FACULTY OF SCIENCE

SYLLABI

FOR

M.Sc. IN NUCLEAR MEDICINE

(SEMESTER SYSTEM)

FOR

EXAMINATIONS 2013-2014
FIRST YEAR

First Semester

Theory = 400 Marks (4 Papers of 100 marks each)
Practicals = 200 Marks (4 Practicals of 50 marks each)
Total Marks = 600 Marks

A. Theory Papers
1. Fundamental Anatomy 100 Marks
2. Applied Mathematics, Biostatistics and Computer Applications 100 Marks
3. Radiation Physics 100 Marks
4. Radiation Biology 100 Marks
Total = 400 Marks

B. Practicals
1. Fundamental Anatomy 50 Marks
2. Applied Mathematics, Biostatistics and Computer Applications 50 Marks
3. Radiation Physics 50 Marks
4. Radiation Biology 50 Marks
Total = 200 Marks

Second Semester

Theory = 400 Marks (4 Papers of 100 marks each)
Practicals = 200 Marks (4 Practicals of 50 marks each)
Total Marks = 600 Marks

A. Theory Papers
1. Molecular Physiology and Cancer Biology 100 Marks
2. Fundamentals of Electronics and Biomedical Instrumentation. 100 Marks
3. Radiation Detection and Measurements 100 Marks
4. Radioisotope Applications and Radiation Safety 100 Marks
Total = 400 Marks

B. Practicals
1. Molecular Physiology and Cancer Biology 50 Marks
2. Fundamentals of Electronics and biomedical Instrumentation 50 Marks
3. Radiation Detection and Measurements 50 Marks
4. Radioisotope Applications and Radiation Safety 50 Marks
Total = 200 Marks
SECOND YEAR

Third Semester

Theory = 400 Marks (4 Papers of 100 marks each)
Practicals = 200 Marks (4 Practicals of 50 marks each)
Total Marks = 600 Marks

A. Theory Papers
1. Nuclear Medicine Imaging and Counting Instrumentation 100 Marks
2. Principles and Practice of Radiological Protection 100 Marks
3. Principles and Practice of Radiopharmacy and Radionuclide Generators 100 Marks
4. Nuclear Medicine Imaging and In-vivo Counting 100 Marks
Total = 400 Marks

B. Practical
1. Nuclear Medicine Imaging and Counting Instrumentation 50 Marks
2. Principles and Practice of Radiological protection 50 Marks
3. Principles and practice of Radio pharmacy and Radionuclide generators 50 Marks
4. Nuclear Medicine Imaging and In-vivo Counting 50 Marks
Total = 200 Marks

Fourth Semester

Theory = 400 Marks (4 Papers of 100 marks each)
Practical = 200 Marks (4 practical of 50 marks each)
Dissertation and Grand Viva = 100 Marks
Total Marks = 700 Marks

A. Theory Papers
1. PET, Cyclotron and Allied Instrumentation. 100 Marks
2. Radiation Dosimetry, Radiobiology and Hospital Practice 100 Marks
3. SPECT and PET Radiopharmaceuticals 100 Marks
4. PET Imaging, Radionuclide Therapy and in-vitro Techniques 100 Marks
Total = 400 Marks

B. Practicals
1. PET, Cyclotron and Allied Instrumentation. 50 Marks
2. Radiation Dosimetry, Radiobiology and Hospital Practice 50 Marks
3. SPECT and PET Radiopharmaceuticals 50 Marks
4. PET Imaging, Radionuclide Therapy and in-vitro Techniques. 50 Marks
Total = 200 Marks

C. Dissertation and Grand Viva 100 Marks
M.Sc. Nuclear Medicine Syllabus
FIRST YEAR - FIRST SEMESTER

Paper – I
FUNDAMENTAL ANATOMY (40 Lectures)

INTRODUCTORY CYTOLOGY (6 Lectures)
Cell: Cell wall and cell membrane, Structure and functions of endoplasmic reticulum (ER), mitochondria, golgi complex, nucleus, lysosomes.

MICROSCOPIC ANATOMY (11 Lectures)
Basic tissue: Epithelial tissue-electron microscopic structure and various structural modifications.
Connective tissue: Blood and its formed elements, loose connective tissue, extracellular components, fixed cellular elements.
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

GROSS ANATOMY (23 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)

