The Radiation Medicine Centre of Bhabha Atomic Research Centre invites applications for undergoing the following post-graduate course under the aegis of Homi Bhabha National Institute (HBNI) (a Deemed University), Mumbai.

1. COURSE : DIPLOMA IN MEDICAL RADIOISOTOPE TECHNIQUES (D.M.R.I.T)

This course equips candidates for working as Nuclear Medicine Technologists in Nuclear Medicine Centres. The training will comprise of a full time schedule of lectures, demonstration, practicals and apprentice programmes. Examinations will be conducted by the Homi Bhabha National Institute (HBNI), Mumbai. Candidates should not hold any other job during the period of training, or join any other training programme.

2. DURATION OF TRAINING : One Academic Year (2017-2018). This programme shall be of one academic year duration consisting of two semesters. There will be examination at the end of every semester.

3. REQUIREMENTS FOR ADMISSION : Bachelor’s degree in Science (B.Sc.) (Chemistry, Physics/Mathematics/Zoology/Microbiology/Biochemistry/Biomatics/Biotechnology with Physics or Chemistry as one of the subject in B.Sc.) with minimum 50% marks. However, whenever stipulation by MHRD/UGC/Statutory Authority is higher than 50% the stipulated % shall be followed. B.Sc. Final year appeared candidates may also apply provided they have obtained at least 50% aggregate marks in I & II year B.Sc. examination.

4. AGE LIMIT : Not more than 35 years as on 1st May 2017. Upper age limit can be relaxed in the case of SC/ST(5 Years), OBC(3 Years), PH category(10 Years) and sponsored candidates. The candidates with physical disabilities limited to the lower extremities, but permitting to stand and move and physically able to carry out the course requirements only will be considered. The selected candidates should be able to discharge the duties of a Nuclear Medicine Technologist.

5. NUMBER OF SEATS : Maximum 10 (Ten) (5 non-sponsored and 5 sponsored). One seat is reserved for SC/ST/OBC candidate either from sponsored or non-sponsored category. * No. of seats indicated are provisional and subject to variation.

Note: Candidates sponsored by institutions with immediate prospect of post training employment in the same institution can apply if they have 50% aggregate marks in B.Sc. in any of the fields mentioned above. They should furnish sponsorship certificate[Annexure-I] from the Head of Institution stating that their salary will be paid during the training period and that they will be employed suitably in the sponsoring Institution following successful completion of training.

6. COMMON ENTRANCE TEST (CET) : Admission criteria will be a CET (Common Entrance Test) of 150 Multiple choice questions. The CET syllabus will be drawn from Science Subjects. 1) Physics 2) Chemistry 3) Maths or Biology of Standard XII or equivalent. Minimum marks to qualify will be 50%. A merit list of qualifying candidates will be made and will be selected in order of merit only. The CET will be held at 11.00 AM on 27/05/2017 at Anushaktinagar, BARC, Trombay, Mumbai - 400094. Admit Card will be generated on 24.05.2017, candidates are required to print Admit Card using their own login details. Without admit card, candidates will not be permitted to appear for CET. The result will also be displayed on the BARC website (www.barc.gov.in / recruit.barc.gov.in) within 15 days of CET.
7. DOCUMENTS SUBMISSION: On the day of CET, printout of online application and attested copies of proof of age, caste and sponsorship letter (as applicable) along with Mark sheet and certificate of HSC and B.Sc. will be collected from the candidates. Candidates who have not obtained results of final year B.Sc. examination may also apply provided they have obtained atleast 50% aggregate marks in the I and II year B.Sc. exam. They may be provisionally called to appear for CET, but have to satisfy the conditions in “Requirements for Admission” mentioned at Para-3 above by 30th June 2017.

8. STIPEND : A Stipend of ₹ 9300/- p.m. (₹ Nine Thousand Three Hundred only) will be given to each non-sponsored trainee. However, no stipend is admissible to sponsored trainees.

9. AWARD OF DIPLOMA :
   i. The Board of Studies shall fix the minimum qualifying marks or grades and other criteria for declaring a student as successful for the award of the Diploma.
   ii. The maximum period allowed for completing the course is two years.
   iii. The examination result of all the candidates shall be communicated to the Dean, HBNI through Dean-Academic of the Constituent Institute. The successful candidates will be awarded Post Graduate Diploma.

10. FEES : No fees for the training programme will be charged by BARC. However, necessary fees of ₹ 4000/- (Rupees Four Thousand Only) as on date as prescribed by Homi Bhabha National Institute (HBNI) will have to be paid. A caution deposit of ₹ 2000/- (₹ Two Thousand only) will have to be remitted by the selected candidates to BARC.

