Course Structure for the Program Post M.Sc. Diploma in Medical Physics

Academic Year: 2026-27

Department of Physics
Adamas University

Distribution of Papers Semester-wise:

Semester – I					
Type of Course	**Paper Name**	**Paper Code**	**No of Papers**	**Credit**	**L-T-P**
Core (Theory I)	RADIATION PHYSICS & RADIATION GENERATORS	PHY21620	1	4	4-0-0
Core (Theory II)	APPLIED MATHEMATICS AND MEDICAL STATISTICS	PHY21621	1	4	4-0-0
Core (Theory III)	RADIATION DETECTION MEASUREMENTS & INSTRUMENTATION	PHY21622	1	4	4-0-0
Core (Theory IV)	DIAGNOSTIC RADIOLOGY AND NONIONIZING RADIATION PHYSICS	PHY21623	1	3	3-0-0
Core (Theory V)	STANDARDIZATION OF RADIATION BEAMS AND SOURCES	PHY21624	1	2	2-0-0
Elective I	COMPUTATIONAL MEDICAL PHYSICS & ARTIFICIAL INTELLIGENCE / CONCEPT OF HEALTH TECHNOLOGY	PHY21625/ PHY21626	1	3	3-0-0
Core (Lab)	RADIATION PHYSICS LAB	PHY22627	1	2	0-0-6
	Total		**6 +1 = 7**	**22**	

Semester II					
Type of Course	**Paper Name**	**Paper Code**	**No of Papers**	**Credit**	**L-T-P**
Core (Theory I)	ANATOMY PHYSIOLOGY PATHOLOGY AND CLINICAL ASPECTS OF MEDICAL IMAGING AND THERAPY	PHY21628	1	3	3-0-0
Core (Theory II)	RADIATION BIOLOGY	PHY21629	1	3	3-0-0
Core (Theory III)	RADIATION DOSIMETRY	PHY21630	1	3	3-0-0
Core (Theory IV)	NUCLEAR MEDICINE AND INTERNAL DOSIMETRY	PHY21631	1	3	3-0-0
Core (Theory IV)	RADIATION THERAPY AND TREATMENT PLANNING	PHY21632	1	5	5-0-0
Core (Theory IV)	RADIATION SAFETY AND REGULATORY ASPECTS	PHY21633	1	5	5-0-0
Core (Lab)	CLINICAL RADIATION PHYSICS LAB	PHY22634	1	2	0-0-6
	FIELD TRAINING (6 weeks)	PHY24635	1	5	
	SEMINAR	PHY25636	1	1	
	Total		**6+1+2= 9**	**24+6=30**	

Second year

Residency: 32 Credits

TOTAL CREDIT: (22 + 30 + 32) = 84

DETAILED SYLLABUS OF
Post M.Sc. Diploma in MEDICAL PHYSICS
Program

Academic Year: 2026-27

DEPARTMENT OF PHYSICS
ADAMAS UNIVERSITY

SEMESTER I

PHY21620: RADIATION PHYSICS & RADIATION GENERATORS (Credit 4, 60 Lectures)

Course Outcome:

1. Refresh the knowledge of nuclear and radiation physics
2. Understand the concept of interaction of radiation with matter
3. Understand the mechanism and technology of various particle accelerators used in medicine and research
4. Understand the mechanism of X-ray generation and technology of X-ray equipment used in medicine, and research.

Course Details:

UNIT I: Nuclear Physics

Nucleus-Scattering experiment, properties, Discovery of neutrons, Experimental determination of size of the nucleus etc. Nuclear forces- properties, spin dependence, charge independence etc. Liquid drop model-Binding energy, semi-empirical mass formula, mass parabola, application in stability of neutron star Radioactivity – α decay - general properties of α particles, spectrum, Gamow's theory, Geiger-Nuttal law

Beta decay- general properties, Fermi theory, spectrum, fall of parity, neutrinos – Positron emission- Electron capture - gamma emission - Internal conversion Laws of radioactivity - Laws of successive transformations and application in dating - Natural radioactive series - Radioactive equilibrium - Nuclear isomerism – Nuclear reactions - Artificial radioactivity – Elementary ideas of fission and its application in nuclear reactors and nuclear weapons – Fusion- energy production in the sun, production of elements in the universe-big bang and stellar nucleosynthesis.

UNIT II: Interaction of Radiation with Matter (related to Radiology)

Interaction of electromagnetic radiation with matter Exponential attenuation - Thomson scattering - Photoelectric and Compton process and energy absorption - Pair production - Attenuation and mass energy absorption coefficients - Relative importance of various processes. Interaction of charged particles with matter - Classical theory of inelastic collisions with atomic electrons - Energy loss per ion pair by primary and secondary ionization - Dependence of collision energy losses on the physical and chemical state of the absorber - Cerenkov radiation - Electron absorption process – Scattering Excitation and Ionization - Radiative collision - Bremmstrahlung - Range energy relation - Continuous slowing down approximation (CSDA) - straight ahead approximation and detour factors - transmission and depth dependence methods for determination of particle penetration - empirical relations between range and energy - Back scattering.

Passage of heavy charged particles through matter - Energy loss by collision - Range energy relation – Bragg curve - Specific ionization - Stopping Power - Bethe Bloch

Formula. Interaction of neutrons with matter - scattering - capture - Neutron induced nuclear reactions.

UNIT III: X-ray Generators

Discovery - Production - Properties of X-rays - Characteristics and continuous spectra - Design of hot cathode X-ray tube - Basic requirements of medical diagnostic, therapeutic and industrial radiographic tubes - Rotating anode tubes - Hooded anode tubes - Industrial X-ray tubes - X-ray tubes for crystallography – Rating of tubes - Safety devices in X-ray tubes – Ray proof and shock proof tubes - Insulation and cooling of X-ray tubes - Mobile and dental units - Faults in X-ray tubes - Limitations on loading. Electric Accessories for X-ray tubes - Filament and high voltage transformers - High voltage circuits – Halfwave and full-wave rectifiers - Condenser discharge apparatus - Three phase apparatus - Voltage doubling circuits - Current and voltage stabilisers - Automatic exposure control - Automatic Brightness Control- Measuring instruments - measurement of kV and mA - timers - Control Panels - Complete X-ray circuit - Image intensifiers and closed circuit TV systems - Modern Trends.

UNIT IV: Accelerator Physics

Historical development of particle accelerators; basic principles of charged particle acceleration; classification of accelerators as electrostatic, circular, and linear; relativistic effects in accelerator physics; fundamental beam dynamics including transverse and longitudinal motion, emittance, and phase space.

Principle and operation of the cyclotron and its limitation due to relativistic mass increase; concepts of the synchrocyclotron and the azimuthally varying field (AVF) cyclotron; Principle of electron linear acceleration and design of accelerating structures; traveling-wave and standing-wave configurations in electron LINACs; RF cavities as accelerating resonators, and waveguides for RF power transmission and beam acceleration; Particle sources including ion sources for protons and heavy ions and electron guns of thermionic and photocathode type with their injection systems and beam characteristics; RF power generation using klystrons, magnetrons, and solid-state amplifiers; Principles of synchrotron and synchro-cyclotron acceleration; beam extraction methods such as electrostatic deflectors and magnetic kickers; systems for energy variation and selection; magnet systems in high-energy accelerators including dipoles, quadrupoles, and superconducting magnets; beam optics, transport lines, scanning magnets, and beamline design; and engineering aspects of vacuum systems required for stable accelerator operation. Medical LINAC and its applications. Accelerator facilities in India.

Textbooks/ References:

1. K.S. Krane. Introductory Nuclear Physics, 2008.

2. J.S. Lilley, Nuclear Physics: Principles and Applications, 2013.
3. R. Eisberg and R. Resnick. Quantum Physics of Atoms, Molecules, Solids, Nuclei and Particles, 2014.
4. J. E. Turner. Atoms, Radiation, and Radiation Protection, 2022.
5. A. Beiser, S. Mahajan, S. Rai Choudhury. Concept of Modern Physics, 2020.
6. Tatjana Jevremovic. Nuclear Principles in Engineering, 2009.
7. J. T. Bushberg, J. A. Seibert, E. M. Leidholdt, J. M. Boone. The Essential Physics of Medical Imaging, 2021.
8. IAEA. Diagnostic Radiology Physics: A Handbook for Teachers and Students, 2014. 9. Rolf Behling. Modern Diagnostic X-ray Sources, 2021. 10. Wangler T.P. RF Linear Accelerators, 2008.

PHY21621: APPLIED MATHEMATICS AND MEDICAL STATISTICS (4 Credits, 60 Lectures)

Course Outcome:

1. Understand the theory of probability, counting and medical statistics and errors with special reference to radiological/medical physics
2. Application of Numerical methods and Monte Carlo simulation in radiation physics
3. To strengthen the knowledge and skill in use of computational techniques and tools for solving the practical problems of radiological sciences

Course Details:

UNIT I: Probability, Statistics and Errors

Probability - addition and multiplication laws of probability, conditional probability, population, variates, collection, tabulation and graphical representation of data. Basic ideas of statistical distributions frequency distributions, averages or measures of central tendency, arithmetic mean, properties of arithmetic mean, median, mode, geometric mean, harmonic mean, dispersion, standard deviation, root mean square deviation, standard error and variance, moments, skewness and kurtosis

Application to radiation detection - uncertainty calculations, error propagation, time distribution between background and sample, minimum detectable limit

Binomial distribution, Poisson distribution, Gaussian distribution, exponential distribution - additive property of normal variates, confidence limits, Bivariate distribution, Correlation and Regression, Chi- Square distribution, t-distribution, F-distribution, null hypothesis & alternate hypothesis with examples.

UNIT II: Numerical Methods

Why numerical methods, accuracy and errors on calculations - round-off error, evaluation of formulae. Iteration for Solving x = g(x), Initial Approximation and Convergence Criteria, Newton-Raphson Method. Taylor series, approximating the derivation, numerical differentiation formulas. Introduction to numerical quadrature, Trapezoidal rule, Simpson's rule, Simpson’s Three-Eighth rule, Boole rule, Weddle rule. Initial value problems, Picard’s method, Taylor’s method, Euler’s method, the modified Euler’s method, Runge- Kutta method.