Practicals:
1. To identify different parts of a human skeleton
2. To identify types of epithelial tissue: (squamous, stratified, pseudostratified) using light microscope.
3. To visualise microanatomical view of musculoskeletal system using light microscope.
4. To visualise microanatomical view of Respiratory system (Larynx, pharynx, trachea, principal bronchi and lungs) using light microscope.
5. To visualise microanatomical view of Digestive system (esophagus, stomach, small and large intestine and rectum) using light microscope.
6. To visualise microanatomical view of Urinary system: (Kidney, urethra and urinary bladder) using light microscope.
7. To visualise microanatomical view of Reproductive system of male: (Testes, Ductes deferens, Seminal vesicle and prostrate) using light microscope.
8. To visualise microanatomical view of Reproductive system of female (Ovary, fallopian tube and uterus) using light microscope.
9. To visualise microanatomical view of Nervous system (neuron, neuroglia, gross anatomy of brain) using light microscope.
10. 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.
11. To determine TLC, red blood cell counts using hemocytometer
12. To study DLC in blood smear.
14. Estimation of activities of enzymes viz alkaline phosphatase, acid phosphatase, SGOT and SGPT

Paper – II

APPLIED MATHEMATICS, BIOSTATISTICS AND COMPUTER APPLICATIONS
(40 Lectures)

Numerical Methods: (10 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. 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 methods, Euler’s method, the modified Euler’s method, Runge-Kutta method.

Monte Carlo: Random variables, discrete random variables, continuous radom 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.

Probability, Statistics and Errors (20 Lectures)
Probability – addition and multiplication laws of probability, conditional probability, population, variates, collection, tabulation and graphical representation of data

Basic idea of statistical distributions frequency distributions, averages or measures of central tendency, arithmetic mean, properties of arithmetic mean, media, node, geometric mean, harmonic mean, dispersion, standard deviation, root mean square deviation, standard error and variance, moments, skewness and kurtosis.

Application to radiation detection-uncertainty calculation, 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

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: 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
Counting and medical statistics (5 Lectures)
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- Preset of rate meters and recorders, efficiency an sensitivity of radiation detectors, statistical aspects of gamma ray and beta ray counting, special consideration in gas counting and counting with proportional counters, statistical accuracy in double isotope technique.

Computational Tools & Techniques: (5 Lectures)
Computational packages: Overview of programming in C++, MATLAB/Mathematica, and SPSS/STATISTICAL in data analysis and graphics.

Practicals

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

Paper – III

RADIATION PHYSICS (40 Lectures)

Radiation Physics (15 Lectures)
Time varying fields and Maxwell’s equations, potential function, electromagnetic boundary conditions, wave equations and their solutions, time harmonic fields. Plane Electromagnetic waves: Plane waves in lossless media, Plane waves in lossy media, group velocity, flow of electromagnetic power and the Poynting vector. Normal incidence at a plane conducting boundary, Oblique incidence at a plane dielectric boundary. Wave guides and cavity resonators: General wave behaviour along uniform guiding structures, parallel-plate wave guide, rectangular and circular wave guides, dielectric wave guides, cavity resonators.

Radioactivity and decay: Laws of radioactivity, types of radiation (α, β, γ, X-ray, n), Decay processes; decay modes, Probability and decay constant. Radioactivity, decay equation, physical half life, mean life; Radioactive series- natural radioactive series & artificial radioactivity; beta particle spectrum; K-electron capture; Cerenkov radiation, characteristic radiation, auger effect, fluorescent yield and Bremsstrahlung radiations, Metastable state and isomeric transition, internal conversion, general aspects of gamma decay, gamma energy decay

Nuclear reactions, Nuclear energy levels; Nuclear isomerism., Bombardment, Conservation Laws, compound nucleus, artificial transmutation, discovery of neutron, Nuclear reaction cross section, neutron activation nuclear fission, fission products, fissile materials, diffusion and slowing down of neutrons, various types of reactors -Fusion and thermo nuclear reactions.

Radiation Units (6 Lectures)
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.

**Radiation generators (12 Lectures)**


**Interactions of x and γ rays with matter (7 lectures)**

Scattering vs absorption: coherent scattering, photoelectric effect, Compton effect, pair production, annihilation radiation, photonuclear disintegration. Total and true absorption coefficients, attenuation of photon beams: attenuation, energy transfer, and energy absorption, exponential attenuation equation, attenuation coefficients, half-value layer, beam geometry. Interactions of particulate radiation: Directly and indirectly ionizing particles, Elastic and inelastic collisions with orbital electrons and the nucleus, linear energy transfer, specific ionization, mass stopping power, range.

**Practicals:**

1. To measure Half Value Layer's 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.
Paper – IV

RADIATION BIOLOGY (40 Lectures)

Radiation Chemistry (4 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 Biology (10 Lectures)
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.
Radiation Molecular Biology: 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.
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 Major Organ Systems (8 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.

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

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.
$^{59}$Fe absorption studies, Techniques for studying absorption of labeled substance, $^{59}$Fe turn over studies, plasma iron clearance
$^{58}$Co/$^{57}$Co: Applications in schilling’s test of vitamin B12 absorption, double tracer technique and whole body counting
$^{60}$Co: in cancer treatment, gamma knife
$^{32}$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.
$^{45}$Ca, $^{65}$Zn and $^{3}$H metabolic studies and other biomedical applications.

