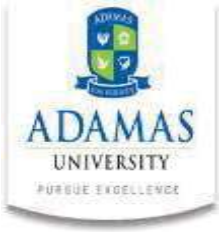
DETAILED SYLLABUS OF
Post M.Sc. Diploma in MEDICAL PHYSICS Program

Academic Year: 2024-25



DEPARTMENT OF PHYSICS
ADAMAS UNIVERSITY

SEMESTER I

PHY21601: RADIATION PHYSICS & RADIATION GENERATORS (Credit 4, 50 Lectures)

UNIT I: Nuclear Physics (10 Lectures)

Review of atomic structure and atomic particles, Radioactivity - General properties of alpha, beta and gamma rays - Laws of radioactivity - Laws of successive transformations - Natural radioactive series - Radioactive equilibrium - Alpha ray spectra - Beta ray spectra - Theory of beta decay - Gamma emission - Electron capture - Internal conversion - Nuclear isomerism - Artificial radioactivity - Nuclear cross sections - Elementary ideas of fission and reactors – Fusion, Atomic reactors.

UNIT II: Interaction of Radiation with Matter (related to Radiology) (12 Lectures)

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 (10 Lectures)

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 **(12 Lectures)**

Particle accelerators for industrial, medical and research applications, The Resonant transformer - Cascade generator - Van De Graff Generator - pelletron – Cyclotron-its limitations –Synchro-Cyclotron- Proton synchrotron- Betatron - Linear Accelerator - Klystron and magnetron-Travelling and Standing wave acceleration- Microtron – Electron Synchrotron. Accelerator facilities in India.

UNIT V: Neutron Generators **(6 Lectures)**

Neutron sources, Neutron production reactions, Radioisotopic neutron sources, operational requirements of neutron generators, Large generator based systems, Cockroft-Walton-type, Compact Neutron generators, Safety and regulations.

Textbooks/ References:

1. R. D. Evans, Atomic Nucleus

2. Preston M.A. Physics of Nucleus

3. Lapp R.E. Nuclear Radiation Physics

4. Segre E. Experimental Nuclear Physics

5. Slack L. Radiations from Radioactive Atoms

6. Oliver R. Radiation Physics in Radiology

7. Crouthamel C.E. Applied Gamma-Ray Spectrometry

PHY21602: APPLIED MATHEMATICS AND STATISTICS (4 Credits, 48 Lectures)

UNIT I: Probability, Statistics and Errors (12 Lectures)

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

UNIT II: Counting and Statistics in Clinical applications (6 Lectures)

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.

Sampling and sampling distributions - confidence intervals. Clinical study designs and clinical trials. Hypothesis testing and errors. Regression analysis.

UNIT III: Numerical Methods (20 Lectures)

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 IV: Computational Tools & Techniques (10 Lectures)

Computational packages: Overview of programming in C++, MATLAB/ Mathematica, and PYTHON in data analysis and graphics.

Textbooks/References:

1. Hoffman. Numerical Methods for Engineers and Scientists – 2nd Edition Revised and Expanded, Marcel Dekker, Inc., 270 Madison Avenue, blew York, NY 10016, Marcel Dekker AG, Hutgasse 4, Postfach 812, CH-4001 Basel, Switzerland.

2. A. C. Bajpai, I. M. Calus and J. A. Fairley Numerical Methods for Engineers and Scientists – A student's course book, John Wiley & Sons

3. Band W. Introduction to Mathematical Physics.

4. Croxton. Elementary Statistics

5. Dahlberg G. Statistical Method of Medical &Biology Students

6. Krasnor M.L. Ordinary Diff. Equation

PHY21603: RADIATION DETECTION MEASUREMENTS & INSTRUMENTATION (4 credits, 48 Lectures)

UNIT I: MEDICAL ELECTRONICS AND INSTRUMENTATION (10 Lectures)

Analog electronics: Semiconductor diodes - JFET - MOSFET - Integrated Circuits - Operational amplifiers (ideal characteristics, different operational circuits - inverting, noninverting amplifiers, adder, sub-tractor, differentiator, integrator. 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.