Monte Carlo: Random variables, discrete random variables, continuous random variables, probability density function, discrete probability density function, continuous probability distributions, cumulative distribution function, accuracy and precision, law of large number, central limit theorem, random numbers and their generation, tests for randomness, inversion random sampling technique including worked examples, integration of simple 1-D integrals including worked examples.

UNIT III: Counting and Statistics in Clinical applications

Statistics of nuclear counting - Application of Poisson's statistics - Goodness-of-fit tests - Lexie's divergence coefficients Pearson's chi-square test and its extension - Random fluctuations Evaluation of equipment performance - Signal-to-noise ratio - Selection of operating voltage - Preset of rate meters and recorders - Efficiency and sensitivity of radiation detectors - Statistical aspects of gamma ray and beta ray counting - Special considerations in gas counting and counting with proportional counters - Statistical accuracy in double isotope technique.

Medical data, descriptive statistics – measure of central tendency - mean, median mode and percentile, Measure of dispersion – range, quartile deviation, standard deviation and coefficient of variation, Sampling techniques and sample size determination, Testing of hypothesis, Test of significance – level of significance, Calculation and interpretation of p value – statistical significance, correlation and regression analysis, sample size calculation, parametric and nonparametric tests. Sampling and sampling distributions - confidence intervals. Clinical study designs and clinical trials. Hypothesis testing and errors. Regression analysis.

Textbooks/References:

1. J. D. Hoffman, S. Frankel. Numerical Methods for Engineers and Scientists, 2001.
2. M.T. Vaughn. Introduction to Mathematical Physics, 2007.
3. Band W. Introduction to Mathematical Physics, 2010.
4. R.Y. Rubinstein and D.P. Kroese. Simulation and the Monte Carlo Method, 2016.
5. Oleg N. Vassiliev, Monte Carlo Methods for Radiation Transport, 2017.
6. W. L. Dunn and J. K. S. Shultis. Exploring Monte Carlo Methods, 2012.
7. M. H. Kalos and P. A. Whitlock. Monte Carlo Methods, 2008.
8. E. B. Podgorsak, Radiation Physics for medical physicists. 2006.

PHY21622: RADIATION DETECTION MEASUREMENTS & INSTRUMENTATION (4 credits, 60 Lectures)

Course Outcome:

1. Understanding the principles of radiation detection and measurement
2. instrumentation
3. Working and operational principle of radiation detectors used for various types
4. of radiation
5. Electronics involved in various radiation detectors and its instrumentation
6. Understanding and use of various radiation monitoring instruments

Course Details:

UNIT I: RADIATION DETECTORS

Principles of radiation detection and general properties of detectors: Principles of radiation detection, modes of detector operation, Pulse height spectra, Counting curves and plateaus, Energy resolution, Detector efficiency, Dead time, detector window.

Gas filled radiation detectors: Various regions of operation of gas filled detectors - Ionization chambers, Proportional counters and GM counters - basic detection mechanism, types of radiation detected, mode of operation, different variants of detectors (e.g. sealed, flow type, high pressure, multi- wire, position sensitive), Types of instruments which uses gas filled detectors – radiation dosimeters, survey meters, contamination monitors - Cylindrical, plane parallel, spherical and well-type ionization chambers, Extrapolation chamber, Scintillation (organic/inorganic) and semiconductor detectors: Advantages of scintillation detectors, properties of ideal scintillator, basic electronic blocks in scintillation detector setup.

Radiation detection mechanism of organic and in-organic scintillators, types of scintillators for various applications. Photon detection devices - PMT, Photo diodes. Principles of detection mechanism in semiconductor detectors and its application for gamma and alpha spectrometry, Diode and MOSFET dosimeters Neutron detectors: Neutron detection by activation, Fast Neutron detection Nuclear track detectors, Self-powered neutron detectors (SPND), BF3, He3, Bubble detectors. New types of detectors: Radiation detection by direct ion storage (DIS), OSL, Diamond, Gel dosimeter, Radiation litmus, Radiographic and radiochromic films. Micro dosimeters / Tissue Equivalent Proportional Counters (TEPCs), Fast response detectors for used in ultra-high dose rate (FLASH)- Plastic Scintillators & Cherenkov Detectors, Faraday Cup for absolute beam current measurement of electrons, protons, and heavy ions.

UNIT II: NUCLEAR ELECTRONICS

Analog electronics: Operational amplifiers (ideal characteristics, different operational circuits - inverting, non-inverting amplifiers, adder, sub-tractor, integrator. Interfacing concepts: Fundamental concepts of interfacing an instrument to PC/Computer, interfacing methods. Power Supply: Low voltage and high voltage power supplies for radiation instruments, Generation of low and high voltages and their specifications, Types of batteries and their specifications. Basic building blocks used in nuclear measurements: Pre amplifiers, types of preamplifiers and selection of proper preamplifier for specific detector, Types of amplifier - linear, bias amplifier, log amplifier, shaping amplifier, Counters, rate meters - diode pump and IC rate meters, SCA, MCA, Coincidence and anti-coincidence circuit blocks.

UNIT III: Radiation Measuring and monitoring devices

Radiation Monitoring Instruments: Dosimeters based on condenser chamber, quartz fiber electrometer, dosimeter based on current measurement, secondary standard dosimeter, Farmer dosimeter, beam therapy dosimeter, clinical dosimeter, isotope calibrator, Radiation field analyzer (RFA). Instruments for personal monitoring: TLD Reader for medical & research applications, TLD Badge Reader, OSLD badge reader, Image analyser for track counting, Densitometer, Electronic pocket dosimeter.

Area monitoring instruments: Portable and fixed area monitors, fixed area monitors, betagamma zone monitor, Survey meters, wide range survey instrument, teletector. Contamination monitoring instruments: portable contamination monitor, hand &foot surface contamination monitor, portal monitor, laundry monitor, floor monitor. Method of estimating activity present inside the body - whole body counter. Neutron monitoring instruments - REM counters.

Unit-IV: Principles of Personnel Monitoring

Design aspects of x-ray, gamma ray and beta TLD personnel monitoring badge used in India – TLD Badge Reader - Occupational dose assessment procedures – audit of personnel monitoring laboratories - national occupational dose registry system. Occupational extremity dosimetry – design and characteristics of extremity dose monitors, Eye lens dose measurements – design and characteristics of the eye lens dosimeters. Neutron personnel monitoring in India – CR39 personnel monitoring badge – calibration and dose assessment procedure. Global trends in personnel monitoring and Newer developments in personnel monitoring.

Textbooks/References:

1. P. Horowitz, W. Hill: Art of Electronics. 2015.
2. Serigo Franco. Design with Operational Amplifiers & Analog Integrated Circuits. 2017.
3. Texas Instruments Application Report SBOA092A: Handbook of Operational Amplifier Applications, 2016.
4. N. Widmer, G. Moss, R. Tocci. Digital Systems - Principles and Applications, 2022.
5. M. M. Mano, M. D. Ciletti. Digital Design-With an Introduction to the Verilog HDL, VHDL, and System Verilog, 2018.
6. IAEATECDOC-363. Selected topics in Nuclear Electronics, 1986.

7. Glenn F Knoll. Radiation Detection & Measurement, 2010.
8. A. Martin, S. Harbison, K. Beach, P. Cole. An Introduction to Radiation Protection, 2019.
9. J. E. Turner. Atoms, Radiation, and Radiation Protection, 2007.
10. N. Tsoulfanidis, S. Landsberger. Measurement and Detection of Radiation, 2021.

PHY21623: DIAGNOSTIC RADIOLOGY AND NONIONIZING RADIATION PHYSICS (3 Credits, 45 Lectures)

Course Outcome:

1. Understanding the process of X-ray based imaging using both conventional and advanced imaging systems such as digital X-ray imaging systems (radiography and mammography), dental imaging systems and computed tomography (CT) scanners
2. Concepts of magnetic resonance imaging (MRI) and ultrasound imaging in diagnosis of various types of cancer
3. Understanding of non-ionizing radiation physics

Course Details:

Unit-I: Principles and Techniques Conventional X-ray Imaging

Physical principle of diagnostic radiology: Interactions of X-rays with human body, differential transmission of x-ray beam, spatial image formation, visualization of spatial image, limitations of projection imaging technique Viz. superimposition of overlying structures and scatter, application of contrast media and projections at different angles to overcome superimposition of overlying structures.

Radiography techniques: Prime factors (kVp, mAs and SID/SFD), influence of prime factors on image quality, selection criteria of prime factors for different types of imaging, different type of projection and slices selected for imaging, objectives of radio-diagnosis, patient dose Vs image quality.

Filters: inherent and added filters, purpose of added filters, beryllium filter, filters used for shaping X- ray spectrum (K-edge filters: holmium, gadolinium, molybdenum).

Scatter reduction: Factors influencing scatter radiation, objectives of scatter reduction, contrast reduction factor, scatter reduction methods; beam restrictors (diaphragms, cones/cylinders & collimators), grids (grid function, different types of stationary grids, grid performance evaluation parameters, moving grids, artifacts caused by grids, grid selection criteria), air gap technique.

Intensifying screens: Function of intensifying screens, screen function evaluation parameters, emission spectra and screen film matching, conventional screens Vs rare earth screens Radiographic Film: Components of radiographic film, physical principle of image formation on film, double and single emulsion film, sensitometeric parameters of film (density, speed, latitude etc.), QA of film developer.

Image quality parameters; sources of un-sharpness, reduction of un-sharpness, factors influencing radiographic contrast, resolution, factors influencing resolution, evaluation of resolution (point spread function (PSF), line spread function (LSF), edge spread function (ESF), modulation transfer function (MTF)), focal spot size evaluation.

QA of conventional diagnostic X-ray equipment: Purpose of QA, QA protocols, QA a test method for performance evaluation of x-ray diagnostic equipment.

Unit-II: Digital Imaging, Interventional Radiology and Mammography

Digital x-ray imaging: Storage phosphor (computed radiography-CR) and DR systems, digital detector technology-indirect conversion digital detectors and direct conversion digital detectors.

Fluoroscopy including interventional procedures: Equipments, fluoroscopic imaging chain components, detector systems, automatic exposure rate control, mode of operation, image quality and radiation dose in fluoroscopy.