11. ACCOMMODATION : Trainees may apply for hostel accommodation. They will have to pay for boarding and lodging. However, accommodation is not guaranteed.

12. SYLLABUS : Syllabus for DMRIT course is annexed [Annexure II].

NOTE :

- No traveling allowances will be paid for attending CET.
- Applications will be accepted online only. Facility for online application will be available from 01/05/2017 to 21/05/2017.
- Photograph : Front face photograph (passport size) with light background should be uploaded with the application.
- Person working in the Central / State Government / Public Sector Undertaking should submit their applications through proper channel. They may however, submit advance copy online. Applications, which are not in the prescribed form (Online) are liable to be rejected.
- For online submission of application visit the website recruit.barc.gov.in.

Hindi version follows
Proforma of letter from Head of Institution for sponsored candidates on the letter head of the Institution
(To be submitted on the day of CET)

Shri/Smt./Kum. ___________________________ is hereby sponsored for undergoing DMRIT training course at the Radiation Medicine Centre, BARC to be conducted during the year 2017-2018. He / She is working in this Institution since _________________. In case he/she is selected for this training course this Institute will pay him/her salary/stipend during the period of the training course.

After successful completion of the training course, we undertake to suitably employ Dr./Shri/Smt./Kum. ___________________________ in our institution so that his/her training in nuclear medicine is properly utilised.

Signature of the Head of the Institution
(The Competent Authority of the Institute authorised to make above commitment)

(Office Seal)
Syllabus for Diploma in Medical Radioisotope Techniques
(DMRIT) – 2015

Scheme

Paper I - Basic Sciences for Nuclear Medicine - 100 marks
Paper II - Radiation Physics, Radiation Biology & Radiation Protection- 100 marks
Paper III - Diagnostic Radiopharmaceuticals & In-vitro Techniques - 100 marks
Paper IV - Instrumentation & Imaging Technology - 100 marks
Paper V - Clinical Nuclear Medicine Techniques - 100 marks

**Basic Sciences for Nuclear Medicine - Paper 1**

1. **Introduction Human Anatomy and Physiology**  
   10 Lectures  
   Human Anatomy, Brief introductory anatomical features of: Cardiovascular system, Respiratory system, Alimentary system, Renal system, Central nervous system, Endocrine systems, Reproductive system, Musculoskeletal system. Hematology. Human Physiology and Pathophysiology.

2. **General Cell Biology & Cellular Physiology**  
   2 Lectures  
   The basic structure of eukaryotic and prokaryotic cell and their internal environment. cell wall, cell membranes. Functions of endoplasmic reticulum, mitochondria, golgi complex, lysosomes. Transport across cell membranes, Functional systems in the cells, Cell reproduction.

3. **Basic Electronics**  
   8 Lectures  
   Fundamentals of electricity and electronics, power supply, electronic circuits, operational amplifiers, transistors, functional block diagrams of R-C circuit, logic circuits, circuit breakers and electronic switches. ADC and DAC.

4. **Basic Mathematics**  
   12 Lectures  
   Basic Mathematics as required for understanding radioactive decay, tracer kinetics, digital signal processing etc. Basic Mathematical functions, Quadratic equations, , Logarithmic, exponential, Differentiation and Integration basic.

5. **Chemistry relevant for radiopharmaceuticals**  
   10 Lectures  

6. **Introduction to Immunology:**  
   2 Lectures  

7. **Basic Biochemistry and Molecular biology**  
   5 Lectures  

8. **Basic Medical Statistics**  
   10 Lectures  
   Basics of Biostatistics, Frequency tables, Probability density function, Binomial distribution, Poisson distribution, Gaussian distribution, Exponential distribution,
Poisson distribution and its application; Normal distribution and its application. Tests of significance, Student’s t-test; Chi-Squared test. Correlation and Regression Analysis.

9. **Introduction to Biology of cancer** 2 Lectures

10. **Basic Medical Terminology** 2 Lectures

11. **Introduction Common hospital practices** 2 Lectures
    Pathogens, Disinfection methods, Sterilisation, Communicable diseases, Nosocomial infections, Hepatitis, HIV, Biohazards, Principles of asepsis - handling of contaminated swabs, used syringes and needles, Bio-waste management.