Interfacing concepts: Fundamental concepts of interfacing an instrument to PC/Computer, interfacing methods. Multiplexer, Demultiplexer ¸Decoders and Encoders - Microprocessors and associated peripherals

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. Regulated power supplies using IC's - DC-DC converter and RF power supplies - Switching mode Power supplies - AC regulators.

UNIT II: Principles of Radiation Detection (20 Lectures)

Principles of Radiation Detection and measurement - Basic principles of radiation detection ˜Gas Filled detectors -Ionisation chambers - Theory and design - Construction of condenser type chambers thimble chambers - Gas Multiplication - Proportional and GM Counters Characteristics of organic and inorganic counters - Dead time And Recovery time - Scintillation detectors (organic/inorganic) - Semiconductor detectors - Chemical systems - Radiographic and Radiochromic films - Thermoluminescent Dosimeters(TLD) - Optically stimulated Luminescence dosimeters (OSLO) - Radiophotoluminescent dosimeters - eutron Detectors - Nuclear track emulsions for fast neutrons -Solid State Nuclear track (SSNTD) detectors - Calorimeters - New Developments.

UNIT III: Radiation Detection and monitoring devices (18 Lectures)

Radiation Monitoring Instruments: Dosimeters based on condenser chamber, quartz fibre electrometer, dosimeter based on current measurement, secondary standard dosimeter, Diode and MOSFET, Vibrating condenser and Varactor bridge types - Secondary standard Therapy level dosimeters -Farmer dosimeter, beam therapy dosimeter, clinical dosimeter, isotope calibrator, Radiation field analyzer (RFA)

Personal monitoring instruments: TLD Reader for medical & research applications, TLD Badge Reader, OSLD badge reader, Film Badge Reader, Densitometer, Digital pocket dosimeter.

Area monitoring instruments: Portable and fixed area monitors, fixed area monitors, beta-gamma 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

Neutron monitoring instruments, Neutron detection by activation, Nuclear track detectors, Self powered neutron detectors (SPND), BF3, 3He, Bubble detectors. REM counter, Method of estimating activity present inside the body - whole body counter.

Calibration of Radiation Protection Instruments: Fundamental concepts of instrument calibration, Basic requirements for calibration, Various parameters checked during calibration, Selection of radioactive sources and source strength for calibration check.

Textbooks/References:

1. Price W.J. Nuclear Radiation Detection

2. Stepanor B.I. Theory Of Luminescence

3. Glenn F Knoll. Radiation Detection & Measurement

4. Albert Paul Malvino. Electronics Principles

5. Robert L. Boylestad. Electronics Devices and Circuit Theory

6. Paul-Horowitz. Art of Electronics

7. Greiner R.A. Semiconductor Devices & Application

8. Crawford R.H. MOSFET in Circut Design

PHY21604: BIOLOGICAL EFFECTS OF IONIZING RADIATION (4 Credits, 56 Lectures)

UNIT I: Cell Biology (6 Lectures)

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 Pathology (10 Lectures)

Anatomy and physiology as applied to radiodiagnosis and radiotherapy - Structure & function of organs and systems & their common diseases: Skin, Lymphatic system, Bone and muscle, Nervous, Endocrine, Cardiovascular, Respiratory, Digestive (Gastro-Intestinal), Urinary, Reproductive, Eye and ear.

Anatomy of human body, nomenclature & Surface anatomy, Radiographic Anatomy (including cross sectional anatomy - identify the different organs/ structures on plain x-rays, CT scans and other available imaging modalities. Normal anatomy & deviation for abnormalities.

Tumour pathology and carcinogenesis, common pathological features of cancers and interpretation of clinico-pathological data

UNIT III: Interaction of Radiation with Cells (6 Lectures)

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.

UNIT IV: Biological Effects of Radiation (9 Lectures)

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 - 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 V: Clinical Aspects of Medical Imaging & Radiation Oncology (15 Lectures)

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.

