

PANJAB UNIVERSITY CHANDIGARH-160014 (INDIA)
(Estd. Under the Panjab University Act VII of 1947-enacted by the Govt. of India)

FACULTY OF SCIENCE

SYLLABUS

FOR

M. Sc. (NUCLEAR MEDICINE)

FOR

EXAMINATIONS 2018-19

Introduction

Nuclear Medicine is an established clinical and research specialty with a wide ranging diagnostic and therapeutic techniques. It can be defined a discipline embracing all applications of radioactive materials in the diagnosis and treatment of various diseases, in medical research and in the study of body functions, both in healthy and diseased state, with the exception of the uses of sealed radiation sources in radiotherapy (W.H.O. Technical report Series 492, 1972). As this is a specialized branch of medicine and is multidisciplinary in nature, it requires skilled / trained manpower.

Aims and Objectives

The postgraduate training program is aimed at developing highly skilled technical manpower in Nuclear Medicine. After completion of the course, the trainee should be able to demonstrate high standards of professional skills and competence/leadership qualities in the field of Nuclear Medicine.

Duration of Course

The duration of the program will be two Academic Years (Two Semesters in each year.)

Number of Seats

General seats	=	10
NRI	=	02
Total seats per year	=	12

Eligibility/Qualification

Minimum Qualifications for admission to M.Sc. first year in Nuclear Medicine will be B.Sc. from a recognized university with Physics and Chemistry (Non-medical Stream) or Chemistry & Zoology/Biotechnology (Medical Stream) as core subjects. Candidates having B.Sc. in Nuclear Medicine/Biophysics shall also be eligible for admission to the course. Candidates with B.Sc. degree in X-ray/Medical Technology, B.Sc. through correspondence and Open University stream are not eligible.

Admission Criteria:

Admission to M.Sc. course in Nuclear Medicine will be through Joint Entrance Test, to be conducted by the Panjab University. The candidates should have passed the graduation (B.Sc.) from a recognized University/Institute with at least 50% marks. While deciding the final merit of the entrance test, a weightage shall also be given to the B.Sc. marks obtained by the candidate, as per the University rules. The cut off percentage marks secured in the entrance test will also be as per the University rules.

Syllabus

The broad outlines of the course are annexed and had been prepared keeping in view the guidelines/ requirements of AERB, BARC, Mumbai.

Teaching and Training

The Centre for Nuclear Medicine, Panjab University, Chandigarh, and the Department of Nuclear Medicine, PGIMER, shall impart the teaching and training to the students, jointly.

Basic and preclinical training will be at the Center for Nuclear Medicine, Panjab University and the clinical training will be at the Department of Nuclear Medicine, PGIMER, Chandigarh.

Dissertation

Every student shall be allotted a project under a supervisor holding a faculty position both from Centre for Nuclear medicine, Panjab University and Department of Nuclear Medicine, PGIMER in the beginning of the second year and will have to submit the dissertation as a precondition for the award of M.Sc. Degree in Nuclear Medicine by Panjab University.

Assessment and Evaluation

In addition to regular internal assessment, theory and practical examinations will be held at the end of each semester.

Award of M.Sc. Degree

The candidates shall have to obtain a minimum of 50% marks in each theory and 50% marks in each practical separately, in each Semester. The candidate shall have to reappear in failing paper(s). However, such candidate will be provisionally promoted to next academic session. The result of next academic session papers will be withheld till passing of the previous paper(s). The Panjab University, Chandigarh shall award the degree.

FIRST YEAR

First Semester

Paper Code: Theory (T) Practical (P)	Title	Theory	Practical	Total Marks
NM-101T NM-101P	Human Anatomy and Cell physiology	100	50	150
NM-102T NM-102P	Radiation Physics and Applied Mathematics	100	50	150
NM-103T NM-103P	Radiation Biology and Chemistry	100	50	150
NM-104T NM-104P	Radiation Detection and Measurements	100	50	150
				Total = 600 Marks

Second Semester

Paper Code: Theory (T) Practical (P)	Title	Theory	Practical	Total Marks
NM-201T NM-201P	Human Physiology, Immunology and Cancer biology	100	50	150
NM-202T NM-202P	Electronics, Biomedical instrumentation and Techniques	100	50	150
NM-203T NM-203P	Biostatistics and Computer applications in Nuclear Medicine	100	50	150
NM-204T NM-204P	Medical Applications of Radioisotopes	100	50	150
				Total = 600 Marks

SECOND YEAR

Third Semester

Paper Code: Theory (T) Practical (P)	Title	Theory	Practical	Total Marks
NM-301T NM-301P	Nuclear Medicine Instrumentation	100	50	150
NM-302T NM-302P	Radiological Protection & Dosimetry-I	100	50	150
NM-303T NM-303P	Principles and Practice of Radiopharmacy	100	50	150
NM-304T NM-304P	Nuclear Medicine Imaging & Non-imaging Procedures	100	50	150
Total = 600 Marks				

Fourth Semester

Paper Code: Theory (T) Practical (P)	Title	Theory	Practical	Total Marks
NM-401T NM-401P	Medical Cyclotron, PET/CT & Allied Instrumentation	100	50	150
NM-402T NM-402P	Radiological Protection & Dosimetry-II	100	50	150
NM-403T NM-403P	Nuclear Medicine Imaging & Radionuclide Therapy	100	50	150
NM-404T NM-404P	Recent advances in Nuclear Medicine	100	50	150
NM-405	Dissertation and Grand Viva	100		100
Total = 700 Marks				

M.Sc. Nuclear Medicine Syllabus

FIRST YEAR - FIRST SEMESTER

Paper I - HUMAN ANATOMY & CELL PHYSIOLOGY (40 Lectures)

CELL ORGANIZATION AND CELL PHYSIOLOGY (15 lectures)

Cell as the basic structural unit, Fine structure of prokaryotic and eukaryotic cell organization, cell organelles, cytoskeleton

Structure and function of cell membrane. Types of transport across cell membrane, Mechanism of transport, Endoplasmic reticulum (ER), mitochondria, golgi complex, nucleus, lysosomes.

Cell cycle, events in cell cycle – G1, S1, G2 phase, Control of cell cycle, Cell division, Cell transportation and malignant tumor growth. Cell aging and death, Apoptosis.

Cell adhesion, cell signaling, concept of receptors, characterization and its function. Receptor – ligand interaction. Signal transduction

Energy requirements in cell metabolism, high energy phosphate bond, electron transfer phenomenon and biological transfer.

Amino acids and proteins, carbohydrates, lipids, nucleic acids, vitamins and coenzymes, its mechanism, bioenergetics. Glycolytic and TCA cycles.

DNA structure, Replication and Repair, RNA synthesis and Translation

GROSS ANATOMY (15 lectures)

Anatomy and Imaging: Anatomical planes, diagnostic imaging techniques.

Back: Component parts (bones, muscles, vertebral canal, spinal nerves, dermatomes), regional anatomy (vertebrae, joints, ligaments, musculature), back surface anatomy.

Thorax: Component parts (thoracic wall, thoracic aperture, diaphragm, mediastinum, pleural cavities, thorax surface anatomy.

Head and Neck: Component parts (skull, cervical vertebrae, hyoid bone, soft palate and muscles in the head and neck.

Abdomen: Component parts (wall, abdominal cavity, inferior thoracic aperture, diaphragm, pelvic inlet, surface anatomy, defining surface projection, liver, kidney and spleen position, gallbladder, pancreas.

Pelvis: Component parts (Pelvic inlet, pelvic walls, pelvic outlet, pelvic floor, pelvic cavity and perineum).

Lower and Upper limb: Component parts (bones and joints, muscles).

MICROSCOPIC ANATOMY (10 lectures)

Epithelial tissue: Electron microscopic structure and various structural modifications.

Connective tissue: Structure, Characteristics, Function, Classification, Modified connective tissue (Blood, Lymph, Bone and Cartilage)

Muscle: Structural and molecular organization of muscle and mechanism of muscle contraction.

Nervous tissue: Neurons, neuroglial cells and nerve fibre. Mechanism of myelination and synapse

Practicals:

- i. To identify different parts of a human skeleton
- ii. To identify types of epithelial tissue: (squamous, stratified, pseudostratified) using light microscope.
- iii. To visualize microanatomical view of musculoskeletal system using light microscope.
- iv. To visualize microanatomical view of respiratory system (larynx, pharynx, trachea, principal bronchi, lungs) of rat using light microscope.
- v. To visualize microanatomical view of digestive system (esophagus, stomach, small and large intestine, rectum) of rat using light microscope.
- vi. To visualize microanatomical view of urinary system (kidney, urethra, urinary bladder) of rat using light microscope.
- vii. To visualize microanatomical view of male reproductive system (testes, Ductus deferens, Seminal vesicle, prostate) of rat using light microscope.
- viii. To visualize microanatomical view of female reproductive system (Ovary, fallopian tube, uterus) of rat using light microscope.
- ix. To visualize microanatomical view of nervous system of rat using light microscope.
- x. To make block and cut section of the embedded tissue with the help of microtome and finally make a slide. To stain the sectioned tissue and prepare a permanent slide after H/E staining.
- xi. To determine TLC, red blood cell counts using hemocytometer
- xii. To study DLC in blood smear.

