Government of India
BHABHA ATOMIC RESEARCH CENTRE

ADVERTISEMENT NO. **1/2016 (R-V)**

LAST DATE FOR RECEIPT OF APPLICATION : **APRIL 15, 2016 (Friday)**

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.**

COURSE: **DIPLOMA IN MEDICAL RADIOISOTOPE TECHNIQUES (DMRIT)**

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.

DURATION OF TRAINING : One Academic Year (2016-2017). This programme shall be of one academic year duration consisting of two semesters. There will be examination at the end of every semester.

REQUIREMENTS FOR ADMISSION : Bachelor's degree in Science (B.Sc.) (Chemistry, Physics, Life Sciences or Nuclear Medicine) or equivalent degree of a University recognized by the University Grants Commission with minimum 50% marks. However, whenever stipulation by MHRD/UGC/Statutory Authority is higher than 50% the stipulated % shall be followed.

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 an employment certificate 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.*

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 in BARC, Trombay, Mumbai. The dates for CET will be announced later and will be available on BARC website.(www.barc.gov.in).

AGE LIMIT : Not more than 35 years as on 1st May 2016. Upper age limit can be relaxed in the case of SC/ST/OBC, sponsored candidates and PH category. 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.

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.

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

AWARD OF DIPLOMA :

1. 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.
2. The maximum period allowed for completing the course is two years.
3. The examination result of all the candidates shall be communicated to the Dean, HBNI through Dean-Academic of the CI. The successful candidates will be awarded Post Graduate Diploma.

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

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

SYLLABUS : The course syllabus can be obtained from Assistant Personnel Officer, Radiation Medicine Centre, Bhabha Atomic Research Centre, Tata Memorial Centre Annexe Building, 4th Floor, Jerbai Wadia Road, Parel, Mumbai – 400 012 by sending a self addressed stamped envelope affixed with ₹10/- postage stamps to the above address in person. The syllabus details will also be available at http://www.hrdbarc.gov.in.

NOTE : No traveling allowances will be paid for attending CET.

HOW TO APPLY :

1. Single copy of the application type written on thick A4 paper should be submitted as per proforma given below and envelop should be superscribed **" D.M.R.I.T COMMON ENTRANCE TEST".**

2. **PHOTOGRAPH :** Two clear front face photographs (passport size) with light background. One should be pasted on the top right hand corner of the application and other, with name of the applicant written in block letters on the reverse, should be enclosed.

3. **ENVELOPE** : Attach a self addressed unstamped envelope (**bilingual-Hindi & English**) (Size: 200 mm x 110 mm) along with the application, for the Common Entrance Test Admission Card.

4. **COPIES OF CERTIFICATES** : Attested copies of B.Sc. Degree (Convocation) Certificate and Marklist alongwith marksheet/certificate of Higher Secondary (XII Std.).

5. **NOTE :** Persons working in the Central / State Government / Public Sector Undertaking should submit their applications through proper channel. They may however, send advance copy. Applications, which are not in the prescribed form or are not accompanied by attested copies of certificates, photographs and self-addressed envelope of the prescribed size are liable to be rejected.

Completed applications, should reach DEPUTY ESTABLISHMENT OFFICER (R-V), BHABHA ATOMIC RESEARCH CENTRE, TROMBAY MUMBAI-400 085 on or before **April 15, 2016**.

CANVASSING IN ANY FORM WILL BE A DISQUALIFICATION

(Last date of receipt of application is 15th April, 2016)

Application No. _____

(For office use only)

APPLICATION FOR ADMISSION TO THE COMMON ENTRANCE TEST FOR D.M.R.I.T.