Practicals
1. To determine the turnover of $^{14}$C glucose in liver slices using radiorespirometric technique.
2. To demonstrate that tritium labeled thiamidine is incorporated in DNA.
3. To study in vivo incorporation of $^{14}$C uracil in RNA.
4. To determine the in-vitro uptake of $^{14}$C labeled amino acids in the given organ slices.
5. To study the bio-kinetics of $^{45}$Ca in understanding its metabolism in bone when administered in an animal.
6. To label the red blood cells using $^{51}$Cr and to determine the efficiency of labeling.
7. To find out the average life span of red blood cells by using $^{51}$Cr radionuclide.
8. To determine the blood volume of a given animal using $^{51}$Cr labeled red blood cells.
9. To prove that spleen is the storehouse of worn out red blood cells by using $^{51}$Cr labeled red blood cells.
SECOND SEMESTER

Paper – I
MOLECULAR PHYSIOLOGY AND CANCER BIOLOGY (40 lectures)

HUMAN PHYSIOLOGY (20 Lectures)
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.
Endocrine system: Brief description of endocrine organs, their hormones, functions of the hormones, diseases produced by excess or deficiency of the hormones.
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.

BIOLOGY OF CANCER (12 Lectures)
Classification, nomenclature and definition of neoplasms. 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 extention, discontinuous extention), transport of cancer cells to distant sites

MOLECULAR BIOLOGY (8 Lectures)
DNA structure, Replication and Repair, RNA synthesis and Translation

Practicals
1. Demonstration of micronucleus assay.
2. To perform DNA fragmentation assay.
3. To perform COMET assay for DNA damage.
4. To study apoptosis using TUNEL assay.
5. To estimate proteins in serum and tissues.
6. To study chromosomal aberrations.
7. To study the cell proliferation using MTT assay.
8. To study muscular activity using actophotmotometer.
9. To study locomotor functions by Rotarod.
10. To study learning and memory process using moris water maze and plus maze
Paper – II

FUNDAMENTALS OF ELECTRONICS AND BIOMEDICAL INSTRUMENTATION
(40 Lectures)

Semiconductor devices (14 Lecturers)
Theory of semiconductors; Conduction in crystals, energy band (qualitative). Intrinsic and extrinsic semiconductors, n-type and p-type semiconductors, majority and minority carriers. pn junction properties forward and reversed bias, PNP and NPN junction transistors, transistor current components, CB, CE and CC configurations Small signal equation and equivalent circuits for transistors, Field effect transistor (FET), Metal oxide filed effect transistor (MOFET), Special devices- SCR, Diac-Triac, Unijunction transistor (UJT) Optoisolator, Zener diode, Tunnel diode, Schottky diode and photodiode; Fabrication and integrated circuits, Simple ideas on operational amplifier, OPAMP, their characteristics and applications.

Digital Circuit System (6 Lectures)
Boolean algebra and logic gates: OR, AND, NOT, NOR, NAND and EXOR gates and their truth table Flip Flops, Shift registers, Counters, Decoders and encoders, Multiplexing and de-multiplexing Analog to digital converter and digital to analog converters. Microprocessors and associated peripherals, Power supplies-Regulated power supplies using IC’S, AC-DC converter and RF power supplies, switching mode power supplies, AC regulators.

Circuits (5 lectures)
Pulse shaping oscillators, regulators, PM tubes, preamplifiers, pulse height analyzers, SCA, MCA, coincidence & anti coincidence circuits, equivalent circuits

Transducers (5 Lectures)
Properties and the principle of transducers: Resistive transducer, thermoresistors, thermistors, Pontemetric transducers, magnetoresistive transducers and their biomedical applications. Inductive transducers, single inducers, mutual inducers, capacitive transducer, biological capacitors.

Biomedical Ultrasound & Medical Laser (10 Lectures)
Introduction to laser, principle of operation of laser, laser tissue interaction, Different types of LASER. Attenuation of LASER in medicine, adverse effects of LASER

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.
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
Paper – III
RADIATION DETECTION & MEASUREMENTS (40 Lectures)

Interaction of charged particle with matter: (6 lectures)
Absorption process, scattering ionization and excitation, Bethe’s equation, radiation energy loss (bremsstrahlung), range of beta particles, backscatter and self absorption, Cerenkov radiation. Interaction of alpha particles, heavy nuclei and fission fragments with matter: Energy loss by collision, range-energy relation and Bragg curve, specific ionization, stopping power.

Interaction of neutrons with matter: (3 lectures)
Neutron capture, elastic scattering, energy transfer and logarithmic energy decrement, inelastic scattering, dependence on E and Z, (n, p), (n, x), (n, y) and other reactions, neutron activation.