UNIT VI: Biological Basis of Radiotherapy (5 Lectures)

Physical and biological factors affecting cell survival, tumour re-growth and normal tissue response **–**Nonconventional fractionation scheme and their effect of re-oxygenation, repair, redistribution in the cell cycle - High LET radiation therapy.

UNIT VII: Time Dose Fractionation (5 Lectures)

Time dose fractionation - Basis for dose fractionation in beam therapy - Concepts for Nominal Standard Dose (NSD), Roentgen equivalent therapy (RET) - Time dose fractionation (TDF) factors and cumulative radiation effects (CRE) - Gap correction, Linear and Linear Quadratic models.

Textbooks/References:

1. Meschan. Normal Radiation Anatomy

2. Hollinshead W.H. Text Book Of Anatomy

PHY22605: RADIATION PHSICS LAB

1. Study of production and attenuation of bremsstrahlung.

2. Measurement of range of beta particles by Feather analysis

3. Study of Backscattering of beta particles and its application.

4. Study of Statistics of Radioactive counting.

5. Study of Voltage and current characteristics of an ion-chamber/GM monitor.

6. Calibration of TL phosphor & TLD reader and its use in dose distribution

measurements.

9. Determination of plateau and resolving time of a GM counter and its application in estimating the self ratio and activity of a beta source.

10. Calibration of a TLD personnel monitoring badge and dose evaluation.

SEMESTER II

PHY21606: RADIATION THERAPY (4 Credits, 66 Lectures)

UNIT I: Beam Therapy (30 Lectures)

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.

Particulate beam therapy - Relative merits of proton, electron, neutron, x-ray and gamma ray beams – Neutron capture therapy - Heavy ion therapy.

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 (12 Lectures)

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: Computers in Treatment Planning (12 Lectures)

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 - dose volume histograms - Indices used for plan comparisons – Hardware and software requirements - beam & source library generation. Networking, DICOM and PACS. Acceptance, commissioning and quality assurance of radiotherapy treatment planning systems using IAEA TRS 430 and other protocols.

UNIT IV: Special and Advanced Techniques of Radiotherapy (12 Lectures)

Special techniques in radiation therapy - Total body irradiation (TBI) - large field dosimetry - total skin electron therapy (TSET) - electron arc treatment and dosimetry - intraoperative radiotherapy.

Stereotactic radiosurgery/radiotherapy (SRS/SRT) - cone and mMLC based X-Knife - Gamma Knife - immobilization devices for SRS/SRT - dosimetry and planning procedures - Evaluation of SRS/SRT treatment plans - QA protocols and procedures for X- and Gamma Knife units - Patient specific QA. Physical, planning, clinical aspects and quality assurance of stereotactic body radiotherapy (SBRT) and Cyber Knife based therapy.

Intensity modulated radiation therapy (IMRT) - principles - MLC based IMRT - step and shoot and sliding window techniques - Compensator based IMRT - planning process - inverse treatment planning - immobilization for IMRT - dose verification phantoms, dosimeters, protocols and procedures - machine and patient specific QA. Concept of Intensity Modulated Arc Therapy (IMAT e.g. Rapid Arc), Image Guided Radiotherapy (IGRT), and Volumetrically Modulated Arc Therapy (VMAT) - Imaging modality, kV cone beam CT (kVCT), MV cone beam CT (MVCT), image registration, plan adaptation, QA protocol and procedures - special phantom, 4DCT. Tomotherapy - principle - commissioning - imaging - planning and dosimetry - delivery - plan adaptation - QA protocol and procedures.