Mammography: Mammography equipment, screen-film mammography, digital mammography detectors, digital detector technology-indirect conversion digital detectors and direct conversion digital detectors, digital breast tomosynthesis and three dimensional imaging, QA of mammography equipments.

Unit – III: Computed Tomography

Principles of X-ray Computed Tomography, CT Generations, Reconstruction Algorithms, CT Equipment and Instrumentation: X-ray tube Design, Filtration, Collimation, Detectors. CT Numbers, Modes of CT Acquisition, Cardiac CT, Dual Energy CT, CT Angiography, CT Dosimetry, Image Quality Assurance tests for CT, CT Image Artefacts. Images in the Fourier Domain, Object Segmentation – Thresholding, K-means and Region Growing, Filtering: Edge Enhancement and Smoothing Filters, Edge Detection, 2D Morphological Operators. Image Registration: Rigid and Non-Rigid Techniques, Affine And Non-Affine Methods, Applications In Multi-Modality Imaging.

Unit – IV: Non-ionizing radiation Physics and Imaging

Sources of non-ionizing radiation - their physical properties. Various types of optical radiations - UV, Visible, FTIR, Raman. IR Sources - IR Sensors for Medical Applications (e.g., thermal imaging, non-contact temperature sensing). First law of photochemistry - Law of reciprocity - Electrical Impedance and Biological Impedance - Principle and theory of thermography - Applications. Safety in use of non-ionizing radiation sources.

Magnetic Resonance Imaging (MRI) : Introduction-overview-basic concepts of MRI and historical perspective; Spin physics: nuclear spin, interactions with applied magnetic field, RF excitation, FID, magnetic resonance, Larmor condition; Basic Sequence: T1, T2, T2* relaxation, Bloch equations, Spin echo, Saturation and recovery, inverse recovery; Imaging principles: Magnetic field gradients, Gradient echo, Contrast to noise ratio, Diffusion imaging; MRI techniques: T1/T2/T2* /PD weighting, Diffusion/Perfusion weighting, Functional MRI; Imaging Considerations: SNR, Image quality, Artifacts, Inhomogeneities, Susceptibility, Contrast agents, Phase contrast, Chemical shift. Gradient eddy current, respiratory motions, voluntary motion, water/fat separation; MRI Machine:

MRI system components, Scanner magnet and coils, gradient coils, Bo homogeneity and shimming, detector design, resonance circuit, MR Safety: RF safety, SAR, Power dissipation, tissue heating, magnetic field shielding; Advance applications: Cardio-vascular MRI, MR angiography.

Ultrasound Imaging: Interaction of sound waves with body tissues, production of ultrasound - transducers – acoustic coupling- image formation - modes of image display - colour Doppler.

Textbooks/References:

1. Carolyn A. MacDonald. An Introduction to X-Ray Physics, Optics, and Applications, 2017.
2. E. Bezak, A.H. Beddoe, L.G. Marcu, M. Ebert and R. Price. Johns and Cunningham's The Physics of Radiology, 2021 (5th Edition).
3. IAEA. Diagnostic Radiology Physics: A Handbook for Teachers and Students, 2014 (http://www-pub.iaea.org/books/IAEABooks/8841/Diagnostic-Radiology-Physics)
4. J. T. Bushberg, J.A. Seibert, E. M. Leidholdt Jr., J. M. Boone. The Essential Physics of Medical Imaging, 2020 (4th Edition).
5. W. R. Hendee, E.R. Ritenour. Medical Imaging Physics, 2002 (4th Edition).
6. S. C. Bushong, and G. Clarke. Magnetic Resonance Imaging, 2014 (4th Edition).
7. R. W. Brown, Y. Chung N. Cheng, E.M. Haacke, M. R. Thompson, R. Venkatesan. Magnetic Resonance Imaging: Physical Principles and Sequence Design, 2014.

PHY21624: STANDARDIZATION OF RADIATION BEAMS AND SOURCES (2 Credits, 30 Lectures)

Course Outcome:

1. Explain the principles, theories, and standards involved in radiation beam and source standardization for X-ray, gamma ray, and brachytherapy dosimetry.
2. Describe neutron and radionuclide standards, neutron dosimetry techniques, and methods used for radioactivity measurement and source standardization.
3. Apply standard calibration procedures for external beam and brachytherapy dosimeters using ionization chambers and reference protocols.
4. Demonstrate the calibration, quality control, and performance evaluation of nuclear medicine dose calibrators and radiation survey instruments.

Course Details:

Unit-I: Radiological Standards for X-rays and Gamma rays

Radiological Standards– Primary Standard, Secondary Standard, Tertiary Standard, National Standard, Reference Standard, Imperfections in measurement, Uncertainty in measurement, Traceability, Properties of dosimeters – Accuracy and precision - Linearity – Dose rate dependence – Energy dependence - directional dependence, Ionometric standards - Charged Particle Equilibrium (CPE), Free Air Ion Chamber (FAIC), Design of parallel plate FAIC, Measurement of Air Kerma/ Exposure. Limitations of FAIC. Bragg-Gray cavity theory, Mathematical expression describing Bragg-Gray principle and its derivation. Burlin and Spencer Attix Cavity theories. Transient Charged Particle Equilibrium (TCPE), Concept of D_{gas}, Cavity ion chambers, Derivation of an expression for sensitivity of a cavity ion chamber.

General definition of calibration factor - N_X, N_K, $N_{D,air}$, $N_{D,W}$. Various steps to arrive at the expression for D_W starting from N_X. $K_{Q,Q0}$ and K_Q, Derivation of an expression for $K_{Q,Q0}$. Standards for Beam Therapy: Description in detail about the Air Kerma standards for Co-60 beams – design features, characteristics, maintenance of the standards. Absorbed dose to water standards – Ionometric standards, Calorimetric standards, Chemical standards, Intercomparison of standards. Standards for Brachytherapy: HDR ^{192}Ir and ^{60}Co sources, Standards for low energy photon emitting brachytherapy sources (^{125}I and ^{103}Pd), Standards for beta sources.

Unit – II: Neutron and Radionuclide Standards

Classification of neutrons, neutron sources, Activation method. Neutron spectrometry, threshold detectors, scintillation detectors & multispheres, Neutron dosimetry, Neutron survey meters – calibration - neutron field around medical accelerators (LINAC, Proton accelerator and medical cyclotrons). Neutron standards - primary standards, secondary standards, Neutron yield and fluence rate measurements, Manganese sulphate bath system, precision long counter, Tissue Equivalent Proportional Counter (TEPC), Methods of measurement of radioactivity - Defined solid angle and 4π counting - Beta gamma coincidence counting. Standardization of beta emitters and electron capture nuclides with proportional, GM and scintillation counters, Standardization of gamma emitters with scintillation spectrometers - Ionization chamber methods – Extrapolation chamber - Routine sample measurements,Liquid counter – Windowless counting of liquid samples – Scintillation counting methods for alpha, beta and gamma emitter – Reentrant ionization chamber methods - Methods using (n, γ) and (n, p) reactions - Determination of yield of neutron sources - Space integration methods - Solid state detectors.

Unit – III: Calibration of Beam and Brachytherapy Dosimeters

Calibration procedure for cylindrical and parallel plate ionization chambers: Thimble Ionization chamber dosimetry systems – Cavity ionization chambers (thimble type and plane-parallel) and electrometers, Beam quality specification, Absorbed dose to water calibration coefficient ($N_{D,W}$), beam quality correction factor $K_{Q,Q0}$, Determination of absorbed dose to water under reference condition from telecobalt machine as per IAEA TRS-398, Correction for influence quantities, Procedure for determination of calibration coefficient of hospital ionization chamber, Procedure for cross calibration. Calibration Procedure for Well Type Ionization Chamber: Specification of brachytherapy source strength- Reference Air Kerma Rate - Air Kerma Strength - Standards for HDR ^{192}Ir and ^{60}Co sources; Well type ionization chambers - reference sources – maximum response point of the well type chamber – source strength measurement using well type ionization chamber (IAEA TECDOC 1274) –correction for influence quantities - procedure for determination of calibration coefficient of hospital well type chamber.

Unit – IV: Calibration of NM Dose Calibrators and Radiation Survey meters

Calibration of Nuclear Medicine Dose Calibrators - Design features of nuclear medicine dose calibrators - performance characteristics – linearity, reproducibility, stability in response - calibration process for NM dose calibrators – estimation of uncertainty – quality control and maintenance of dose calibrators.

Calibration of Radiation Protection Instruments: Fundamental concepts in calibration of radiation survey meters, Basic requirements for calibration, Various parameters checked during calibration, Selection of radioactive sources and source strength for calibration check – details of applicable standard.

Textbooks/References:

1. Joseph Magill and Jean Galy. Radioactivity Radionuclides and Radiation, 2005.
2. IAEA TRS 374, Calibration of Dosimeters used in Radiation Therapy, 1994.
3. P. Andreo, D.T. Burns, A.E. Nahum, J. Seuntjens, F.H. Attix. Fundamentals of Ionizing Radiation Dosimetry, 2017.
4. F. H. Attix. Introduction to Radiological Physics and Radiation Dosimetry, 2004.
5. Karl-Heinrich Beckurts, Karl Wirtz, Neutron Physics, 2013.

PHY21625 (Elective): COMPUTATIONAL MEDICAL PHYSICS AND ARTIFICIAL INTELLIGENCE (3 credits, 45 Lectures)

Course Outcome:

1. Utilize MATLAB and related computational tools for medical image processing, visualization, and basic machine learning applications.
2. Develop Python programs for scientific computing, data analysis, visualization, and file handling using standard libraries and packages.
3. Explain fundamental concepts of artificial intelligence, statistical modeling, and performance evaluation techniques used in predictive analytics.
4. Apply machine learning and deep learning techniques for data-driven problem solving, model validation, and AI-based healthcare applications.

Course Details

Unit -I: Computational Packages

Familiarization with mathematical packages such as MATLAB, Mathematica. MATLAB - environment, data types, operators, flow control, functions, I/O, array manipulation – Executing MATLAB programs, scripts, functions. Data reading, manipulation, display & plotting in MATLAB.