Gas filled detectors (5 Lectures)
Theory of ionization chamber, design consideration in an ionization chamber, operating voltage, theory and construction of condenser type of chambers and thimble chambers; gas multiplication, Proportional counters- design and characteristics. Geiger-Muller counters – design consideration, dead time and recovery time, operation.

Scintillation detectors-Organic and Inorganic scintillation detectors (4 Lectures)
Scintillation detector principles- light collection and mounting, scintillation characteristics- light output, decay time, photo peaks, Compton valley, edge and plateau, backscatter peak, iodine escape peak, annihilation peak. Pulse height selector and resolution of energies, FWHM an energy calibration, geometric efficiency, intrinsic efficiency. Bismuth germanate detector, barium Fluoride detector, technetium orthosilicate detectors, yttrium orthosilicate detector, semiconductor detectors. Ge(li) detector, Si(Li) detector, Cadmium zinc-telluride detector.

Liquid scintillation counters (3 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.

General systems for operation and detection (6 lectures)
Neutron detectors: Basic principles and applications. Well counter – Geometry factor, dual radionuclide counting. Radiation calorimetry, photographic dosimetry. Chemical dosimetry: salient feature of chemical dosimeters. Spectrophotometry: Beer-Lambart’s Law, definition of transmittance and absorbance (optical density), molar absorption and coefficient, Fricke dosimeter, FBX dosimeter, ceric, sulphate dosimeter, Low dose level dosimeters (aqueous benzoic acid, terephthalic acid, aqueous trimesic acid); High dose level dosimeters (red perspex HX, polyvinyl chloride, radio chromic dye and cellulose triacetate films).

Thermo luminescent Dosimeters & Autoradiography (5 Lectures)
Physics of TLD, characteristics TLD phosphors, glow curves, dose and energy response, sensitivity and application in-dosimetry and personnel monitoring devices. Use of photographic emulsions stripping film technique, dipping method, grain density counting and track counting, X-ray films, intensifying screens, fluoroscopy.

Semiconductor detectors (2 lectures)
Semiconductors junction and surface barrier detectors, high purity germanium detectors, their response and, characteristics.
Instruments for counting, gamma ray spectrometry (3 lectures)
PM tubes, preamplifiers, amplifiers, pulse height analyzers, coincidence & anti coincidence circuits, TPHC, MCA, scalers and timers, high voltage supply, gamma ray spectrometry.

Whole body counting studies (3 lectures)
Whole body counting: principles 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.

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 absorbed by different organs by using FBX dosimeter.
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 of GM counter.
12. To determine the efficiency of GM counter and find out the strength of the unknown radioactive source.
13. To demonstrate how well type gamma ray spectrometer can be used as a whole body counter for small animals.
14. To demonstrate the retention of activity in organ of interest or whole body by using scintillation counter and whole body counter.

Paper – IV
RADIOISOTOPE APPLICATIONS AND RADIATION SAFETY (40 Lectures)

BIO-MEDICAL APPLICATIONS OF RADIONUCLIDES (20 Lectures)
Thyroid radio active uptake measurements: Tracer dose, use of carrier, standard and phantom, shielding and collimation, factors affecting thyroide radioactive iodine uptake, PBI-131, thyroid stimulation test, thyroid clearance rate thyroid suppression test, perchlorate discharge test, uptake of radiolabel T3 by red cells, T3 charcoal test.

131I therapy for treatment of hyperthyroidism, thyroid follicular carcinoma.

125I applications: Radio-immuno assays of T3, T4, TSH and other hormones, uptake by thyroid and treatment of thyroid disorders.

123I applications

99mTc applications in medical imaging of different organs and dynamic/ function studies.

201Tl/82Rb – myocardial uptake/perfusion imaging, 67Ga for scintigraphy of tumors and infections.

18FDG in brain, heart and tumor imaging

Radionuclides in therapy: 89Sr, 186Re-HEDP, 153Sm-EDTMP, lutetium-177
RADIATION PROTECTION (10 lectures)

Principles of radiation protection – Quantities used in radiation protection, Justification of practice, optimization of protection and Individual dose and risk limits, regulatory aspects of radiological safety, Control of internal and external hazards.

Radioactive waste disposal - decontamination of labs, clothes, hands, glassware, gloves, metals, plastics, paints and bricks, decontamination of person, decontamination of room Radioisotopic waste, general principles, liquid and solid waste, disposal of solid, liquid and gaseous effluents/ waste, decaying storage transfer to authorized personal, management of sealed and unsealed sources.

