asia) (2004).

 W.H. Press et al., Numerical Recipes in C (Cambridge University Press)

 C.P. Robert and G. Casella, Monte Carlo Statistical Methods (Springer 2004)

 Tao Pang, An Introduction to Computational Physics (Cambridge University Press)

 Binder Kurt and Heermann Dieter W., Monte Carlo Simulation in Statistical Physics (Springer)

**Phys 603: Research development and Writing**

**Course Description**

Research methodology: meaning of research, objectives of research, motivation in research, types of research, research approach, significance of research, methods versus methodology, research process, criteria of good research; Defining the research problem, basic principles of experimental designs, data sources and methods of data collection, multivariate analysis techniques, thesis format: the preliminary matters (the title page, a page for acknowledgement and pages(s), purpose, hypothesis, literature review, methodology, data analysis, limitations, results, discussion, conclusions, references and appendixes (if any), scientific article writing.

**Learning Outcomes**

Upon completion of this course students should be able to:

 Formulate research problems and objectives and to determine what problem is researchable

 Gain insight into the aspects of literature and studies partially and closely related to the study

 Differentiate the four kinds of research designs and identify the strengths and limitations of each design

 Identify the qualities of a good research instrument

 Diagnose correct statistical tools to answer the research problems

 Analyze and interpret raw data in terms of quantity, quality, attribute, trait, pattern, trend and relationships

 Follow the widely accepted format and style of writing in the academic community

**References**

 Cargill M. and O. Connor, Writing Scientific Research Articles Strategy and Steps. John Willey & Son Ltd, , 2009

 Davis M., Scientific Papers and Presentations. Ap Academic Press, 2005.

 Matthews J. R. and Matthews R. W., Successful Scientific Writing; A step-by-step guide for the biological and medical sciences. Cambridge University Press, Cambridge, 2008.

 Wilson E., School based Research: A guide for education students. Sage. London, 2009.

**Phys 621: Statistical Mechanics**

**Course Description**

Statistical ensembles**:** Micro-canonical ensemble**,** Canonical ensemble**;** Grand-canonical ensemble**,** Classical and quantum distributions: Maxwell-Boltzmann distribution**;** Bose-Einstein distribution**:** Bosecondensation**,** Photon statistics – Black body radiation**;** Fermi-Dirac distribution**:** Electron gas**,** Ising model**,** Thermodynamic potentials**,** Internal energy, Free energy.

**Objective:** This Course is designed to provide students with advanced knowledge and techniques in Statistical Physics.

**Learning Outcomes**

Upon successful completion of this course, the student should be able to

 demonstrate clear understanding of microscopic and macroscopic systems,

 understand basic statistical concepts required to describe physical systems,

 obtain various mean values using the statistical distribution function, apply statistical approaches in studying different properties of a system, The applications of laws of thermodynamics,

 employ Maxwell-Boltzmann, Bose-Einstein and Fermi-Dirac statistics in describing a given system,

 discuss about different properties of substances related with their movement by using kinetic theory of transport process,

 able to apply their newly acquired knowledge in their research.

**Text:** F. Reif, Fundamentals of Statistical and Thermal Physics, McGraw–Hill, International Edition

**References**

 K. Huang, Statistical Physics, 2nd edition, John Wiley’s and Sons.

 R. K. Pathria, Statistical Mechanics, 2nd edition, Butterworth Heinemann.

 Satya Prakash, Kedar Nath Ram, Statistical Mechanics, Nath Publication (2008)

**Phys 681: Electromagnetic Theory**

**Course Description**

Maxwell’s equations, Poynting theorem, Electromagnetic waves in a homogeneous medium, Plane waves, Wave propagation in a conducting medium and in a dielectric medium, Polarization, Reflection and refraction of plane waves, Power loss in a plane conductor, Coherent and incoherent light, Wave equation for vector and scalar potentials, The Lienard – Wiechert potentials, Electric and magnetic fields due to a uniformly moving charge and an accelerated charge, The power radiated by an accelerated charge.

