Course Content - Department of Nuclear Science

NS 1001	Fundamentals of Nuclear Science	NS 4901	Nuclear Electronics
NS 1002	Nuclear Techniques	NS 4902	Ethics
NS 1003	Computational Methods in Nuclear Science	NS 4903	Nuclear Regulations
NS 2005	Radiochemistry	NS 4904	Radiochemical Methods
NS 2006	Basic Imaging Science	NS 4905	Non-Destructive Testing
NS 3017	Applied Nuclear Science	NS 4906	Nuclear Technology in Physical Science
NS 3025	Radiobiology	NS 4907	Industrial Training
NS 3026	Nuclear Knowledge Management	NS 4908	Industry Oriented Research Project
NS 3018	Health Physics	NS 4029	Diagnostic Radiology II
NS 3110	Human Anatomy	NS 4005	Clinical Education
NS 3120	Nuclear Medicine I	NS 4030	Nuclear Technology and Environment
NS 3023	Diagnostic Radiology	NS 4033	Nuclear Medicine II
NS 3022	Statistics for Nuclear Science	NS 4031	Human Physiology
NS 3901	Radiobiology	NS 4006	Seminar and Essay
NS 3902	Nuclear Power	NS 4032	Radiotherapy Physics
NS 3904	Mathematics for Nuclear Science	NS 4007	Research Project
NS 3019	Medical Physics	NS 4108	Clinical Practice I
NS 3905	Radiation Protection	NS 4109	Clinical Practice II
NS 3906	Nuclear Techniques in Biology		

Course Code	NS 1001	No. of Credits	3
Course Name	Fundamentals of Nuclear Science	No. of lecture hours	45
		No. of Practical hours	0

Rationale: This course gives basic introduction to the subject of Nuclear Sciences. Applications of radioisotopes and ionizing radiation is used in all areas of science and technology and contribute significantly towards sustainable development while improving the quality of life.

Prerequisites: None

Intended Learning Outcomes: At the end of this course students should be able to

- define terms related to radioactivity,

- explain the types of interaction of radiation with matter

- compare different types of radiation detectors

- identify basic radiation protection principles

- describe applications of nuclear science in day today life and apply radioactive decay law and protection principles in practical situations

Course Content: Stability of the Nucleus, Radioactive decay law, radioactive equilibrium, Radioactive decay calculations, Types of radioactive decay: alpha decay, beta decay, gamma emission, spontaneous fission; Radiation interactions; Radiation Detection methods; Nuclear reactor and particle accelerator-based applications in biology, medicine and physics; Nuclear reactions and the production of radioisotopes ;Use of neutrons in biology, chemistry, physics and in industry; Radiation in environment: Natural radiation background; Application of radioisotopes and radiation in biology, chemistry, medicine and physics; Radiation exposure methods: Internal and external; Radiation Protection

Method of Evaluation: End of semester written examination (70%) and in-class assignments (30%)

Suggested references: Keller, C. (1988) *Radiochemistry*, Ellis Horwood Ltd.

Course Code	NS 1002	No. of Credits	1
Course Name	Nuclear Techniques	No. of lecture hours	15
		No. of Practical hours	0

Rationale: This course gives an overview of applications of nuclear techniques that can be applied in various fields.

Prerequisites: None

Intended Learning Outcome: At the end of this course the students will be able to

- identify different nuclear techniques
- identify applications of nuclear technology

Course Content: Why and when the nuclear technology is used: broad areas where the technology is used; Medicine, diagnostic and therapeutic procedures, determine iron deficiency; Agriculture: obtain better cultivars, determine soil characteristics, soil erosion, sterile insect technique; Animal studies: determine best locally available feed material; Use of Co-60 irradiators; radiometric dating methods

Methods of Evaluation: End of semester exam (70%) Continuous assessments (30%)

Suggested References:

Tsipenyuk, Y.M. (1997) *Nuclear Methods in Science and Technology: Fundamental and Applied Physics Series*, Institute of Physics Publishing Ltd Bristol and Philadelphia

Moses,A.J.(2013) *Nuclear Techniques in Analytical Chemistry: International series of monographs in analytical chemistry* Elsevier Science

Course Code	NS 1003	No. of Credits	2
Course Name	Computational Methods in Nuclear Science	No. of lecture hours	0
		No. of Practical hours	60

Rationale: This course introduces computational methods for solving physical problems applicable to nuclear science.

Prerequisites: NS 1001

Intended Learning Outcome: At the end of this course students will be able to

- Identify the basic computational methods used in nuclear science
- Describe radioactive sample analysis using computer methods
- Interpret the relationship of a given series of radiation counts
- Explain radiation shielding process using computer simulation

Course Content:

Basics of Scientific Programming **:**Variable declaration, Arithmetic operations, For/while loops, If condition, Logical operations, Array/matrix operations, Simple operations using complex numbers; Radioactive sample analysis using matrix method; Computer based error estimation in radioactive calculations ; Computer aided graphing: Least square fitting, Curve fitting (Linear Interpolation, Smooth Splines, Cubic Splines); Computer based Statistical interpretation of nuclear data; Applications of Numerical Methods in Nuclear Science**:** Calculating activities of samples using numerical differentiation, Integration for Dose calculation, Solving Radioactive decay equation and exponential energy absorption; Simulate radiation shielding process

Method of Evaluation:

In-class assessments (50%); In-class group assignments (50%)

References:

Sirca, S., & Horvat, M. (2012) Computational methods for physicists: compendium for students, Springer Science & Business Media.

Smith, D. L. (1991) *Probability, statistics, and data uncertainties in nuclear science and technology*, volume 4, American Nuclear Society.

Course Code	NS 2005	No. of Credits	3
Course Name	Radiochemistry	No. of lecture hours	45
		No. of Practical hours	0

Rationale: This course covers the chemical behavior of radioisotopes and their applications

Prerequisites: None

Intended Learning Outcome: At the end of this course the students should be able to

- explain the different nuclear reactions
- explain chemical behavior of radionuclides in nuclear fuel cycle, radiopharmaceuticals and radio tracer applications
- solve problems using nuclear spectrometry
- discuss reaction effects applicable in radiopharmaceuticals, forensics and mineral extraction methods

Course Content: Nuclear structure, modal and properties**;** Nuclear Reactions: classifications**;** Decay Kinetics**:** Alpha decay, beta decay and gamma decay; Fission reactions**:** general properties of actinides and reactions, uranium chemistry: naturally occurring compounds, properties and complexation of uranium, uranium enrichment; plutonium chemistry: compounds and properties of plutonium**;** chemistry in reactor fuel and fuel reprocessing; speciation of uranium in water; synthesis of radioisotopes: radio tracer synthesis, radiolabeling methods; Separation methods**:** solvent extraction, radio-chromatography; radiometric titration, isotope dilution methods; use of radiotracers in yield determination, Introduction to radiopharmaceuticals: reactions of radiolabeling methods, purity and stability of labelled compounds; introduction to Nuclear forensics: relevant radiochemical methods and nuclear spectrometry methods**;** Radiochemistry in Medical applications

Methods of Evaluation: End of semester exam (70%) Continuous assessments (30%)

Suggested References:

Malcolme-Lawes, D. J. (1979) *Introduction to Radiochemistry,* The Macmillan Press Ltd

Konya, J. Nagy,N.M. (2012) *Nuclear and Radiochemistry*, Elesvier Inc.