DICOM file functions in MATLAB: reading, displaying medical images, processing & analysis Machine learning and fuzzy logic in MATLAB context

MATLAB lab sessions – read DICOM image, process and display, simple ML/fuzzy logic demo

Unit-II: Python programming

Fundamentals of Python; Basic operators in Python; Working with Data - Data Types (Numeric, String, Set, List, Tuple, Dictionary); Operators in python; Python Keywords and Identifiers; Python program flow - If statement, Else statements, Range statement, While loop, For loop, Break, Pass, Continue etc.; Object and class; Python user defined and built-in Functions; Python Modules – Import statement and built-in; File manipulation – Open, close, write, read; Python arrays; Python packages for data science – Numpy and Matplotlib (in depth) - for data analysis and visualization; Handling of excel files using python library.

Unit-III: Basics of Artificial Intelligence

Historical background pertaining to the development of AI; Logistic regression for predictive modeling -definition and interpretation of the logistic and logit function, Problem, data, model, fit, and evaluation for logistic regression; Regression, classification and decision boundary definition - difference between regression and classification, converting problem between problem types, interpretation of output of model; Receiver operating characteristic (ROC) analyses - basic concept and interpretation, True positive, true negative, false positive, false negative, Type I and Type II errors, sensitivity and specificity, area under the curve (AUC)); Co-variance, correlation, regression, R2 – definitions, interpretations, analysis

Unit-IV: Machine Learning

Machine learning categories - supervised learning, unsupervised learning, reinforcement learning, hybrid learning categories, semi-supervised learning, self-supervised learning); Machine learning models and data analytics tools - Linear and logistic regression, neural networks, dimensionality reduction, support vector machine, decision trees and random forests, gradient boosting, K-means cluster analysis, metrics of evaluation);

Training and validation of machine learning models - mathematics of training, data augmentation, model selection and regularization, forward and backward stepwise predictor selection, ridge regression, LASSO, training methods, hyper parameter optimization, required sample size, bias-variance trade-off, over fitting, handling colinearity of predictors (Variance inflation factor, VIF), model validation, cross-validation (K-fold, leave-one-out), bootstrap, generalizability, external validation, calibration;

Deep learning - deep learning and neural networks, convolutional neural networks, recurrent neural networks, long short-term memory (LSTM) networks, transformer networks, transformer networks for text, vision and swin transformer networks for image processing, generative adversarial networks - synthetic images; transfer learning, domain adaptation, augmentation, metrics of evaluation (DICE)

Data management - data collection including data retrieval, data quality assessment, data curation, anonymization and de-identification, labeling and segmentation, harmonization, standardization, robustness, overview of AI-based clinical applications, AI-related ethical issues.

Textbooks/References:

1) J. D. Hoffman, S. Frankel. Numerical Methods for Engineers and Scientists, 2001.
2) M.T. Vaughn. Introduction to Mathematical Physics, 2007.
3) Band W. Introduction to Mathematical Physics, 2010.
4) Abhishek Singh. Essential Python for Machine Learning, 2023.
5) John Whittington. Python from the Very Beginning, 2023.
6) R.Y. Rubinstein and D.P. Kroese. Simulation and the Monte Carlo Method, 2016.
7) Oleg N. Vassiliev, Monte Carlo Methods for Radiation Transport, 2017.
8) W. L. Dunn and J. K. S. Shultis. Exploring Monte Carlo Methods, 2012.
9) M. H. Kalos and P. A. Whitlock. Monte Carlo Methods, 2008.
10) E. B. Podgorsak, Radiation Physics for medical physicists. 2006.

11) Gilmer Valdes, Lei Xing Artificial Intelligence in Radiation Oncology and Biomedical Physics 2023
12) Iori Sumida, Artificial Intelligence in Radiation Therapy, 2022
13) Issam El Naqa, Martin J. Murphy, Machine and Deep Learning in Oncology, Medical Physics and Radiology, 2022

PHY21626 (ELECTIVE): CONCEPT OF HEALTH TECHNOLOGY (3 Credits, 45 Hours)

Course Outcome:

1. Explain the concepts, scope, and institutional framework of Health Technology Assessment (HTA) in global and Indian healthcare systems.
2. Describe the principles, processes, quality standards, and stakeholder roles involved in conducting Health Technology Assessments.
3. Apply evidence synthesis and economic evaluation methods for assessing the clinical and cost effectiveness of health technologies.
4. Analyze ethical, legal, political, and policy aspects of HTA and evaluate its application in healthcare decision-making and resource allocation.

Course Details:

UNIT I: Introduction to Health Technology Assessment

Health Technology Assessment (HTA) – Scope of HTA in radiotherapy, nuclear medicine, diagnostics, and public health programs – Multidisciplinary nature of HTA: economics, epidemiology, ethics, policy – Historical evolution of HTA in USA, Canada, and Europe – Formation of INAHTA – Emergence of HTA in developing countries and Asia (HITAP, NICE International) – Importance and role of HTA in health systems – Evidence-based policy making – Priority setting and resource optimization – Role in Universal Health Coverage (UHC) – HTA in India: Institutional structure under DHR–ICMR – Role, objectives, and governance structure – HTAIn manual and its relevance – Conducive factors for HTA in Asia: Policy drivers, political commitment, capacity development

UNIT II: Principles and Framework of HTA

Core principles of HTA – Transparency, accountability, scientific rigor, stakeholder involvement – Relevance, timeliness, ethical soundness – HTA triangle: Clinical, Economic, Social/Ethical dimensions – Relationship with Evidence-Based Medicine (EBM) and Comparative Effectiveness Research (CER) – HTA process steps: Topic nomination and prioritization – Scoping and protocol development – Evidence synthesis and appraisal – Formulating recommendations – Policy uptake and monitoring – Quality assurance and evaluation: Internal and external review – HTAIn quality check guidance(ICMR) – Reporting standards: HTAIn template, PRISMA, CHEERS checklist – Stakeholder engagement: Policymakers, clinicians, economists, patient groups

UNIT III: Methodologies in Health Technology Assessment

Evidence synthesis – Systematic review – Meta-analysis – Critical appraisal – Databases: PubMed, Cochrane Library – Clinical effectiveness and safety evaluation: Clinical trial data – Observational studies – Surrogate and patient-relevant outcomes – Economic evaluation: Cost-Effectiveness Analysis (CEA) – ICER –Cost-Utility Analysis (CUA) – QALY, DALY – Cost-Benefit Analysis (CBA) – WTP – Cost-Minimization and Budget Impact

Analysis (BIA) – Modeling techniques: Decision tree – Markov models – Sensitivity analysis – Discounting – Uncertainty analysis – Reporting economic evidence – CHEERS checklist – Interpretation of incremental cost ratios

UNIT IV: Ethical, Legal, and Political Dimensions of HTA

Ethical dimensions – Patient autonomy – Beneficence – Justice – Non-maleficence – Balancing cost and access – Public acceptability and transparency – Legal framework: Health technology regulations – Approval processes (CDSCO, FDA, CE) – Intellectual property and patent laws – Data privacy, consent, and confidentiality – Political and institutional factors: Power structures – Policy priorities – Role of advocacy, media, political economy – Case discussions: Pricing of cancer drugs – Medical device regulation – Framework for managing conflicts of interest – Transparency protocols – Governance

UNIT V: HTA in Practice - Global and Indian Perspectives

HTAIn – India's HTA system – Institutional framework under Department of Health Research – Process: Topic selection – Assessment – Appraisal – Decision – Examples: Cost-effectiveness of dialysis, knee implants, screening programs – International HTA models: NICE (UK), CADTH (Canada), PBAC (Australia), HITAP (Thailand) – HTA and reimbursement systems in developed and developing nations – Integration with health policy: HTA for Universal Health Coverage – National Health Policy linkages – Public health technology prioritization – Future of HTA: Digital health – AI – Genomics – Personalized medicine – Challenges: Capacity building – Sustainability

References/Textbooks

1) Drummond MF, Sculpher MJ, Claxton K, Stoddart GL, Torrance GW. Methods for the Economic Evaluation of Health Care Programmes, 5th Edition, Oxford University Press, 2015.
2) Banta D, Jonsson E. History of Health Technology Assessment, Academic Press, 2009.
3) Oortwijn W, Jansen M, Baltussen R. Health Technology Assessment: Methods and Applications, Springer, 2020.
4) HTAIn Manual, Indian Council of Medical Research, 2018
5) Drummond MF et al., Key Principles for the Improved Conduct of HTA, International Journal of Technology Assessment in Health Care, 2008.
6) HTAIn Manual (ICMR, 2018)
7) Chootipongchaivat S. et al., Conducive Factors to the Development of HTA in Asia, 2016
8) WHO, Health Technology Assessment: A Global Overview
9) Luce BR et al., EBM, HTA, and CER: Clearing the Confusion, Milbank Quarterly, 2010
10) Kieslich K et al., Accounting for Technical, Ethical, and Political Factors in Priority Setting, Health Systems & Reform, 2016

PHY22627: RADIATION PHSICS LAB (2 Credits, Each experiment of 3 hours' duration)

Course Outcomes:

1. Understanding radiation physics and mathematical concepts applied to
2. radiological processes
3. Construction, characterisation and calibration of various radiation detectors
4. and use of spectrometry techniques in radiological physics
5. Preparation, standardisation and uses of chemical dosimeters
6. Preparation, standardisation and safety aspects of sealed/unsealed radiation

List of Experiments

1. Study of production and attenuation of bremsstrahlung radiation.

2. Study of absorption and backscattering of gamma rays in different materials

3. Measurement of range of beta particles by Feather analysis.

4. Study of backscattering of beta particles and its applications.

5. Study of voltage and current characteristics of an ionization chamber.

6. Calibration of thermoluminescent dosimeter (TLD) and its use in radiation dose measurements.

7. Determination of plateau and resolving time of a G.M. counter and its application in estimating the shelf-ratio and activity of a beta source.