Transport of radioactive material and designing of radiation laboratory (5 lectures): - storage and transport of waste, transport index. Classification of radiation labs, design of areas for radioisotope laboratories, criteria for grading laboratories using unsealed radioisotopes

STOCHASTIC AND NONSTOCHASTIC EFFECTS OF RADIATION (5 Lectures)


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 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 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 $^{99m}$Tc $O_4^{-}$ and labeled pharmaceuticals.
11. To determine the Rf of radiopharmaceuticals using different solvents.
SECOND YEAR - THIRD SEMESTER

Paper - I
NUCLEAR MEDICINE IMAGING AND COUNTING INSTRUMENTATION
(35 Lectures)

Rectilinear scanner and Photography (4 Lectures)
Basic problems: 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.
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

Gamma Camera (11 Lectures)
Basic principles of gamma camera, collimators - parallel hole, divergent, convergent pinhole, fan beam, slant hole collimator. NaI (Tl) detector, position determining circuits, display. Gamma camera-computer interface- ADC/DAC. Performance characteristics and image quality.
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) (10 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 (3 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 (2 lectures)
Principles and applications, QC of Dose calibrator

Instruments in Radiation Safety (5 lectures)
Principle and uses of Ionization chambers, Proportional counters, GM tubes
Practical
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. Determine the half life of a radionuclide with the help of a Dose Calibrator.
5. Evaluate the geometric/volumetric variation of the radioactivity using Dose Calibrator.
6. Determine the Intrinsic uniformity of Gamma Camera.
7. Determine the extrinsic uniformity of Gamma Camera for the given collimator.
8. Perform experiment to determine the spatial resolution and linearity of Gamma Camera.
9. Determine the COR of the Gamma Camera.
10. Devise an experiment to measure the pixel size for 128X128 and 256X256 matrix size of the Gamma Camera.
11. Determine the dead time by two sources method and determine count rate at 20 \% count loss.
12. Determine the system sensitivity with different collimators.
13. Perform the total performance test on the SPECT gamma camera.

Paper – II

PRINCIPLES AND PRACTICE OF RADIOLOGICAL PROTECTION (35 Lectures)

General principles of radiation protection (15 lectures)

Radioactive decontamination and waste disposal (6 lectures)
Radioactive decontamination of labs, clothes, hands, glassware, gloves, metals, plastics, paints and bricks, .decontamination of person, decontamination of room Radioisotopic waste, general principles, liquid and solid waste, storage and transport of waste, disposal of solid, liquid and gaseous effluents/ waste, decaying storage transfer to authorized personal, management of sealed sources, quality management program, administration/misadministration of radiopharmaceuticals, release of patients administered with radiopharmaceuticals.
Regulatory Aspects & Licensing (7 lectures)
Role of National and International Organizations like AERB, MCI, NMC, BRIT, BARC, IAEA, ICRP

Transportation of radioactive substances (7 Lectures)
Historical background, classification of radioactive materials, general packing requirements, transport documents, labeling and marking of packages, testing and approval of transport container for radioactive materials, Transport of large radioactive sources and fissile material, exemptions from regulations, transport emergencies, Regulations for different modes of transporting radioactive material including transport by post.

Practical
1. To determine the half life of a radioactive material.
2. Radiation exposure: effect of distance, Shielding and time.
3. Study of energy dependence of a pocket dosimeter and a survey meter
4. Demonstration of transport of radioactive materials
5. Radiation absorbed dose calculations exercises
7. Monitor the given item for contamination, if found contaminated, then perform the decontamination using contamination monitor.
8. Perform the wipe test on the floor and determine the level of contamination on the floor.
9. Demonstration of TLD badges, Pocket dosimeters.
10. To perform Radiation survey around the cyclotron and Radio-iodine therapy Ward.
Paper – III
PRINCIPLES AND PRACTICE OF RADIOPHARMACY AND RADIONUCLIDE GENERATORS
(35 Lectures)

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.

Radionuclide production and characteristics (10 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. Short-lived
radionuclide generators: \(^{99m}\)Mo-\(^{99}\)Tc, \(^{188}\)W-\(^{188}\)Re, \(^{113}\)Sn-\(^{113m}\)In, \(^{68}\)Ge-\(^{68}\)Ga: \(^{82}\)Sr-\(^{82}\)Rb, \(^{81}\)Rb-\(^{81m}\)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 \(^{99m}\)Mo /\(^{99}\)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.

Specific methods of labeling (5 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, radiiodinated
compounds, radiiodination of proteins, antibodies/monoclonal antibodies. Labeling with
\(^{99m}\)Tc: \(^{99m}\)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 \(^{99m}\)Tc chelates .
Labeling with \(^{111}\)In: labeling of leucocytes and platelets, antibodies, \(^{111}\)In-penteterotide,

Quality control of radiopharmaceuticals (8 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 \(^{99}\)Mo/ \(^{98}\)Mo(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: (4 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.

**Practical**
1. Demonstration of $^{99}$Mo-$^{99m}$Tc column generator.
2. To separate $^{99m}$Tc from $^{99}$Mo and determine the efficiency of extraction.
3. Perform the quality control of elute from $^{99}$Mo-$^{99m}$Tc Generator.
4. To determine the Rf of $^{99m}$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
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.