Suggested Books:

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| • Gray's Anatomy for Students | Richard L Drake, Vogl and Mitchell |
| • Principles of Anatomy and Physiology | Tortora and Derrickson |
| • Human Anatomy (Vol I,II, III) | B D Chaurasia |
| • Cell & Molecular Biology | De Robertis |
| • Molecular Biology of the Cell | Alberts, Bray, Lewis, Raff |
| • Cell Signaling | Morgan |
| • Biochemistry | Lehninger |
| • Biochemistry | Stryer |
| • Basic Medical Biochemistry | Smith Marks & Libermann |
| • Biochemistry | Harper |

FIRST YEAR - FIRST SEMESTER

Paper II – RADIATION PHYSICS AND APPLIED MATHEMATICS (40 Lectures)

RADIATION PHYSICS (8 lectures)

Nuclear Structure and Radioactive decay

Nuclear structure - atomic number, mass number, isotopes, isobars; Radioactivity - laws of radioactive decay, half-life, mean life, effective half-life. Types of radioactive disintegrations, specific activity, carrier-free radioactivity; Statistics of radioactive decay and propagation of statistical errors. Energy of ionizing radiation, electron capture.

Laws of successive transformations - radioactive equilibrium: secular, transient and no-equilibrium. natural radioactive series, artificial radioactivity & production of radioisotopes, nuclear cross sections, elementary ideas about nuclear fission, fusion, reactors and neutron sources.

Characteristics of alpha, beta (electron, positron and electron capture) and gamma decay and their spectra, internal-conversion, phenomenon of annihilation and pair production, positron emission, annihilation radiations, metastable state and isomeric transitions, X-rays: characteristic and continuous spectrum, Auger effect.

Interactions of Nuclear Radiations (12 Lectures)

Interaction of electromagnetic radiation with matter: coherent scattering, photoelectric effect, Compton effect, pair production and relative importance of these processes. Attenuation of photon beams: attenuation, energy transfer and energy absorption - attenuation and mass energy absorption coefficients, half-value layer and X-ray filters.

Interaction of charged particles with matter: directly and indirectly ionizing particles, elastic and in-elastic collisions, Energy loss of charged particles (electron and heavy charged particles) in medium, Stopping Power - Bethe Bloch Formula, Range energy relation - Bragg curve, Energy loss of electrons and positrons in matter - collision and radiative loss, range energy relation - Continuous slowing down approximation (CSDA). Dependence of collision energy losses on the physical and chemical state of the absorber, empirical relations between range and energy, back scattering, Cherenkov radiation.

Interaction of neutrons with matter: elastic scattering, energy transfer, logarithmic energy decrement, inelastic scattering, dependence on E and Z, neutron induced reactions - neutron capture, (n, p), (n, x), (n, y) etc. neutron activation.

Principle and working of X-ray tube, application of filters; Microwave generator - Klystron and magnetron, Particle accelerators for industrial, medical and research applications, Cyclotron, Betatron, Linear Accelerator — Travelling and Standing Wave Acceleration. Details of accelerator facilities in India.

APPLIED MATHEMATICS

Numerical Methods: (4 lectures)

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.

Differential Calculus: (5 lectures)

Differentiation – Derivative of a function of a real variable, derivatives of circular and inverse circular function, hyperbolic and inverse hyperbolic functions, successive differentiation, Leibnitz theorem (statement without proof) and simple problems.

Integration: (3 lectures)

Primitive, different methods of integration – integration by substitution and integration by parts, definite integrals and its properties, double integrals (simple cases only)

Linear Algebra: (4 lectures)

Definition of a matrix, adjoint and inverse of a square matrix, orthogonal matrix, rank of a matrix, elementary transformation of a matrix – reduction of a matrix to normal and echelon forms.

Determinant of square matrix of order n, its properties, multiplication of determinants.

Vector Analysis: (4 lectures)

Dot and cross product of vectors, products of three or more vectors, derivative of a vector with respect to scalar parameter, gradient of a scalar point function, solenoidal and irrotational vectors.

Practicals:

1. To measure Half Value Layer of β and γ emitters and determine linear mass absorption coefficients.
2. To study the factors producing background counts.
3. To study self absorption using beta emitting radioisotopes.
4. To study the back scatter of beta particle.
5. To study the absorption of radiation by solvents and to determine the counting errors originating from sample geometry.
6. To study how to avoid certain errors in handling carrier free solutions.
7. To determine absorption coefficients of biological tissues with β and γ radioactive sources of different energies.
8. To study the change in activity of a sample consisting of two independently decaying radioisotopes.
9. To study the statistics of radioisotopic measurements and observe the effect of background on the counting statistics.
10. To determine the half lives of radioactive isotopes

Suggested Books:

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| • Physics in Nuclear Medicine | Cherry, Sorenson, Phelps |
| • The essential Physics of Medical Imaging | Bushberg, Seibert, Leidholdt |
| • Medical Imaging Physics | William R.Hendee |
| • Introduction to Medical Physics | Arid |
| • Medical Physics | Cameron |
| • Radiation detection | Knoll |
| • Mathematical Models in Biology –An Introduction | Allman & Rhodes |
| • Introduction to Mathematical Physics | C.Harper (Prentice Hall of India) |
| • Field and Wave Electromagnetics | David Cheng |
| • Introduction to Mathematical Physics | Michael T vaughn |
| • Numerical Methods for Engineers and Scientists | Hoffman |
| • Numerical Methods for Engineers and Scientists | Bajpai, I.M. Calcus & J. |
| • Introductory Methods of Numerical Analysis | S.S. Sastry |
| • Introduction to Mathematical Physics | Michael T vaughn |

FIRST YEAR - FIRST SEMESTER

Paper III - RADIATION BIOLOGY AND RADIATION CHEMISTRY (40 lectures)

RADIATION UNITS (4lectures)

Units of radioactivity: Becquerel, Curie, specific activity, carrier free activity, resonance absorption and Mossbauer Effect. Quantities and units: Dose, roentgen unit of exposure, radiation sensitivity of biological materials, radiation absorbed dose (RAD, Gray), radiation weighting factor, Relative biological effectiveness (RBE), Quality factors, Roentgen Equivalent man (REM), Sievert, equivalent dose, effective dose, collective equivalent dose, total effective dose equivalent.

MOLECULAR AND CELLULAR RADIOBIOLOGY (10 lectures)

Radiation Chemistry: direct and indirect effects of radiations, radiation chemical yields and G-values, formation of free radicals, radiolysis of water, radiation effects on simple chemical systems, interactions of free radicals with several solutes. Direct versus indirect effects in aqueous solutions. Reactions in aqueous, organic and inorganic solutions.

Radiation effects on Cell: membrane, energy metabolism, synthetic processes, chromosomes, chromosomal type aberrations, chromatid type aberrations, sub chromatid aberrations, relation between aberration structure and the mitotic and meiotic cycles. Radiation effects on cell division. Bystander Effect, Apoptotic and Mitotic death.

Radiation effect on biomolecules: Radiation effects on proteins, nucleic acids, carbohydrates, lipids, polymerases, transferases, isomerases and anti-oxidative enzymes.

Radiation and independent cell systems: target Theory, multitarget theory, target size, multihit theory, multitarget multihit theory. Cellular Injury and Dose reponse Models, Linear and Linear Quadratic model.

Differential cell response: Criteria of radiosensitivity, factors affecting sensitivity, average interphase chromosomal volume, ploidy, nuclear factors, cytoplasmic factors, categories of mammalian cell sensitivity, specific classifications of mammalian cell sensitivity.

RADIATION EFFECTS ON HUMAN BODY SYSTEM (10 lectures)

Radiation effects on major organ systems: Hematopoietic system (Spleen, bone marrow, Lymphoid tissue, thymus) and Blood, vascular system, digestive system, respiratory system, urinary system, nervous system, reproductive system, endocrine system and immune system.

Acute radiation effects: Lethality, acute radiation syndrome in mammals, effects of prenatal development, radiation effects on regeneration.

Radiation Carcinogenesis. Deterministic and Stochastic effects. Repair of Radiation Damage. Effects of radiation on embryo and fetus.

MODIFICATION OF RADIATION RESPONSE (3 lectures)

Physical modifications of radiation injury, relative biological effectiveness, linear energy transfer, dose rate effect, chronic irradiation, biological factors influencing radiation response, age, diet, genetic constitution, oxygen concentration, temperature etc.

RADIATION CHEMISTRY

Basic Chemistry (5 lectures)

Various concepts of acids bases and buffers – ionic product of water – pH – determination of pH – hydrolysis constant – buffer solution – Henderson Hasselbach equation – determination of pH by indicators, glass electrode.

Ionic bonds – lattice energy of ionic compound – Born-Landé equation. Born-Haber cycle – covalent character of ionic bond . covalent bond – hybridization involving s,p,d and f orbitals – SP³, SP², SP, dSP³, d² SP³ hybridization. Co-ordination compounds

Rates of reactions – factors influencing rates of reactions – order and molecularity – first, second and third order – units – derivation of first order rate equation – half life – influence of temperature on reaction rates – Arrhenius equation. Calculation of Arrhenius parameters.

Radio Activity and Isotopes (4 lectures)

Radio activity – units- stability of nucleus – N/P ratio, mass defect – binding energy – theory of nuclear disintegration – decay law, half life period – radioactive equilibrium. Radioactive series – nuclear reactions – nuclear reactions induced by P,N,D – nuclear fission – fusion – reactors.

Production of radioisotopes: from nuclear reactors by (n, γ), Isotopes and their separation taking examples of Mo-99, I-131.

Basic Radiopharmaceutical Chemistry (4 lectures)

Characteristics of an ideal radiopharmaceutical and quality control. Physicochemical techniques and its application in radio pharmacy: Chromatography, Electrophoresis and Spectroscopy.