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**Radiation Physics, Radiation Biology & Radiation Protection - Paper -II**

1. **Origin & Types of Radiation** 4 Lectures
   Stability of nuclides - binding energy forces and nuclear forces, Laws of radioactivity, Units of radioactivity. Decay modes, Types of radiation (α, β, γ, X-ray, n). Radionuclide chart, . Laws of successive transformations, Theories of alpha, beta and positron emission; beta particle spectrum; K shell electron capture; Cerenkov radiation, characteristic radiation, Auger effect, Bremsstrahlung radiations, Metastable state and isomeric transition, internal conversion. Nuclear reactions, Nuclear reaction cross section, neutron activation with thermal neutrons, Nuclear isomerism, nuclear fission, fission products, nuclear reactors.

2. **Interaction of radiation with matter** 5 Lectures
   Gamma ray interactions - Excitation, ionization, photoelectric effect, Compton effect, pair production, annihilation radiations, specific ionization and linear energy transfer; Charged Particle interactions: range of charged particles, . Interaction of neutrons with matter, Elastic scattering. Importance of these interactions in radiology and nuclear medicine.

3. **Gas filled detector** 3 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, characteristics of organic and inorganic quenchers, operation

4. **Scintillation detectors – (Organic and inorganic)** 3 Lectures
   Atomic basis of scintillation. Scintillation process. Dopants. Inorganic and Organic Scintillators, Comparision of properties by comparison of characteristics like stability, light output, decay time, intrinsic efficiency, dead time, considerations on fabrication and cost.

5. **Gamma Ray Spectrometry** 5 Lectures
peak. Gamma ray spectrometer – calibration, energy resolution, integral and differential counting, linearity, counting efficiency.

6. Statistics of counting: 3 Lectures
Poisson distribution, Poisson approximation to radioactive decay, measures of counting error, accuracy and precision, standard error, counting in low background and high background scenarios, net count rates and standard deviation of count rates. Gaussian distribution and propagation of errors. Distribution of counting times to minimise errors.

7. Semiconductor detectors: 2 Lectures
Semiconductors junction and surface barrier detectors, Diode detectors, Ge(Li) detectors, High Purity Germanium detectors, their response and characteristics, energy calibration and detector efficiencies, cadmium-zinc- telluride detector. Room temperature semiconductor diodes

8. Liquid Scintillation Counters 2 Lectures
Composition of liquid scintillator, scintillation cocktail: primary solute, secondary solute and organic solvent (toluene, 1,4 dioxane, anthracene) and solubilizing agents for tissues, PM tubes, Coincidence circuits and count display systems. Quenching, Quench corrections methods: Internal standard method, external standard method and channel ratio.

9. Radiation Biology 8 Lectures
Radiolysis of water, interactions of free radicals, Direct versus indirect effects. Influence of LET, oxygen and various compounds on free radical forming reactions
Target Theory, Multitarget theory, Target size, Multihit theory, Multitarget multihit theory.

Radiation effects on macromolecules, cell membrane, chromosomes. Chromosomal type aberrations. Radiation effects on cell division. Radiation effects on microorganisms and independent cell systems.


Radiation effects on major organ systems: hematopoietic system, digestive system, reproductive system, nervous system. Effects of Ionizing Radiation on the Embryo and Fetus. Teratogenic and delayed effects.

Linear Energy Transfer, Relative biological effectiveness, Dose rate effect, chronic irradiation, factors influencing radiation response - oxygen concentration, Temperature etc.

Acute radiation effects: Lethality, Stochastic and Nonstochastic effects of radiation: Late effects in normal tissue systems and organs, Radiation carcinogenesis, genetic effect of radiation, radiation induced mutations, dose effect relationship, pre-natal effects of radiation, types of genetic disorders, risk estimation, direct method, doubling dose method, uncertainties.

Low Dose Exposure to Ionizing Radiation: Medical, Natural background, Radon. Radiation Hormesis

10. Personnel monitoring devices 4 Lectures
Film badges, Ring badges, Thermoluminescent dosimeters (TLD’s), Pocket dosimeters. Characteristics of TLD phosphors, Glow curves, dose and energy response, sensitivity and application in dosimetry and personnel monitoring devices.

11. Radiation Protection: 8 Lectures
Principles of radiation protection, time, distance, shielding. Quantities and units: Exposure, absorbed dose, radiation weighting factor, Relative biological effectiveness (RBE), concept of radiation weighting factor $W_R$, Sievert, equivalent dose, concept of tissue weighting factor, $W_T$, effective dose, committed equivalent dose, committed effective dose, dose limits. Risk factors, basis for ICRP dose limits for occupational exposure, ALARA, exposure of embryo / fetus, younger persons, occupational exposures, members of the public, risks associated with recommended limits. ALI & DAC

Exposure rate & Shielding calculations by defining types of materials, and thickness needed using attenuation coefficients.