8. Output measurement of a gamma chamber using Fricke dosimeter

9. Calibration of a TLD personnel monitoring badge and evaluation of personnel doses.

10. Calibration of Gamma ray spectrometer [NaI(Tl)] and identification of unknown sources using multichannel analyser.

11. Determination of HVT and TVT in different materials for gamma rays.

12. Calibration of neutron personnel monitoring badge and personnel dose evaluation

13. Study of REM counter response with distance and energy of neutron source.

14. Assessing Deep Learning based segmentation in radiotherapy applications.

15. Radiation protection survey around neutron irradiation installation/facility

16. Measurement of reference output of megavoltage x-rays generated by medical electron linear accelerator

20. Measurement of output of high energy electron beams used in radiotherapy

SEMESTER II

PHY21608: ANATOMY PHYSIOLOGY PATHOLOGY AND CLINICAL ASPECTS OF MEDICAL IMAGING AND THERAPY (3 Credits, 45 Lectures)

Course Outcome:

1. Knowledge of cell biology, human anatomy, physiology and tumour pathology
2. Understanding of mechanism and outcome of interaction of radiation with human cells and associated biological effects
3. Basic knowledge of clinical aspects of medical imaging and radiation oncology and detailed knowledge of biological basis of radiotherapy
4. Thorough knowledge of dose fractionation in radiotherapy and time-dose models.

Course Details:

Unit-I: Cell Biology

Cell physiology and biochemistry - Structure of the cell - Types of cells and tissue, their structures and functions - Organic constituents of cells - Carbohydrates, fats, proteins and nucleic acids - Enzymes and their functions - Functions of mitochondria, ribosomes, Golgi bodies and lysosomes -Cell metabolism-DNA as concepts of gene and gene action - Mitotic and meiotic cell division - Semi conservative DNA synthesis, Genetic variation Crossing over, mutation, chromosome segregation - Heredity and its mechanisms.

Unit-II: Anatomy, Physiology and Tumour Pathology

Anatomy and physiology as applied to radiodiagnosis and radiotherapy - General anatomical terminology – Levels of structural organization – Cells, tissues, organs, and systems – Overview of organ systems – Anatomical planes and positions – Skeletal system: bones and joints, classification and functions – Muscular system: types of muscles, mechanism of contraction – Cardiovascular system: structure and function of heart, major vessels, and blood circulation – Lymphatic system: lymph nodes, lymph circulation, and clinical significance. Respiratory system – anatomy of lungs, mechanism of respiration, regulation of breathing – Digestive system – structure and function of alimentary canal, liver, pancreas –Urinary system – structure of nephron, urine formation and regulation – Endocrine system – pituitary, thyroid, adrenal, and pancreas – Nervous system – brain, spinal cord, peripheral nerves, synaptic transmission, reflex arc – Reproductive system (male and female): structure, function, and hormones – Sensory organs: anatomy and physiology of eye and ear. Basics of human genetics – structure and function of DNA and RNA – gene expression, mutations, chromosomal aberrations, and genetic disorders – Oncogenes, tumour suppressor genes, and molecular basis of cancer – Cell cycle and mechanisms of carcinogenesis – Tumour pathology: types, classification, grading, and staging – Interpretation of clinico-pathological data - Differences between benign and malignant tumours – Mechanisms of tumour spread: local invasion, lymphatic and hematogenous metastasis – Tumour markers and biopsy interpretation – Genetic predisposition and familial cancers.

Unit-III: Radiographic Anatomy and Cross-sectional Imaging

Radiographic anatomy of head, thorax, abdomen, pelvis, and extremities – Identification of anatomical landmarks on plain X-rays, CT, MRI, and PET/CT images – Surface and sectional anatomy of organs and structures – Radiological interpretation of normal variations – Identification of major vessels, muscles, and bones in imaging modalities – Correlation between imaging anatomy and radiation treatment planning – Radiographic anatomy of CNS, skeletal, and visceral systems.

Unit- IV: Clinical Aspects of Radiation Oncology

Radiation Therapy, Surgery, Chemotherapy, Hormone Therapy, Immunotherapy & Radionuclide therapy, Benign and malignant disease, Methods of spread of malignant disease, Staging and grading systems, Treatment intent - Curative & Palliative, Cancer prevention and public education and Early detection & Screening. Site specific signs, symptoms, diagnosis and management: Head and Neck, Breast, Gynaecological, Gastro-Intestinal tract, Genito-Urinary, Lung & Thorax, Lymphomas & Leukemias & Other cancers including AIDS related cancers. Patient management on treatment - side effects related to radiation and dose - Acute & Late - Monitoring and common management of side effects - Information and communication. Professional aspects and role of medical physicists: General patient care - Principles of professional practice - Medical terminology - Research & Professional writing - Patient privacy - Ethical & cultural issues. Legal aspects - Confidentiality, Informed consent, Health and Safety.

Textbooks/References

1. Molecular Biology of the Cell, Bruce Alberts et al., Garland Science, 7th Edition, 2022.
2. Essential Cell Biology, Bruce Alberts et al., W.W. Norton & Garland Science, 6th Edition, 2023.
3. Cell and Molecular Biology, E. D. P. De Robertis and E. M. F. De Robertis, Lippincott Williams & Wilkins, 8th Edition, 2005.
4. Lewin’s Genes, Benjamin Lewin, Jones & Bartlett Learning, 12th Edition, 2017.
5. Biochemistry, Jeremy M. Berg, John Tymoczko and Lubert Stryer, W.H. Freeman, 9th Edition, 2019.
6. Guyton and Hall Textbook of Medical Physiology, John E. Hall, Elsevier, 15th Edition, 2021.
7. Ross and Wilson Anatomy and Physiology in Health and Illness, Anne Waugh and Allison Grant, Elsevier, 14th Edition, 2022.
8. Gray’s Anatomy for Students, Richard Drake, A. Wayne Vogl and Adam Mitchell, Elsevier, 5th Edition, 2023.
9. Clinically Oriented Anatomy, Keith L. Moore, Arthur F. Dalley and Anne M. R. Agur, Wolters Kluwer, 9th Edition, 2022.
10. Human Anatomy and Physiology, Elaine N. Marieb and Katja Hoehn, Pearson, 12th Edition, 2022.

11. Robbins and Cotran Pathologic Basis of Disease, Vinay Kumar, Abul K. Abbas and Jon C. Aster, Elsevier, 11th Edition, 2022.
12. Basic Pathology, Vinay Kumar, Abul K. Abbas and Jon C. Aster, Elsevier, 11th Edition, 2023.
13. The Biology of Cancer, Robert A. Weinberg, Garland Science, 3rd Edition, 2023.
14. Molecular Biology of Cancer, Lauren Pecorino, Oxford University Press, 5th Edition, 2021.

PHY21629: RADIATION BIOLOGY (3 Credits, 45 Lectures)

Course Outcome:

1. Explain the mechanisms of radiation interaction with cells, cellular damage, repair processes, and factors influencing radiosensitivity.
2. Describe the somatic and genetic effects of radiation exposure and evaluate radiation-induced health risks.
3. Analyze the radiobiological principles underlying radiotherapy, including tumour response, radioresistance, and fractionation strategies.
4. Apply radiobiological models and time-dose fractionation concepts to estimate biological effects and optimize radiotherapy treatment protocols.

Course Details:

Unit-I Interaction of Radiation with Cells

Action of radiation on living cells - Radiolytic products of water and their interaction with biomolecule- Nucleic acids, proteins, enzymes, fats - Influence of oxygen, temperature - Cellular effects of radiation- Mitotic delay, chromosome aberrations, mutations and recombinations - Giant cell formation, cell death Recovery from radiation damage - Potentially lethal damage and sublethal damage recovery - Pathways for repair of radiation damage. Law of Bergonie and Tribondeau. Survival curve parameters - Model for radiation action - Target theory - Multihit, Multitarget - Repair misrepair hypothesis - Dual action hypothesis - Modification of radiation damage - LET, RBE, dose rate, dose fractionation - Oxygen and other chemical sensitizers - Anoxic, hypoxic, base analogs, folic acid, and energy metabolism inhibitors - Hyperthermic sensitization - Radio-protective agents – Cultured cell line and animal experimentation methods for assessing radiation damage – Oxygen enhancement ratio – Dose modifying factors.

Unit-II: Biological Effects of Radiation

Somatic effects of radiation - Physical factors influencing somatic effects - Dependence on dose, dose rate, type and energy of radiation, temperature, anoxia, - Acute radiation sickness - LD 50 dose - Effect of radiation on skin and blood forming organs, digestive tract - Sterility and cataract formation - Effects of chronic exposure to radiation - Induction of leukaemia - Radiation Carcinogenesis - Risk of carcinogenesis - Animal and human data - Shortening of life span – Concept of projection models and risk estimation -In-utero exposure - Genetic effects of radiation - Factors affecting frequency of radiation induced mutations- Dose-effect relationship - first generation effects - Effects due to mutation of recessive characteristics- Genetic burden - Prevalence of hereditary diseases and defects - Spontaneous mutation rate - Concept of doubling dose and genetic risk estimate.

Unit-III: Biological Basis of Radiotherapy

Tumour growth kinetics, Experimental model systems for studying radiobiology of radiotherapy, Physical and biological factors affecting cell survival, tumour re-growth and normal tissue response -Causes of clinical radioresistance, Hypoxia and reoxygenation in radiotherapy, Non-conventional fractionation scheme and their effect of reoxygenation, repair, redistribution in the cell cycle, 4 Rs of radiotherapy, Rationales of Multiple fraction daily (MFD) and Continuous hyper accelerated fractionation (CHART) methods, New modalities of radiotherapy, High LET radiation therapy.

Unit-IV: Time Dose Fractionation

Time dose fractionation - Basis for dose fractionation in beam therapy - Concepts for Nominal Standard Dose (NSD), Equivalent Single Dose (ESD), Roentgen equivalent therapy (RET) - Time dose fractionation (TDF) factors and cumulative radiation effects (CRE) - Gap correction, Linear and Linear Quadratic (LQ) models, LQ model for fractionated radiotherapy and concept of Biological Equivalent Dose (BED), BED for fractionated radiotherapy, Estimation of α/β dose using clinical data, BED correction for gap, BED for brachytherapy, Concept of switching between treatment modalities, BED for MFD and CHART protocols, Concept of incomplete repair, correction for BED and normal tissue complication in MFD and CHART.

Textbooks/References

1. A. Waugh, A. Grant. Ross and Wilson Anatomy and Physiology in Health and Illness, 2022.
2. E. J. Hall, A.J. Giaccia. Radiobiology for the radiologist, 2018.
3. Edward L Alpen. Radiation Biophysics, 1998.
4. Hollinshead W.H., C. Rosse, P. Gaddum-Rosse. Text Book of Anatomy, 2008.
5. G. Gordon Steel. Basic Clinical Radiobiology, 2002.
6. Irene Harris. Clinical Aspects of Radiation Oncology, 2015.
7. Hasan Murshed. Fundamentals of Radiation Oncology: Physical, Biological and Clinical Aspects, 2019.