Morss, L.R. Edelstein, N.M. Fuger,J. The *Chemistry of the Actinide and Transactinide Elements* 3rd ed. Vol 1-5, Springer

Course Code	NS 2006	**No. of Credits**	3
Course Name	Basic Imaging Science	**No. of lecture hours**	30
		No. of Practical hours	30

Rationale: To construct digital images from raw data acquired by medical equipment such as CT, MRI and Ultrasound requires specialized knowledge. The course introduces the student to various forms image formations in the context of diagnostic medical imaging. Often medical images are further processed to classify and extract biological information (e.g. tumour volume, calcium score, relaxation time, blood flow velocity). In this course, students will also gain practical experience in basic image processing techniques and will implement them on medical images using a high level programming language.

Prerequisites: NS 1003

Intended Learning Outcome:

At the end of this course students will be able to

- describe formation and representation of medical images
- construct images using raw data obtained from various imaging modalities.
- process an image in such a way that the image features can be adequately represented and extracted in a compact form amenable to subsequent recognition and classification.

Course Content: Image formation – digital representation of medical images, Fourier Transform, Convolution, Point Spread and Transfer Function, sampling theory – Nyquist Theorem, Whittaker-Shannon Theory, sampling artefacts, aliasing, noise, mathematics of image formation - back projection reconstruction, Fourier reconstruction. Image processing techniques – linear and non-linear filtering, frequency space filtering; Morphological processing - dilation and erosion, extraction of connected components, region filling, opening by reconstruction: Features - single parameter shape descriptors, texture features based on statistical measures, principal component analysis; Image segmentation - Intensity thresholding, region growing.

Methods of Evaluation: End of semester exam (70%) Continuous assessments (30%)

Suggested References:

Hendee, W.R.; Ritenour E.R. (2002) *Medical Imaging Physics*, Willy-Liss Inc., New York.

Gonzalez, R. C.;, Woods, R. E. (2002). *Digital Image Processing*, Pearson Education Inc.

Solomon, C., & Breckon, T. (2011). *Fundamentals of Digital Image Processing: A Practical Approach with Examples in Matlab*. Hoboken, John Wiley & Sons, NJ.

Course Code	NS 3017	No. of Credits	3
Course Name	Applied Nuclear Science	No. of lecture hours	30
		No. of Practical hours	30

Rationale: This course unit gives an overall idea of what is nuclear science and how it can be useful in various fields. It revises the basic theory and then discuss about detection methods, analytical techniques, protection methods and applications of nuclear science.

Prerequisites: None

Intended Learning Outcomes: At the end of this course the students will be able review the basic theories of nuclear science and be able to explain their applications to industrial and clinical uses. They should be able to analyze radioactive samples using different nuclear analytical techniques. In addition they should be able to estimate radiation safety aspects of a radioactive component. During the practical hours, students will be able to describe the operations of basic radiation detection devices and should be able apply nuclear analytical techniques for analysis.

Course Content: Types of Radiation, their properties, disintegration of unstable nuclei, radiation sources. Units and definitions. Basic equations of Radioactive decay. Nuclear decay schemes, examples, Internal conversion, X-rays in radioactive decay. Properties of nuclear radiation, Interaction of radiation with matter, Interaction of alpha and beta particles, gamma rays, neutrons, attenuation coefficient, Bragg Curve, Detection and measurement of radiation: Gas filled detectors, scintillation detectors, and semiconductor detectors. Passive detection methods, Neutron detection, Radiation spectroscopy, statistics of Nuclear measurements. Experimental study: Determination of very long and very short half lives, Identification of isotope. Absolute measurement of radioactivity, Coincidence method with applications. Radiation protection and safety Internal and external radiation protection, Radiation shielding, Radiological monitoring systems. Special properties of radioisotopes accounting for their widespread use. Radioisotopes as tracers: Examples of applications in hydrology, agriculture, medical, physical and chemical sciences Application of large radiation sources: Polymer modification, sterilization of medical supplies, food preservation, and insect control, radiotherapy, Nuclear analytical techniques: Neutron activation analysis, XRF, PIXE, Isotope dilution Radiometric dating methods: Dating of U containing samples, C-14 dating, Tritium dating, TL dating, Fission track dating.

Methods of Evaluation: End of semester examination (60%), practical (30%) and In class assignments (10%)

Suggested References: Knoll, G.F. 2011, Radiation Detection and Measurement, John Wiley & Sons Inc. 2011, ISBN: 978-0-470-13148-0;

Martin, A., Harbison, S.A.Beack K.,Cole, P. 2012, An Introduction to Radiation Protection, CRC Press FL ISBN: 2012, 978-1-444-14607-3;

Course Code	NS 3025	No. of Credits	3
Course Name	Radiobiology	No. of lecture hours	45
		No. of Practical hours	0

Rationale: Becoming familiar with the mechanisms of different types of biological effects following exposure to ionizing radiation is an essential part of education in Nuclear Science. This unit discusses how radiation interact with biological systems and the effects of the radiation in living organisms.

Prerequisites: Level I and II Biology OR Chemistry OR Physics core courses

Intended Learning Outcomes: At the end of this course the students will be able to Identify the importance of radiation with respect to the biological systems. They will also be able to explain the use of radiation to protect cells and organs in the human body.

Course Content: Principles of cell biology. Principles of radiobiology. Biologic interactions and measurement of effects: Direct and Indirect action, Radiolysis of water, Linear energy Transfer and Relative Biological Effectiveness. The effects of radiation at the molecular and sub cellular levels: effect of radiation on macro molecules, radio sensitivity of the nucleus, chromosome damage. Cellular effects of radiation: giant cells, inter phase death and apoptosis, radiation cell death and reproductive capacity. Target theories and cell survival curves: radio sensitivity of the different phases of the cell cycle, Elkind recovery. Reparable Damage: division delay, position of G2 block recovery from sub lethal damage, repair mechanism, recovery from potentially lethal damage. Early effects of radiation: acute radiation syndromes whole body irradiation, cellular basis of the total body syndromes, cell renewal systems, LD50, human syndromes. Local tissue damage: effects of irradiation on gonads and skin, the immune system. Late effects of radiation: life span shortening, genetic damage cytogenetic damage, doubling dose, Foetal irradiation Prenatal and Neonatal death, congenital malformation, childhood malignancies, other malignant Diseases. Radiation effect Factors: Dose and rate effects, oxygen effect, radiosensitisers and radioprotectors, hypoxic cell sensitisers.

Methods of Evaluation: End of semester examination (70%), In class assignment (30 %)

Suggest References: Nias, A.H.W. An Introduction to Radiobiology, John Willey & Sons, 1998, ISBN: 9780471975908

Coggle, J.E. Biological effects of Radiation, Taylor & Francis, 1983, ISBN : 9780850662382

Dowd, S.B. Tilson, E.R. Allen, A. Practical Radiation Protection and Applied Radiobiology, W.B. Saunders, 1999, ISBN : 9780721675237

Hall, E.J. Giaccia, A.J. Radiobiology for Radiologists, Lippincott Williams & Wilkins, 2012,ISBN : 9781451154184

Course Code	NS 3018	No. of Credits	3
Course Name	Health Physics	No. of lecture hours	30
		No. of Practical hours	30

Rationale: To ensure the health and safety of radiation workers, the knowledge about protection principles is essential. The course unit covers the quantification of radiation dose and radiation protection methods

Prerequisites: NS 2003 Fundamentals of Nuclear Science

Intended Learning Outcomes: At the end of this course, students will be able to describe the technical aspects of radiation protection and safety in diagnostic and therapy.