12. Radiation dosimetry 7 Lectures
Metabolic pathways of radioisotope deposition, beta particle dosimetry; Equilibrium Dose rate equation. Gamma dose calculation, Specific gamma ray constant ($\Gamma$) and average geometrical factor. MIRD method of internal dose calculation, Absorbed Fraction and calculation of absorbed dose.

13. Transport of radioactive material: 2 Lectures
Classification of radioactive materials, general packing requirements, transport documents, Type of package, Transport Index, Category of package, approval requirements, TREMCARD.

14. Radiological emergency: 1 Lecture
Radioactive decontamination. Mitigation of consequences: Contamination, 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.

15. Radioactive waste management: 2 Lectures

Diagnostic Radiopharmaceuticals & In-vitro Techniques - Paper III

1. Production of reactor & accelerator produced radionuclides 5 Lectures

2. Compartmental Analysis 4 Lectures
Compartmental analysis and its applications in Nuclear Medicine, Assumptions in Compartmental model, Application of Differential equations, Open and closed models, Single compartment, two compartment and multicompartment models, reversible and irreversible exchanges, Mammary and Caternary models, Problems on
radioactive generators, biological elimination processes of radiopharmaceuticals. Distributed Models.

3. Radionuclide Generators

5 Lectures
Principles of generator system, parent-daughter equilibrium, mathematical principles. $^{99}$Mo-$^{99m}$Tc generator – solvent extraction, column generator, yield of $^{99m}$Tc and other generators; $^{188}$W/$^{188}$Re, $^{90}$Sr/$^{90}$Y, $^{113}$Sn/$^{113m}$In, $^{68}$Ge/$^{68}$Ga; ultra short-lived radionuclide generators: $^{82}$Sr-$^{82}$Rb, $^{81}$Rb-$^{81m}$Kr.

4. Radiopharmaceutical Chemistry

2 Lectures
General physicochemical properties of radioactive compounds: distinction between radionuclide, radiochemical and radiopharmaceuticals, carrier concept (carrier-free, carrier added, no carrier added). Chemistry of tracer radionuclide metals: hydrolysis, reduction-oxidation, concentration methods, radiolytic decomposition. Study of Phosphorous (P), Chromium (Cr), Cobalt (Co), Iron (Fe), Indium (In), Thallium (Tl), Technetium-99m (Tc), Iodine (I), Yttrium (Y), Strontium (Sr), Rhenium (Re), Samarium (Sm), Lutetium-177 (Lu), radioactive gases (i.e. Xenon Xe-133, Xe-127, Kr-81m) & positron emitting nuclides like Fluorine (F), Oxygen (O), Carbon (C), Nitrogen (N), Copper (Cu), Rubidium (Rb), Gallium (Ga)

5. Development of radiopharmaceuticals

1 Lecture

6. Modes of localisation:

2 Lectures
Substrate specific radiopharmaceutical localization, biochemical, metabolic trapping, enzyme inhibitor, enzyme substrate, receptor-binding biochemical or drug, antibodies to tumor associated antigens. Substrate nonspecific radiopharmaceutical localization: diffusion, compartmental space, capillary blockade, cell sequestration, phagocytes, chemisorptions.

7. Methods of radionlabeling:

2 Lectures
Isotope exchange reactions, introduction of foreign label, labeling with bi-functional chelating agents, biosynthesis, recoil labeling, excitation labeling. 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.

8. Specific methods of labeling - Radioiodination:

2 Lectures

9. Specific methods of labeling – Technetium labeling

4 Lectures
Chemistry of Technetium with respect to oxidation states, reduction methods, technetium tin-ligand reactions in aqueous solution, hydrolysis, re-oxidation, complexation, carrier effects, radiolytic decomposition. Labelling with $^{99m}$Tc: formation of $^{99m}$Tc-complexes by ligand exchange, structure of $^{99m}$Tc-complexes, oxidation states of $^{99m}$Tc in radiopharmaceuticals and kits for $^{99m}$Tc: DTPA, GHA, DMSA, MIBI, MAG3, MDP, phytates, ECD, EC, IDA compounds and Sulfur Colloid. Dextran, colloid and labeled particles. Metal chelate and conjugates, $^{99m}$Tc-tricarbonyl core, $^{99m}$Tc-nitrido compounds, $^{99m}$Tc-Hynic-TOC.
Kit formulation of radiopharmaceuticals and their classification. Additives, stabilisers and preservatives

10. **Radiolabeling of Cells:** 2 Lectures
Methods of labeling for blood pool studies and detection of gastrointestinal bleeding - Tc-99m red blood cells (i.e. In-vitro, In-vivo and modified In-vivo), Tc-99m RBC’s (denatured) for spleenic imaging, Tc-99m / In-111 - Leucocytes (i.e. Methods of radiolabeling for inflammation / abscess localization), Cr-51 red blood cells (i.e. Methods of radiolabeling for blood volume measurement & Spleenic Sequestration studies), In-111platelets (i.e. Methods for radiolabeling).