Practicals:

1. Effects of ionizing radiation on DNA (fragmentation studies).
2. To perform micronucleus assay in x-irradiated rat tissue samples
3. *In vitro* spleen colony forming assay in x-irradiated rat tissue samples
4. Intestinal colonogenic assay in x-irradiated rat tissue samples.
5. Lipid peroxidation assay in x-irradiated rat tissue samples
6. Chromosomal aberrations testing following ionizing radiation exposure
7. Lymphocyte extraction and counting following whole body x-irradiation to rats
8. Effect of pH on binding efficiency
9. Effect of temperature on binding efficiency
10. Effect of drug concentration on binding efficiency

Suggested Books:

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| • Radiobiology for the radiologists | Eric J Hall |
| • Physics and Radiobiology of Nuclear Medicine | Gopal Saha |
| • Introduction to Radiation Biology | B Uma Devi, Nagarathanam, Rao |
| • Radiation Biology | Casarett |
| • Elements of Radiobiology | Selman |
| • Physics and Radiobiology of Nuclear Medicine | Gopal B. Saha |
| • Introduction to Health Physics | Herman Cember and Thomas Johnson |

FIRST YEAR - FIRST SEMESTER

Paper IV - RADIATION DETECTION & MEASUREMENTS (40 Lectures)

RADIATION DETECTORS (2 lectures)

Principle of radiation detection and types of detectors

GAS FILLED DETECTORS (3 lectures)

Theory of ionization chamber- design consideration in an ionization chamber, operating voltage. Proportional counters- design and characteristics, gas multiplication. Geiger-Muller counters – operation and design consideration, dead time and recovery time. Theory and construction of condenser type of chambers and thimble chambers.

SCINTILLATION DETECTORS-ORGANIC AND INORGANIC SCINTILLATION DETECTORS (6 lectures)

Scintillation detector principles- inorganic NaI (TI), Bismuth germanate detector, barium Fluoride, and organic detectors light collection and mounting, yttrium orthosilicate detector; scintillation characteristics- light output, decay time. Features of gamma ray spectra - photo peaks, Compton valley, edge and plateau, backscatter peak, iodine escape peak, annihilation peak. Pulse height selector, energy resolution and calibration, geometric efficiency, intrinsic efficiency,

LIQUID SCINTILLATION COUNTERS (4 lectures)

Composition of liquid scintillator (scintillation cocktail): primary solute, secondary, solute and organic solvent (toluene, 1, 4 dioxane, anthracene) and solubilizing agents for tissues, coincidence circuits and display. Quenching and quench correction methods: Internal standard method, external standard method and channel ratio.

SEMICONDUCTOR DETECTORS (4 lectures)

Semiconductors junction, surface barrier detectors, high purity germanium detectors, response and characteristics.

Neutron detectors: Basic principles and applications.

Well counter – Geometry factor, dual radionuclide counting.

COUNTING AND MEDICAL STATISTICS (6 lectures)

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

Statistics of nuclear counting-application of Poisson statistic- 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, statistical aspects of gamma ray and beta ray counting, statistical accuracy in double isotope technique.

WHOLE BODY COUNTING STUDIES (3 lectures)

Whole body counting: principles of whole body counting, design of whole body counting system, stationary systems, single and multiple crystal systems, chair geometry, moving systems, calibration of whole body system, clinical and other applications of whole body counters.

GENERAL SYSTEMS FOR OPERATION AND DETECTION (12 lectures)

Use of photographic emulsions stripping film technique, dipping method, grain density counting and track counting, X-ray films, intensifying screens, fluoroscopy.

Physics of TLD, characteristics TLD phosphors, glow curves, dose and energy response, sensitivity and application in-dosimetry and personnel monitoring devices.

OSLD Reader for medical and research applications, TLD Badge Reader, OSLD badge reader, Digital pocket dosimeter.

Area monitoring instruments: Portable and fixed area monitors, beta-gamma zone monitor, Survey meters, wide range survey instrument, teletector,

Contamination monitoring instruments: portable contamination monitor, hand and foot surface contamination monitor, portal monitor, laundry monitor, floor monitor

Neutron monitoring instruments, REM counter

Calibration of Radiation Protection Instruments: Fundamental concepts of instrument calibration, Basic requirements for calibration and various parameters checked during calibration.

Practicals

1. To prepare FBX dosimeter and check its linearity with different radiation exposures.
2. To estimate the radiation dose absorbed by different organs by using FBX dosimeter.
3. To determine the energy resolution of spectrometer and effect of scatter in source volume
4. To learn the mode of operation of a scintillation counter and its operating characteristics.
5. To identify unknown radionuclide on the basis of its principal energy by using scintillation counter
6. To determine the radiation response of thermo luminescent dosimeter (TLD)
7. To find out the spectrum of energies emitted by a radioisotope by using gamma ray – spectrometer.
8. Gamma ray spectrometry with a single channel analyzer.
9. Effect of EHT and gain on spectrometer using a mixture of two radionuclides.
10. Demonstration of liquid scintillation counter.
11. To determine the plateau of GM tube and find out the dead time/ resolving time.
12. To determine the efficiency of GM counter and find out the strength of the unknown radioactive source
13. To demonstrate well type gamma ray spectrometer can be used as a whole body counters.
14. To demonstrate the retention of activity in whole body by using scintillation counter and whole body counter.

Suggested Books:

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| • Radiation detection | Knoll |
| • Nuclear Physics (Narosa Pbl. House) | I. Kaplan |
| • Nuclear Radiation Physics (Prentice Hall) | R.E. Lapp |
| • Radiations from Radioactive Atoms (Govt. Print. Off.). | L. Slack & K. Way |
| • Radiation Physics in Radiology (Springer). | R. Oliver |
| • Field and Wave Electromagnetics (Addison-Wesley) | D.K. Cheng |
| • Semiconductor Devices: Physics and Technology (Wiley). | S.M. Sze |

FIRST YEAR - SECOND SEMESTER

PAPER I - HUMAN PHYSIOLOGY, IMMUNOLOGY AND CANCER BIOLOGY (40 LECTURES)

HUMAN PHYSIOLOGY (20 lectures)

Endocrine system: Brief description of endocrine organs, their hormones, functions of the hormones, diseases produced by excess or deficiency of the hormones. Feedback mechanisms. Special emphasis on Thyroid (Thyroid hormone production, hormonal control)

Heart: The heart as a pump, normal ECG, methods of recording ECG

Respiratory system: General physiological functions of respiratory system.

Nervous System: Structure, function and organization of nervous system, signal transmission at synapses

Functions of Digestive system: Brief study of different digestive juices and their functions

Urinary systems: Physiology of urine formation

Reproductive system: Oogenesis and ovulation in females, spermatogenesis in males.

IMMUNOLOGY (10 lectures)

Innate and acquired immunity, cell mediated and humoral immunity, antibodies and their production, Immunochemical assays (Radioimmunoassay, ELISA, IHC, western blotting etc)

BIOLOGY OF CANCER (10 lectures)

Classification, nomenclature and definition of neoplasm. Transformed cells and cell lines, cancer cells differentiation, alterations in cancer cell behavior, diminished contact inhibition and defects in cell to cell metastasis.

Cancer Invasion and Metastasis- Stages of metastasis (Invasion, local extension, discontinuous extension), transport of cancer cells to distant sites

Cancer biomarkers, histological alterations, Oncogenes and tumor suppressor genes, tumor progression

Practicals

1. Thyroid hormone testing using RIA and IRMA kits
2. Development of experimental models of cancer
3. Histological processing of experimental tumors.
4. Protein expression of tumor suppressor genes like p53, Bcl2, Bax etc.
5. To extract DNA from blood and tissue sample.
6. To detect apoptotic cells using TUNEL assay.

Suggested Books:

- Text Book of Medical Physiology
- Principles of Anatomy and Physiology
- Physiology
- The biology of Cancer
- Introduction to Cancer Biology

Guyton and Hall
Tortora and Derrickson (Wiley).
Chatterjee
Robert A Weinberg
Momna Hejmadi

FIRST YEAR - SECOND SEMESTER

Paper II – ELECTRONICS, BIOMEDICAL INSTRUMENTATION AND TECHNIQUES (40 Lectures)

SEMICONDUCTOR DEVICES (6 Lecturers)

Theory of semiconductors: energy band (qualitative), intrinsic and extrinsic semiconductors, n-type and p-type semiconductors, majority and minority carriers. p-n junction properties forward and reversed bias, pnp and npn transistors and their characteristics.

DIGITAL CIRCUIT SYSTEM (4 Lectures)

Boolean algebra and logic gates: OR, AND, NOT, NOR, NAND and EXOR gates. Analog to digital converter and digital to analog converters. Power supplies-Regulated power supplies.

INSTRUMENTS FOR COUNTING, GAMMA RAY SPECTROMETRY (5 lectures)

Electronics of PM tubes, preamplifiers, amplifiers, pulse height analyzers, coincidence & anti coincidence circuits, TPHC, MCA, scalers and timers, high voltage supply in gamma ray spectrometry.

TRANSDUCERS (4 Lectures)

Properties and the principle of transducers: Resistive transducer, thermoresistors, thermistors, Potentiometric transducers, magnetoresistive transducers and their biomedical applications. Inductive transducers, single inducers, mutual inducers, capacitive transducer, biological capacitors.