(To be filled in by the applicant)

Passport Size **Photograph**

1. Advertisement No. : **1/2016-R-V**

2. Name (Surname first)(Shri/Smt/Kum) : _____
(in Capital Letters)

3. Date of Birth : Date _____ Month _____ Year _____

4. Address for Correspondence (in block letters):

_____

_____

_____City : _____

State : _____ **Pin** : _____

Telephone:_____ Mobile No:_____

e-mail : _____

5. Permanent Address (in block letters):

_____

_____

City : _____ State : _____

Pin : _____

6. Nationality : _____

7. SC/ST/OBC/PH : _____ Caste : _____

8. Educational Qualification and Professional Qualification :

Examination	University/ Board/ Institution	Year	Subjects	Class/ Grade	Total marks obtained	% of marks

9. Are you sponsored candidate : Yes / No

DECLARATION

I hereby declare that,

(i) The information furnished above is correct to the best of my knowledge and belief.

(ii) I am aware that my application is liable to be rejected if the information given above is incomplete or found to be incorrect.

Date: _____ _____
Signature of the candidate

CHECK LIST

Make sure that the following documents have been attached to your application FOR by putting a **X** in the box applicable.

1. Application form completed and signed. ☐
2. Self addressed envelope attached. ☐
3. Two Photographs one pasted and another enclosed. ☐
4. An attested copy of each of the following Certificates attached. ☐
   - 4.1 Date of Birth Certificate ☐
   - 4.2 H.S.C. Certificate/Mark Sheet ☐
   - 4.3 B.Sc. Degree Convocation Certificate ☐
   - 4.3 B.Sc. Mark Sheets ☐
   - 4.4 Experience Certificate ☐
   - 4.5 SC/ST/OBC/PH certificate (if applicable). ☐
5. For Sponsored Candidates : Sponsoring letter from Head of Institution ☐
6. Check list signed and attached. ☐

Date: _____ _____
Signature of the candidate

Proforma of letter from Head of Institution for sponsored candidates on the letter head of the Institution
(To be attached to the application)

Shri/Smt./Kum. _____ is hereby sponsored for undergoing DMRIT training course at the Radiation Medicine Centre, BARC to be conducted during the year 2016-2017. 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 1 - 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**

Inorganic Chemistry, Organic Chemistry, Mechanisms of Organic Reactions, Physical Chemistry of Macromolecules, TLC &HPLC.

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

Structure and function of immune system, Immune response – humoral and cell-mediated immune response – primary and secondary responses. antigens, antibodies, structure of Ab's, classification of antibodies, antigen-antibody interaction, and monoclonal antibodies. New generation antibodies.

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

Introduction to carbohydrates, proteins, nucleic acids, enzymes, lipids. Protein structure and protein 3-dimensional shape, structure-function relationship, proteins purification, Nature of enzyme catalyzed reactions, their regulation, inhibition and mechanisms. Structure and function of carbohydrates and their importance in central metabolism. Structures and nature of fatty acids and lipids found in biological membranes. Lipid Metabolism. Nucleic Acids and Biological Information Flow. Related Biochemical and molecular biology techniques.

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**

Neoplastic processes. Inflammatory & Degenerative processes. Classification and nomenclature of neoplasms.

10. Basic Medical Terminology **2 Lectures**

Descriptive – describing shape, color, size, function, etc, and eponyms. Word root for eg. Myocarditis (prefix)(root)(suffix). Prefix change, Suffix change. -itis, -osis, -ectomy, -otomy, -ostomy, a/an -, micro -, macro -, mega -/ -megaly, -scopy/ -scopic with examples. Pathological Nomenclatures Specially For Tumours.

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.

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**

Construction of a Gamma Ray Spectrometer. Components of GRS. Detection principle – light collection, light guide, and Photomultiplier tubes. Coincidence & anti coincidence circuits. Single channel analyzer, multi channel analyzer. Study of gamma ray spectrum: photopeaks, compton valley, edge and pleateau, characteristic X-ray peak, backscatter peak, Iodine escape peak, annihilation peak, coincidence

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 scintilator, scintillation cocktail: primary solute, secondary solute and organic solvent (toluene, 1,4 dioxane, anthracene) and solublizing 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.