11. **PET radiopharmaceuticals:** 6 Lectures
Positron emitters and radiochemistry to produce, $^{18}$F-Sodium Fluoride, $^{18}$F-Fluorodeoxyglucose (FDG), $^{18}$F-Fluorodopa, $^{18}$F-Fluorothymidine (FLT), $^{18}$F-MISO, $^{18}$F-FAZA, $^{18}$F-FET, $^{18}$F-FBA, $^{11}$C-Sodium Acetate, $^{13}$NH$_3$ and H$_2^{15}$O.

12. **Molecular Imaging probes:** 1 Lecture
Basics of molecular imaging, methodology of molecular imaging, Various receptor imaging agents, ligands and labelling of molecules. $^{111}$In-penteterotide, $^{68}$Ga-DOTA. Conventional labeling of proteins, oligodeoxynucleotide antisense probes, reporter genes for imaging, gene therapy, gene delivery.

13. **Quality control of Radiopharmaceuticals** 4 Lectures
General Schemes, Physicochemical tests: physical characteristics, pH and ionic strength, radionuclide purity, radiochemical purity, chemical purity, radio assay, QC of kits – radiochemical purity, sterility check, membrane filtration, chromatography, pyrogen test, bio-distribution studies, Mo break through test. breakthrough of methyl ethyl ketone, alumina. QA of PET radiopharmaceuticals by TLC scanner, HPLC and gas chromatography (GC).

14. **Therapeutic applications of radionuclides** 1 Lecture
Choice of radionuclide - $^{131}$I, $^{32}$P, $^{89}$Sr, $^{153}$Sm, $^{186}$Re, $^{90}$Y, $^{177}$Lu.
Choice of radiopharmaceuticals for hyperthyroidism, thyroid carcinoma, neural crest tumours, painful bone metastasis, polycythemia vera, rheumatoid arthritis, osteoarthritis, hepatocellular carcinoma, radiolabeled antibodies for therapy, malignant effusion in pleural and peritoneal cavities, pretargeted Radioimmunotherapy of solid tumours.

15. **Nanotechnology** 1 Lecture
Concepts and its biomedical applications, liposomes, aerosols, nanoparticles, immuno-liposomes, drug delivery systems

16. **Design of Radiopharmacy laboratory:** 3 Lectures
Regulatory requirements, Pharmaceutical aspects, Radiation protection aspects, Local constraints, Design of hospital pharmacy, stocking of consumables and labels, disposable materials. Laminar airflow (LAF) hood, its testing and maintenance. Centralized Nuclear Pharmacy, Considerations & layouts. Automated Modules. Licenses & Procurement of Radiopharmaceuticals. Trace of delayed shipments, surveys, wipe tests, packaging, disposal, storage requirements, and record keeping logs.

17. **Diagnostic In-vitro Techniques:** 7 Lectures
Principle of RIA, Immunoradiometric assay (IRMA), Enzyme linked immunosorbent assay (ELISA), Fluorescent immunoassay (FIA), Chemiluminescent Immunoassay
(CLIA), Methods of receptor assays. In-vitro Uptake studies, In-vitro radiorespirometry, Quality Control Parameters and methods and Applications for hormones & drugs, example of assays for T\textsubscript{3}, T\textsubscript{4}, TSH, free hormones, thyroid antibodies and thyroglobulin, other hormones and drugs.

**Instrumentation & Imaging Technology - Paper - IV**

1. **QC of Radiation Protection Instruments**  
   2 Lectures  
   QC of - Ionization chamber Type, Geiger-Muller Counter, pocket dosimeter, Dose calibrator, Scintillation type Gamma ray spectrometer, Zone monitors.