ULTRASOUND (5 Lectures)

Ultra sound generators, properties of ultrasound- waves and its propagation in biological tissues, Pulse echo techniques, cavitation phenomenon, Doppler principle, involvement in design of medical instruments- scan A, scan B. scan M, ultrasound motion senses, dynamics of blood flow, Physiological effects of ultrasound in therapy, adverse effects of ultrasound waves.

Introduction to laser, principle of operation of laser, laser tissue interaction, Different types of LASERS, applications of LASER in medicine, adverse effects of LASER.

NUCLEAR MAGNETIC RESONANCE (4 Lectures)

Quantum mechanical description, Bloch equations, experimental techniques- NMR spectrometer, cw NMR and FT NMR; NMR spectrum- chemical shift, longitudinal and transverse relaxation times; Basic principle of MRI.

ATOMIC ABSORPTION SPECTROPHOTOMETER (3 Lectures)

Atomic Absorption spectroscopy, basic principle and working, applications in biomedicine

MASS SPECTROMETRY (3 Lectures)

Principle and working of Mass Spectrometer, applications in biology and medicine.

ELECTROCARDIOGRAPHY (2 Lectures)

Principle and working of electrocardiograph. Biomedical applications of electrocardiography

SEPARATION TECHNIQUES (4 Lectures)

Principles and applications, chromatography, paper TLC techniques, centrifugation, electrophoresis, Ultraviolet-visible spectroscopy : Basic principle and applications

Practicals

1. To measure AC voltage signal and its frequency using an oscilloscope and to study NPN & PNP transistor and characteristic of multivibrator.
2. To use an Oscilloscope as a display for studying the half wave rectifier and to set up LC filter circuit, L and C filter circuits and study the waveform obtained on the oscilloscope. Find the ripple factor in each case.
3. Two stage RC coupled amplifier - frequency response.
4. Construction of a voltage multiplier.
5. Characteristics of a regulated power pack.
6. OPAMP circuits - Inverting and non inverting amplifiers.
7. Integrator and differentiator circuit using OPAMP.
8. To demonstrate ECG in normal and treated animals.
9. To demonstrate electrical impedances in biological tissues
10. Characteristics of LED
11. Characteristics of Photo diode
12. Characteristics of PN junction diode
13. Characteristics of Zener diode
14. Familiarization of components: Active, Passive, Symbols, Identification, Specification and Testing
15. Familiarization of Equipments : Voltmeter and Ammeter, Multimeter (analog and digital)
16. Passage of Laser through optical fibres using small semiconductor lasers and optical fibres.

Suggested Books:

- Principles of Applied Biomedical Instrumentation Geddes, Baker
- Semiconductor Devices: Physics and Technology (Wiley). S.M. Sze
- Integrated Electronics (McGrew Hill). Millman and Halkias
- OPAMPS and Linear Integrated Circuits Ramakant A. Gayakwad
- Electronic Principles (McGrew Hill). A.P. Malvino
- Techniques for Nuclear and Particle Physics experiments W.R. Leo

FIRST YEAR - SECOND SEMESTER

PAPER III - BIOSTATISTICS AND COMPUTER APPLICATIONS (40 Lectures)

INTRODUCTION TO BIOSTATISTICS AND STATISTICAL TERMS (4 Lectures)

Statistics – Biostatistics and Biometry- Descriptive and Inferential Biostatistics – Sample and test Biostatistics – Statistical Terms - Limitations of Statistical Methods – Aims of Biostatistics –Applications of Biostatistics.

COLLECTION OF DATA (4 Lectures)

Census and Sampling Methods of Data Collection – Necessity of Sampling – Types of Sampling Methods Random or Probability Sampling – Nonrandom or Non Probability Sampling.

CLASSIFICATION OF DATA AND FREQUENCY DISTRIBUTION (3 Lectures)

Data – Data collection – Data Processing – Data Summarization – Classification of Data – Methods of classification of Data – Differences Between Classification and Tabulation – Formation of Frequency Distribution.

PRESENTATION OF DATA TABULAR REPRESENTATION OF DATA – GRAPHIC REPRESENTATION OF DATA (3 Lectures)

– Line Diagram – Histogram – Frequency Polygon – Frequency Curve – Cumulative Frequency Curve or Ogive – Scatter or Dot Diagram – Bar Diagram – Pictogram – Cartogram.

MEASURES OF CENTRAL TENDENCY AND DISPERSION (3 Lectures)

Average – Objectives of Averages - Characteristics of an Ideal Measure of Central Tendency – Types of Averages - Mean, Median, Mode – Meaning of Dispersion – Measures of Dispersion – Range, Standard Deviation – Coefficient of Variation, Standard Error.

CORRELATION AND REGRESSION (3 Lectures)

Correlation – Types of Correlation – Measures of Simple Correlation – Rank Correlation. Regression – Simple Regression – Regression Equation – Regression Coefficients.

PROBABILITY (5 Lectures)

Important Terms and Concepts – Sample point, Sample space, Trial and Event; Classical Definition of Probability – Frequency Definition of Probability –Rules of Probability (Addition Rule and Multiplication Rule) Random variable and Probability Distribution – Binomial Distribution, Poisson Distribution and Normal Distribution. 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

TEST OF HYPOTHESIS AND TESTS OF SIGNIFICANCE (5 Lectures)

Statistical Inference, Test of Significance, Procedure for Carrying out test of Significance – Computation of Test of Significance – Test for the mean of a Normal Population.

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

The basic idea of significance tests, Tests of hypothesis for the parameters of normal distribution (two sample problems also) including testing for population proportions. Confidence intervals for the parameters of normal distribution (two sample problems also).

CATEGORICAL DATA: (4 Lectures)

Measurements scales, tests of associations, Chi-square test, Yate's correction. Sensitivity, Specificity, Predictive value and ROC curve, Analysis of variance (ANOVA), one way and two way classifications, Multi-variate analysis of variance (MANOVA).

Non Parametric Statistics: Sign-test, Wilcoxon-signed rank test, Mann Whitnet U-statistic

SPSS/STATISTICAL in data analysis and graphics (6 Lectures)

Practicals

1. To study structural and conformational characteristics of various bio-molecules using molecular modeling.
2. To demonstrate the use of various scientific languages like FORTRAN, C++ for scientific applications.
3. To study various DOS commands for scientific applications Demonstration of SPSS statistical software.
4. Demonstration of MATLAB software.
5. Demonstration in Excel and Power point.

Suggested Books:

- | | |
|---|-------------------------------|
| • Methods in Biostatistics | Mahajan |
| • Methods of Biostatistics | Bhaskararao |
| • Statistical and Mathematical Techniques in NM | GS Pant |
| • Biostatistics: A foundation for the analysis in the Health Sciences | Wayne W. Daniel., John Wiley. |
| • Fundamental of Statistics Vol.-I & II | A.M.Goon, M.K.Gupta & B.Das |
| • Essentials of Medical Statistics, Blackwell publishers | Betty Kirkwood |
| • Object Oriented Programming with C++ | E.Balaguruswamy. |
| • A First Course in Computers | Sanjay Saxena. |
| • Calculus (Pearson Education, 2003) | G.B.Thomas and R.L.Finney |
| • Statistical methods of Medical & Biology Students | G. Dahlberg |
| • C++ How to Program | Deitel & Deitel |
| • Let us C | Kanetkar |

FIRST YEAR - SECOND SEMESTER

Paper IV - Medical Applications of Radioisotopes (40 Lectures)

PRINCIPLES OF RADIATION SAFETY AND CONTROL (10 lectures)

Concept of maximum permissible exposures, Internal and external radiation hazards, classification of radioisotope laboratories, safe transportation, decontamination procedures and waste disposal.

RADIONUCLIDES IN BIOLOGY (15 lectures)

Concept of uptake of radionuclides in the organ of interest, effective half life/ biological half life in specific organs and whole body. ^{51}Cr labeling with red blood cells: applications in blood volume measurement, spleen uptake, red cell survival studies, red cell volume and proteins turn over Theoretical aspects of tracer techniques and basic requirements for radiotracer investigations.

^{32}P applications in polycythemia vera and leukemia

^{14}C applications in urea breath test, Radiorespirometry, in vitro uptake and turnover studies using ^{14}C glucose, ^{14}C amino acids and fatty acids.

^3H applications in autoradiography and metabolic studies.

^{59}Fe absorption studies, Techniques for studying absorption of labeled substance, ^{59}Fe turn over studies, plasma iron clearance

$^{58}\text{Co}/^{57}\text{Co}$: Applications in schilling's test of vitamin B12 absorption, double tracer technique and whole body counting

BIO-MEDICAL APPLICATIONS OF RADIONUCLIDES (15 lectures)

Thyroid radioactive uptake measurements: Tracer dose, use of carrier, standard and phantom, shielding and collimation, factors affecting thyroidal radioactive iodine uptake, PBI-131, thyroid stimulation test, thyroid clearance rate thyroid suppression test, perchlorate discharge test, T3 charcoal test.

^{131}I therapy for treatment of hyperthyroidism and thyroid follicular carcinoma.

^{125}I applications: General principle of radioimmunoassay (RIA), ^{125}I applications in radioimmunoassay of T3, T4, TSH and other hormones. Principle of immunoradiometric assay(IRMA).

$^{99\text{m}}\text{Tc}$ applications in medical imaging of different organs and dynamic /function studies.

$^{201}\text{Tl}/^{82}\text{Rb}$ – myocardial uptake/perfusion imaging, ^{67}Ga for scintigraphy of tumors and infections,

^{18}F FDG in brain, heart and tumor imaging

Radionuclides in therapy: Applications of ^{89}Sr , ^{186}Re -HEDP, ^{153}Sm -EDTMP, lutetium-177 for treatment of different organ system disorders.

