FACULTY OF SCIENCE

SYLLABI

FOR

M.Sc. NUCLEAR MEDICINE

1st to 4th SEMESTER

EXAMINATION 2011-2012
Introduction
Nuclear Medicine is an established clinical and research specialty with a wide ranging diagnostic and therapeutic techniques. It can be defined as 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 skilled technical manpower in Nuclear Medicine. They should be able to demonstrate high standards of professional skills, competence/leadership qualities.

Duration of Course
2 Academic Years. There shall be two semesters in each year.

No. of Seats
General seats = 08
NRI = 02
Total seats per year = 10

Admission Criteria:

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 or Chemistry & Biology as core subjects. Candidates having B.Sc. in Nuclear Medicine /Radiation Sciences, Biophysics and Pharmacy shall also be eligible for admission to the course.

Admission
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 (BSc) 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 departments of Biophysics & Physics of Panjab University, Chandigarh, and the Department of Nuclear Medicine of PGIMER, shall impart the teaching and training to the students, jointly. However, few other departments of these Institutes may also be involved in this teaching programme.

First year of the teaching/training will be mainly in the Panjab University in the departments of Biophysics & Physics under the Institute for emerging areas in science and technology (CEAST).

Second year of the teaching and the clinical training shall be mainly in the Department of Nuclear Medicine at PGIMER, Chandigarh.

Dissertation

Every student shall be allotted a project under a supervisor in the beginning of the second year and will submit the dissertation at least one month prior to the final examination.

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 aggregate in theory and 50% marks in aggregate in practicals after each academic session, failing which, the candidate shall be reverted back and shall be awarded M.Sc degree in Nuclear Medicine after fulfilling the conditions. The Panjab University, Chandigarh shall award the final degree.
Semester I

Theory = 300 Marks (3 Papers of 100 marks each)
Practicals = 150 Marks (3 Practicals of 50 marks each)
Total Marks = 450 Marks

A. Theory Papers

1. Fundamental Biology. 100 Marks
2. Applied Mathematics, Biostatistics and Computer Applications. 100 Marks
3. Radiation Physics. 100 Marks
Total = 300 Marks

Practicals

1. Fundamental Biology. 50 Marks
2. Applied Mathematics, Biostatistics and Computer Applications. 50 Marks
3. Radiation physics. 50 Marks
Total = 150 Marks

Semester II

Theory = 300 Marks (3 Papers of 100 marks each)
Practicals = 150 Marks (3 Practicals of 50 marks each)
Total Marks = 450 Marks

A. Theory Papers

1. Fundamentals of Electronics and Biomedical instrumentation. 100 Marks
2. Radiation Detection and Measurements. 100 Marks
3. Radiation Biology and Radioisotopes applications. 100 Marks
Total = 300 Marks

Practicals

1. Fundamentals of Electronics and biomedical instrumentation. 50 Marks
2. Radiation Detection and Measurements. 50 Marks
3. Radiation Biology and Radioisotopes applications. 50 Marks
Total = 150 Marks
SECOND YEAR

Semester III

Theory = 300 Marks (3 Papers of 100 marks each)
Practicals = 150 Marks (3 Practicals of 50 marks each)
Total Marks = 450 Marks

A. Theory Papers
1. Nuclear Medicine and Allied Instrumentation. 100 Marks
2. Radionuclides Generators and Radiopharmaceuticals. 100 Marks
3. Radiation Safety and Dosimetry. 100 Marks
Total = 300 Marks

Practicals
1. Nuclear Medicine and Allied Instrumentation. 50 Marks
2. Radionuclides Generators and Radiopharmaceuticals. 50 Marks
3. Radiation Safety and Dosimetry. 50 Marks
Total = 150 Marks

Semester IV

Theory = 200 Marks (2 Papers of 100 marks each)
Practicals = 100 Marks (2 practicals of 50 marks each)
Dissertation = 100 Marks
Grand Viva = 50 Marks
Total Marks = 450 Marks

A. Theory Papers
1. Nuclear Medicine Imaging and Radionuclide therapy. 100 Marks
2. Recent Advances in Nuclear Medicine. 100 Marks
Total = 200 Marks