PHY21630: RADIATION DOSIMETRY (3 Credits, 45 Lectures)

Course Outcome:

1. Understanding of radiation quantities and units
2. Detailed knowledge of various radiation sources including their production process application aspects
3. Competency to perform absolute, reference and relative radiation dosimetry with various radiation generators and sources Competency Based Curriculum for "Medical Physics" (Intellectual property of National Commission for Allied and Healthcare Professions, Ministry of Health and Family Welfare) Page | 227
4. Knowledge and skill in dosimetry of neutron and standardisation of radionuclides
5. Understanding radiation chemistry and use of chemical dosimetry techniques

Course Details

UNIT I: Radiation Quantities and Units

Radiation quantities and units – Radiometry – Particle flux and fluence – Energy flux and fluence – Cross Section – Linear and mass attenuation coefficients - Mass energy transfer and mass energy absorption coefficients - Stopping power - LET - Radiation chemical yield - W value - Dosimetry - Energy imparted - Absorbed dose - Kerma - Exposure - Air kerma rate constant - Charged particle equilibrium (CPE) – Relationship between Kerma, absorbed dose and exposure under CPE - Dose equivalent - Ambient and directional dose equivalents [(H*(d) and H'(d)] - Individual dose equivalent penetrating Hp(d) – Individual dose equivalent superficial Hs(d)

UNIT II: Radiation Sources

Radiation sources - Natural and artificial radioactive sources - Large scale production of isotopes – Reactor produced isotopes - Cyclotron produced isotopes - Fission products - industrial uses – Telecobalt and Brachy Caesium sources – Gold seeds - Tantalum wire - 125I Sources - Beta ray applicators - Thermal and fast neutron sources - Preparation of tracers and labeled compounds - Preparation of radio colloids.

UNIT III: Dosimetry of X- and Gamma Ray Beams

Dosimetry of beam therapy equipment - IAEA TRS 398 and IAEA TRS 398 (Rev). Measurement of D_W for External beams from ^{60}Co teletherapy machines: Reference conditions for measurement, Type of ion chambers, Phantom, Waterproof sleeve, Derivation of an expression for Machine Timing error, Procedure for evaluation of Temperature and pressure correction: Thermometers and pressure gauges. Measurement of temperature and pressure. Saturation correction: derivation of expression for charge collection efficiency of an ion chamber based on Mie theory. Parallel plate, cylindrical and spherical ion chambers, K_{sat} , Two voltage method for continuous and pulsed beams, Polarity correction. Measurement of DW for high-energy photon beams from Linear accelerators: Beam quality, beam quality index, beam quality correction coefficient, Cross calibration. Measurement of DW for high energy Electron beams from linear accelerators: Beam quality, beam quality index, beam quality correction coefficient, Cross calibration using intermediate beam quality. Quality Audit Programmes in Reference and Non- Reference conditions.

Small Field Dosimetry: IAEA TRS 483 and other protocols – Dosimetry of small field from gamma knife, x-knife and cyber knife, dosimetry of tomotherapy beams. Calibration of brachytherapy sources - Apparent activity - Reference Air Kerma Rate - Air Kerma Strength – IAEA TRS 492 - Calibration of HDR ^{192}Ir and ^{60}Co sources - Calibration of ^{125}I and beta sources - room scatter correction.

UNIT IV: Radiation Chemistry and Chemical Dosimetry

Definitions of free radicals and G-value - Kinetics of radiation chemical transformations - LET and dose rate effects - Radiation Chemistry of water and aqueous solutions, peroxy radicals, pH effects. adiation Chemistry of gases and reactions of dosimetry interest - Radiation polymerization, effects of radiation on polymers and their applications in dosimetry - Formation of free radicals in solids and their applications in dosimetry. Dosimetry principles - Definitions of optical density, molar absorption coefficient, BeerLambert's law, spectrophotometry - Dose calculations - Laboratory techniques - Reagents and procedures - Requirements for an ideal chemical dosimeter - Fricke dosimeter - FBX dosimeter - Free radical dosimeter - Ceric sulphate dosimeter - Other high and low level dosimeters – Use of chemical dosimeters in radiotherapy and other applications of radiations.

Textbooks/References

1. Joseph Magill and Jean Galy. Radioactivity Radionuclides and Radiation, 2005.
2. IAEA TRS 374, Calibration of Dosimeters used in Radiation Therapy, 1994.
3. IAEA TRS 398, Absorbed Dose Determination in External Beam Radiotherapy, 2000.
4. IAEA TRS 483, Dosimetry of Small Static Fields Used in External Beam Radiotherapy, 2017.
5. IAEA TRS 492, Dosimetry in Brachytherapy, 2023.
6. P. Andreo, D.T. Burns, A.E. Nahum, J. Seuntjens, F.H. Attix. Fundamentals of Ionizing Radiation Dosimetry, 2017.
7. F. H. Attix. Introduction to Radiological Physics and Radiation Dosimetry, 2004.
8. J. W. T. Spinks, R. J. Woods. An Introduction to Radiation Chemistry, 1990.
9. A. Mozumder. Fundamentals of Radiation Chemistry. 1999.
10. Karl-Heinrich Beckurts, Karl Wirtz, Neutron Physics, 2013.

PHY21631: NUCLEAR MEDICINE AND INTERNAL DOSIMETRY (3 Credits, 45 Lectures)

Course Outcome:

1. Knowledge of working principles and use of open isotope-based imaging systems such as Gamma Camera, Single Photon Emission Tomography (SPECT), Positron Emission Tomography (PET)
2. Understanding of the technology and use of medical cyclotron and
3. Understanding the technique of Internal dosimetry techniques

Course Details

Unit-I: Physics of Nuclear Medicine

Introduction to Nuclear Medicine (NM), Unsealed Sources, Production of Radionuclide used in NM; Reactor based Radionuclides, Accelerator based Radionuclides, Photonuclear activation, Equations for Radionuclide Production, Radionuclide Generators and their operation principles. Production of radiopharmaceuticals from Short lived positron emitters, Various usages of Radiopharmaceuticals. In-vivo Non-imaging procedures; Thyroid Uptake Measurements, Blood Volume studies. Life Span of RBC, Blood Volume studies, Life Span of RBC, Renography, etc. General concept of Radionuclide Imaging and Historical developments. Digital Image Acquisition, Display and Processing Systems. Frame mode acquisition, List mode acquisition. Choice of Matrix size, Image Display systems, Different Imaging Techniques: Basic Principles, Planar / 2D Imaging Techniques. Static, Dynamic, Gated. 3D Imaging Techniques - Basic Principles and Problem, Focal Plane Tomography, Emission Computed Tomography, Single Photon Emission Computed Tomography, Positron Emission Tomography.

Various Image Reconstruction Techniques during Image formation such as Back Projection and Fourier based Techniques, Iterative Reconstruction method and their drawbacks. Attenuation Correction, Correction Scatter, Resolution Correction, Artifacts or Sources of Error.Image Quality Parameters: Uniformity, Spatial Resolution, Factor affecting Spatial Resolution, Methods of Evaluation of Spatial Resolution, Contrast, Noise, Recovery Coefficient. NEMA Protocols followed for Quality Assurance / Quality Control of Imaging Instruments. Working of Medical Cyclotron, Radioisotopes Produced and their characteristics. In-vitro Technique: RIA/IRMA techniques and its principles.

Unit-II: NM Imaging Equipment

The Rectilinear Scanner and its operational principle, Basic Principles and Design of the Anger Camera / Scintillation Camera; System components, Detector System and Electronics, Different types of Collimators, Design and Performance Characteristics of the Converging, Diverging and Pin hole Collimator, Image Display and Recording Systems, Scanning camera, Limitation of the Detector System and Electronics.Physics and working principles of SPECT, PET, SPECT-CT, PET-CT, PET-MRI imaging, PET Instrumentations, Annihilation Coincidence Detection, PET Detector ad Scanner Design, Data Acquisition for PET, 2D/3D, Time of Flight imaging, Data corrections and Quantitative Aspect of PET, Image reconstruction techniques: back projection, Fourierbased, iterative methods - Attenuation, scatter, and resolution correction - Image quality parameters: spatial resolution, contrast, noise - QA/QC protocols as per national and international standards (IEC/NEMA) - Standard operating procedures for imaging equipment.Working of Medical Cyclotron, Radioisotopes Produced and their characteristics. Radiation safety aspects of medical cyclotron facility.Planning and Shielding Calculations during the installation of SPECT, PET/CT and Medical Cyclotron in the Nuclear Medicine Department.

Unit-III: Radionuclide Therapy

Treatment of Thyrotoxicosis, Thyroid cancer with 131I, use of 32P and 90Y for palliative treatment, Radiation Synovectomy and the isotopes used. Peptide Receptor Radionucleide Therapy (PRRT), applications of 177Lu & 225Ac. Concept of Delay Tank and various Waste Disposal Methods used in Nuclear Medicine. High-dose therapy room shielding calculations, Radiological safety aspects during servicing and maintenance - Emergency preparedness: spillage, personnel contamination, power failure - Cyclotron auxiliary equipment and control software as applied to therapy - Safety protocols for therapy delivery.

Unit-IV: Internal Dosimetry

Biodistribution and kinetic analysis of radiotracer concentration, Compartmental Modelling, Single Compartmental Model, Two Compartmental Model with Back Transference, Two Compartmental Model without Back Transference. Catenary & Mammillary models.

Classical Methods of Dose Evaluation; Beta particle Dosimetry; Equilibrium Dose Rate Equation, Beta Dose Calculation Specific Gamma Ray Constant, Gamma Ray Dosimetry, Geometrical Factor Calculation, Dosimetry of Low Energy Electromagnetic Radiation. Internal Radiation Dosimetry, MIRD Schema for Dose calculations; Basic procedure and some practical problems, Cumulative Activity, Equilibrium Dose Constant, Absorbed Fraction, Specific Absorbed Fraction, Dose Reciprocity Theorem, Mean Dose per unit Cumulative Activity and Problems related to the Dose Calculations. Limitation of MIRD Technique. individual dose calculations using Monte Carlo technique, Voxel based dosimetry.