Practicals

1. Use of gamma ray scintillation counter for measuring in vivo thyroid uptakes following administration of carrier-free ^{131}I .
2. To study the influence of carrier on *in-vivo* uptake of carrier-free ^{131}I by the thyroid.
3. To find out the bio-distribution of a given radionuclide in a given animal.
4. To perform perchlorate discharge test.
5. To determine the thyroid clearance rate.
6. To determine the PBI- ^{131}I in blood.

7. To measure the blood volume of a given animal using ^{99m}Tc labeled red blood cells.
8. To prove that spleen is the storehouse of worn out red blood cells by using ^{99m}Tc labeled red blood cells.
9. To find out the target / non target ratio of ^{99m}Tc labeled pharmaceuticals.
10. To determine the biological half life of $^{99m}\text{Tc O}_4$ and labeled pharmaceuticals.
11. To determine the Rf of radiopharmaceuticals using different solvents.
12. To label the red blood cells using ^{51}Cr and to determine the efficiency of labeling.
13. To determine the blood volume of a given animal using ^{51}Cr labeled red blood cells.
14. To find out the average life span of red blood cells by using ^{51}Cr radionuclide
15. To prove that spleen is the storehouse of worn out red blood cells by using ^{51}Cr labeled red blood cells
16. To study the bio-kinetics of ^{45}Ca in understanding its metabolism in bone when administered in an animal.
17. To determine the turnover of ^{14}C glucose in liver slices using radiorespirometric technique.
18. To find out the bio-distribution of a given radionuclide in a given animal.
19. To plot the standard curve for the given Radioimmunoassay (T3/T4 test).

Suggested Books:

- | | |
|---|----------------------------|
| • Radiation Safety for Unsealed Sources | G. S. Pant |
| • Radiation Biology for the Radiologists | Eric J Hall |
| • An Introduction to Radiation Protection in Medicine | J. V. Trapp and T. Kron |
| • Radio immunoassay Principles & Practices | Pillai & Bhandarkar |
| • Nuclear Medicine in Vitro | B. Rothfield |
| • Principles of Nuclear Medicine | Henry N. Wagner (Jr.) |
| • Nuclear Medicine Technology and Techniques | Bernier, Christian, Langan |
| • Principles & Practice of Nuclear Medicine | Early & Sodee |

SECOND YEAR - THIRD SEMESTER

Paper I - Nuclear Medicine Instrumentation (40 Lectures)

BASICS (7 Lectures)

Collimation, scattering and attenuation, block diagram, principle of working, effect of scanning speed, dot factor, time constant, line spacing, film density, information density, photo recording display, contrast enhancement and clinical applications.

GAMMA CAMERA (10 Lectures)

Basic principles of gamma camera, collimators - parallel hole, divergent, convergent pinhole, fan beam, slant hole collimator. NaI (TI) detector, position determining circuits, display.

Gamma camera-computer interface- ADC/DAC. Performance characteristics and image quality.

Criteria of installation of Gamma camera. Selection of gamma camera – specifications and other aspects, automatic acquisition of images. Purchasing and monitoring equipment performance. , trouble shooting.

Gamma camera for PET imaging.

QC OF GAMMA CAMERA: Gray scale calibration, uniformity, tuning of camera, spatial distortion and resolution, Phantoms for QC, software phantoms, Internet based QC

SPECT (Single photon emission computerized tomography) (8 Lectures)

Theory aspects, rotating gamma camera and the couch, single or multiple section devices multi detector SPECT, Data collection: SPECT v/s planar camera, SPECT acquisition – step & shoot/continuous, matrix selection, rotating arc selection. Image reconstruction techniques, filters, artifacts in SPECT (attenuation correction, non-uniformity corrections, correction with combined SPECT-CT system), effect of scatter & scatter correction, noise, partial volume effects. Performance characteristics

PROBE SYSTEMS (4 Lectures)

Gamma probe, Thyroid uptake probe, basic components, system set-up and calibration, flat field collimator, iso-response curve and working distance. QC of uptake probe.

DOSE CALIBRATOR (3 Lectures)

Principles and its applications, QC of Dose calibrator

INSTRUMENTS IN RADIATION SAFETY (8 Lectures)

Principle and uses of Ionization chambers, proportional counters, GM tubes

Structure of an x-ray film, single and double emulsion films, types of films, cross over effect. Characteristic curve of a photographic emulsion, variations in characteristic curve with development, use of filter color, UV and Polaroid

Practicals

1. Perform the calibration of Uptake Probe.
2. Determine the isoresponse curve for the flat field collimator.
3. Perform Quality Control of Dose Calibrator.
4. Line Spread Function
5. Phantom studies for scintigraphy
6. Determine the half life of a radionuclide with the help of a Dose Calibrator.
7. Evaluate the geometric/volumetric variation of the radioactivity using Dose Calibrator.
8. Determine the Intrinsic uniformity of Gamma Camera.
9. Determine the extrinsic uniformity of Gamma Camera for the given collimator.
10. Perform experiment to determine the spatial resolution and linearity of Gamma Camera.
11. Determine the COR of the Gamma Camera.
12. Devise an experiment to measure the Pixel size for 128X128 and 256X256 matrix size of the Gamma Camera.
13. Determine the Dead time by two sources method and determine count rate at 20 % count loss.
14. Determine the system sensitivity with different collimators.
15. Perform the total performance test on the SPECT gamma camera.

SECOND YEAR - THIRD SEMESTER

PAPER II - RADIOLOGICAL PROTECTION & DOSIMETRY (40 Lectures)

RADIATION QUANTITIES AND UNITS (6 Lectures)

Activity (Becquerel & Curie), energy, exposure (C/kg & Roentgen), LET, charged particle equilibrium (CPE), mass attenuation coefficient, mass stopping power, air kerma, Terna, absorbed dose (Gray & Rad), radiation weighting factors (W_R), tissue weighting factors (W_T), equivalent dose (Sievert & Rem), effective dose (Sievert & Rem), Collective Effective dose (Person Sv), Annual Limit of Intake {ALI} (Becquerel), Derived Air Concentration {DAC} (Becquerel/m³), personnel dose equivalent, committed dose.

BASIC PRINCIPLES OF RADIATION DETECTION (8 Lectures)

Bragg Gray cavity Theory, Interaction co-efficient, interaction cross section, fluence, mass energy transfer and absorption co-efficient.

Gas filled detectors – Ionization chamber (Free air ionization chamber, Well type, Cylindrical, Parallel-Plate) – Theory and design – construction of thimble ionization chambers, gas multiplication – Proportional and GM counters & their characteristics, radiation absorbed dose measurement (standard calibration protocols).

Alternate standard methods of dose measurements (Film, TLD, OSL, diodes, chemical dosimeters and Monte Carlo Simulation)

GENERAL PRINCIPLES OF RADIATION PROTECTION AND LIMITS (8 Lectures)

Principles of radiation protection- time, distance and shielding, specific gamma ray constant (Γ) and method of calculation for essential isotopes. Radiation weighting factor, linear energy transfer (LET), Relative biological effectiveness (RBE), Quality factors, equivalent dose, effective dose, collective equivalent dose, total effective dose equivalent, REM, Sievert

Natural radiation exposure, cosmic radiation, terrestrial radiation, nuclear fall outs and medical exposures, Basis for exposure limits, ALARA, Radiation dose limits-occupational exposures, members of the public, trainee, maximum permissible doses- (ICRP, AERB recommendations), exposure of embryo/fetus younger persons, risks associated with recommended limits.

RADIATION MEASURING & MONITORING INSTRUMENTS (8 Lectures)

Film badges, film densitometers, TLD badge, Thermo luminescent dosimeter readers for medical applications – Calibration, dose calibrators, Digital pocket dosimeters using solid state devices, GM counters – Pan cake, Teletector and use of survey meters– Gamma area (Zone) alarm monitors –Contamination

Monitors for alpha, beta and gamma radiation – Hand and Foot monitors, Air Monitors for radioactive particulates and Gases, Neutron Monitors. Details of commercially instruments and systems. Use of dose constraints for staff and pregnant women. ICRP and National radiation safety standards Instruments.

TRANSPORTATION OF RADIOACTIVE SUBSTANCES (3 Lectures)

Historical background, classification of radioactive materials, general packing requirements, transport documents, labeling and marking of packages, transport of large radioactive sources and fissile material, exemptions from regulations.

RADIOACTIVE DECONTAMINATION AND WASTE DISPOSAL (7 Lectures)

Radioactive decontamination of labs, clothes, hands, glassware, gloves, metals, plastics, paints and bricks, decontamination of person, decontamination of room, general principles, administration/misadministration of radiopharmaceuticals, release of patients administered with radiopharmaceuticals.

Origin and types of waste, classification of Radioactive waste, liquid, gaseous and solid waste, storage, transport, disposal of all type of waste, disposal of animal carcasses and radioactive foliage, disposal limits for ground burial and sanitary sewage system, incineration, disposal of long-lived and indispersible radioactive wastes. Management of decaying radioactive source (sealed/unsealed sources) storage and transfer to authorized personal,

Practicals

1. To determine the half-life of a radioactive material.
2. Radiation exposure measurement: effect of distance, Shielding and time.
3. Radiation absorbed dose calculations exercises
4. Study of energy dependence of a pocket dosimeter and a survey meter
5. Demonstration of transport of radioactive materials
6. Monitor the given item for contamination, if found contaminated, then perform the Decontamination using contamination monitor.
7. Perform the wipe test on the floor and determine the level of contamination on the floor.
8. Demonstration of TLD badges, Pocket dosimeters.
9. To perform Radiation survey around the cyclotron and Radio-iodine therapy Ward.
10. To calculate weighted CTDI (body and head) using ion chamber for QA testing of CT machine.