Course content: Quantities and units used in radiation protection and health physics; Background radiation; Physical and biological aspects of the use of ionizing radiation in hospitals, industrial and academic institutions; External and internal hazards of radiation and methods of evaluation; Elements of a radiation protection programme; Basic principles and techniques of radiation protection; Principle of radiation dosimetry, personal dosimetry and work place monitoring; Radiation safety, protection and legislation: isotope storage, transportation, handling, shielding (including room design for diagnostic radiology, teletherapy and Brachytherapy), personnel protection, waste disposal; National and international regulations and standards.

Method/s of evaluation: End of semester examination (70%) and Continuous assessment (30%).

Suggested reading: Introduction to Health Physics (Herman Cember and Thomas E Johnson)
Radiation Protection in Hospitals (R. F. Mold)
An introduction to Radiation Protection (A. Martin and S. A. Harbisor)
ICRP Publications (1990)

Course Code	NS 3026	No. of Credits	2
Course Name	Nuclear Knowledge Management	No. of lecture hours	30
		No. of Practical hours	0

Rationale: This course covers the strategies of nuclear knowledge management, which helps to develop and preserve the existing nuclear knowledge in various nuclear science related institutions.

Prerequisites: None

Intended Learning Outcome: At the end of this course, the students should be able to

- explain knowledge as a key safety and economic asset in nuclear sector and the implementation of an integrated approach to Nuclear Knowledge Management (NKM).
- discuss various dimensions of NKM as a key business management tool, including HR & talent management, and information management.

Course Content: Integrated approach in nuclear knowledge management, Principles of knowledge sharing culture, Motivation and communication in NKM, Nuclear information management, Planning & modelling for a NKM program, Competency mapping, Succession planning, NKM risk assessment. NKM roles and responsibilities, Knowledge capture methods, Important technologies in nuclear information management, Digital information preservation, Case studies; Nuclear power plants, research reactor facilities, Medical isotope generators.

Methods of Evaluation: End of semester exam (70%) Continuous assessments (30%)

Suggested References:

Blokdyk,G. (2018) *Nuclear knowledge management: Complete Self-Assessment Guide* Create space Independent Publishing Platform.

International Atomic Energy Agency (2011) *Comparative Analysis of Methods and Tools for Nuclear Knowledge Preservation*, Nuclear Energy Series No. NG-T-6.7, IAEA, Vienna.

International Atomic Energy Agency (2008) *Planning and Execution of Knowledge Management Assist Missions for Nuclear Organizations*, IAEA-TECDOC-1586, IAEA, Vienna

International Atomic Energy Agency (2012) Knowledge Management for Nuclear Research and Development Organizations, IAEA-TECDOC-1675, IAEA, Vienna

Course Code	NS 3110	**No. of Credits**	3
Course Name	Human Anatomy	**No. of lecture hours**	45
		No. of Practical hours	0

Rationale: This course unit is designed to identify gross anatomical structures and define the major organ systems, which is essential in studying diagnostic and therapeutic radiology.

Prerequisites: None

Intended Learning Outcomes: At the end of this course, student will be able to identify and describe the structure of different human system.

Course content: Cell structure & functional organization; Epithelia; Connective tissue and basic histology; Histology of bone and cartilage; Muscles and nerves; Respiratory system; GIT; GUT; CVS; Surface anatomy (tissue planes); Bone anatomy and anatomical landmarks; CVS & RS-Basic (gross anatomy); GIT (gross anatomy); GUT (renal, male and female) anatomy; Anatomy of Thorax: anatomy of thoracic wall and respiration, lungs & pleura (with surface marking), heart and pericardium (with surface marking), mediastinum, sectional anatomy of thorax; Anatomy of abdomen and pelvis: anterior abdominal wall, stomach, intestines, peritoneum, posterior abdominal wall, liver and billiary system, rectum & anal canal, male genital system, female genital system, pelvic diaphragm and perineum, sectional anatomy of abdomen; Head and neck: root of the neck, structure of the neck, parotid & submandibular region, infratemporal fossa and TM Joint, brain (gross anatomy) and cross sectional, cross sectional anatomy of head and neck, spinal cord (cross sectional and sagittal); Upper Limb: mammary gland, axilla and pectoral region (cross sectional), shoulder joint and arm (cross sectional), forearm and hand (Cross sectional); Lower Limb: hip joint and gluteal region (cross sectional), knee joint and popliteal fossa, leg and foot.

Method/s of evaluation: End of semester examination (70%) and Continuous assessment (30%)

Suggested reading: Human Anatomy, Martini FM, Timmosons MJ and McKinely MP 3rd Edition, (2000)
Anatomy in Diagnostic Imaging, Pleckenstein P and Tranum-Jenson J
Clinical oriented anatomy, Moore K L Dalley AA 4th Edition (1999)
An imaging Atlas of Human Anatomy, Wier J and Abraham PH 4th Edition. (1997) Introduction to sectional Anatomy, MadenME

Course Code	NS 3120	No. of Credits	3
Course Name	Nuclear Medicine I	No. of lecture hours	30
		No. of Practical hours	30

Rationale: This course unit is designed to provide knowledge on the use of radioactive isotopes in diagnosis and radiotherapy.

Prerequisites: None

Intended Learning Outcomes: At the end of this course, the students will be able to develop a broad knowledge of preparing radiopharmaceuticals for diagnosis and therapy in nuclear medicine department.

Course content: Physics of nuclear medicine and radio pharmaceuticals: radio isotopes in medical diagnosis in vitro and in vivo procedures, scintillation counters, specific activity, effective half-life, cyclotron - produced radio nuclides, reactor produced radio nuclides, radio isotope generators, method of preparation, radio pharmaceuticals and methods of labeling, characteristics of specific radio pharmaceuticals, quality control of radio pharmaceuticals. Nuclear Pharmacy: Design, operation, storage, dispensing; Radioactive and biological waste disposal; Diagnostic and therapeutic uses of radio pharmaceuticals in Nuclear Medicine. Auger gamma camera: design criteria, resolution, sensitivity measurements, choice of collimators, comparison between them, quality control in instrumentation.

Method/s of evaluation: End of semester examination (70%) and Continuous assessment (30%)

Suggested reading: Text Book on Nuclear Medicine, Wilson, M. A.
Principles and Practice of Nuclear Medicine Early, P. J and Sodee D B. Fundamentals of Nuclear Pharmacy, Saha G. B Physics of Nuclear Medicine, Cherry S. P, Sorenson J. A and Phelps, M. E

Course Code	NS 3023	No. of Credits	3
Course Name	Diagnostic Radiology	No. of lecture hours	30
		No. of Practical hours	30

Rationale:

Prerequisites: NS 2003 Fundamentals of Nuclear Science

Intended Learning Outcomes:

At the end of this course, the students will be able to develop a broad knowledge of the basic radiological physics concepts, interaction of ionizing radiation with matter and instrumentation. Students will be motivated to apply their knowledge into the medical setting that they can be able to understand the concepts qualitatively in more complicated cases in the future courses and research.