**Objective:** The objective of the module is to develop understanding of Maxwell’s equations, the generation and propagation of electromagnetic waves. It introduces the method of calculating the radiation emitted by an accelerating charge.

**Learning Outcomes**

Upon successful completion of this course, the student should be able to:

 Describe electromagnetic waves and wave propagation and their interaction with matter.

 Demonstrate skills in the use of vector algebra and analysis, using Maxwell’s equations in integral and differential form.

 Demonstrate electromagnetic concepts in other fields of physics such as electronics,

**Text:** J. D. Jackson, Classical Electrodynamics (3rd Edition).

**References**

 J. Griffiths, Introduction to Electrodynamics, Pearson Prentice Hall, 3rd edition (1999).

 J. R. Reitz., F.J. Milford and R.W. Christy, Foundations of Electromagnetic Theory, 3rd edition, Narosa Publishing House (1979).

 E. C. Jordon and K.G. Balmain, Electromagnetic Waves and Radiating Systems, 2nd edition, Prentice Hall of India (1998).

**Phys 683: Anatomy and physiology for medical physics**

**Course Description**

Musculoskeletal system, cardiovascular system, respiratory system, digestive system, endocrine glands, skull, eye, central nervous system, sensory organs. Structure and function of the cell, transport and control processes, muscles, blood and immune functions, heart, vascular system and blood circulation, respiratory tract and breathing, kidney, neurophysiology, listening, sight, hormonal system, metabolism.

**Practical session**: Anatomy and function using different imaging modalities

**Learning Outcomes**

Upon successful completion of this course, the student:

 Should be able to interpret common medical terminology from knowledge of Greek and Latin root words.

 Should be able to identify gross anatomical structures, define the major organ systems, and describe the physiological mechanisms for repair, maintenance, and growth.

 Anatomical structures and physiological function should be correlated with the imaging modalities used to view them.

**References**

 TORTORA, G.J., DERRICKSON, B.H., Principles of Anatomy and Physiology. John Wiley & Sons, Inc., New Jersey, USA (2011).

 WEIR, J., ABRAHAMS, P.H., SPRATT J.D., SALKOWSKIET L.R., Imaging Atlas of Human Anatomy, 4th Edition*.* Mosby, Maryland, USA (2010).

**Phys 684: Basic Medical Electronics and Instrumentation**

**Course Description**

Capacitor, resistor, electric current Coulomb’s Law, Electric Field, Gauss’ Law, Electric Potential, Electric Potential Energy, Capacitors and Dielectric, Electric Circuits, Magnetic Field, Bio-Savart’s Law, Ampere’s Law, Electromagnetic Induction, Inductance, Circuits with Time Dependent Currents Multiple Transistor Circuits. Open-Loop Amplifiers, Ideal Amplifier, Approximation Analysis, Open-Loop Gain, Number Systems, Boolean Algebra, Logic Gates, Combinational Logic, instrumentation

**Learning Outcomes**

Upon successful completion of this course, the student:

 analyze direct and alternating current circuits containing different electric elements and solve circuit problems

 describe properties of capacitors , resistor and dielectrics,

 explain the construction of the operational amplifier;

 analyze and synthesize operational amplifier circuits;

**References**

 Bernard Grob, Basic Electronics, 4th ed., McGraw Hill International Book Company, London, (1983).

 Raymond A. Serway, Physics: For Scientists & Engineers, 6th ed., Thomson Bruke, 2004

 Close K.J and J Yarwood. Experimental Electronics for Students, London Chapman and Hall, Halsted Press Book, John Woley and Sons, (1979).

 3. Tayal D.C. Basic Electronics. 2nd ed. Himalaya Publishing House Mumbai, (1998).

**Phys 685: Introduction to Radiation protection**

**Course Description**

Introduction, historical perspective and sources of radiation, Radiation protection detection and measurement (Geiger-Mueller (GM), proportional counters, scintillators, TLDs, ionization chambers, neutron detectors), Exponential attenuation, half-value layer (HVL), inverse square law, tenth value layer (TVL), Shielding calculations, Operational dosimetry, Legal framework for radiation protection, Occupational, public exposure and annual limits, Emergency procedures, As low as reasonably achievable (ALARA) concept, Justification, Radioactive transport and waste management, Risk assessment and communication of risk

**Practical session:** Radiation Survey of a clinical installation and shielding calculation.

**Learning Outcomes**

Upon successful completion of this course, the student:

 Work in radiation protection institutes.