Textbooks/References:

1. H. E. Johns and Cunningham. The Physics of Radiology

2. Faiz M. Khan, The Physics of Radiation Therapy, Lippincott Williams & Wilkins, Philadelphia, 3rd edition, 2003.

3. Faiz M. Khan, Roger A. Potish, Treatment Planning in Radiation Oncology, Williams & Wilkins, Baltimore, 1998.

4. S. Webb. The physics of three dimensional radiation therapy, Institute of Physics publishing, Philadelphia, 1993.

5. S. Webb. The physics of conformal radiotherapy, Institute of Physics publishing, Philadelphia, 1997.

6. S. Webb. Intensity Modulated radiation therapy, Institute of Physics publishing, Philadelphia, 2001.

7. S.K. Jani. CT simulation for radiotherapy, Medical Physics Publishing, Madison, WI, 1993

8. J. Van Dyk. The Modern Technology of Radiation Oncology, Medical Physics Publishing, Madison, WI, 1999.

9. S.C. Klevenhagen Physics and dosimetry of therapy Electron beams, Medical Physics Publishing, Madison, WI, 1996.

10. Thomas Bortfeld · Rupert Schmidt-Ullrich, Wilfried De Neve · David E.Wazer (Editors). Image- Guided IMRT. Springer Berlin Heidelberg, 2006.

11. D. Baltas, L. Sakelliou and N. Zamboglou The Physics of Modern Brachytherapy for Oncology CRC Press, Taylor and Francis Group, 6000 Brooken Sound Parkway NW Suite 300, Boca Raton – FL 33487-2742.

12. S. H. Levitt, J. A. Purdy, C. A. Perez and S. Vijayakumar (Editors). Technical Basis of Radiation Therapy Practical Clinical Applications - 4th Revised Edition, Springer Berlin Heidelberg New York

13. Jack Van Dyke. Physics of Radiation Oncology.

PHY21607: RADIATION DOSIMETRY AND STANDARDIZATION (4 Credits, 55 Lectures)

UNIT I: Radiation Quantities and Units (6 Lectures)

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 (5 Lectures)

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 & Standardization of X- and Gamma Ray Beams (15 Lectures

Standards - Primary and Secondary Standards, Traceability, Uncertainty in measurement. Charged Particle Equilibrium (CPE), Free Air Ion Chamber (FAIC), Design of parallel plate FAIC, Measurement of Air Kerma/ Exposure. Limitations of FAIC. Bragg-Gray theory, Mathematical expression describing Bragg-Gray principle and its derivation. Burlin and Spencer Attix Cavity theories. Transient Charged Particle Equilibrium (TCPE), Concept of Dgas, Cavity ion chambers, Derivation of an expression for sensitivity of a cavity ion chamber. General definition of calibration factor - NX, NK, ND, air, ND,W. IAEA TRS277: Various steps to arrive at the expression for DW starting from NX. TRS398: ND, W, Q : ND, W : KQ,Q0 :KQ , Derivation of an expression for KQ,Q0. Calorimetric standards - Intercomparison of standards.

Measurement of DW for External beams from 60Co 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, Ksat , 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.

Standardization of brachytherapy sources - Apparent activity - Reference Air Kerma Rate - Air Kerma Strength - Standards for HDR 192Ir and 60Co sources - Standardization of 125I and beta sources – IAEA TECDOC 1274 - room scatter correction. Calibration of protection level instruments and monitors.

UNIT IV: Neutron Standards & Dosimetry (9 Lectures)

Neutron classification, neutron sources, Neutron standards - primary standards, secondary standards, Neutron yield and fluence rate measurements, Manganese sulphate bath system, precision long counter, Activation method. Neutron spectrometry, threshold detectors, scintillation detectors & multispheres, Neutron dosimetry, Neutron survey meters, calibration, neutron field around medical accelerators.

UNIT V: Standardization of Radionuclides (8 Lectures)

Methods of measurement of radioactivity - Defined solid angle and 4□ 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, □) and (n, p) reactions - Determination of yield of neutron sources - Space integration methods - Solid state detectors.

UNIT VI: Radiation Chemistry and Chemical Dosimetry (12 Lectures)

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 – Radiation 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 - Description of irradiators from dosimetric view point - Dosimetry principles - Definitions of optical density, molar absorption coefficient, Beer- Lambert'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 - Applications of chemical dosimeters in Radiotherapy and industrial irradiators.