**Paper - IV**

**NUCLEAR MEDICINE IMAGING AND IN-VIVO COUNTING (35 Lectures)**

*Diagnostic In-Vivo Techniques (35 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, T3/T4 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.

**Cardiac studies**- static blood pool imaging, Rest/stress myocardial imaging, infarct imaging, MUGA, gated blood pool study, first pass study (shunt detection), \(^{201}\)Tl imaging

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

**Bone marrow**: Radiopharmaceuticals and imaging techniques studies- red-cell mass estimation, RBC survival and sequestration studies, \(^{51}\)Cr gastrointestinal blood pool loss study, plasma volume estimation using \(^{125}\)I-HAS and ferrokinetic studies.

**Miscellaneous studies**- \(^{67}\)Ga imaging, Lacrimal scintigraphic imaging, Lymphatic imaging, adrenal imaging using \(^{131}\)I-MIBG,

**Practical**
1. To perform Bone scan (3-phase, whole body and statics)
2. To perform MPI.
3. To perform Lung perfusion study
4. To perform Renogram study (using DTPA/EC)
5. To perform DMSA scan
6. To perform DRCG
7. To perform Gated Blood pool scintigraphy.
8. To perform Salivary scintigraphy
9. To perform Solid GET
10. To perform GER
11. To perform Liver scan using SC
12. To perform Hepatobiliary study.
13. To perform Brain SPECT study
14. To perform adrenal imaging using iodine \(^{131}\)I-MIBG
15. To perform thyroid scan
16. To perform parathyroid scan
17. To perform whole body Iodine-131 scan
18. To perform RAIU
Cyclotron (8 Lectures)
Basic working principles and instrumentation of cyclotron, type of cyclotron, cyclotron generated radionuclides, cyclotron shielding, neutron detection and other quality control procedures.

Positron Emission Tomography (10 lectures)
Introduction, PET and coincidence detection: Basic principles of PET imaging, Pet detector and scanner designs detectors – BGO, NaI (Tl), LSi; Attenuation correction with transmission sources – $^{68}$Ge, $^{137}$Cs. Data corrections: normalization, uniformity correction, scatter correction, random correction. 2-D and 3-D reconstructions, performance characteristics of PET imagers. Daily, weekly and monthly Quality control of the PET/CT. PET v/s SPECT, Dedicated and hybrid PET systems. Performance characteristics, Modeling and quantification in PET.

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 (5 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 (5 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
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 (7 Lectures)
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.
Radiation Dosimetry (10 Lectures)
Radiation dosimetry for external radioactive source and internally deposited radioactive dose; compartment analysis; Single Compartment, Two Compartment model, beta particle dosimetry; Equilibrium Dose rate equation, Calculation of Beta dose.

Gamma dose calculation, Specific gamma ray constant (\( \Gamma \)), Geometrical factor and average geometrical factor. 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.

Potential Exposure and Emergency Plans (7 lectures)
Potential exposure and safety assessment, 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.

Transportation of PET Radiopharmaceuticals (3 lectures):
Practice as per AERB guidelines and recommendations of international regulatory bodies

Radiation Biology (10 Lectures)
Biological effects of ionizing radiation, stochastic and non-stochastic effects, genetic effects, somatic effects, effects in-utero,

Design of Radiation Centers (5 Lectures)
Design and safety aspects of planning a nuclear medicine department, cyclotron facility and PET centre, design of laboratories or various sizes & capacity as per the norms of BARC. Design of radiation labs, types of labs, security of sources and radioactive cautions signs and labels.

Patient Care and Hospital practice (5 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 while 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.
- Regular participation in weekly journal club, Seminar and other periodical CME programs.

Neutron activation analysis (NAA), radiomicrobiology, fluorescent scanning etc
Practical
1. Demonstrations regarding the calculations of exposure doses and safety aspects
2. Demonstration of scheduling of patients
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

PAPER – III
SPECT AND PET RADIOPHARMACEUTICALS (40 Lectures)

Characteristics of Specific SPECT radiopharmaceuticals: (25 Lectures)
Chemical name, oxidation state of $^{99m}$Tc and structure of $^{99m}$Tc 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 following radiopharmaceuticals in different organs.