B. Practicals
1. Nuclear Medicine Imaging and Radionuclide therapy. 50 Marks
2. Recent Advances in Nuclear Medicine. 50 Marks
Total = 100 Marks

C. Dissertation 100 Marks

D. Grand Viva 50 Marks

Instructions for the examiners:

There shall be 12 short-answer type questions in each paper, and the students have to attempt 10 questions. Each paper shall be of three hours duration.
FIRST YEAR

FIRST SEMESTER

Paper – I : FUNDAMENTAL BIOLOGY (50 Lectures)

MICROSCOPIC ANATOMY (10 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 (20 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.
ABDOMEN: Component parts (wall, abdominal cavity, inferior thoracic aperture, diaphragm, pelvic inlet, surface anatomy, defining surface projection, kidney and spleen position.
PELVIS: component parts (Pelvic inlet, pelvic walls, pelvic outlet, pelvic floor, pelvic floor, pelvic cavity and perineum).
LOWER AND UPPER LIMBS: Component parts (bones and joints, muscles)
HEAD and NECK: Component parts (skull, cervical vertebrae, hyoid bone, soft palate and muscles in the head and neck.

HUMAN PHYSIOLOGY (15 Lectures)

Thyroid: Thyroid hormone production giving stress to role of iodine in detail
Heart: The heart as a pump, cardiac cycle, cardiac contractility, rhythmic excitation, normal ECG, methods of recording ECG, vectorial analysis of ECG, cardiac arrhythmias.
Respiratory system: General physiological functions of respiratory system.
Digestive system: Brief study of different digestive juices, their functions, digestion and absorption.
Urinary systems: Physiology of urine formation, collection and excretion, water and electrolyte balance.
Endocrine system: Brief description of endocrine organs, their hormones, functions of the hormones, diseases produced by excess or deficiency of the hormones.
Reproductive system: oogenesis and ovulation in females, spermatogenesis in males. Hormonal regulation in sperm formation and ovum formation.

INTRODUCTORY CYTOLOGY, BIOCHEMISTRY & BIOLOGY OF CANCER (5 Lectures)

Cell: Cell wall and cell membrane, Structure and functions of Endoplasmic reticulum (ER), mitochondria, golgi complex, nucleus, lysosomes.
Brief introduction of structure and function of carbohydrates, proteins / enzymes, nucleic acids, lipids.
Cell signaling, glycolytic and TCA cycles.
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.
Books:
5. De Robertis : Cell and Molecular Biology, 8th ed. (BI Publication)

Practicals
1. To identify different parts of a human skeleton
2. To identify types of epithelial tissue: (squamous, stratified, pseudostratified) systems 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, lungs) systems using light microscope.
5. To visualise microanatomical view of Digestive system (esophagus, stomach, small and large intestine, rectum)
7. To visualise microanatomical view of Reproductive system of male: Testes, Ductes deferens, Seminal vesicle, prostate using light microscope.
8. To visualise microanatomical view of Reproductive system of female: Ovary, fallopian tube, uterus 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 alakaline phoshatase, Acid phophatase, SGOT and SGPT.
Paper – II : APPLIED MATHEMATICS, BIOSTATISTICS AND COMPUTER APPLICATIONS

(50 Lectures)

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

Numerical Methods: (15 Lectures)

Why numerical methods, accuracy and errors on calculations – round off error, evaluation of formulae. Iteration for Solving \( x = g(x) \), initial approximation and convergence criteria, Newton Raphson method.

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.

Counting and medical statistics (8 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 and 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.

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

Computational Tools & Techniques: (7 Lectures)

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

Books:

1. Hoffman : Numerical Methods for Engineers and Scientists, 2\textsuperscript{nd} ed. (Marcel Dekker).
5. F.E. Croxton: Elementary Statistics with Applications in Medicine and the Biological Sciences (Dover Publications).
8. Deitel & Deitel: C++ How to Program (Prentice Hall of India).

Practicals
1. To demonstrate the use of C++ for scientific applications.
2. To study various Basic Linux 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 statistical software.