Course content: Radiation: electromagnetic radiation and their characteristics, types of radiation; Interactions of ionizing radiations with matter; Particle interaction with matter: charged particle such as alpha particles, protons, electrons, beta particles, positrons and uncharged particle such as neutron; X-rays and gamma interaction with matter: Rayleigh scattering, Compton scattering, photo electric absorption, pair production; Range of secondary electrons; Bragg curve; Attenuation and absorption coefficients; Stopping powers; Linear energy transfer (LET); Mean free path (MFP); Radiation dosimetry: exposure, kerma, absorbed dose, equivalent dose, effective dose, charged particle equilibrium (CPE); Bagg-Gray cavity theory; Practical ion chambers; X-ray radiology: X-ray tubes and production of X-rays, X-ray spectrum, interaction of X-rays with the patient, attenuation, radiographic contrast, film construction, role of intensifying screens, film processing, X-ray image properties, characteristics curve, introduction of mammography and fluoroscopy; Quality assurance of radiographic units; Principles of computed tomography: principles of reconstruction tomography, obtaining X-ray profiles, collimation and detection systems, CT numbers, reconstruction algorithms, image display, performance evaluation, artifacts, historical development, technical parameters and considerations affecting scan quality, detailed clinical applications to specific anatomical areas, advanced and interventional clinical applications, quality assurance tests on computed tomography.

Method/s of evaluation: End of semester examination (70%) and Continuous assessment (30%)

Suggested reading: Introduction to Radiological Physics and Dosimery (Frank Herb Attix)
The Essential Physics of Medical Imaging (Jerrold T Bushberg et al)
Absorption of Ionizing Radiation (Anderson DW)
The physics of Radiology (Johns HE, Cunningham JR)
Introduction to Computed Tomography (Ellis H et al)

Course Code	NS 3022	No. of Credits	3
Course Name	Statistics for Nuclear Science	No. of lecture hours	30
		No. of Practical hours	30

Rationale:

Prerequisites: NS 3023 Diagnostic Radiobiology

Intended Learning Outcomes: At the end of the course the student will be able to describe the basic concept of statistics, statistical tests and nuclear counting statistics.

Course content: Types of data; Population and sample characteristics: definitions, examples, measures of the central tendency and variability, and their properties; The basics of probability theory: experiments, events, operations with events, the concept of probability, rules of probability calculation in special cases, conditional probability, Baye's theorem, diagnostic tests, random variable, moments, binomial, Poisson, exponential and normal distributions; Inferential statistics; Point and interval estimation; Sampling distributions; Central limit theorem; Statistical tests: the aim and steps of hypothesis testing, p-values, level of significance, one-sample Z, t-test, paired t-test, two-sample Z, t-tests, F test for testing equality of variances, two way contingency table, Chi-square test for independence, correlation and simple linear regression, significance of the correlation coefficient, hypothesis tests for the coefficients of regression line; Nuclear counting statistics.

Method/s of evaluation: End of semester examination (70%) and Continuous assessment (30%).

Suggested reading: Schaum's Outline of Probability and Statistics (Murray R. Spiegel, John J. Schiller, R. Alu Srinivasan)
Medical Statistics: A Textbook for the Health Sciences (David Machin, Michael J Campbel)
An Introduction to Medical Statistics: Martin Bland, Publisher: Oxford Medical Publications

Course Code	NS 3901	No. of Credits	3
Course Name	RADIOBIOLOGY	No. of lecture hours	45
		No. of Practical hours	0

Rationale: Becoming familiar with the mechanisms of different types of biological effects following exposure to ionizing radiation is an essential part of education in Nuclear Science. This unit discusses how radiation interact with biological systems and the effects of the radiation in living organisms.

Prerequisites: Level I and II Biology OR Chemistry OR Physics core courses

Intended Learning Outcomes: At the end of this course the students will be able to Identify the importance of radiation with respect to the biological systems. They will also be able to explain the use of radiation to protect cells and organs in the human body.

Course Content: Principles of cell biology. Principles of radiobiology. Biologic interactions and measurement of effects: Direct and Indirect action, Radiolysis of water, Linear energy Transfer and Relative Biological Effectiveness. The effects of radiation at the molecular and sub cellular levels: effect of radiation on macro molecules, radio sensitivity of the nucleus, chromosome damage. Cellular effects of radiation: giant cells, inter phase death and apoptosis, radiation cell death and reproductive capacity. Target theories and cell survival curves: radio sensitivity of the different phases of the cell cycle, Elkind recovery. Reparable Damage: division delay, position of G2 block recovery from sub lethal damage, repair mechanism, recovery from potentially lethal damage. Early effects of radiation: acute radiation syndromes whole body irradiation, cellular basis of the total body syndromes, cell renewal systems, LD50, human syndromes. Local tissue damage: effects of irradiation on gonads and skin, the immune system. Late effects of radiation: life span shortening, genetic damage cytogenetic damage, doubling dose, Foetal irradiation Prenatal and Neonatal death, congenital malformation, childhood malignancies, other malignant Diseases. Radiation effect Factors: Dose and rate effects, oxygen effect, radiosensitisers and radioprotectors, hypoxic cell sensitisers.

Methods of Evaluation: End of semester examination (70%), In class assignment (30 %)

Suggest References: Nias, A.H.W. An Introduction to Radiobiology, John Willey & Sons, 1998, ISBN: 9780471975908

Coggle, J.E. Biological effects of Radiation, Taylor & Francis, 1983, ISBN: 9780850662382

Dowd, S.B. Tilson, E.R. Allen, A. Practical Radiation Protection and Applied Radiobiology, W.B. Saunders, 1999, ISBN : 9780721675237

Hall, E.J. Giaccia, A.J. Radiobiology for Radiologists, Lippincott Williams & Wilkins, 2012,ISBN : 9781451154184

Course Code	NS 3902	No. of Credits	3
Course Name	NUCLEAR POWER	No. of lecture hours	45
		No. of Practical hours	0

Rationale: With demand for electricity increasing, nuclear energy is an essential part of energy program in many countries. It is considered as a clean and reliable energy source. This unit gives an overall knowledge of how we can use nuclear energy as an energy source while discussing the practical issues of a nuclear power plant.

Prerequisites: Level I and II Biology OR Chemistry OR Physics core courses

Intended Learning Outcomes: At the end of this course the students will be able to illustrate the process of nuclear energy production in nuclear reactors, including planning, operation, control as well as the radiation waste management. They will also be able to evaluate the pros and cons of use of nuclear power compared to other energy sources

Course Content : Methods of production of nuclear energy, Different types of nuclear reactors : Isotope batteries, fusion reactors, nuclear reactors; structural components of nuclear power plant system; Types of nuclear reactors; nuclear power generation process in nuclear reactors, operating conditions, neutron irradiation; Recycling of nuclear fuel; Advantages of nuclear power compared to other energy sources. Nuclear weapon production and non-proliferation issues; Environmental, economical and political Issues on nuclear power plant generation; Nuclear waste management

Methods of Evaluation: End of semester examination (70%), In class assignment (30 %)

Suggested References: Keller, C.; Radiochemistry, Ellis Horwood Ltd. UK 1988, ISBN : 0-7458-0522-1

Course Code	NS 3904	No. of Credits	3
Course Name	MATHEMATICS FOR NUCLEAR SCIENCE	No. of lecture hours	30
		No. of Practical hours	30

Rationale: The mathematics knowledge obtained in the first two years is not adequate to understand some concepts in nuclear technology. This course unit covers the basic mathematical and computational knowledge required for solving mathematical problems in nuclear technology.

Prerequisites: Level I and II Biology OR Chemistry OR Physics core courses; AM 1008: Only for Biological science/Biochemistry & Molecular Biology students

Intended Learning Outcomes: At the end of this course the students will be able to describe methods of solving linear differential equation and integration. The students will be able to handle mathematical problems in nuclear science with the help of MATLAB.