$^{99m}$Tc -Sodium Pertechnetate ..............................................
$^{99m}$Tc - Labeled Human Serum Albumin ..............................
$^{99m}$Tc - Macroaggregated Albumin ......................................
$^{99m}$Tc -Phosphonate and Phosphate Radiopharmaceuticals .......
$^{99m}$Tc-Sulfur Colloid ............................................................
$^{99m}$Tc - Albumin Colloid (Nanocolloid) .................................
$^{99m}$Tc Pentetate (DTPA) .........................................................
$^{99m}$Tc-Mercaptoacetylglycylglycylglycine (MAG3) ..............
$^{99m}$Tc-Dimercaptosuccinic Acid (DMSA)
$^{99m}$Tc-Labeled Red Blood Cells ..............................................
$^{99m}$Tc-Iminodiacetic Acid Derivatives .....................................
$^{99m}$Tc-Hexamethylpropylene Amine Oxime .........................
$^{99m}$Tc-Ethyl Cysteinate Dimer ..............................................
$^{99m}$Tc-Sestamibi .................................................................
$^{99m}$Tc - Tetrofosmin ..............................................................
$^{123}$I- or $^{131}$I-Metaiodobenzylguanidine (MIBG)
$^{201}$TI- Thallous Chloride

Characteristics of PET radiopharmaceuticals: (15 lectures)
Clinical applications of the radiopharmaceutical, quality control, pharmacokinetic data, radiation dose. Mechanism of localization of following radiopharmaceutical in different organs.

$^{18}$F- Sodium Fluoride ..........................................................
$^{18}$F- Fluorodeoxyglucose (FDG) ...........................................
$^{18}$F- Fluorodopa .................................................................
$^{18}$F- Fluorothymidine (FLT) .................................................
$^{15}$O-Water .................................................................
$^{n,15}$O-Butanol .................................................................
$^{13}$N-Ammonia .................................................................
Physical and chemical characteristics of Positron emitters, synthesis of 18-FDG, $^{11}$CO$_2$, $^{13}$NH$_3$ and $^{18}$O, recent trends in radiopharmaceuticals and search for novel SPECT and PET radiopharmaceuticals.

Practicals

1. Preparation of $^{99m}$Tc – MDP and its QC
2. Preparation of $^{99m}$Tc – DTPA and its QC
3. Preparation of $^{99m}$Tc – DMSA and its QC
4. Preparation of $^{99m}$Tc – EC and its QC
5. Preparation of $^{99m}$Tc – Sestamibi and its QC
6. Preparation of $^{99m}$Tc – S. Colloid
7. Preparation of $^{99m}$Tc – HMPAO
8. Preparation of $^{99m}$Tc – MAA
9. Preparation of $^{99m}$Tc – ECD and its QC
10. Demonstrations regarding determination of target to non target ratios for various SPECT and PET radiopharmaceuticals in experimental models.

PAPER – IV

PET IMAGING, RADIONUCLIDE THERAPY AND IN-VITRO TECHNIQUES (40 Lectures)

Basic Molecular Imaging (12 lectures)

PET studies: Methods of performing PET/CT procedures in cardiology, Neurology and Oncology, gated PET/CT studies (respiratory and cardiac gating). Use of $^{18}$FDG and NH$_3$ 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 (14 Lectures)

Treatment of bone pain: use of $^{32}$P-orthophosphate, $^{90}$Sr-Strontium chloride, $^{186}$Re-HEDP, $^{153}$Sm-EDTMP. Radioimmunotherapy. Pre and post therapy imaging and patient preparation, Radiation Synovectomy, Treatment of hyperthyroidism, thyroid cancer whole body imaging – use of $^{131}$I.

Treatment of polycythemia Vera and leukemia. Treatment of malignant effusion in pleural and peritoneal cavities

Advances in Radionuclide Therapy.

In vitro techniques: (14 Lectures) Principals of RIA, standard curve, data analysis, QC and applications. Methods of receptor assays, hormones, drugs, T3 charcoal uptake test RIA estimation – T3, T4, TSH and thyroid antibodies, thymoglobulin. Methods of receptor assays, hormones, drugs, Chemiluminiscence
Immunoradiometric assay (IRMA)- theory, operation and applications,
Enzyme linked immunosorbent assay (ELISA), Fluorescent immunoassay, Immune reactions useful in bioassays – precipitin reaction, immunodiffusion, complement fixation assay, agglutination. Immunelectrophoresis – cross over and rocket electrophoresis, Fluorescent activated cell sorting.

GFR plasma sample method

Gastric intestinal protein loss estimation using $^{51}$Cr-chromic chloride, Vitamin $B_{12}$ absorption study and Schilling Test, etc.

Red-cell mass estimation, RBC survival and sequestration studies, $^{51}$Cr gastrointestinal blood pool loss study, plasma volume estimation using $^{125}$I-HAS and Ferrokinetic studies.

Practicals
1. Plot the standard curve for the given Radioimmunoassay (T3/T4 test).
2. To calculate GFR using plasma sample method
3. To determine the pipetting error in the assay
4. To perform Cr-51 blood volume study
5. To demonstrate Cr-51 splenic sequestration study
6. To set a protocol for PET imaging for Oncology patient
7. To set a protocol for PET imaging for cardiac viability study
8. To set a protocol for PET imaging using N-13 ammonia for myocardial perfusion
9. To perform an Iodine-131 whole body survey scan
10. To demonstrate Iodine-131 therapy in a thyroid cancer patient
11. To demonstrate monitoring and discharge from the ward of a high dose Iodine 131 patient
12. To demonstrate and monitor iodine therapy for thyrotoxicosis
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.