Textbooks/References:

1. Joseph Magill and Jean Galy. Radioactivity Radionuclides Radiation, European Commission Joint Research Centre, Institute for Transuranium Elements, P. O. Box 2340, 76125 Karlsruhe, Germany

2. IAEA TRS 374, Calibration of Dosimeters used in Radiation Therapy

3. F. H. Attix. Introduction to Radiological Physics and Radiation Dosimetry, Viley-VCH, Verlog, 2004.

4. Field. Clinical Use of Radioisotopes

PHY21608: RADIATION SAFETY TECHNIQUES, (4 Credits, 64 Lectures)

UNIT I: Radiation Protection Standards (7 Lectures)

Radiation dose to individuals from natural radioactivity in the environment and man-made 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 – System of protection for intervention - Categories of exposures – Occupational, Public and Medical Exposures - Permissible levels for neutron flux - Factors governing internal exposure - Radionuclide concentrations in air and water - ALI, DAC and contamination levels

UNIT II: Principles of Monitoring and Protection (6 Lectures)

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 (15 Lectures)

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.

UNIT IV: Applications & Safety in the Industrial, Agricultural and Research uses of Radiation (18 Lectures)

Physical principles of industrial radiography - Comparison of X-ray radiography and gamma radiography - Choice of source - Exposure containers - Photographic film technique - Radiographic Contrast Definition of sensitivity - Intensifying screens - Penetrameters.

Industrial Fluoroscopy - Comparison of fluoroscopy and radiography - Image intensifier. Special techniques - Microradiography, flash radiography_ stereo - radiography - X-ray diffraction - Neutron radiography and electron radiography.

Physical principles in the industrial application of radioisotopes - Use of sealed sources - Radioisotope gauges – Use of transmission and scattering gauges for measurement of thickness, density and composition – Level indicators - Bremsstrahlung gauges Beta and gamma backscattering gauges and their applications – Neutron scattering gauges - Principles and applications of X-ray fluorescence techniques.

Applications in agriculture and research – Radioisotope tracer applications - General principles - Selection of radiotracer Dilution technique - Some examples of applications in agriculture, biology and research areas. Planning of radiation installations and isotope laboratories in industry - Facilities for storage, handling and field operations, Planning of radioisotope laboratories for agriculture and research Institutions - Design of gamma gardens for agriculture.

Radiation protection measures and hazards evaluation in industrial and agricultural establishments - X and gamma ray radiography - X-ray diffraction apparatus - Radioisotope gauges - Tracer applications for radioisotopes in agriculture and industry Gamma chamber - Radiation sterilization - Irradiation of food and drugs - PANBIT and ISOMED - Luminising industry - Radiation protection in Industrial Radiographic Installations - Enclosed, open top, open field and sky shine. Tritium and C-14 monitoring – Monitoring of Spillage - Contamination and control.

UNIT V: Radioactive Waste Disposal (4 Lectures)

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.

UNIT VI: Transport of Radioisotopes (4 Lectures)

Transportation of radioactive substances - Historical background - 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

UNIT VII: Legislation (5 Lectures)

Physical protection of 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 National legislation – Regulatory framework – Atomic Energy Act – Atomic Energy (Radiation Protection) Rules – Applicable Safety Codes, Standards, Guides and Manuals – Regulatory Control – Licensing,

Inspection and Enforcement – Responsibilities of Employers, Licensees, Radiological Safety Officers and Radiation Workers – National inventories of radiation sources – Import, Export procedures

UNIT VIII: Radiation Emergencies and their Medical Management (5 Lectures)

Radiation accidents and emergencies in the use of radiation sources and equipment in industry and medicine - Radiographic cameras and teletherapy units - Loading and unloading of sources - Loss of radiation sources and their tracing - Typical accident cases. Radiation injuries, their treatment and medical management – Case histories. Prophylaxis and decorporating agents

Textbooks/References:

1. Herman Cember. Introduction to Health Physics
2. Atomic Energy Act 1962
3. AERB Radiation Protection Rules 2004
4. ICRP 1990 Recommendations
5. ICRP 2007 Recommendations
6. IAEA Basic Safety Standards 115, 1997
7. IAEA Basic Safety Standards, 2012
8. Shapiro J. Radiation Protection
9. Mckenzie. Radiation Protection in Radiotherapy
10. Mawson C.A. Management Of Radioactive Wastes

PHY21609: MEDICAL IMAGING TECHNIQUES (4 Credits, 52 Lectures)

UNIT I: Principles of Diagnostic X-ray Conventional Imaging (12 Lectures)

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: 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 test methods for performance evaluation of x-ray diagnostic equipment.