Course Content: Calculus: limit theory, differentiation, integration, sequences, series, various techniques for solving differential equations, ODE solvers in MATLAB; Functions (odd and even); Elementary linear algebra: Systems of Linear Equations, the algebra of vectors and matrices, the inverse of a matrix, matrix operations, elimination and decomposition methods for solving linear systems of equations, applications of eigenvalues and eigenvectors, vector spaces, linear transformations, and least squares techniques, matrix inversion with solving linear systems using MATLAB; Fourier methods: periodic functions, introduction to Fourier series and Fourier transforms, discrete Fourier transform, FFT methods, Laplace Transforms.

Methods of Evaluation: End of semester examination (70%) practical and in-class assignments (30%)

Suggested References:Cember, H. and Johnson, T.E., 2009. Health Physics (4th ed). McGraw. pp. 85-140 Friedman, N.A., 1979. Calculus and Mathematical Models. Prindle,Weber and Schmidt. Easton R.L., 2010.

Fourier Methods in Imaging. Wiley Griffith, D., 1982.

MATLAB Mathematics 7.0. MathWorks Inc.2004

Course Code	NS 3019	No. of Credits	3
Course Name	MEDICAL PHYSICS	No. of lecture hours	45
		No. of Practical hours	0

Rationale: Main area of application of radiation is in Medicine. This course unit is designed to discuss the use of radiation in medical imaging and diagnostics. Other applications of Physics in Medicine will also be discussed.

Prerequisites: Level I and II Biology OR Chemistry OR Physics core courses

Intended Learning Outcomes: At the end of this course, the students will be able to describe the physics behind the different clinical imaging and radiotherapy treatment techniques and delivery. They will also be able to describe the theoretical principles of detectors and dosimeters used for radiation detection and measurement.

Course Content: Revising types of radiation and radiation interactions with matter. Introduction to X-rays transmission image; X ray production; X-ray beam properties; X-ray generator; X-ray tube construction; X ray Imaging detectors (conventional/digital); Image parameter; Fluoroscopy; Mammography; Computed tomography: physical principles, data acquisition concepts, image reconstruction, image quality and artifact, quality control programs in hospitals, radiation dose in CT; External beam radiotherapy: superficial machines, orthovoltage machines, Cobalt-60 machine, linear accelerators, treatment parameters and treatment time calculations; Nuclear medicine: Radioisotopes; introduction of planar, single photon emission tomography (SPECT), positron emission tomography (PET); Magnetic Resonance Imaging (MRI): Physics of magnetic resonance, signal detection, pulse sequences, hardware, Imaging methods; Ultrasound: propagation of ultrasonic waves in biological tissues, principles of ultrasonic measuring and imaging instrumentation, modes of scanning, biological effects of ultrasound; Detectors and dose meters: gas filed dosimeters, solid state dose meter, personal dosimeters; Radiation Protection: the basic physics of radiation protection, distance, time, shielding, physical and biological aspects of the use of ionizing radiation, radiation quality factor, equivalent dose; effective dose; radiation protection principles and philosophy, occupational, public exposure, annual limits; radioactive transport and waste management.

Methods of Evaluation: End of semester examination (70%), Continuous assessments (20%) and report on a clinical visit to a radiotherapy treatment hospital (10%)

Suggested References:

Jerrold T. Bushberg , The Essential Physics of Medical Imaging, 2002, ISBN:0683301187

Podgorsak, E.B. Radiation oncology physics: a handbook for teachers and students, International Atomic Energy Agency, 2005, ISBN : 9789201073044

Khan, F.M. Gibbons, J.P. Khan's The physics of radiation therapy, Lippincott Williams & Wilkins, 2014, ISBN: 9781451182453

Levitt, S. H. Purdy, J.A. Perez, C.A. Philips, P. Technical Basis of radiation therapy, Springer Heidelberg Doerdrecht London NY 2012 ISBN: 978-3-642-11572-1

Course Code	NS 3905	No. of Credits	3
Course Name	RADIATION PROTECTION	No. of lecture hours	45
		No. of Practical hours	0

Rationale: To ensure the health and safety of radiation workers, knowledge about protection principles is essential. The course units covers the quantification of radiation dose, the hazardous levels and the radiation protection methods used in medical and industrial applications.

Prerequisites: Level I and II Biology OR Chemistry OR Physics core courses

Intended Learning Outcomes: At the end of the course, students will be able to describe dosimetric quantities and their measurement units and explain the biological effects of radiation. They will be able to explain the ICRP framework on radiation protection. Also they will able to estimate the doses to individuals due to external and internal exposure and discuss the methods of minimizing them

Course content: Review of fundamentals, Quantities and measurements, Biological effects of ionizing radiation, Principles of radiation protection and the international framework, Regulatory control , Assessment of Protection against occupational exposure, Medical exposures in diagnostic radiology, radiotherapy and nuclear medicine, Exposure of the public due to practices, Intervention in situations of chronic and emergency exposure, personnel monitoring

Method/s of evaluation: End of semester examination (70%) and Continuous assessment (30%)

Suggested References: Cember, H. Introduction to health Physics McGraw Hill Professional, 1996, ISBN : 9780071054614

IAEA publications

Course Code	NS 3906	No. of Credits	3
Course Name	Nuclear Techniques in Biology	No. of lecture hours	30
		No. of Practical hours	30

Rationale: There is a tremendous potential in solving many problems in biology using nuclear techniques. This unit covers applications of radiation and nuclear techniques in agriculture, food industry and biological research and developments

Prerequisites: Level I and II Biology OR Chemistry OR Physics core courses

Intended Learning Outcomes: At the end of this course the students will be able to explain various applications of nuclear techniques used in agriculture and medical fields. The students will be able to evaluate the benefits and issues of those techniques compared to other conventional methods used in the relevant fields.

Course Content: General Introduction to nuclear techniques, Tracer Methodology, N-15 Determination, Mutations, Isotope and Radiation Techniques in Soil and Waste Management and Crop Nutrition Studies, Nuclear Techniques in Pesticide Research, Insect and Pest Control, Animal diseases and Their Vectors, Animal Production and Health, Food and Environmental Protection, Principles of Radiation Protection

Methods of Evaluation: End of semester examination (70%) Reports/ presentations based on field trips (30%)

Suggested References: Chandrasekharan, H., Gupta, N. Fundamentals of Nuclear Science - Application in Agriculture, Northern Book Centre, 2006, ISBN : 9788172112004

Loaharanu, P.,Thomas, P. 2001, Irradiation for Food Safety and Quality CRC Press, 2001, ISBN : 9781587160813

IAEA Bulletins : https://www.iaea.org/sites/default/files/publications/magazines/bulletin/bull21-2/212_305482935.pdf

Course Code	NS 4901	No. of Credits	3
Course Name	NUCLEAR ELECTRONICS	No. of lecture hours	30
		No. of Practical hours	30

Rationale: Nuclear instruments are used in every phase of atomic energy staring from assessing health hazards to prospecting nuclear materials. In this units students will be introduced to implementation of pulse handling and processing from the users point of view rather than the designers point of view using functional or black box approach.

Prerequisites: Level I and II Biology OR Chemistry OR Physics core courses ; NS3017

Intended Learning Outcomes: At the end of this course the students will be able to apply the knowledge and practical skills in acquisition and processing of electrical signals generated. During the practical hours, students will be able to get acquainted with the techniques for amplitude and timing data acquisition.