2. **Medical Cyclotron-Radionuclide Production**  
   4 Lectures  
   Reactors and charged particle accelerators. Physics of linear accelerator, cyclotron, synchro-cyclotron, isochronous cyclotron. Medical cyclotron: threshold energy, nuclear cross section, q value, RF frequency, magnets, beam focusing and extraction, target design. Types and makes their advantages and limitations. Safety Concerns. Cyclotron produced radionuclides, Cyclotron based generators.

3. **Collimator Systems**  
   4 Lectures  
   Counting Geometry & Need for Collimator, Types of Collimator- Parallel Hole, Slant Hole, Rotating Hole, Focussing, Convering Hole and Diverging Hole Collimators, Material design with regards to Cost, Geometric Efficiecy and Resolution. Pinhole Collimator and its Adaptation in Gamma Camera.

4. **Probe systems**  
   2 Lectures  
   Thyroid uptake probe, basic components, system set-up and calibration, flat field collimator, iso-response curve and working distance.

5. **Rectilinear scanner:**  
   2 Lectures  
   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. Focal plane and depth of focus.

6. **Gamma Camera:**  
   5 Lectures  

7. **Application of Computers in Nuclear Medicine**  
   3 Lectures  
   Image Acquisition Matrix, Byte Mode and Word Mode, Frame Mode Acquisition, List mode, Static, Dynamic and Gated Acquisition, Image Display methods, Image Perception and Analysis, Image Manipulations and Presentations, Background Correction Methods, Image Interpolation, Region of Interest Analysis, Time Activity Curves and General Filters and Normalisation methods, Automated ROI’s and Computational methods.

8. **Single Photon Emission Computerized Tomography:**  
   5 Lectures  
   Principles of Tomography, longitudinal and transverse or axial tomography, Theoretical aspects of image acquisition & reconstruction techniques, filters, artifacts in SPECT, effect of scatter & scatter correction, noise, role of collimators, rotating gamma camera, single or multiple detector devices, data collection, SPECT acquisition – step & shoot/continuous. Whole body SPECT, SPECT v/s planar camera, SPECT v/s other modalities (CT, MRI, Ultrasonography)

9. **Positron Emission Tomography Equipment:**  
   5 Lectures  
   Gamma camera for PET imaging. Dedicated and hybrid PET systems. Principles of PET imaging, detectors assembly, various corrections in PET, 2-D and 3-D acquisitions, performance of PET imagers, sensitivity, spatial resolution. PET Detectors, Attenuation correction, TOF concept, instrumentation, data collection, data
correction, data storage, reconstruction, quality control, Performance characteristics, NECR, NEMA specifications, PET v/s SPECT, PET Protocols.

10. **Multicrystal Gamma Camera and Intraoperative probes**  
2 Lectures
Emerging designs and considerations of Multicrystal Gamma Camera and Intraoperative probes. Discussions on Standards and Quality Control. Small animal imaging systems.

11. **Overview of Whole body counting system:**  
1 Lecture
Whole body counting: principles of whole body counting, design of whole body counting system, stationary systems, single and multiple crystal systems, shadow shield geometry, moving systems, calibration of whole body system, clinical and other applications of whole body counters.

12. **Medical Informatics:**  
2 Lectures
Image Formats, Concept of DICOM (Digital image communication in medicine) and DICOM-RT and etc, DICOM and interfile conversion software, Interfacing; TCP/IP protocols, PACS (Picture Archiving and Communication System); Telemedicine

13. **Biomedical Ultrasound**  
2 Lectures
Ultrasound generators, properties of ultrasound waves and its propagation in biological tissues, Pulse echo techniques, Scan types. Doppler principle.

14. **Magnetic Resonance Imaging (MRI)**  
2 Lectures
Physics of magnetic resonance, MRI equipment its advantage over CT / Ultrasound, – Image artifacts – MRI safety. Principal of FMRI (functional magnetic resonance imaging), MR spectroscopy, MRI contrast, Limitations and uses of MRI. Configuration of machines available

15. **Radiological Instrumentation - CT scanner**  
4 Lectures
Discovery - Production - Properties of X-rays, basic requirements for diagnostic tubes, Classification of tubes, Filters, Measurement of kV and mA, CT detectors, CT acquisition, CT reconstruction, CT attenuation correction, CT dose index, dose length product, Radiation dose, CT-PET fusion, Quality Control of CT, Scanner design, Spiral Computed Tomography, Difference between conventional single slice, multislice, spiral and electron beam CT. Comparison of patient radiation doses and effects of slice thickness.