Textbooks/References

1) C. Shah, M. Bradshaw, I. Dalal. Nuclear Medicine: A Core Review, 2021.
2) S. R. Cherry, J. A. Sorenson and M.E. Phelps. Physics in Nuclear Medicine. 2012.
3) H. A. Ziessman, J. P. O'Malley, J. H. Thrall. Nuclear Medicine: The Requisites (Requisites in Radiology), 2013.
4) Henry N. Wagner. A Personal History of Nuclear Medicine, 2006.

PHY21632: RADIATION THERAPY AND TREATMENT PLANNING (5 Credits, 75 Lectures)

Course Outcome:

1. Understanding the technology and working principles of various beam therapy equipment such as Telecobalt machine, Medical electron linear accelerators (LINAC), and medical proton accelerator
2. Understanding the technology and use of brachytherapy equipment, sources and techniques as well as dosimetry and treatment planning in brachytherapy • Competence in medical radiation dosimetry, quality assurance of various radiotherapy equipment and use of computers in radiation treatment planning including optimisation and associated radiation safety
3. Thorough knowledge and competence in applying special and advanced techniques of radiation therapy such as total body irradiation (TBI), total skin electron therapy (TSET), stereotactic radiosurgery/radiotherapy (SRS/SRT), stereotactic body radiotherapy (SBRT), intensity modulated radiotherapy (IMRT), image guided radiotherapy (IGRT), volumetric modulated radiotherapy (VMAT) and associated patient specific quality assurance

Course Details

UNIT I: Beam Therapy

Description of low kV therapy x-ray units - spectral distribution of kV x-rays and effect of filtration – thoraeus filter - output calibration procedure. Construction and working of telecobalt units - source design - beam collimation and penumbra - trimmers and breast cones. Design and working of medical electron linear accelerators - beam collimation – asymmetric collimator - multileaf collimator - dose monitoring - electron contamination. Output calibration of 60Co gamma rays, high energy x-rays and electron beams using IAEA TRS 398, AAPM TG 51 and other dosimetry protocols. Relative merits and demerits of kV x-rays, gamma rays, MV x-rays and electron beams. Radiotherapy simulator and its applications. CT and virtual simulations.

Central axis dosimetry parameters - Tissue air ratio (TAR) Back scatter/ Peak scatter factor (BSF/PSF) - Percentage depth doses (PDD) - Tissue phantom ratio (TPR) - Tissue maximum ratio (TMR) - Collimator, phantom and total scatter factors. Relation between TAR and PDD and its applications - Relation between TMR and PDD and its applications. SAR, SMR, Off axis ratio and Field factor. Build-up region and surface dose. Tissue equivalent phantoms. Radiation filed analyzer (RFA). Description and measurement of isodose curves/charts. Dosimetry data resources.

Beam modifying and shaping devices - wedge filters - universal, motorized and dynamic wedges- shielding blocks and compensators. Treatment planning in teletherapy - target volume definition and dose prescription criteria- ICRU 50 and 62 - SSD and SAD set ups -

two and three dimensional localization techniques - contouring - simulation of treatment techniques - field arrangements - single, parallel opposed and multiple fields - corrections for tissue inhomogeneity, contour shapes and beam obliquity - integral dose. Arc/ rotation therapy and Clarkson technique for irregular fields - mantle and inverted Y fields. Conventional and conformal radiotherapy. Treatment time and Monitor unit calculations.

Clinical electron beams - energy specification - electron energy selection for patient treatment - depth dose characteristics (Ds, Dx, R100, R90, R50, Rp etc.) - beam flatness and symmetry - penumbra - isodose plots - monitor unit calculations - output factor formalisms - effect of air gap on beam dosimetry - effective SSD.

Hadron therapy - General concept, specifications of the equipment, beam calibration and dosimetry, immobilization, positioning and alignment systems, acceptance & commissioning, QA/QC, Record & verify, Networking, Oncology information system, Relative merits of proton, electron, neutron, heavy ions, x-ray and gamma ray beams - Neutron capture therapy - Heavy ion therapy, Preview of IMPT.

Quality assurance in radiation therapy - precision and accuracy in clinical dosimetry - quality assurance protocols for telecobalt, medical linear accelerator and radiotherapy simulators - IEC requirements - acceptance, commissioning and. quality control of telecobalt, medical linear accelerator and radiotherapy simulators. Portal and in-vivo dosimetry. Electronic portal imaging devices.

UNIT II: Brachytherapy

Definition and classification of brachytherapy techniques - surface mould, intracavitary, interstitial and intraluminal techniques. Requirement for brachytherapy sources - Description of radium and radium substitutes - 137Cs, 60Co, 192Ir, 125I and other commonly used brachytherapy sources. Dose rate considerations and classification of brachytherapy techniques - Low dose rate (LDR), high dose rate (HDR) and pulsed dose rate (PDR). Paterson Parker and Manchester Dosage systems. ICRU 38 and 58 protocols. Specification and calibration of brachytherapy sources – RAKR/AKS and Absorbed Dose to Water calibration - IAEA TECDOC 1274 and ICRU 72 recommendations – Point and line source dosimetry formalisms - Sievert Integral – AAPM TG-43/43U1 and other dosimetry formalisms.

After loading techniques - Advantages and disadvantages of manual and remote after loading techniques. AAPM and IEC requirements for remote afterloading brachytherapy equipment. Acceptance, commissioning and quality assurance of remote after loading brachytherapy equipment. ISO requirements and QA of brachytherapy sources. Integrated brachytherapy unit.

Brachytherapy treatment planning - CT/MR based brachytherapy planning - GEC ESTRO recommendations - forward and inverse planning – DICOM image import / export from OT - Record & verification. Brachytherapy treatment for Prostate cancer. Ocular brachytherapy using photon and beta sources. Intravascular brachytherapy - classification - sources - dosimetry procedures - AAPM TG 60 protocol. Electronic brachytherapy (Axxent, Mammosite, etc.).

UNIT III: Radiotherapy Treatment Planning

Scope of computers in radiation treatment planning - Review of algorithms used for treatment planning computations - Pencil beam, double pencil beam, Clarkson method, convolution superposition, lung interface algorithm, fast Fourier transform, Inverse planning algorithm, Monte Carlo based algorithms.

Treatment planning calculations for photon beam, electron beam, and brachytherapy - Factors to be incorporated in computational algorithms. Plan optimization - direct aperture optimization – beamlet optimization - simulated annealing - biological optimization, multi-criterion optimizations,- dose volume histograms (qualitative and quantitative) - Indices used for plan comparisons – Hardware and software requirements - beam & source library generation.

Networking, DICOM and PACS, archieval and restore, big data management, role of cloud-based solutions. Acceptance, commissioning and quality assurance of radiotherapy treatment planning systems using IAEA TRS 430 and other protocols. Basic concept of AI for radiotherapy treatment planning and dosimetry

UNIT IV: Special and Advanced Techniques of Radiotherapy

Special techniques in radiation therapy - Total body irradiation (TBI) - large field dosimetry - total skin electron therapy (TSET), Total Marrow Lymphoid Irradiation (TMLI) - electron arc treatment and dosimetry - intraoperative radiotherapy, AAPM and IAEA task group reports.

Stereotactic radiosurgery/radiotherapy (SRS/SRT) - cone and mMLC based X-Knife - Gamma Knife immobilization devices for SRS/SRT - including baseplate, masks (open/close), positioning devices and alignment devices -dosimetry and planning procedures - Evaluation of SRS/SRT treatment plans - QA protocols and procedures for X- and Gamma Knife units - Patient specific QA, Film dosimetry for SRS/SRT, various films available for QA, EBT and EBT-XD. Physical, planning, clinical aspects and quality assurance of stereotactic body radiotherapy (SBRT) and Cyber Knife based therapy. Preliminary concepts of ZAP-X solutions for SRS/SRT, IAEA TRS 483.

Intensity modulated radiation therapy (IMRT) - principles - MLC & compensator based IMRT - step and shoot and sliding window techniques - Compensator based IMRT - planning process - inverse & forward treatment planning-immobilization, patient positioning, setup and alignment devices for IMRT - dose verification phantoms, dosimeters, protocols, ICRU 83, machine and patient specific QA, AAPM TG reports and protocols. Concept of Volumetric Modulated Arc Therapy (VMAT), Image Guided Radiotherapy (IGRT) - concept, definitions, protocols and recommendations, 4DCBCT/4DMVCT, gated CBCT, Hybrid Medical Linac: CBCT-Linac, MR-Linac, PET/CTLinac for adaptive radiotherapy, Concept of Adaptive Radiotherapy-image registration, dose accumulation and adaptation, QA protocol and procedures - special motion management phantom, 4DCT, Ring gantry accelerators (Radixact, Halcyon, Tomotherapy) - principle - commissioning - imaging - planning and dosimetry - delivery - plan adaptation - QA protocol and procedures. Concepts of radiomics and dosiomics - principles of quantitative feature extraction from imaging and 3D dose distributions

Surface guided/optically guided RT - concepts, mechanism, hardware, software, imaging techniques, Prospective & retrospective imaging and respiratory waveforms, integration with 4DCT, treatment planning system and treatment machine, phase based and amplitude-based gating, DIBH, DEBH, posture corrections, face recognition & safety, suitability for photons and protons, AAPM TG recommendations.