Paper – III: RADIATION PHYSICS (50 Lectures)

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

Radiation Physics (25 Lectures)

Radioactivity and decay laws: Types of radiation (α, β, γ, n, X-ray), decay modes, probability and decay constant, physical half life, mean life. Natural radioactivity & decay series, secular equilibrium, artificial radioactivity, beta particle spectrum, internal conversion, general aspects of gamma decay, gamma energy decay, Nuclear isomerism.

Nuclear reactions: nuclear reaction, cross-section, conservation laws, artificial transmutation, discovery of neutron, neutron classification, neutron sources, neutron activation, nuclear fission, fission products, fissile materials, diffusion and slowing down of neutrons, various types of reactors - fusion and thermo nuclear reactions.

Radiation generators (12 Lectures)


Particle accelerators for industrial, medical and research applications – The resonant transformer – cascade generator, Vande Graff Generator, pelletron, cyclotron, betatron, synchro-cyclotron, linear accelerator – Klystron and magnetron, travelling and standing wave acceleration, microtron. Electron synchrotron, proton synchrotron. Details of accelerator facilities in India.
Interactions of x and γ rays with matter: (8 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.

Radiation Units (5 Lectures)
Units of radioactivity: Becquerel, Curie, specific activity, carrier free activity, 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.

Books:
2. I. Kaplan : Nuclear Physics (Narosa Pbl. House)
3. R.E. Lapp : Nuclear Radiation Physics (Prentice Hall)
4. L. Slack & K. Way : Radiations from Radioactive Atoms (Govt. Print. Off.).
5. R. Oliver : Radiation Physics in Radiology (Springer).

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.
SECOND SEMESTER

Paper – I : FUNDAMENTALS OF ELECTRONICS AND BIOMEDICAL INSTRUMENTATION (50 Lectures)

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

Semiconductor devices (10 Lecturers)
Intrinsic and extrinsic semiconductors, n-type and p-type semiconductors, pn-junction properties forward and reversed bias, Zener diode, photo diode, PNP and NPN junction transistors, transistor current components, CB, CE and CC configurations, field effect transistor (FET), metal oxide filed effect transistor (MOFET). Simple ideas on operational amplifier, OPAMP, their characteristics and applications.

Digital Circuit System (8 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, 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.

Electric accessories for X-ray tubes (5 Lectures)
Filament and high voltage transformers, high voltage circuits, condenser discharge apparatus, three phase apparatus, voltage doubling circuits, current and voltage stabilizers, automatic exposure control, automatic brightness control, measuring instruments, measurement of kV and mA timers, control panels, complete X-ray circuit, image intensifier and close circuit TV System, modern trends.

Radiography (7 Lectures)
High–voltage radiography, low voltage radiography, contrast media, radiographic grids, magnification radiography, digital radiography. Single crystal scintillation camera, scintillation camera operation, multiple-crystal scintillation camera, tomography, computed tomography, reconstruction algorithm, scan motions, SPECT & PET.

Nuclear Magnetic Resonance and MRI (10 Lectures)
Angular momentum of the nucleus, Magnetism and the Magnetic Dipole, Moment, MDM in a magnetic field, MDM for Rotating Charges, Larmor Frequency, Energy States for Nuclear Spin Systems. NMR parameters, Magnetization Vector, RF Field, the rotating coordinate system, Free induction decay, T1 and T2 relaxation, Mechanisms for relaxation, spin-Echo Techniques, Use of Fourier Transforms. Instrumentation -NMR System. Magnetic resonance as probe of the body-MRI, Gradient magnetic fields, Slice Selection, Phase Encoding, Frequency Encoding; Safety Considerations, Recent Developments, Functional MRI.

Biomedical Ultrasound & Medical Laser (8 Lectures)
Ultra sound generators, properties of ultrasound- waves and its propagation in biological tissues, pulse echo techniques, Doppler principle, 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 LASER. Attenuation of LASER in medicine, adverse effects of LASER

Fiber optic scopes (2 lectures)
Snell’s law, total internal reflection, fiber optics as waveguides, image conduits made with fiber optics, Medical fiber optic scopes: their construction, fiber size, image resolution, coherent versus incoherent bundles, use of CCD cameras.
Books:

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 – II: RADIATION DETECTION & MEASUREMENTS (50 Lectures)

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

Interaction of charged particle with matter: (5 lectures)
Absorption process, scattering ionization and excitation, Bethe’s equation, radiation energy loss (bremstrahlung), 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: (4 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-Mueller counters – design consideration, dead time and recovery time, operation.