 Provide public consultations in radiation protections principle.

 Explain the ways of waste management, Risk assessment and communication of risk

**References**

 CEMBER, HERMAN, AND JOHNSON, THOMAS, Introduction to Health Physics. McGraw-Hill Medical, New York, USA (2008).

 INTERNATIONAL ATOMIC ENERGY AGENCY, Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards – Interim Edition General Safety Requirements Part 3, IAEA, Vienna (2011).

 INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, The 2007 Recommendations of the International Commission on Radiological Protection, ICRP Publication 103, ICRP, Ottawa (2007).

**Phys 686: Physics and radiotherapy**

**Course Description**

Treatment Machines for External Beam Radiotherapy , Calibration of Megavoltage Beams of X-Rays & Electrons, Dosimetry of Radiation Fields, Clinical Treatment Planning: Manual Method, Treatment Planning: Computer-Based, Brachytherapy Treatment Planning, Brachytherapy( Sources & DosesSievert Integral, Design of Implants, Distribution Rule for Interstitial Implants, Air-Kerma Strength Calculation, Radiographic Localization of Implants, 3-D Image-Based Implants), Effects of Radiation Exposure, Quality Assurance

**Learning Outcomes**

Upon successful completion of this course, the student:

 Discuss the role of management of cancer treatment

 Characterize collimated beams and relate with fundamental dosimetric quantity

 Discusses the physical characteristics and clinical methodology

 Solve problems on topics included in the syllabus

**References**

 Radiation Therapy Physics, 3/ed, William R. Hendee, et.al.

 Radiation Oncology Physics, IAEA, 2005.

**Phys 688: Radiobiology**

**Course Description**

Classification of radiation in radiobiology , Cell-cycle and cell death, Effect of cellular radiation, oxygen effect, Type of radiation damage (tissue, organ and whole body), Cell survival curve, Dose-response curve, Early and late effects of radiation; effects on the developing embryo, Modelling, LQ model, α/β ratio, Fractionation, EQD2Gy, Dose rate effect, TCP, NTCP and EUD, Tolerance doses and volumes, (QUANTEC), Normal and tumor cell therapeutic ratio, Radio sensitizers, protectors.

**Practical session:** Measurement of a Survival Curve

**Learning Outcomes**

Upon successful completion of this course, the student:

 Would discuss the biological consequence of ionizing radiation

 Discuss the biological effect of radiation

**References**

 BEIR, Report No. VI. “Health Effects of Exposure to Radon.” (National Academy Press,Washington, DC, 1999).

 A.P. Casarett. Radiation Biology. (Prentice-Hall, Englewood Cliffs, NJ, 1968).

 H. Cember. Introduction to Health Physics. 3rd ed. (McGraw Hill, New York, 1996).

 G.V. Dalrymple. Medical Radiation Biology. (W.B. Saunders Co., Philadelphia, PA, 1973).

 G.D. Fullerton, R.G. Waggener, D.T. Kopp et al. Biological Risks of Medical Irradiation. AAPM Monograph No. 5. (American Institute of Physics, New York, 1980).

 E.J. Hall. Radiobiology for the Radiologist. 4th ed. (J.B. Lippincott, Philadelphia, PA, 1994).

**Phys 781: Health Physics**

**Course Description**

Introductions and Historical Perspective, Interaction Physics as Applied to Radiation Protection, Operational Dosimetry, Radiation Detection Instrumentation, Shielding: Properties and Design, Statistical interpretation of instrument response, Radiation Monitoring of Personnel, Internal Exposure, Environmental Dispersion, Nuclear Regulatory, Commission (NRC) air and water dispersion models, Biological Effects, High/Low Level Waste Disposal

**Learning Outcomes**

Upon successful completion of this course, the student:

 Discuss about detection mechanism and shielding analysis

 Students should have explain about importance of medical physics in varied environment

**References**

 G.D. Fullerton, R.G. Waggener, D.T. Kopp et al. Biological Risks of Medical Irradiation. AAPM Monograph No. 5. (American Institute of Physics, New York, NY, 1980).