**Clinical Nuclear Medicine Techniques - Paper V**

1. **Non-imaging applications of radionuclides**  
4 Lectures
$^{51\text{Cr}}$ labeled RBC’s for blood volume, red cell volume measurement, spleen uptake, red cell survival studies. Schilling’s test using $^{58\text{Co}}/^{57\text{Co}}$ for vitamin B12 absorption, applications of $^{14\text{C}}$ radiorespirometry for H.Pylori ulcers, Ferrokinetic studies using radioisotopes of Iron.

**Important:** Common in all In-Vivo Techniques is a discussion on choice of radiopharmaceuticals and its dose, choice of equipment, imaging considerations, patient preparation & instruction, selection of imaging parameters, interventional approaches, quantitative data analysis, display, filming or its report generation.

2. **Thyroid studies**  
3 Lectures
Thyroid imaging and uptake ($^{99\text{Tc}}$ and $^{131\text{I}}$), Perchlorate discharge test, $T_3/T_4$ suppression test, TSH stimulation test. $^{131\text{I}}$ whole-body imaging. Post Therapy Scans.

3. **Lung imaging studies**  
4 Lectures
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 using MAA, Microsphere, pulmonary embolism.

4. **Liver-spleen imaging**  
   2 Lectures  
   Liver imaging for Diffuse and Focal liver diseases, Dynamic Liver studies, Quantitative methods for Hepatic Perfusion Index, Blood pool liver studies, portosystemic shunt evaluation by Per-rectal Scintigraphy.

5. **Hepatobiliary imaging**  
   3 Lectures  
   Hepatobiliary imaging protocols, Neonatal hepatitis versus Biliary atresia, Gall bladder dynamic studies using IDA compounds. Deconvolution analysis, Hepatic Extraction Fraction, Interventional methods.

6. **Gastrointestinal studies**  
   5 Lectures  
   Oesophageal transit time studies, Gastric oesophageal reflux, gastric emptying time, Duodeno-gastric reflux, Meckel’s diverticulum imaging, GI bleeding with $^{99m}$Tc-RBC, Bile leak studies.

7. **Cardiac studies**  
   6 Lectures  
   First pass study (shunt detection), Importance of Electrocardiogram (ECG), gated blood pool study, MUGA, Ejection fraction, Fourier analysis, Wall motion analysis, Infarct avid imaging, Rest / Stress myocardial imaging, Gated SPECT, Pharmacological stress, Bulls Eye analysis, Severity scores. Use of $^{201}$Tl, $^{18}$FDG and $^{13}$NH$_3$ for cardiac studies.

8. **Bone imaging**  
   3 Lectures  
   Routine bone (whole body and spot) imaging, bone flow study, quantitative bone scan-sacroiliac index, 3-phase bone scans, Bone SPECT. Bone imaging in Metabolic Disorders. MDP retention studies, $^{18}$F-Fluoride Bone Scans.

9. **Renal imaging studies**  
   10 Lectures  
   Standard Renogram, Diuretic renogram, Captopril renogram, Renal Perfusion analysis, Differential function, GFR estimation by Gates Method, Renal transplant studies, Background subtraction methods, Rutland Patlak-Plot, Plasma Sampling methods, Advantages and Disadvantages of various GFR estimation methods, Ureteric reflux study, Interventional methods, Direct radionuclide cystography, Cortical Renal Scans, Differential function by Geometric Mean.

10. **Brain imaging**  
    3 Lectures  
    Cerebral blood flow dynamic studies, Blood Brain Barrier imaging, Perfusion Imaging, Brain SPECT, Interventional methods, Cisternography, CSF leak.

11. **Tumour Imaging:**  
    2 Lectures  
    $^{18}$F-FDG PET Scans on Oncologic Staging and Evaluation of Post therapy status. Imaging for Medullary Carcinoma of Thyroid, Neural Crest Tumours, Apoptotic Imaging. Post Therapy Scans.

12. **Lymphoscintigraphy & Sentinel Node Scintigraphy**  
    2 Lectures  
    Use of Labelled Leukocyte, $^{99m}$Tc-Ciprofloxacin, $^{68}$Gallium for detection of Infectious foci. Discussion of imaging preferences.

13. **Infection and inflammation**  
    2 Lectures  

14. **Salivary gland imaging**  
    1 Lecture  
    Dual isotope technique and Subtraction scans. $^{99m}$Tc-MIBI wash out studies.

15. **Parathyroid Imaging**  
    1 Lecture  
    Imaging techniques for visualisation of Bone marrow infiltration

16. **Bone marrow imaging**  
    1 Lecture  

17. **Lymphoscintigraphy & Sentinel Node Scitigraphy**  
    2 Lectures
18. Scrotal Imaging 1 Lecture
19. Dacryoscintigraphy 1 Lecture
20. Scintimammography 1 Lecture
Early and Delayed Imaging. Special Positions and Restraining means.