Scintillation detectors-Organic and Inorganic scintillation detectors (6 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. Liquid scintillation counters: 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 (10 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 (8 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 (4 Lectures)**
- Semiconductors junction and surface barrier detectors, high purity germanium detectors, their response and, characteristics.

**Instruments for counting, gamma ray spectrometry (5 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, 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.

**Books:**

2. W.R. Leo : Techniques for Nuclear and Particle Physics experiments (Narosa).

**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 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 counters 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 – III: RADIATION BIOLOGY AND RADIOISOTOPE APPLICATIONS (50 Lectures)**

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

**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 (12 Lectures)**

**Radiation Effects (10 Lectures)**
Radiation effects on major organ systems: Hematopoietic system, vascular system, digestive system, respiratory system, urinary system, nervous system, reproductive system, endocrine system and immune system. Modification of radiation injury: 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. Stochastic and nonstochastic effects of radiation: Late effects in normal tissue systems and organs, radiation carcinogenesis, mechanism of radiation carcinogenesis, risk of carcinogenesis, animal and human data, shortening of life span, genetic effect of radiation, factors affecting frequency of
radiation induced mutations, dose effect relationship, pre-natal effects of radiation, types of genetic disorders, risk estimation, direct method, doubling dose method, uncertainties.

**Bio-medical applications of radionuclides (20 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, uptake of radiolabel T3 by red cells, T3 charcoal test. Introduction to treatment of hyperthyroidism and thyroid carcinoma.

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

$^{51}$Cr labeling with red blood cells: applications in blood volume measurement, spleen uptake, red cell survival studies, red cell volume, proteins turn over.

$^{59}$Fe absorption studies, $^{59}$Fe turn over studies, plasma iron clearance

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

$^{60}$Co: Treatment of different carcinomas, gamma knife

$^{32}$P applications in polycythemia vera and leukemia

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

$^{14}$C applications in urea breath test, whole body counting, $^{14}$C Glycolic breath test, palmitic acid, Radio-respirometry, in vitro uptake studies using $^{14}$C glucose, $^{14}$C amino acids and $^{3}$H thymidine

$^{45}$Ca, $^{65}$Zn and $^{3}$Hmetabolic studies and other biomedical applications.

Radioactive decontamination

**Radioactive decontamination and waste disposal: (4 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 and unsealed sources

**Books:**

1. P.A. Casserette : Radiation Biology (Prentice Hall)

**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 study the effects of ionizing radiations on the activities of enzymes.
7. Use of gamma ray scintillation counter for measuring in vivo thyroid uptakes following administration of carrier-free $^{131}$I.
8. To study the influence of carrier on in-vivo uptake carrier free $^{131}$I by the thyroid.
9. To find out the bio-distribution of a given radionuclide in a given animal.
10. To label the red blood cells using $^{51}$Cr and to determine the efficiency of labeling.
11. To find out the average life span of red blood cells by using $^{51}$Cr radionuclide.
12. To determine the blood volume of a given animal using $^{51}$Cr labeled red blood cells.
13. To measure the blood volume of a given animal using $^{99}$Tc labeled red blood cells.
14. To prove that spleen is the storehouse of worn out red blood cells by using $^{51}$Cr labeled red blood cells.
15. To find out the target / non target ratio of $^{99m}$Tc labeled pharmaceuticals.
16. To determine the biological half life of $^{99m}$Tc O$_4$ and labeled pharmaceuticals.
SECOND YEAR
THIRD SEMESTER

Paper – I  NUCLEAR MEDICINE AND ALLIED INSTRUMENTATION
(50 Lectures)

Rectilinear scanner (6 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.

Gamma Camera (16 Lectures)
Basic principles of gamma camera, collimators - parallel hole, divergent, convergent pinhole, fan beam, slant hole collimator. NaI (p) detector, position determining circuits, display. Gamma camera-computer interface- ADC/DAC.
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.