SECOND YEAR - THIRD SEMESTER

Paper III - Principles and Practice of Radiopharmacy (40 Lectures)

RADIONUCLIDE PRODUCTION AND CHARACTERISTICS (3 Lectures)

Production of radioisotopes by artificial methods – reactor produced, cyclotron produced radionuclide generators. Physical & chemical characteristics of radionuclides used in nuclear medicine, Criteria for selection of the radionuclides for diagnosis and therapy.

RADIONUCLIDE GENERATORS (4 Lectures)

SPECT and PET radionuclide generators: ^{99}Mo - $^{99\text{m}}\text{Tc}$, ^{188}W - ^{188}Re , ^{113}Sn - $^{113\text{m}}\text{In}$, ^{68}Ge - ^{68}Ga , ^{82}Sr - ^{82}Rb , ^{81}Rb - $^{81\text{m}}\text{Kr}$
Radionuclide generator system: principles of generator system, Parent-daughter equilibrium. Solvent extraction, liquid column generator, solid column generator, elution efficiency and factors affecting elution yield. Performance and quality control of $^{99}\text{Mo}/^{99\text{m}}\text{Tc}$ generator.

DESIGN AND DEVELOPMENT OF RADIOPHARMACEUTICALS (5 Lectures)

Characteristics of Ideal radiopharmaceutical, general considerations, factors affecting the design of radiopharmaceuticals: compatibility, stoichiometry, charge and size of the molecule, protein binding solubility, stability and bio-distribution. Important factors in labeling, efficiency of labeling process, chemical stability of the product, denaturation or alteration, isotope effect, storage conditions, specific activity, radiolysis, purification analysis, shelf life. Cold kit preparation & contents, lyophilization techniques.

REGULATORY CONSTRAINTS (3 Lectures)

Regulatory constraints: pharmaceutical aspects, radiation protection aspects, local constraints, Regulations, ethics and registration of radiopharmaceuticals
Design of hospital pharmacy, laboratories, radionuclide stores.

SPECIFIC METHODS OF LABELING (6 Lectures)

Methods of radiolabelling : isotope exchange reactions, introduction of foreign label, labeling with bi-functional chelating agents, biosynthesis, recoil labeling, excitation labeling, substitution reactions.
Radio iodination: Principle of radio-iodination, methods of radio-iodination: Monochloride method, chloramines T method, Electrolytic method, enzymatic method, conjugation method, demetallation method, iodogen method, iodo bed method, radioiodinated compounds, radioiodination of proteins, antibodies/monoclonal antibodies.
Labeling with $^{99\text{m}}\text{Tc}$: $^{99\text{m}}\text{Tc}$ chemistry: Technetium complexes, role of reducing agent in Radiolabeling, technetium coupling with biologically active modules. Precursors and chelating agents needed for the labelling of Biomolecules, cellular labeling with Tc99m chelates.
Labeling with ^{111}In : labeling of leucocytes and platelets, antibodies, ^{111}In -pentetate, ^{111}In -pentetate, ^{111}In -pentetate.

QUALITY CONTROL OF RADIOPHARMACEUTICALS (6 Lectures)

Determination of chemical purity, determination of tin(II), Determination of radiochemical purity, determination of radionuclide purity, sterility testing of radiopharmaceuticals, pyrogen testing of radiopharmaceuticals, bio-distribution studies
Physicochemical tests: physical characteristics, pH and ionic strength,
QC for $^{99}\text{Mo}/^{99\text{m}}\text{Tc}$ (stable molybdenum) by performing breakthrough tests : Breakthrough of Methyl ethyl ketone, alumina.
QA of PET radiopharmaceuticals by TLC scanner, HPLC and Gas Chromatography (GC).
QC in hospital radiopharmacy practices - includes aseptic practices & pharmaceutical safety aspects. Good manufacturing practice (GMP), ISO and ISI standards in radiopharmaceuticals.

PHYSICOCHEMICAL TECHNIQUES: (5 Lectures)

Principle of purification and separation of molecular components in Low pressure open chromatography, (TLC, paper, column) HPLC, gas chromatography.

Basic principle and application of Mass spectroscopy, Nuclear magnetic resonance spectroscopy (NMR), flow cytometry in nuclear medicine.

CHARACTERISTICS OF SPECIFIC SPECT RADIOPHARMACEUTICALS (4 Lectures)

Chemical name, oxidation state of Tc99m and structure of Tc99m complex formed, cold kit specifications, amount/volume/size of the contents, labeling procedure, physical and chemical characteristics of radionuclide used for labeling, clinical applications of the radiopharmaceutical, quality control, pharmacokinetic data, radiation dose. Mechanism of localization of radiopharmaceuticals in different organs.

CHARACTERISTICS OF PET RADIOPHARMACEUTICALS (4 Lectures)

Physical and chemical characteristics of Positron emitters, synthesis of 18-FDG, $^{11}\text{CO}_2$, $^{13}\text{NH}_3$ and H_2^{15}O , Production of F-18 FDG and other F-18 Radiopharmaceuticals, ^{68}Ga labelled compounds. Recent trends in radiopharmaceuticals and search for novel SPECT and PET radiopharmaceuticals. Clinical applications of the radiopharmaceutical, quality control, pharmacokinetic data, radiation dose.

Practicals

1. Demonstration of ^{99}Mo - $^{99\text{m}}\text{Tc}$ column generator.
2. To separate $^{99\text{m}}\text{Tc}$ from ^{99}Mo and determine the efficiency of extraction.
3. Perform the quality control of elute from ^{99}Mo - $^{99\text{m}}\text{Tc}$ Generator.
4. To determine the Rf of $^{99\text{m}}\text{Tc}$ and the given labeled compounds by using ascending chromatography.
5. Perform the Radiochemical Purity of the given radiopharmaceutical, using Paper chromatography.
6. Prepare single vial kit preparation of radiopharmaceutical.
7. Prepare double vial kit preparation of radiopharmaceutical. Prepare ECD
8. Prepare triple vial kit preparation of radiopharmaceutical. Prepare the Sulphur colloid.
9. Prepare a radiopharmaceutical involving boiling step. Prepare Mebrofenin.
10. To study the formation of MAA and study its bio-distribution
11. To prepare solid meal for GET study.
12. Perform RCP of ^{18}F -FDG by thin layer chromatography Scanner.
13. To perform QC of FDG using gas chromatography.
14. To perform Bacterial endotoxin test on FDG.
15. Demonstrations regarding determination of target to non target ratios for various SPECT and PET radiopharmaceuticals in experimental models.
16. Preparation of ^{68}Ga labeled compounds.

SECOND YEAR - THIRD SEMESTER

PAPER IV - IMAGING AND NON-IMAGING PROCEDURES (40 LECTURES)

DIAGNOSTIC *IN-VIVO* TECHNIQUES (28 lectures)

Renal imaging studies: Diuretic renogram, captopril renogram, standard renogram, uretic reflux study, renal transplant studies, static renal study.

Bone imaging: Routine bone (whole body and spot) imaging, bone flow study, quantitative bone scan-sacroiliac quantitative study, 3-phase bone scans.

Liver-spleen study, bone marrow imaging, spleen imaging with denatured RBC's

Gastrointestinal study- Hepatobiliary imaging, Gall bladder dynamic studies using IDA compounds, gastric oesophageal reflux, gastric emptying time, biliary reflux, Meckel's diverticulum imaging, GI bleeding with ^{99m}Tc -RBC, Salivary gland imaging (static/dynamic)

Endocrine studies-Thyroid imaging and uptake (^{99m}Tc and ^{131}I), Perchlorate discharge test, T_3/T_4 suppression test, TSH stimulation test. ^{131}I whole-body imaging, parathyroid imaging, adrenal cortex imaging, ^{131}I -MIBG imaging, testicular imaging.

Lung imaging studies -Ventilation lung imaging studies using gases (^{133}Xe , ^{81m}Kr), Inhalation imaging using aerosols, aerosols generators, mucociliary clearance, COPD, Pulmonary permeability using DTPA, perfusion imaging (MAA, Microsphere) –pulmonary embolism.

Central nervous study- cerebral blood flow dynamic studies, static brain imaging, cisternography and ventriculoatrial and ventriculoperitoneal shunts.

Miscellaneous studies- Lacrimal scintigraphic imaging, Lymphatic imaging, Venography, adrenal imaging using ^{131}I -MIBG, Bone marrow imaging, Infection & Inflammation imaging, Tumour Imaging, ^{67}Ga imaging

IN-VIVO NON-IMAGING TECHNIQUES (12 Lectures)

GFR plasma sample method, Radioiodine Thyroid uptake, RBC survival study, Splenic sequestration study, Estimation of blood volume, Red cell volume, plasma volume, Vitamin B_{12} absorption study Iron absorption study.