UNIT II: 6.2 Digital X-Ray Imaging and Computed Tomography (10 Lectures)

Xero-radiography, mammography, Interventional radiology, digital radiography (CR and DR systems), digital subtraction techniques, Conventional tomography (principle only), orthopan tomography (OPG), Computed Tomography (CT), QA of CT equipment

UNIT III: Nuclear Imaging and Internal Dosimetry (20 Lectures)

Physics of Nuclear Medicine (12 L)

Introduction to Nuclear Medicine, Unsealed Sources, Production of Radionuclide used in Nuclear Medicine; Reactor based Radionuclides, Accelerator based Radionuclides, Photonuclear activation, Equations for Radionuclide Production, Radionuclide Generators and their operation principles. Various usages of Radiopharmaceuticals.

In-vivo Non-imaging procedures; Thyroid Uptake Measurements, Renogram, Life Span of RBC, Blood Volume studies, Life Span of RBC etc. General concept of Radionuclide Imaging and Historical developments.

Radionuclide Imaging: Other techniques and Instruments; 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, Digital Image Processing Systems, Scanning Camera, Limitation of the Detector System and Electronics.

Different Imaging Techniques: Basic Principles, 2D Imaging Techniques, 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, Scatter Correction, Resolution Correction, Other requirements or Sources of Error.

In-vitro Technique: RIA/IRMA techniques and its principles.

Physics of PET and Cyclotron: Principles of PET, PET Instrumentations, Annihilation Coincidence Detection, PET Detector and Scanner Design, Data Acquisition for PET, Data corrections and Quantitative Aspect of PET, Working of Medical Cyclotron, Radioisotopes Produced and their characteristics.

Treatment of Thyrotoxicosis, Thyroid cancer with I-131, use of P-32 and Y-90 for palliative treatment, Radiation Synovectomy and the isotopes used. Concept of Delay Tank and various Waste Disposal Methods used in Nuclear Medicine.

Planning and Shielding Calculations during the installation of SPECT, PET/CT and Medical Cyclotron in the Nuclear Medicine Department.

Internal Dosimetry (8 L)

Internal Radiation Dosimetry: Different Compartmental Model; Single Compartmental Model, Two Compartmental Model with Back Transference, Two Compartmental Model without Back Transference. 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.

MIRD Technique 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.

UNIT IV: Magnetic Resonance Imaging (MRI) (7 Lectures)

Physics of Nuclear Magnetic Resonance imaging and its application in the field of diagnostics (MRI principle), proton density, relaxation time T1 & T2 images- Image characteristics- MRI system components – Magnets, Magnetic field, Gradients, Magnetic field shielding, Radio frequency systems, computer functions- imaging process –Image artifacts – MRI safety. Advantage and disadvantage of the MRI against other medical imaging methods.

UNIT V: Ultrasound Imaging (3 Lectures)

Physics of ultrasound imaging, interaction of sound waves with body tissues, production of ultrasound- transducers- acoustic coupling- image formation – modes of image display- colour Doppler., uses in diagnosis, Image quality description & patient risk

Textbooks/References:

1. Curry, T.S., Dowdey, J.E., Murry, R.C., (1990), Christensen's introduction to the physics of diagnostic radiology (4th ed.), Philadelphia : Lea & Febiger.

2. Bushberg, S.T., Seibert, J.A, Leidholt, E.M. & Boone, J.M. (1994), The essential physics of medical imaging, Baltimore: Williams & Wilkins.

3. Dendy, P.P. & Heaton, B. (2nd ed.), Physics for diagnostic radiology, Bristol & Philadelphia: Institute of Physics Publishing.