Probe Systems & Photography (6 lectures)
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- principles and its applications , QC of Dose calibrator
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

Computed Tomography (7 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 (7 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.

Practicals
1. Perform the calibration of Uptake Probe.
2. Determine the iso-response 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 : RADIONUCLIDES GENERATORS AND RADIOPHARMACEUTICALS**

(50 Lectures)

**Regulatory Constraints (6 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 (14 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. Formulation of radiopharmaceuticals and their classification, radiopharmacology of major products. Short-lived radionuclide generators: ⁹⁹Mo-⁹⁹mTc, ¹⁸⁸W-¹⁸⁸Re, ¹¹³Sn-¹¹³mIn, ⁶⁸Ge-⁶⁸Ga: ⁶²Sr-⁶²Rb, ⁸¹Rb-⁸¹Kr Radionuclide generator system: principles of generator system, Parent-daughter equilibrium. Solvent extraction, liquid column generator, solid column generator, yield of daughter radioactivities. Mechanism of localization of radiopharmaceutical in different organs, recent trends in radiopharmaceuticals, iodination and technique of iodination. Various receptor imaging, ligands and labelling of molecules.

**Design and development of radiopharmaceuticals (12 lectures)**


**Specific methods of labeling (12 lectures)**

Chemistry of technetium Labelling with ⁹⁹ᵐTc: formation of ⁹⁹ᵐTc-complexes by ligand exchange, structure of ⁹⁹ᵐTc-complexes, oxidation states of ⁹⁹ᵐTc in radiopharmaceuticals and , kits for ⁹⁹ᵐTc: DTPA, GHA, DMSA, MAG3, MDP, phytates, ECD, EC, IDA compounds and S-colloid etc., colloid and labeled particles, additives/ preservatives.
Labeling with ¹¹¹In : labeling of leucocytes and platelets, antibodies, ¹¹¹In-penteterotide, Positron emitters and radiochemistry to produce 18-FDG, ¹⁵CO₂, ¹³NH₃ and H₂¹⁵O
Quality control in nuclear medicine procedures (6 Lectures)

QC of kits – radiochemical purity, sterility check, membrane filtration, chromatography, pyrogen test, bio-distribution studies, 99Mo break through test.

Physicochemical tests: physical characteristics, pH and ionic strength, radionuclide purity, radiochemical purity, chemical purity, radio assay, QC for 99Mo/ 98Mo(stable molybdenum) by performing breakthrough tests: Breakthrough of Methyl ethyl ketone, alumina. Breakthrough test for Indium-113m and Sn-113 and zirconium.

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.

Practicals

1. Demonstration of 99Mo-99mTc column generator.
2. To separate 99mTc from 99Mo and determine the efficiency of extraction.
3. Perform the quality control of elute from 99Mo-99mTc Generator.
4. To determine the Rf of 99mTc 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 18F-FDG by thin layer chromatography Scanner.
13. To perform QC of FDG using gas chromatography.
14. To perform Bacterial endotoxin test on FDG.

Paper – III : RADIATION SAFETY AND DOSIMETRY(50 Lectures)

General principals of radiation protection (12 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.

Potential Exposure and Emergency Plans (5 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.

Regulatory Aspects & Licensing (6 lectures)
The Atomic Energy Act, Rules issued under the Act, Surveillance procedures issued under the Rules, Notifications issued under RPR, 1971, AERB Safety Directive, Safety code for NM facility, Duties of Medicalphysicist/Technologists/ Radiopharmacists/RSO, 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. Historical background of legislation in the atomic energy field, need for control of radiation exposure at national and international levels, national control through acts with supporting regulation at central and state levels international control through specialized agencies, third party liability andinsurance in the atomic energy field;

Design of radiation centers (6 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.

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.

Radiation dosimetry (8 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 (Γ), 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.
Practicals

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.
FOURTH SEMESTER

Paper – I: Nuclear Medicine imaging and radionuclide therapy (50 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.

Liver 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), placental imaging

Central nervous study - cerebral blood flow dynamic studies, static brain imaging, cisternography and ventriculoatrial and ventriculoperitoneal shunts. Use of $^{201}$Tl, $^{18}$FDG and NH$_3$ for cardiac studies.