Course Content: Analog circuits: linear pulse amplifiers, various means for pulse shaping, amplifiers with variable gain, operational amplifiers, arithmetic operations on pulse amplitudes, window amplifiers, integrators, fast pulse amplifiers. Digital circuits: basic digital circuits, scalars and registers, logical and arithmetical digital circuits, memories. Analog-to-digital converters: pulse height discriminators, digital encoding of the pulse height, pulse shape discriminators. Evaluation of the time information: coincidence circuits, pulse shapers for coincidence circuits and time-to-digital converters, digital encoding of the time Interval. Data Processing: simple counting systems, single- and multi-channel analyzers, time of fly particle detection technique.

Methods of Evaluation: End of semester examination (60%), practical (30%) and in class assignments (10%)

Suggested References:

Nicholson, P.W. Nuclear Electronics, John Wiley & Sons, 1974, ISBN : 9780471636977
Kowalsky, E. Nuclear Electronics, Springer-Verlag New York Heidelberg Berlin, 1970

Course Code	NS 4902	No. of Credits	2
Course Name	ETHICS	No. of lecture hours	30
		No. of Practical hours	0

Rationale: Ethics is the branch of study dealing with what is the proper course of action in any situation. The course unit is designed to make the students aware of the ethical issues based on radiation applications and how to handle with them in professional environment.

Prerequisites: Level I and II Biology OR Chemistry OR Physics core courses

Intended learning outcomes: At the end of this course, the students will be able to identify and analyze an ethical issue in the science and research and the various ethical interests in the scientific and professional environment.

Course content: Ethical Principles: historical evolution of ethical principles, moral/ethical theories (virtue, justice, rights, duty, utilitarianism), ethics versus laws; Ethical encounters or dilemmas; Professional Conduct: honesty, conflict of interest, respect for all people, employment; Research Ethics: funding, proposals, manuscripts, scientific misconduct, identifying and reporting misconduct, conflict of interest, bias in research design, publication practices (authorship, publication and peer etc.), collaborative research, supervisors and advisors, research on animals and human; Education ethics: teacher, students, student confidentiality, fair evaluation, academic honesty and integrity, academic freedom; Science and society; Safety and the laboratory; Safety and the environment.

Methods of evaluation: End of semester examination (70%) and Continuous assessment (30%).

Suggested References: D'Angelo, J. Ethics in Science: Ethical Misconduct in Scientific Research. J. D'Angelo ISBN-13: 978-1439840863. This is available as a free download www.nap.edu/catalog/12192/on-being-a-scientist-a-guide-to-responsible-conduct-in. Any other relevant articles (journals, newspapers, internet, etc).

Course Code	NS 4903	No. of Credits	2
Course Name	NUCLEAR REGULATIONS	No. of lecture hours	30
		No. of Practical hours	0

Rationale: Becoming familiar with the mechanisms of elements of regulatory infrastructure for radiation protection and safety is important for anyone working with radiation. This course unit is designed to make the students aware of regulations, safety assessments and emergency preparedness in nuclear applications.

Prerequisites: Level I and II Biology OR Chemistry OR Physics core courses

Intended Learning Outcomes: At the end of this course the students will be able to apply the elements of a regulatory infrastructure for radiation protection and the safe use of radiation sources.

Course Content: Legal framework for radiation protection and the safe use of radiation sources : scope of basic legal framework, Statutory base; enabling legislation; The regulatory authority: Mandate of regulatory authorities, Responsibilities, organization, adequate resources, Training, qualification of staff, Advisory committees & consultants; Regulatory systems: Need for a Regulatory programme, The set of regulations (performance or prescriptive), Safety Requirements and Safety Guides, International Standards, System of notification, Authorization, licensing and control of radiation sources including criteria for waste storage and disposal, exemptions, clearance, Responsibilities of licensees and employers, Relationship between regulator and regulated, feedback, National inventory of radiation sources; orphan sources; import, export, transport and security, Safety assessment; compliance with the safety requirements; inspection; enforcement, Training requirements, Emergency preparedness; investigations of accident and management of emergencies, Dissemination of information on protection and safety and communication with the public, Co-operation between employers (sharing safety and security information, individual monitoring records, etc.) Assessment of effectiveness of the regulatory programmes: Management of quality system, Collection and Analysis of Data, Levels of programme Assessments, Programme performance criteria

Methods of Evaluation: 70 % end of semester examination : 30 % Case studies

Suggested references: IAEA Bulletins

Course Code	NS 4904	No. of Credits	3
Course Name	RADIOCHEMICAL METHODS	No. of lecture hours	30
		No. of Practical hours	30

Rationale: Radiochemistry is chemistry of radioactive elements. This course units discusses different analysis methods using radioisotopes, applicable in research and developments

Prerequisites: Level I and II Biology OR Chemistry OR Physics core courses; NS3017

Intended Learning Outcomes: At the end of this course the students will be able to apply the radiochemical techniques used to analyses radioactive samples. The students will be able to evaluate the pros and cons of different radiochemical methods compared to conventional analysis methods and will be able to justify in choosing the best analytical method for a given application. In addition they will be able to design radiochemical procedures for case studies.

Course content: Special features of radiochemistry, availability of radioactive elements, destructive and non-destructive methods for qualitative determination of naturally occurring radioactive elements, Determination of radon and radium isotopes in an air sample, Tracer methods for inorganic compounds, organic compounds and biomolecular analysis, isotope dilution analysis, isotope exchange method, radiometric titration, activation analysis, radiochemical activation analysis, radiochemical separation techniques : solvent extraction, ion exchange, , radio electrophoresis, radio chromatography, radioisotopes in hydrology

Methods of evaluation: 60 % end of semester examination, 30 % practical sessions and 10% in class assignments.

Suggested References: Coomber, D. I. Radiochemical Methods in Analysis Springer Science & Business Media, 2012, ISBN : 9781461344018

Golakiya, B.A. Radio Tracer Techniques for agriculturists and biologists, New India Publishing, 2008, ISBN : 9788189422974

J. Lehto, X. Hou: Chemistry and analysis of radionuclides, Wiley-VCH Weinheim, 2010, ISBN: 978-3-527-32658-7

Course Code	NS 4905	No. of Credits	3
Course Name	NON DISTRUCTIVE TESTING	No. of lecture hours	30
		No. of Practical hours	30

Rationale: The term Non-destructive testing (NDT)is used for the examination of materials and components in such a way that allows materials to be examined without changing or destroying them. This course unit covers non-destructive applications of radiation used in industry for inspections, testing and quality control. Other NDT methods will also be discussed.

Prerequisites : Level I and II Biology OR Chemistry OR Physics core courses ; NS3017

Intended Learning Outcomes: At the end of the course the students should be able to explain the theory and applications of several non-destructive testing methods. They should be able to evaluate applications and limitations of each method in order to select for a given case.