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<thead>
<tr>
<th>Name of Book</th>
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<tr>
<td>Cell &amp; Molecular Biology</td>
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<td>Molecular Biology of the Cell</td>
<td>Alberts, Bray, Lewis, Raff</td>
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<td>Molecular Biology of Gene</td>
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<td>Gene -V</td>
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<td>Text Book of Medical Physiology</td>
<td>Guyton</td>
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<td>Basic Medical Biochemistry</td>
<td>Smith Marks &amp; Libermann</td>
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<td>Text Book of Microbiology</td>
<td>Panikar</td>
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<td>Methods in Biostatistics</td>
<td>Mahajan</td>
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<td>Methods of Biostatistics</td>
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<td>Statistical and Mathematical Techniques in NM</td>
<td>GS Pant</td>
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<td>Essentials of Medical Statistics, Blackwell publishers</td>
<td>Betty Kirkwood</td>
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<tr>
<td>Object Oriented Programming with C++</td>
<td>E. Balaguruswamy.</td>
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<td>A First Course in Computers</td>
<td>Sanjay Saxena.</td>
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<tr>
<td>Introduction to Mathematical Physics</td>
<td>C. Harper (Prentice Hall of India)</td>
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<td>Field and Wave Electromagnetics</td>
<td>David Cheng</td>
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<td>Principles of Applied Biomedical Instrumentation</td>
<td>Geddes, Baker</td>
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<td>Mathematical Models in Biology –An Introduction</td>
<td>Allman &amp; Rhodes</td>
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<td>Radiation detection</td>
<td>Knoll</td>
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<td>Handbook of Health Physics and Radiological Health</td>
<td>Shleien, Slaback, Birkey</td>
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<td>Physics and Radiobiology of Nuclear Medicine</td>
<td>Gopal Saha</td>
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<td>Radiation Biology</td>
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<td>Elements of Radiobiology</td>
<td>Selman</td>
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<td>The essential Physics of Medical Imaging</td>
<td>Bushberg, Seibert, Leidholdt</td>
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<td>Physics in Nuclear Medicine</td>
<td>Cherry, Sorenson, Phelps</td>
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<td>Medical Imaging Physics</td>
<td>William R. Hendee</td>
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<td>Introduction to Medical Physics</td>
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<td>Advances in Diagnostic Medical Physics</td>
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- Radiation Dosimetry
- Fundamentals of Nuclear Pharmacy
- Radiopharmaceuticals
- Text Book of Radiotherapy
- Radio immunoassay Principles & Practices
- Nuclear Medicine in Vitro
- Principles of Nuclear Medicine
- Nuclear Medicine Technology and Techniques
- Principles & Practice of Nuclear Medicine
- Basics of PET Imaging
- PET and PET/CT in Oncology
- Nuclear & PET Techniques
- Interventions in Nuclear Medicine
- An Atlas of Clinical Nuclear Medicine
- Clinical SPECT Imaging

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)
- IAEA activities in Nuclear Safety by IAEA

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

Books
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Text Book of Medical Physiology
Principles of Anatomy and Physiology
Text Book of Human Histology with Colour Atlas
Biochemistry, 4\textsuperscript{th} ed. (WH freeman and company)

Guyton and Hall
Tortora and Derrickson (Wiley).
Inderbir Singh
Lubert Stryer
Cell and Molecular Biology, 8th ed. (BI Publication)  
Gray’s Anatomy for students  
Numerical Methods for Engineers and Scientists  
Numerical Methods for Engineers and Scientists  
Introductory Methods of Numerical Analysis  
Introduction to Mathematical Physics  
Statistical methods of Medical & Biology Students  
C++ How to Program  
Let us C  
Atomic Nucleus (McGraw Hill)  
Nuclear Physics (Narosa Pbl. House)  
Nuclear Radiation Physics (Prentice Hall)  
Radiations from Radioactive Atoms (Govt. Print. Off.). L. Slack & K. Way  
Radiation Physics in Radiology (Springer).  
Field and Wave Electromagnetics (Addison-Wesley)  
***********  
Semiconductor Devices: Physics and Technology (Wiley).  
Integrated Electronics (McGrew Hill).  
OPAMPS and Linear Integrated Circuits (Pearson Education).  
Electronic Principles (McGrew Hill).  
Principles of Applied Biomedical Instrumentation (Wiley).  
Medical Imaging Physics (Wiley-Liss)  
Radiation Detectors and Instrumentation (Wiley).  
Techniques for Nuclear and Particle Physics experiments (Narosa).  
The Physics of Radiation Therapy (Lippincott Williams and Wilkins).  
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  
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