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, gastrointestinal protein loss estimation using $^{51}$Cr-chromic chloride, Lymphatic imaging, adrenal imaging using $^{131}$I-MIBG, Vitamin B$_{12}$ absorption study and Schilling Test, etc.

In-vitro studies - 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, thyroglobulin. 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. Immuno-electrophoresis – cross over and rocket electrophoresis, Fluorescent activated cell sorting.

GFR plasma sample method

Therapeutic applications of radionuclides (15 Lectures)

Treatment of bone pain: use of 32P-orthophosphate, 99Sr- Strontium chloride, 186Re-HEDP, 153Sm-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

**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 Bone scan (3-phase, whole body and statics)
5. To perform Renogram study (using DTPA/EC)
6. To perform Brain SPECT study
7. To perform Gated Bloodpool scintigraphy.
8. To perform DMSA scan
9. To perform DRCG
10. To perform Solid GET
11. To perform GER
12. To perform Lung perfusion study
13. To perform MPI.
14. To perform Liver scan using SC
15. To perform Hepatobiliary study.

**Paper – II : RECENT ADVANCES IN NUCLEAR MEDICINE (50 Lectures)**

**Positron Emission Tomography (13 lectures)**

Introduction, **PET and coincidence detection**: Basic principles, detectors – BGO, NaI (Tl), LSI; Attenuation correction with transmission sources – $^{68}$Ge, $^{137}$Cs. Principles of PET imaging, the PET imager, the detector, uniformity correction, scatter correction, random correction, 2-D and 3-D reconstructions, performance of PET imagers, sensitivity spatial resolution PET v/s SPECT, Dedicated and hybrid PET systems. Performance characteristics, Modeling and quantification in PET.

Clinical application of PET in oncology, cardiology and neurology. Methods of performing various PET procedures. Methods of performing PET/CT procedures in cardiology, Neurology and Oncology, Gated PET/CT studies (respiratory and cardiac gating).

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

**Cyclotron (7 Lectures)**

Basic Principles of cyclotron, Positron emitting isotopes, Basic concept and quality control procedures

**Fusion imaging (6 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

**Internet In NM, Telemedicine & Nanotechnology (10 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 MATLAB® and Mathematica® software packages; Advances in Radionuclide Therapy.

Nanotechnology: Concepts and its biomedical applications

**Basic molecular research and Imaging (7 lectures)**
Use of CT for imaging of small animals using PET and SPECT. Animal conditioning, dynamic studies and other applications of multimode PET+SPECT+CT.

**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.
- Regular participation in weekly journal club, Seminar and other periodical CME programs.

**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.

**Dissertation**

100 Marks

**Suggested Books and Journals**

<table>
<thead>
<tr>
<th>Name of Book</th>
<th>Editor’s Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cell &amp; Molecular Biology</td>
<td>De Robertis</td>
</tr>
<tr>
<td>Molecular Biology of the Cell</td>
<td>Iberts, Bray, Lewis, Raff</td>
</tr>
<tr>
<td>Molecular Biology of Gene</td>
<td>Watson</td>
</tr>
<tr>
<td>Gene –V</td>
<td>enzamini</td>
</tr>
<tr>
<td>Cell Signaling</td>
<td>organ</td>
</tr>
<tr>
<td>Recombinant DNA</td>
<td>Tooze, Tustz</td>
</tr>
<tr>
<td>Text Book of Medical Physiology</td>
<td>Guyton</td>
</tr>
<tr>
<td>Physiology</td>
<td>Chatterjee</td>
</tr>
<tr>
<td>Biochemistry</td>
<td>Lehninger</td>
</tr>
<tr>
<td>Basic Medical Biochemistry</td>
<td>Stryer</td>
</tr>
<tr>
<td>Biochemistry</td>
<td>Smith Marks &amp; Libermann</td>
</tr>
<tr>
<td>Text Book of Microbiology</td>
<td>Harper</td>
</tr>
<tr>
<td></td>
<td>Panikar</td>
</tr>
</tbody>
</table>
• Methods in Biostatistics
  Mahajan
• Methods of Biostatistics
  Bhaskararao
• Statistical and Mathematical Techniques in NM 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
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

**************