Practicals

1. Drawing of blood from patients
2. Determination of blood glucose using glucometer
3. To perform Bone scan (3-phase, whole body and statics)
4. To perform MPI.
5. To perform Lung perfusion study
6. To perform Renogram study (using DTPA/EC)
7. To perform DMSA scan
8. To perform DRCG
9. To perform Gated Blood pool scintigraphy.
10. To perform Salivary scintigraphy
11. To perform Solid GET
12. To perform GER
13. To perform Liver scan using SC
14. To perform Hepatobiliary study.
15. To perform Brain SPECT study
16. To perform adrenal imaging using iodine 131 MIBG
17. To perform thyroid scan
18. To perform parathyroid scan
19. To perform whole body Iodine-131 scan
20. To perform RAIU
21. To calculate GFR using plasma sample method

SECOND YEAR – FOURTH SEMESTER

Paper I - MEDICAL CYCLOTRON, PET/CT & ALLIED INSTRUMENTATION (40 Lectures)

MEDICAL CYCLOTRON (7 Lectures)

Basic working principles and instrumentation of cyclotron, type of cyclotron, cyclotron generated radionuclides, cyclotron shielding, neutron detection and other quality control procedures.

Medical Cyclotron Principles and Working

Production of F-18, C-11, N-13, O-15,

PET AND COINCIDENCE DETECTION (12 Lectures)

Basic principles of PET imaging, PET detector and scanner designs detectors – BGO, NaI (TI), L(Y)SO; Time of Flight Attenuation correction with transmission sources – ^{68}Ge , ^{137}Cs . Techniques for image registration .

Data corrections: normalization, uniformity correction, scatter correction, random correction.

Reconstruction, Filtered Back Projection, Iterative reconstruction: general principles, Maximum likelihood reconstruction, 2-D and 3-D reconstructions, performance characteristics of PET imagers.

Image Display, Displaying PET images, Maximum Intensity Projection Images (MIPs), Quantification, from measured disintegration events to activity concentration . Performance characteristics, Kinetic modelling and Standardized Uptake Value (SUV)

Daily, weekly and monthly Quality control of the PET/CT.

PET v/s SPECT, Dedicated and hybrid PET systems.

COMPUTED TOMOGRAPHY (5 Lectures)

Principles of Tomography, longitudinal and transverse or axial tomography, multisection radiography. Principles of CT, design of equipment, reconstruction of algorithms and various biomedical applications. CT QC.

MR/CT/ULTRASOUND IMAGING (4 Lectures)

Physics of magnetic resonance, magnetic resonance imaging, MRI equipment and principle, its advantage over CT/ Ultrasound, functional magnetic resonance imaging, limitations and uses of MRI.

FUSION IMAGING (4 Lectures)

Definition, introduction, Software and hardware fusion of images

SPECT/ CT Fusion Imaging: Principles, applications, limitations and uses

PET/CT Fusion Imaging: Principles, applications, limitations and uses

PRE-CLINICAL 'SMALL-ANIMAL' PET SCANNERS (3 Lectures)

Use of CT, PET and SPECT for imaging of small animals. Animal conditioning, dynamic studies and other applications of multimode PET+SPECT+ CT.

INTERNET IN NM, TELEMEDICINE & NANOTECHNOLOGY (5 Lectures)

Newer Computer applications in Nuclear Medicine - Medical Data Communications and Computer Networks. Communication protocols: standard used, FTP, TCP/IP protocols, DICOM and interfile conversion software, PACS, Telemedicine infrastructure-software and hardware used, Remote sensing telecommunication, information technology, challenges to telemedicine and Medical applications of Telemedicine. Demonstration in MTLAB® and Mathematica® software packages;

Nanotechnology: Concepts and its biomedical applications

Practicals

1. Perform experiment to calibrate PET/CT
2. Demonstration of Cyclotron
3. Perform preconditioning of cyclotron
4. Perform beam targeting experiment in cyclotron
5. Perform synthesis of 18-F FDG
6. Demonstration of methods of acquisition of PET/CT procedures in cardiology, Neurology and Oncology.
7. Demonstration of SPECT/ CT Fusion Imaging principles.
8. Demonstration of PET/CT Fusion Imaging principles.

SECOND YEAR – FOURTH SEMESTER

PAPER II - RADIOLOGICAL PROTECTION & DOSIMETRY (40 Lectures)

DOSE EVALUATION METHODS (8 Lectures)

Compartmental Model- single compartment model, two compartment model with and without back transference
Beta particle dosimetry, Calculation of Beta dose, Gamma dose calculation, Geometrical factor and average geometrical factor. Radiation dosimetry for external radioactive source and internally deposited radioactive source; compartment analysis; Single Compartment, Two Compartment model, Equilibrium Dose rate equation, MIRD method of internal dose calculation, Absorbed Fraction and calculation of absorbed fraction, calculation of dose, age dependent dose coefficient for various radiopharmaceuticals. Dosimetric considerations in isotope therapy, radiobiological interpretation of dose delivery (radiobiological Models).

RADIATION BIOLOGY (5 Lectures)

Biological effects of ionizing radiation, cell survival curve, RBE, LET & OER their relationship, stochastic and non-stochastic effects, genetic effects, somatic effects, effects in-utero, four R's of radiobiology, radiobiological Models-Target theories, LQ model, relative effectiveness, biological equivalent dose BED, tumor control probability (TCP), normal tissue complication probability (NTCP), therapeutic Ratio, bioassay-biological dosimeters etc.

POTENTIAL EXPOSURE AND EMERGENCY PLANS (5 Lectures)

Potential exposure and safety assessment, Accident situations involving radioisotopes Mitigation of consequences: emergency plans – Lost source, stuck source, Contamination, Off-site accidents, Patient accidental exposure: Radiation emergencies, preparedness and record keeping, large scale spillage, leakage of radioactivity substance to environment, accidental inhalation, death of a patient with radioactivity etc.

PLANNING & DESIGN OF NUCLEAR MEDICINE LABS & RADIATION GENERATING EQUIPMENT ROOMS (5 Lectures)

Design and safety aspects of planning and Shielding Design of Nuclear medicine department with cyclotron facility [Neutron activation analysis (NAA)] and PET Centre, planning & Design of- Radiation Research laboratories of various sizes & capacity as per the norms of AERB, Security and safety measures of radioactive Sources and radioactive cautions signs and labels.

LEGISLATION (10 Lectures)

National legislation – Regulatory framework – Atomic Energy Act – Atomic Energy (Radiation Protection) Rules – Applicable Safety Codes (NM facility), Standards, Guides and Manuals –Regulatory Control –Licensing Inspection and Enforcement – Responsibilities of Employers, Licensees, Radiological Safety Officer and Radiation professionals/Workers (Medical Physicist/Technologists/Radio pharmacists).

Regulatory clearance-Approval of NM Lab, Physician & RSO, Regulatory consent, authorization- for disposal of radioactive "waste and safe transport of radioactive materials. Ethics, Registration of radiopharmaceuticals and their use.

Radiation Safety Program, Radiation Safety Committee, Personnel Monitoring, Responsibilities for Implementation of Basic Safety Standards Requirements. Role of National and International Organizations (AERB, IAEA, ICRU, ICRP, AAPM, NCRP, BIPM, UNSCEAR etc.)

PATIENT CARE AND HOSPITAL PRACTICE (7 Lectures)

Behavioral science (Care of the patient): Management of ambulatory and non-ambulatory patients and aids for this, elementary hygiene and cleanliness, nursing care, first aid, principles of asepsis- handling of contaminated swabs, used syringes and needles, handling of secretions, sterilisation methods, preparation of patients for general nuclear medicine procedures, precautions-administration of radiopharmaceutical to children, nursing and care taking mothers and pregnant women

- Planning & scheduling of the patient work load.
- Economic aspects of nuclear medicine and cost-effectiveness of nuclear medicine procedures.
- Public relations.

Practical

1. Emergency preparedness drill.
2. Demonstrations regarding the calculations of exposure doses and safety aspects
3. To prepare layout plan for different types of nuclear medicine laboratories
4. Designing of a PET department depending upon number of patients per week
5. Calculation of shielding for a given radionuclide and Patient workload
6. Demonstration of scheduling of patients

SECOND YEAR – FOURTH SEMESTER

PAPER III - NUCLEAR MEDICINE IMAGING & RADIONUCLIDE THERAPY (40 Lectures)

CARDIAC STUDIES (5 Lectures)

static blood pool imaging, Rest/stress myocardial imaging, infarct imaging, MUGA, gated blood pool study, first pass study (shunt detection), ²⁰¹Tl imaging

BASIC MOLECULAR IMAGING (8 Lectures)

PET in the clinical setting: Kinetic modelling and Standardized Uptake Value (SUV), Staging and use of PET in staging, Recurrence/re-staging, Monitoring response to therapy, Early response assessment, Radiotherapy planning, Advances in imaging techniques & image processing including fusion techniques.

Need for image fusion in clinical imaging PET and SPECT, Clinical need for PET/CT and SPECT/CT, FDG - PET imaging in different tumor types, Clinical PET/CT - Other applications, Cardiac applications, Neurology applications, Infection and inflammation imaging, image guiding for radiotherapy & stereotactic surgeries.

PET STUDIES (7 Lectures)

Methods of performing PET/CT procedures in cardiology, Neurology and Oncology, Gated PET/CT studies (respiratory and cardiac gating). Use of ¹⁸F-FDG and ¹³N-NH₃ for cardiac studies.

Oncology and nuclear medicine: molecular targets for cancer diagnosis, Clinical application of PET in oncology, cardiology and neurology, use of PET in treatment planning and to study treatment response

THERAPEUTIC APPLICATIONS OF RADIONUCLIDES (20 Lectures)

General precaution regarding contamination and radiation dosage
Pre and post therapy imaging and patient preparation

Radio iodine therapy for Thyrotoxicosis : Dosage administration - Precaution to be followed
Radio iodine therapy for Thyroid malignancy: Dosage administration - Precaution and care of patient

Iodine-131 - MIBG Indications - Dosage - Administration - Precaution to be taken during administration.