Course content: Advantages and limitations of non-destructive methods compared to destructive testing methods, Applications of NDT methods: Liquid penetrant testing (PT),General procedure for liquid penetrant inspection, Penetrant processes and equipment, Areas of application of liquid penetrants, Advantages and limitations of liquid penetrants, NDT methods : (1) Magnetic particle testing (MT):fundamental principles and methods of magnetization, general procedure for magnetic particle testing, equipment for magnetic particle inspection, applications of the magnetic method of testing, advantages and limitations of magnetic particle inspection, (2) Eddy current testing (ET):
fundamental principles, equipment and procedure for eddy current testing, applications of eddy current testing , advantages and limitations of eddy current testing, (3) Radiographic testing, fundamental principles, general procedure for radiographic testing, different forms of radiographic testing, applications of radiographic testing method, advantages and limitations of radiographic testing
(4) Ultrasonic testing : fundamental principles, equipment for ultrasonic testing, general procedure for ultrasonic testing, applications of ultrasonic testing, advantages and limitations of ultrasonic testing
Overview of other methods of NDT: acoustic emission, thermal methods, computer tomography
Radio tracers and applications in industry: radioisotope gauges used in industry, comparison and selection of NDT methods

Methods of Evaluation: 70% of end of semester examination and 30% from the practical sessions
Suggested References: Practical Non Destructive Testing Baldev Raj, T. Jayakumar, M. Thavasimuthu, Woodhead Publishing Ltd 2nd Ed. ISBN 1-85573-600-4
IAEA Publications

Course Code	NS 4906	No. of Credits	2
Course Name	NUCLEAR TECHNOLOGY IN PHYSICAL SCIENCE	No. of lecture hours	30
		No. of Practical hours	0

Rationale: There are many applications on radiation in physical science other than the NDT. This unit is designed to cover the physical science applications of radiation in industry for inspections, sterilization, analysis methods and research work.

Prerequisites: Level I and II Biology OR Chemistry OR Physics core courses; NS3017

Intended Learning Outcomes: At the end of this course the students will be able to explain different physical science applications of nuclear technology; They should be able to apply nuclear technology in analysis work such as tracer applications, forensic, dating and use of other analytical techniques; They also will be able to explain the radioactive waste management aspects.

Course content: Nuclear gauges : Principle of nuclear gauges; different types : gamma, beta, neutron. Different modes of operation : transmission, backscatter. Applications of gauges for quality control and process control; safety aspects of nuclear gauges**.** Radiation sterilization, crosslinking in polymers, grafting, changing gemstone properties, isotope hydrology**.** Applications of Radioisotope tracers : ventilation, velocity in pipes, flow at phase changes, Leak detections, testing of gas filled cables, mixing efficiency : solid, gas slurries. Radiometric dating: carbon dating, uranium-lead dating, tritium dating, fission track dating: principles and applications**.** Analytical techniques : x ray fluorescence, gamma spectroscopy, activation analysis**.** Industrial radioactive waste management: Importance of radioactive waste, classification of radioactive waste; Radioactive waste treatment steps, Pretreatment methods, treatment methods. Radioactive waste management methods : decay delay, confine, dilute

Method of Evaluation: 70% end of semester examination, 10% in class presentation and 20% continues assignments

Suggested References: Rainey, S.V. Hogben, H.W. The Elements of Industrial Radiography, Association of Engineering and Shipbuilding Draughtsmen, 1956

http://slideplayer.com/slide/4508792/

IAEA bulletins

Course Code	NS 4907	No. of Credits	6
Course Name	INDUSTRIAL TRAINING	No. of lecture hours	0
		No. of Practical hours	180

Rationale: Industrial training allows the students to link between the theory and the technology.

Prerequisites : Level I and II Biology OR Chemistry OR Physics core courses; NS3017

Intended Learning Outcomes: At the end of this course the students will be able to apply the theatrical knowledge to make decisions in real situations.

Course Content : None

Method of Evaluation : 2 supervisors should be assigned, one from the relevant industry and the other one from the faculty to evaluate the final report submitted at the end of industrial training.

Suggested References: Based on the research project

Course Code	NS 4908	No. of Credits	6
Course Name	INDUSTRY ORIENTED RESEARCH PROJECT	No. of lecture hours	0
		No. of Practical hours	180

Rationale: An Industrial based research project carried out based on industry environment enhance their ability to solve practical issues in an organization.

Prerequisites : Level I and II Biology OR Chemistry OR Physics core courses; NS3017

Intended Learning Outcomes: At the end of this course the students will be able to analyze industrial based scientific issues and apply their knowledge to bring solutions for them.

Course Content : None

Method of Evaluation : 2 supervisors should be assigned, one from the relevant industry and the other one from the faculty to evaluate the final report submitted at the end of the research work which was carried out in an industry.

Suggested References: Based on the research project

Course Code	NS 4029	No. of Credits	3
Course Name	Diagnostic Radiology II	No. of lecture hours	30
		No. of Practical hours	30

Rationale :

Prerequisites: NS3023 Diagnostic Radiology I

Intended Learning Outcomes:
At the end of this course, students will be able to describe the technical and scientific details of non-ionizing medical magnetic resonance and ultrasound devices and their use in diagnostic disease.

Course content: Non-ionizing radiation and their properties; Ultrasound imaging: properties of the ultrasound, interaction of ultrasonic waves with biological tissues, transducers, acoustic impedance, principles of ultrasonic measuring and imaging instrumentation, biological effects of ultrasound, artifacts, Doppler ultrasound, quality assurance tests on ultrasound imaging; Introduction to MR physics: the origin of the magnetic moment, definition of units used in MRI and the behavior of the magnetic moment in a magnetic field, chemical-shift; MRI instrumentation: the basic hardware elements of a MRI system, the construction and design of RF and gradient coils; Magnetic Resonance Imaging (MRI): principles of MRI, spatial localization techniques, relaxation times, imaging methods, reconstruction techniques, hazards, quality assurance, clinical applications of MRI, care of patient, technical parameters and considerations, scan techniques for specific anatomical areas, Specific clinical applications, artifacts, quality assurance tests on magnetic resonance imaging.

Method/s of evaluation: End of semester examination (70%) and Continuous assessment (30%).

Suggested reading:
MRI in Practice (Westbrook C and Kaut C)
The Essential Physics of Medical Imaging (Jerrold T Bushberg et al)
Handbook of MRI Technique (Westbrook C)

Course Code	NS 4005	No. of Credits	1
Course Name	Clinical Education	No. of lecture hours	0
		No. of Practical hours	30

Rationale:
The aim of this unit is to introduce students to a clinical environment.

Prerequisites: None

Intended Learning Outcomes: Students will be able to discuss the ethics, health law, and patient care relevant to clinical practice. They will be able to develop skills to work in a health care team.

Course content:
The students are placed in major hospitals where Nuclear Medical Imaging, Diagnostic Radiography and Radiotherapy are done.

Method/s of evaluation: Clinical writing report.

Suggested reading: Any book relevant to the topic. Use of Medical Dictionary is recommended.

Course Code	NS 4030	No. of Credits	3
Course Name	Nuclear Technology and Environment	No. of lecture hours	30
		No. of Practical hours	30

Rationale: Man made radioactive sources can affect the natural environment which should be continuously monitored for safety purposes. In addition Nuclear Techniques can be used to improve the polluted environment due to various human activities. This course unit is explain different nuclear techniques used to solve for environmental problems.

Prerequisites: NS 2004 Nuclear Technology in Sri Lanka

Intended Learning Outcome: At the end of this course the students will be able to discuss the uses of radiation solving environmental issues; discuss the advantages and disadvantages of nuclear techniques. They should be able to analyze the impact of radiation on the environment.