 ICRP No. 26. Recommendations of the International Commission on Radiological Protection. (Elsevier Science, 1977).

 ICRP No. 60. 1990 Recommendations of the International Commission on Radiological Protection. (Elsevier Science, 1990).

 ICRU, Report No. 20. “Radiation Protection Instrumentation and its Application.” (International Commission on Radiation Units and Measurements, Bethesda, MD, 1971).

 ICRU, Report No. 22. “Measurement of Low-Level Radioactivity.” (International Commission on Radiation Units and Measurements, Bethesda,MD, 1972).

**Phys 782: Radiation physics and dosimetry**

**Course Description**

Overview of Modern Physics, Photon interactions, Neutron interactions, Charged particle interactions, Multiple scattering theories, Stopping power, Restricted, unrestricted, Linear energy transfer (LET), Transport Equation, Introduction to Monte Carlo Techniques, Overview of Non-ionizing radiation physics, Charged particle equilibrium, Fano theorem, Cavity theory, Radiation standards, Calibration traceability, Calibration coefficients e.g. absorbed dose to air (ND,air) and water (ND,w),Radiation dosimeters, Reference dosimetry protocols, Small field dosimetry

**Practical session**:

- Measurements with ionization chambers in Co-60, X ray, and accelerator beams

- Water Tank Scanning

- Measurements with solid state dosimeters (TLD, metal-oxide semiconductor field-effect transistors (MOSFET), optically stimulated luminescent dosimeters (OSLD), film)

- Reference dosimetry calibration of clinical beams using an International protocol, e.g. IAEA TRS 398

**Learning Outcomes**

Upon successful completion of this course, the student:

 Explain the sources of nuclear radiation;

 Describe the radiation field qualitatively and quantitatively;

 Identify major interaction of ionizing radiation with matter;

 Identify detectors and principles of their operation

 Should discuss about dosimetry

**References**

 PODGORSAK, E. B., Radiation Physics for Medical Physicists (Biological and Medical Physics, Biomedical Engineering), Springer, New York, USA (2010).

 ATTIX, FRANK H., Introduction to Radiological Physics and Radiation Dosimetry. Wiley, USA (1986).

 ROGERS, D.W.O., AND CYGLER, JOANNA, Clinical Dosimetry Measurements in Radiotherapy: AAPM 2009 Summer School, Medical Physics Pub Corp, Madison, USA (2009),

 KNOLL, GLENN F., Radiation Detection and Measurement. Wiley, USA (2010).

**Phys 783: Radio diagnostics**

**Course Description**

Production of X-rays, X-ray, generator type, X-ray spectra, absorption, properties of the projection, scattered radiation, intensifying screens and X-ray films, storage foils, xeroradiography, image noise. Conventional tomography Pan tomography, image amplifier, MTF, methods of digital imaging, computed tomography, X-ray dose load.

**Practical Session:**

- X ray tube output dependence on HVL, tube voltage, tube current, exposure time, beam filtration and distance

- Image quality assessment (contrast, resolution, modulation transfer function)

**Learning Outcomes**

Upon successful completion of this course, the student:

 Discuss production of X – ray, image noise,

 Describe about interaction of radiation with matter

 Discuss about radiographic, image quality, X – ray computed tomography and imaging system, methods of digital imaging, computed tomography, X-ray dose load

**References**

 Radiation Oncology Physics, IAEA, 2005;

 The Physics of Diagnostic Imaging, Dowestt & Kenny;

 Quality Management in the Imaging Sciences, J.Papp;

**Phys 784: Physics of Nuclear Medicine I**

**Course Description**

Radioactivity & Nuclear Transformation, Radionuclide Production, Radiopharmaceuticals Laboratory Instrumentation, The Gamma Camera, Camera Performance, Physical basics of radioactive decay, radio nuclides, measurement of activity in vivo, whole body counters, probe measurement, imaging procedures: collimators, gamma camera, SPECT; PET.