Treatment of bone pain: use of ³²P-orthophosphate, ⁸⁹Sr- Strontium chloride, ¹⁸⁶Re-HEDP, ¹⁵³Sm-EDTMP, ¹⁷⁷Lu etc.

Radiation Synovectomy: Intra articular Therapy
Intravascular particulate radio nuclide therapy for HCC, liver mets
Labeled receptor, peptides (Lu-177 DOTATATE/PSMA therapy)
Radioimmunotherapy: Labeled Monoclonal antibodies
Radiolabeled skin patches
Treatment of polycythemia Vera and leukemia.
Treatment of malignant effusion in pleural and peritoneal cavities
Advances in Radionuclide Therapy.

Practicals

1. To set a protocol for PET imaging for Oncology patient
2. To set a protocol for PET imaging for cardiac viability study
3. To set a protocol for PET imaging using N-13 ammonia for myocardial perfusion
4. To perform an Iodine-131 whole body survey scan
5. To demonstrate Iodine-131 therapy in a thyroid cancer patient
6. To demonstrate monitoring and discharge from the ward of a high dose Iodine 131 patient
7. To demonstrate and monitor iodine therapy for thyrotoxicosis

SECOND YEAR – FOURTH SEMESTER

PAPER IV - RECENT ADVANCES IN NUCLEAR MEDICINE (40Lectures)

Recent advances related to Nuclear Medicine Instrumentation **(10Lectures)**

Recent advances related to Radiopharmaceuticals **(10 Lectures)**

Recent advances related to Radionuclide therapy **(10 Lectures)**

Recent advances related Nuclear Medicine and Molecular Imaging **(10 Lectures)**

Practicals:

Related to recent advances under different topics

Suggested Books and Journals

Note: The books indicated as text-book(s) are suggestive of the level of the coverage. However, any other book may be followed.

<u>Name of Book</u>	<u>Editor's Name</u>
• Cell & Molecular Biology	De Robertis
• Molecular Biology of the Cell	Alberts, Bray, Lewis, Raff
• Molecular Biology of Gene	Watson
• Gene –V	Benzamin
• Cell Signaling	Morgan
• Recombinant DNA	Tooze, Tustz
• Text Book of Medical Physiology	Guyton
• Physiology	Chatterjee
• Biochemistry	Lehninger
• Biochemistry	Stryer
• Basic Medical Biochemistry	Smith Marks & Libermann
• Biochemistry	Harper
• Text Book of Microbiology	Panikar
• Methods in Biostatistics	Mahajan
• Methods of Biostatistics	Bhaskararao
• Statistical and Mathematical Techniques in NM	GS Pant
• Biostatistics: A foundation for the analysis in the Health Sciences	Wayne W. Daniel., John Wiley.
• Fundamental of Statistics Vol.-I & II	A.M.Goon, M.K.Gupta & B.Das
• Essentials of Medical Statistics, Blackwell publishers	Betty Kirkwood
• Object Oriented Programming with C++	E.Balaguruswamy.
• A First Course in Computers	Sanjay Saxena.
• Calculus (Pearson Education, 2003)	G.B.Thomas and R.L.Finney
• Introduction to Mathematical Physics	C.Harper (Prentice Hall of India)
• Field and Wave Electromagnetics	David Cheng
• Principles of Applied Biomedical Instrumentation	Geddes, Baker
• Mathematical Models in Biology –An Introduction	Allman & Rhodes
• Radiation detection	Knoll
• Handbook of Health Physics and Radiological Health	Shleien, Slaback, Birkey
• Physics and Radiobiology of Nuclear Medicine	Gopal Saha
• Radiation Biology	Casarett
• Elements of Radiobiology	Selman
• The essential Physics of Medical Imaging	Bushberg, Seibert, Leidholdt
• Physics in Nuclear Medicine	Cherry, Sorenson, Phelps
• Medical Imaging Physics	William R.Hendee
• Introduction to Medical Physics	Arid
• Medical Physics	Cameron
• Advances in Diagnostic Medical Physics	Pant GS

- Quality Controls of NM Instrumentation Pant GS
- Quality Control in NM, Radiopharmaceutical, Instrumentation & In-vitro Assays Rhodes Buek
- Radiation Safety for unsealed Sources Pant GS
- Radiation Dosimetry Attix, Poesch
- Fundamentals of Nuclear Pharmacy Gopal Saha
- Radiopharmaceuticals Gopal Subramaniam
- Text Book of Radiopharmacy Sampson
- Radio immunoassay Principles & Practices Pillai & Bhandarkar
- Nuclear Medicine in Vitro B. Rothfield
- Principles of Nuclear Medicine Henry N. Wagner (Jr.)
- Nuclear Medicine Technology and Techniques Bernier, Christian, Langan
- Principles & Practice of Nuclear Medicine Early & Sodee
- Basics of PET Imaging Gopal Saha
- PET and PET/CT in Oncology Pehr, Biersack, Coleman
- Nuclear & PET Techniques Christian
- Interventions in Nuclear Medicine Richard P. Spencer
- An Atlas of Clinical Nuclear Medicine Fogelman & Maisey
- Clinical SPECT Imaging Elissa Lipcon Kramer
- Text Book of Medical Physiology Guyton and Hall
- Principles of Anatomy and Physiology Tortora and Derrickson (Wiley).
- Text Book of Human Histology with Colour Atlas Inderbir Singh
- Biochemistry, 4th ed. (WH freeman and company) Lubert Stryer
- Cell and Molecular Biology, 8th ed. (BI Publication) De Robertis
- Gray's Anatomy for students Drake, Vogl & Mitchell :
- Numerical Methods for Engineers and Scientists Hoffman
- Numerical Methods for Engineers and Scientists Bajpai, I.M. Calculus & J.
- Introductory Methods of Numerical Analysis S.S. Sastry
- Introduction to Mathematical Physics Michael T vaughn
- Statistical methods of Medical & Biology Students G. Dahlberg
- C++ How to Program Deitel & Deitel
- Let us C Kanetkar
- Atomic Nucleus (McGraw Hill) R.D. Evans
- Nuclear Physics (Narosa Pbl. House) I. Kaplan
- Nuclear Radiation Physics (Prentice Hall) R.E. Lapp
- Radiations from Radioactive Atoms (Govt. Print. Off.). L. Slack & K. Way
- Radiation Physics in Radiology (Springer). R. Oliver
- Field and Wave Electromagnetics (Addison-Wesley) D.K. Cheng
- Semiconductor Devices: Physics and Technology (Wiley). S.M. Sze
- Integrated Electronics (McGraw Hill). Millman and Halkias
- OPAMPS and Linear Integrated Circuits Ramakant A. Gayakwad
- Electronic Principles (McGraw Hill). A.P. Malvino
- Principles of Applied Biomedical Instrumentation (Wiley). L.A. Geddes & L.E. Baker
- Medical Imaging Physics (Wiley-Liss) W.R.Hendee & E.R.Ritenour
- Radiation Detectors and Instrumentation (Wiley). Glenn F. Knoll

- Techniques for Nuclear and Particle Physics experiments
 - The Physics of Radiation Therapy
 - Medical Imaging Physics (Wiley-Liss)
 - Radiation Biology (Prentice Hall)
 - Introduction to Radiation Biology
 - Radiation Safety for Unsealed Sources
 - Radiation Biology for the Radiologists
 - An Introduction to Radiation Protection in Medicine
 - Fundamentals of Nuclear Pharmacy 5th ed. (Springer).
 - Physics and Radiobiology of Nuclear Medicine
 - Introduction to Health Physics
 - Physics in Nuclear Medicine
- W.R. Leo
 F.M. Khan
 Hendee & Ritenour
 P.A. Casserette
 Uma Devi, Nagarathnam, Satish Rao
 G. S. Pant
 Eric J Hall
 J. V. Trapp and T. Kron
 Gopal B. Saha
 Gopal B. Saha
 Herman Cember and Thomas Johnson
 Cherry,. Sorenson, Phelps

Safety Codes

- AERB Safety Manual and AERB Safety Guide
- AERB Safety Code (Nuclear Medicine Laboratories)
- AERB Safety Code (Transport of Radioactive Materials)
- AERB Safety Guide (Standards of Safety in Transport of Radioactive Material)
- AERB Safety Guide (Procedure for Forwarding, Transport, Handling and Storage of Radioactive Consignments)
- IAEA activities in Nuclear Safety by IAEA
- Atomic Energy Act 1962.
- AERB Radiation Protection Rules 2004.
- AAPM Task Group-108,
- AAPM Report No. 1, 39, 74
- NCRP Report No. 51, 147
- AERB Guidelines on radiation emergency procedures and Safety Guide revised, 2011.
- Eric J. Hall, Amato J. Giaccia: Radiobiology for the Radiologist, 6thed. (JP Lippincott Company).
- MIRDO Pamphlets

Journals

- International journal of radiation application instrumentation-part B
- Nuclear Medicine and Biology
- Medical Physics
- Journal of Nuclear Medicine Technology
- Journal of Nuclear Medicine
- European Journal of Nuclear Medicine
- Seminars in Nuclear Medicine
- Nuclear Medicine Annual
- World Journal of Nuclear Medicine
- Annals of Nuclear Medicine
- Indian Journal of Nuclear Medicine
- Hellenic Journal of Nuclear Medicine