4. Johns, H.E. & Cunningham, J.R. (1983), The physics of radiology (4th ed.), Springfield, IL : Charles C. Thomas

5. E. Seeram. X-ray imaging equipment, An introduction (1985), Springfield, IL: Charles C. Thomas.

6. Hendee, W.R. & Ritenour, R. (1993), Medical Imaging Physics (3rd ed.), St. Louis: C.V. Mosbey.

7. Chesney, D.N. & Chesney, M.O., X-ray equipment for student radiographers (3rd ed.), New Delhi: CBS Publishers & Distributors.

8. Chesney, D.N. & Chesney, M.O., Radiographic imaging (4th ed.), New Delhi: CBS Publishers & Distributors.

9. Hashemi, R.H, Bradley, W.G. & Lisanti, C.J. MRI the basics, Philadelphia: Lippincot Williams & Wilkins.

10. Sprawls, P., Magnetic resonance imaging principles, methods and techniques, Madison, Wisconsin: Medical Physics Publishing.

11. Simon R. Cherry, James A. Sorenson, Michael E. Phelps, Physics in Nuclear Medicine (3rd ed.), SAUNDERS an imprint of Elsevier.

12. Ramesh Chandra, Nuclear Medicine Physics (5th ed.), Lea & Febiger, Philadelphia.

13. Antonio Fernando Goncalves Rocha and John Charles Harbert, Text Book of Nuclear Medicine: Basic Science, Lea & Febiger, Philadelphia.

14. Pail J. Early, M.A. Razzak and D, Bruces Sodee, Text book of Nuclear Medicine Technology. The C.V. Mosby Company.

15. A.L. Baert and K. Sartor, Diagnostic Nuclear Medicine (2nd ed.). Springer.

16. Gopal B. Saha, Fundamental of Nuclear Pharmacy (5th ed.). Springer.

17. Dale L. Bailey, David W. Townsend, Peter E. Valk and Michael N. Maisey. Springer.Janet F. Eary and Winfried Brenner, Nuclear Medcine Therapy. Informa Health Care.

18. J. F. Fowler, Nuclear Particles in Cancer Treatment, Adam Hilger Ltd., Philadelphia, 1981.

PHY22610: RADIATION THERAPY & DOSIMETRY LAB

1. Dose output measurement of high energy x-rays and electron beams used in radiotherapy treatment.
2. Dose output measurement of electron beams used in radiotherapy treatment.
3. Determination of percentage depth dose of photon and electron beams.
4. In-phantom dosimetry of a brachytherapy source.
5. Familiarisation with treatment planning procedure using a computerised radiotherapy treatment planning system.
6. Dose planning in cancer of uterine cervix
7. In-vivo dosimetry
8. Dose rate measurement of teletherapy/Linear accelarator machines using chemical dosimeter
9. Calibration of therapy level dosimeter using cross-calibration method.
10. Calibration of survey instruments and pocket dosimeter.
11. Study of voltage and current characteristics of therapy level dosimeter.
12. Study of absorption and backscattering of gamma rays-Determination of HVT.

PHY22611: QUALITY ASSURANCE & RADIATION PROTECTION LAB

1. Determination of radiation field, flatness, symmetry and penumbra of external photon beam
2. Dose verification in MRT
3. Verification of mechanical and radiation isocentre of a teletherapy/LINAC machine
4. Absorption and backscattering of gamma rays - Determination of HVT.
5. Radiation protection survey of Linear accelerator (LINAC) installation
6. Quality assurance of a diagnostic x-ray machine.
7. Radiation protection survey of brachytherapy installation
8. Leakage level measurement of Linear accelerator equipment
9. Radiation protection survey of diagnostic radiology installations
10. Leakage level measurement of a diagnostic x-ray machine
11. Evaluation of characteristics of a radiographic image.
12. Study and calibration of thyroid uptake measurement unit.
13. AKS/ RAKR measurement of an HDR brachytherapy source using well type and cylindrical ionisation chambers.
14. Survey of a radioisotope laboratory and study of surface and air contamination.