**Learning Outcomes**

Upon successful completion of this course, the student:

 Discuss about basic principle of radioactivity and nuclear transformation

 Analysis of imaging procedure

 Solve problems on topics included in the syllabus.

**References**

 INTERNATIONAL ATOMIC ENERGY AGENCY, Nuclear Medicine Physics: A Handbook for Teachers and Students, IAEA, Vienna (under preparation) (2013)

 BUSHBERG, JERROLD T., ET AL, The Essential Physics of Medical Imaging, Lippincott Williams & Wilkins, Philadelphia (2011).

 CHERRY, S.R., SORENSEN, J.A., AND PHELPS, M.E., Physics in Nuclear Medicine, Saunders, Philadelphia (2003).

 INTERNATIONAL ATOMIC ENERGY AGENCY, Applying Radiation Safety Standards in Nuclear Medicine, Safety Report Series No. 40, IAEA, Vienna (2005).

 INTERNATIONAL ATOMIC ENERGY AGENCY, Radiation Protection in Newer Medical Imaging Techniques: PET/CT, Safety Report Series No. 58, IAEA, Vienna (2008).

**Phys 785: Physics of Nuclear medicine II**

**Course Description**

Basics of tracer kinetics, compartment models, dose calculation, in vivo investigation; body

Scan with SPECT, computer-aided diagnostic methods, functional images.

**Practical session**: Calibration of the sensitivity of a Gamma Camera Gamma ray spectroscopy **Learning Outcomes**

Upon successful completion of this course, the student:

 Discuss about basics of tracker kinetics and functional images

 Analysis of computer – aided diagnostic methods

 Solve problems on topics included in the syllabus.

**References**

 INTERNATIONAL ATOMIC ENERGY AGENCY, Nuclear Medicine Physics: A Handbook for Teachers and Students, IAEA, Vienna (under preparation) (2013)

 BUSHBERG, JERROLD T., ET AL, The Essential Physics of Medical Imaging, Lippincott Williams & Wilkins, Philadelphia (2011).

 CHERRY, S.R., SORENSEN, J.A., AND PHELPS, M.E., Physics in Nuclear Medicine, Saunders, Philadelphia (2003).

 INTERNATIONAL ATOMIC ENERGY AGENCY, Applying Radiation Safety Standards in Nuclear Medicine, Safety Report Series No. 40, IAEA,Vienna (2005).

 INTERNATIONAL ATOMIC ENERGY AGENCY, Radiation Protection in Newer Medical Imaging Techniques: PET/CT, Safety Report Series No. 58, IAEA, Vienna (2008).

**Phys 787: Physics of Medical Imaging II**

**Course Description**

Fundamental of magnetic resonance, image reconstruction, image contrast & image sequences, principle of ultrasound, Ultrasound Imaging , basic principle of nuclear medicine, nuclear imaging, radiobiology and risk management, radiation protection: clinical practices, Covers the basic principles of mathematical analysis, the Fourier transform, interpolation and approximation of functions, sampling theory, digital filtering and noise analysis. Analog-to digital conversion, psycho-physiological bases and display, hardcopy, transformation intensity histograms, linear and non-linear filters, Fourier transform. Tomographic image reconstruction using algebraic and analytical methods, spatial transformations in 2D and 3D, image fusion and registration, compression, and data management

**Learning Outcomes**

Upon successful completion of this course, the student:

 Should explain the physics of magnetic resonance

 Discuss nuclear imaging, basic principle of nuclear medicine

 Would have better know how from their practical attachment

 Solve mathematical expression of medical imaging

**References**

 Medical Imaging Physics, 4ed., R. Hendee & R. Ritenour

 The Essential Physics of Medical Imaging, 2ed, J.T. Bushberg, et. Al