Textbooks/References:

1. E. Bezak, A. H. Beddoe, L.G. Marcu, M. Ebert, R. Price. Johns and Cunningham's the Physics of Radiology, 2021 (5th edition).
2. J. P. Gibbons. Khan's The Physics of Radiation Therapy, 2019 (6th Edition).
3. T. Pawlicki, D. J. Scanderbeg, G. Starkschall. Hendee's Radiation Therapy Physics, 2016 (4th Edition).
4. Jacob Van Dyk. The Modern Technology of Radiation Oncology, Vol 1, 1999.
5. Jacob Van Dyk. The Modern Technology of Radiation Oncology, Vol 2, 2005.
6. Jacob Van Dyk. The Modern Technology of Radiation Oncology, Vol 3, 2013.
7. Jacob Van Dyk. The Modern Technology of Radiation Oncology, Vol 4, 2020.
8. D. Greene, P.C. Williams. Linear Accelerators for Radiation Therapy, 2017.
9. P.W. Sperduto and J. P. Gibbons. Khan's Treatment Planning in Radiation Oncology (5th edition), 2021.
10. P. Xia, A. Godley, C. Shah, G. M.M. Videtic, J. Suh (Editors). Strategies for Radiation Therapy Treatment Planning, 2018.
11. G.M.M. Videtic and N. M. Woody (Editors). Handbook of Treatment Planning in Radiation Oncology, 2014
12. T. Bortfeld, R. Schmidt-Ullrich, W. De Neve, D. E. Wazer. Image Guided IMRT, 2006.
13. D. Baltas, L. Sakelliou and N. Zamboglou. The Physics of Modern Brachytherapy for Oncology, 2006.
14. S. H. Levitt, J. A. Purdy, C. A. Perez and S. Vijayakumar. Technical Basis of Radiation Therapy Practical Clinical Applications, 2012 (4th Revised Edition).
15. IAEA TRS 398, Absorbed Dose Determination in External Beam Radiotherapy, 2000.
16. IAEA TRS 483, Dosimetry of Small Static Fields Used in External Beam Radiotherapy, 2017.
17. IAEA TRS 492, Dosimetry in Brachytherapy, 2023.
18. ICRU Report 97: MRI-Guided Radiation Therapy Using MRI-Linear Accelerators, 2022

19. ICRU Report 93: Prescribing, Recording, and Reporting Light Ion Beam Therapy, 2016
20. ICRU REPORT 89: Prescribing, Recording, and Reporting Brachytherapy for Cancer of the Cervix, 2013.
21. ICRU Report 83: Prescribing, Recording, and Reporting Photon-Beam Intensity Modulated Radiation Therapy (IMRT), 2010.
22. ICRU Report 62: Prescribing, Recording and Reporting Photon Beam Therapy (Supplement to ICRU Report 50), 1999.
23. ICRU Report 50, Prescribing, Recording, and Reporting Photon Beam Therapy, 1993

PHY21633: RADIATION SAFETY AND REGULATORY ASPECTS (5 Credits, 75 Lectures)

Course Outcome:

1. Comprehensive knowledge of radiation protection standards and recommendations towards occupational and public safety
2. Competence in radiation monitoring, evaluation of external/internal radiation hazard, assessment of safety status of a radiation facility and control of contamination
3. Thorough knowledge of radiation safety in the medical uses of radiation which involves planning of medical radiation installations, evaluation of hazard and radiation waste disposal
4. Knowledge of the concepts of radioactive waste disposal like sources of waste including classification, treatment techniques of waste and disposal of used radiation sources and radiation generators
5. Detailed knowledge in transportation of radioactive substances including packaging, documentation, shipment, emergencies and regulations
6. Familiarization with National Legislations (acts, rules, standards, and guides) for the use of radiation in various applications
7. Knowhow of radiation emergencies and their medical management

Course Details

UNIT I: Radiation Protection Standards

Radiation dose to individuals from natural radioactivity in the environment and manmade sources. Basic concepts of radiation protection standards - Historical background - International Commission on Radiological Protection and its recommendations – The system of Radiological Protection – Justification of Practice, Optimisation of Protection and individual dose limits – Radiation and tissue weighting factors, equivalent dose, effective dose, committed equivalent dose, committed effective dose – Concepts of collective dose- Potential exposures, dose and dose constraints – Exposure SituationsPlanned, Emergency and Existing Categories of exposures – Occupational, Public and Medical Exposures - Factors governing internal exposure - Radionuclide concentrations in air and water - ALI, DAC and contamination levels. Brief introduction to IAEA Safety Standards (Part 1 to7).

UNIT II: Principles of Monitoring and Protection

Evaluation of external radiation hazards - Effects of distance, time and shielding - Shielding calculations - Personnel and area monitoring - Internal radiation hazards – Radio toxicity of different radionuclides and the classification of laboratories – Control of contamination – Bioassay and air monitoring – chemical protection – Radiation accidents – disaster monitoring

UNIT III: Safety in the Medical Uses of Radiation

Planning of medical radiation installations – General considerations – Design of diagnostic, deep therapy, telegamma and accelerator installations, brachytherapy facilities and medical radioisotope laboratories.

Evaluation of radiation hazards in medical diagnostic and therapeutic installations - Radiation monitoring procedures - Protective measures to reduce radiation exposure to staff and patients - Radiation hazards in brachytherapy departments and teletherapy departments and radioisotope laboratories - Particle accelerators Protective equipment - Handling of patients - Waste disposal facilities - Radiation safety during source transfer operations Special safety features in accelerators, reactors.

Planning of radiation installations and isotope laboratories for biomedical research - Radiation protection measures and hazards evaluation in biomedical research establishments

UNIT IV: Radioactive Waste Disposal

Radioactive wastes – sources of radioactive wastes - Classification of waste - Treatment techniques for solid, liquid and gaseous effluents – Permissible limits for disposal of waste - Sampling techniques for air, water and solids – Geological, hydrological and meteorological parameters – Ecological considerations.

Disposal of radioactive wastes - General methods of disposal - Management of radioactive waste in medical, industrial, agricultural and research establishments. Atomic Energy (radioactive Waste Disposal) Rules, 1987.Environmental impact assessment for discharge of radioactive wastes, interim storage, safe management of disused sources.

UNIT V: Transport of Radioisotopes

Transportation of radioactive substances - - General packing requirements - Transport documents - Labeling and marking of packages - Regulations applicable for different modes of transport - Transport by post - Transport emergencies - Special requirements for transport of large radioactive sources and fissile materials - Exemptions from regulations – Shipment approval – Shipment under exclusive use – Transport under special arrangement – Consignor’s and carrier’s responsibilities types of transport package, category of package, TREM card, transport index

UNIT VI: Legislation

National legislation – Regulatory framework – Atomic Energy Act – Atomic Energy (Radiation Protection) Rules – Applicable Safety Codes, Standards, Guides and Manuals, relevant international standards such as IEC, ISO etc. – Regulatory Control – Licensing, Inspection and Enforcement – Responsibilities of Employer, Licensee, Radiological Safety Officer and Radiation Worker– IAEA Code of conduct-Import & Export of radioactive sources- Graded approach of regulation-Exemption, exclusion and clearance. AERB Safety Directives.

Physical protection of sources – Categorization of radioactive sources, Safety and security of sources during storage, use, transport and disposal – Security provisions: administrative and technical – Security threat and graded approach in security provision, preparation of security plans for cat-1&2 sources.

UNIT VIII: Radiation Emergencies and their Medical Management

Radiation accidents and emergencies in the use of radiation sources and equipment in industry and medicine -Industrial radiography devices, GIC, GRAPF etc. and teletherapy, Brachytherapy, Nuclear Medicine- Loading and unloading of sources in teletherapy, brachytherapy, GRAPF etc.- Loss of radiation sources and their tracing - Typical accident cases. Radiation injuries, their treatment and medical management- Case histories. Prophylaxis and decorporating agents. Orphan and vulnerable sources, emergency handling accessories, emergency preparedness plan and its familiarization, estimation of doses while handling emergency situations, reporting emergency to regulatory body and other relevant authority.

Textbooks/References:

1. H. Cember, T.E. Johnson. Introduction to Health Physics, 2008.
2. Atomic Energy Act 1962.
3. AERB Radiation Protection Rules 2004.
4. ICRP 60 Recommendations, 1990.
5. ICRP 103 Recommendations, 2007.
6. Shapiro J. Radiation Protection: A Guide for Scientists, Regulators and Physicians, 2002.
7. IAEA Safety Standards – General Safety Requirements Part 3:2014
8. Atomic Energy (Radioactive Waste Disposal) Rules, 1987.
9. J. V. Trapp and T. Kron. An Introduction to Radiation Protection in Medicine, 2008.
10. IAEA Safety Standards Series No. SSG-46: Specific Safety Guides - Radiation Protection and Safety in Medical Uses of Ionizing Radiation, 2018.

PHY22634: CLINICAL RADIATION PHYSICS LAB (2 Credits, 20 Each experiment of 3 hours' duration)

Course Outcome:

1. Study and evaluation of parameters involved in X-ray diagnostic and associated radiation safety
2. Practical knowledge of measuring the strength of open isotopes, thyroid uptake, patient monitoring and safety assessment of nuclear medicine imaging and therapy facilities
3. Skill of radiation dose measurement in beam therapy, brachytherapy, and nuclear medicine
4. Practical knowledge of architecture and capabilities of radiotherapy treatment planning systems
5. Practical competence in radiation protection survey of various medical installations and safety assessment

List of the Experiments:

1. QA of a medical diagnostic x-ray machine and radiation protection survey of its installation

2. Calibration and study with thyroid uptake probe

3. Radiation protection survey including air contamination measurement of high dose therapy facility

4. Measurement of reference output of a telecobalt machine used in external beam therapy

5. Measurement of total scatter factor of Co-60 gamma rays used in beam therapy

6. Measurement and analysis of PDD curve of high energy photon beams used in radiotherapy

7. Measurement and analysis of PDD curve of high energy electron beams used in radiotherapy

8. Measurement of source strength of HDR brachytherapy source using well chamber

9. Integrity test of a brachytherapy source

10. Study with contaminated surfaces and procedures for decontamination

11. Calibration check of a radiation survey meter

12. Radiation protection survey for an industrial radiography camera

13. Radiation protection survey of teletherapy installations

14. Analysis of patient specific QA plan for IMRT/VMAT

15. Measurement of shift in mechanical isocentre and its coincidence with radiation isocentre of a teletherapy machine

16. Measurement of inter- and intra-leaf transmissions of a multileaf collimator (MLC)

17. Quality assurance (QA) tests of a PET machine

18. Measurement of TG 43 dosimetry parameters of a brachytherapy source

19. 3DRCT/IMRT/VMAT treatment planning using a computerized RTPS

20. Radiation protection survey of a medical cyclotron

21. Imaging and dosimetry quality assurance of a computed tomography scanner

22. Calibration of survey meters and pocket dosimeters.

23. Familiarization with construction and testing of radiation protection monitors.

24. Calibration and cross calibration of cylindrical and plane parallel ionization chambers used in external beam therapy