Course Content: Nuclear power advantages and disadvantages, environmental impact on nuclear weapons, nuclear waste disposal. Nuclear Analytical techniques in environmental monitoring: NAA,XRF,PIXE. Radiation processing of sewage sludge, biomass conversion, flue gases such a sulfur dioxide, nitrogen oxides, food irradiation. Radiation sources used for environmental applications

Methods of Evaluation: End of Semester examination (70%), practicals and in class assignment (30%)

Suggested References: International Atomic Energy Authority (IAEA) Bulletins

Course Code	NS 4033	No. of Credits	3
Course Name	Nuclear Medicine II	No. of lecture hours	45
		No. of Practical hours	0

Rationale:

Prerequisites: NS3120 Nuclear Medicine I

Intended Learning Outcome:

Course content: Using radio nuclides to evaluate the function of the following systems: musculoskeletal, respiratory, central nervous, endocrine, haematopoietic, cardiovascular, gastrointestinal, reticuloendothelial and genitourinary; Specialized aspects of nuclear medicine methodology in vivo non-imaging studies; Nuclear medicine methodology for pediatrics; Miscellaneous Imaging procedures: adrenal gland imaging, tumour imaging, thrombus detection, limphoscintigraphy, gastric emptying, gastrointestinal bleeding detection, inflammatory diseases, infection imaging, parathyroid imaging; The role of nuclear medicine in therapy; Therapeutic uses of radio pharmaceuticals: treatment of hyperthyroidism, treatment of thyroid cancer, treatment of bone pain.

Method/s of evaluation: End of semester examination (70%) and Continuous assessment (30%).

Suggested reading: The Image Processing Hand Book , John C Russ, (2000)
Hand Book of Medical Imaging , Processing and Analysis, Isac N Bankman , (2000)

Course Code	NS 4031	No. of Credits	2
Course Name	Human Physiology	No. of lecture hours	30
		No. of Practical hours	0

Rationale: This course unit is designed because of the fact that an excellent working knowledge of Physiology is critical to understanding Pathology, and diagnosis

Prerequisites: NS3010 Human anatomy

Intended Learning Outcomes: At the end of this course the students will be able to describe the fundamental mechanisms underlying normal function of cells, tissues, organs, and organ systems of the human body and explain the basic mechanisms of homeostasis by integrating the functions of cells, tissues, organs, and organ systems. They will be able to apply the knowledge of functional mechanisms and their regulation to explain the pathophysiology underlying common diseases.

Course content: Fundamental mechanisms that apply to all areas of body function: these include body fluid compartments, diffusion, osmosis, membrane transport, cell membrane physiology, and general principles of nerve and muscle function; Cardiovascular Physiology; Renal Physiology: maintenance of body fluid, electrolyte, and pH homeostasis, long-term regulation of blood pressure; Endocrine physiology: hormone receptors and the intracellular signaling mechanisms; Defense system.

Method/s of evaluation: End of semester examination (70%) and Continuous assessment (30%).

Suggested reading: Human Anatomy & Physiology, 9th edition, Elaine Marieb & Katja Hoehn
Medical Physiology Boron & Boulpaep

Course Code	NS 4006	**No. of Credits**	3
Course Name	Seminar and Essay	**No. of lecture hours**	0
		No. of Practical hours	90

Rationale:

Dependencies: None

Intended Learning Outcomes: At the end of this module, students will be able to perform a literature search and be able to explain how the theory of science is applied in medical setup. They will be able to present scientific material which they have reported and to respond to questions that may arise during presentations.

Course content: Seminar on a current application in Medical Radiation Science.

Method/s of evaluation: Report and a presentation.

Suggested reading: Any references relevant to the topic

Course Code	NS 4032	No. of Credits	3
Course Name	Radiotherapy Physics	**No. of lecture hours**	30
		No. of Practical hours	30

Rationale:

Prerequisites: NS2003 Fundamentals of Nuclear Science

Intended Learning Outcome: At the end of this course, the students will be able to describe the physics behind the different clinical radiotherapy treatment techniques and delivery. They will also be able to demonstrate the relevant instrumentation and principles of quality assurance and quality control checks applied to the radiotherapy equipments.

Course content: External beam radiotherapy equipment: superficial machines, orthovoltage machines, linear accelerators, machine using isotopes, simulators; Tumour localization and cross sectional information; Dose determination for external beams; Fixed source-axis distance techniques; Fixed source-surface distance techniques; Isodose charts; Dose normalization; Correction for inhomogeneities; Single-field treatment techniques; multiple-field treatment techniques; Dose prescription; Use of wedge filters, tissue compensation filters and bolus; patient immobilization devices; Target volume determination in clinical practice: gross tumour volume (GTV), clinical Target volume (CTV), planning target volume) PTV and relevant ICRU recommendations; Treatment planning: 2-D planning and 3D-conformal radiation therapy (3D-CRT) treatment planning; Treatment verification methods and dose delivery; Quality control of treatment planning systems; Modern technologies in radiation: IMRT/IGRT, total body irradiation (TBI), stereotactic radiosurgery (SRS), total skin electron irradiation (TSEI), particle therapy (protons, heavy ions); Introduction of a HDR Brachytherapy; Equipments for dosimetry and physical quality assurance (QA); Calibration of photon and electron beams with cavity ion chambers: determination of absorbed dose in free space and in water for photons and electron beams; Quality assurance protocols for brachytherapy and radiotherapy.

Method/s of evaluation: End of semester examination (70%), Continuous assessment (20%) and Report on a clinical visit to a radiotherapy treatment hospital (10%)

Suggested reading:
Radiation oncology physics: a handbook for teachers and students (Podgorsak FB)
The physics of radiation therapy (Khan FM)
Technical Basis of radiation therapy (Seymour H, James AP, Carlos AP and Philip P)

Course Code	NS 4007	No. of Credits	8
Course Name	Research Project	No. of lecture hours	0
		No. of Practical hours	240

Rationale: This course unit enables the students to have research exposure relevant to nuclear medical sciences.

Prerequisites: None

Intended Learning Outcomes: At the end of this research project, students will be able to perform a literature search, write a scientific report and produce a scientific presentation, work in the context of a research group.

Course content: The development of introductory research skills that enable students to participate in research within their and complementary professions, and participate successfully in higher degree research courses, is one of the aims of the undergraduate course. The project is designed to allow students to research a topic of essentially their choosing. The project need related to nuclear medical science practice or procedure and should be approved by the Head/ Department of Nuclear Science.

Method/s of evaluation: Written Report (dissertation) 70%, Oral Presentation 30%

Suggested reading: Books relevant to the research topic

Course Code	NS 4108	No. of Credits	2
Course Name	Clinical Practice I	No. of lecture hours	0
		No. of Practical hours	60

Rationale :

Prerequisites: NS4005 Clinical Education

Intended Learning Outcomes: At the end of this practical session, students will be able to apply the theoretical knowledge on Nuclear Medicine procedures in real life situations and illustrate the nuclear medicinal procedures

Course content: This course provides the student with the opportunity to experience, apply, and develop, generic health science and profession specific knowledge, skills and attitudes in the clinical setting. The students will be placed in a hospital where nuclear medicine is practiced.

Method/s of evaluation: Clinical written reports and the supervisor reports

Suggested reading: None

Course Code	NS 4109	**No. of Credits**	2
Course Name	Clinical Practice II	**No. of lecture hours**	0
		No. of Practical hours	60

Rationale:

Prerequisites: NS4005 Clinical Education

Intended Learning Outcomes: At the end of this practical session, students will be able to apply the theoretical knowledge of MRI and CT in real life situations; compare and contrast the differences in practicing Nuclear Medicine procedures and Radiography procedures

Course content: Same as clinical practice I. The students will be placed in another hospital or another department of the same hospital where CT, Radiography, MRI and fluoroscopy are used.

Method/s of evaluation: Clinical written reports and the supervisor reports

Suggested reading: None