21. Hysterosalphingography 1 Lecture
22. Contrast Agents 2 Lectures
Contrast media agents: Oral, IV – ionic/nonionic, Rectal, Intrathecal, Catheters, Types/indication/chemical makeup etc. Iodinated contrast materials, Characteristics of iodinated contrast materials, Water solubility and hydrophilicity, Osmolality, High osmolar contrast media (HOCM), Low osmolar contrast media (LOCM), Advantages of LOCM, Disadvantages of LOCM, Viscosity, Calcium binding, Iodine concentration, Adverse reactions. Substitution of barium based contrast instead of iodinated oral contrast, Indications for steroid premedication, Contraindications for steroid premedication.

23. Radiation protection in NM - Regulatory Aspects 8 Lectures
Guidance level for diagnostic administration, misadministration and preventive measures, reporting of misadministration.
Radiation hazards– evaluation and control; Annual Limit of Intake and Derived Air Concentration; AERB directive for dose limits. Protection of Staff, Public and Environment, radiation surveillance procedures. Use of dose constraints for staff and pregnant women. Radiation monitoring- external exposure monitoring, area and environmental monitoring (radiation field and contamination monitoring, air monitoring); decontamination procedures; radiation protection in diagnostic and therapeutic nuclear medicine - protection of the patient.
Layout of Nuclear Medicine Laboratory, Design of radiation labs, types of labs, Security of Sources and radioactive cautions signs and labels. Therapy Wards and Radiation Protection Measures. Patient Discharge Limits.
Practicals

Practicals – Physics
1. To measure Half Value Layer of β and γ emitters and to measure the absorption coefficients of different materials with gamma rays and beta particles
2. To study back scatter.
3. To determine the half life of a radioactive material.
4. To study the change in activity of a sample consisting of two independently decaying radioisotopes (or a mixture of isotopes)
5. To determine the plateau of GM tube and find out the dead time/ resolving time of GM counter.
6. To determine the efficiency of GM counter and find out the activity of the given unknown radioactive source.
7. Gamma ray spectrometry of $^{137}\text{Cs}$ with a single channel analyzer
8. To find out the spectrum of energies emitted by a radioisotope by using gamma ray spectrometer. (e.g. $^{131}\text{I}$)
9. To study the statistics of radioisotopic measurements and observe the effect of background on the counting statistics.
10. To determine the energy resolution of spectrometer
11. To study the energy linearity of given spectrometer
12. To observe gamma ray spectrum of the given two radionuclide sources (A and B) and identify composition of a tube containing mixture of these two radionuclide sources by evaluating scatter fraction.
13. To identify unknown radionuclide on the basis of its principal energy by using scintillation counter.
14. To study iso- response curve of Flat Field Collimator.
15. To study the line spread function of a parallel hole collimator at various depths.
16. To perform Quality Control of Planar Gamma Camera and assess uniformity by Flood source method.
17. To study the counting errors originating from sample geometry and determine Critical Volume for counting in a well counter.
18. To perform Tomography with Jaszczak Phantom and evaluate the results
19. Quality Controls of SPECT/CT system (Demonstration)
20. Quality Controls of PET/CT system (Uniformity, Attenuation correction, Partial volume effect, Co-registration evaluation of SPECT/CT & PET/CT, SUV measurements) (Demonstration)

Practicals - Radiopharmaceutical & Clinical Techniques
1. Perform Radioimmunoassay & IRMA.
2. To perform quality control of Dose Calibrator.
4. To prepare $^{99m}\text{Tc}$ labeled radiopharmaceuticals involving the use of a single and a double vials preparations
5. Determination of $^{99}\text{Mo}$ breakthrough in $^{99m}\text{Tc}$
6. Q.C. of radiopharmaceuticals by paper chromatography & to determine the Rf of $^{99m}\text{Tc}$ and the given labeled compounds by using ascending chromatography.
7. Rapid determination of radiochemical purity of radiopharmaceuticals.
8. Q.C. of PET radiopharmaceuticals by TLC scanner and HPLC
9. To estimate pipetting error and Estimation of Unknown Volume by Dilution principle.
10. Perform nuclear medicine imaging and process the data (Demonstration)
11. Biodistribution study of radiopharmaceuticals. (Demonstration)

Apprentice Program:

420 hours (roughly eight months of Apprentice in various areas of Nuclear Medicine @3hrs per day)