Differential cell sensitivity. Criteria of sensitivity, Factors affecting sensitivity. Anti-oxidative enzymes: Super Oxide dismutase, Catalase, Glutathione reductase, Glutathione -S- transferase, Monoamine oxygenase, Glutathione peroxidase.

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.

Other types of dosimeters - radiation calorimetry, photographic dosimetery, chemical dosimetry. Bioassays. Bio-dosimetry, Extrimity dosimetry.

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 (Γ) 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

Segregation, Collection and Safe disposal, Delay tank facility. Radioactive & Biohazardous Waste Disposal Methods - Decay in Storage, Separation by Half Life, Incineration, Sewer or Atmosphere. Airborne Radiation Exposure Measurements, Effluent Concentration (lodine-131, Lutetium-177, etc).

Diagnostic Radiopharmaceuticals & In-vitro Techniques - Paper III

1. Production of reactor & accelerator produced radionuclides 5 Lectures

Reactors and charged particle accelerators. Nuclear reactors: neutron energy and neutron flux, neutron cross section, targets and specific activities, mathematical principles, general radiochemistry. Charged particle accelerators: physics of liner accelerator, cyclotron, synchro-cyclotron, isochronous cyclotron. Medical cyclotron: threshhold energy, nuclear cross section, q value, RF frequency, magnets, beam focusing and extraction, target design. Types and makes. Cyclotron produced radionuclides, cyclotron based generators.

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**

Empirical and Rational approaches to design, charge and size of the molecule, protein binding solubility, stability and bio-distribution. Structure- activity relationship. Biological properties of radiopharmaceuticals, pharmacokinetics, distribution, metabolism, excretion.

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 radiolabeling: **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**

Principle of radioiodination, methods of radioiodination: monocholoride method, Chloramine T method, Electrolytic method, Enzymatic method, Conjugation method, Demetallation method, Iodogen method, Iodo Bead method. Radioiodinated compounds (meta-lodobezyiguanidine (MIBG), amphetamines, ortho-iodohippurate), radioiodination of peptides, proteins, antibodies/monoclonal antibodies.

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, MAG_3, MDP, phytates, ECD, EC, IDA compounds and Sulfur Colloid. Dextran, colloid and labeled particles.

Metal chelate and congugates, ^{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 inflamation / 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).
QC in hospital radiopharmacy practices - includes aseptic practices & pharmaceutical safety aspects. Good manufacturing practice (GMP), ISO and ISI standards in radiopharmaceuticals.
Adverse reactions to and altered biodistribution of radiopharmaceuticals, iatrogenic alterations in the biodistribution of radiopharmaceuticals
Regulations, ethics and registration of radiopharmaceuticals.

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_3, T_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: threshhold 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**

Scintillation camera, Basic principles of gamma camera, collimators, NaI (T) detector, position determining circuits, Display. Gamma camera-computer interface-ADC/DAC. Correction Circuits. Criteria of Selection & installation of Gamma camera, Frontiers of Gamma Camera Technology: Avalanche photodiodes, CZT detectors.

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}Cr labeled RBC's for blood volume, red cell volume measurement, spleen uptake, red cell survival studies. Schilling's test using ^{58}Co/^{57}Co for vitamin B12 absorption, applications of ^{14}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 (^{99m}Tc and ^{131}I), Perchlorate discharge test, T_3/T_4 suppression test, TSH stimulation test. ^{131}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, Uretic 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 for Oncologic Staging and Evaluation of Post therapy status. Imaging for Medulary Carcinoma of Thyroid, Neural Crest Tumours, Apoptotic Imaging. Post Therapy Scans.

12. Lymphoscintigraphy & Sentinel Node Scintigraphy **2 Lectures**

13. Infection and inflammation **2 Lectures**

Use of Labelled Leukocyte, ^{99m}Tc-Ciprofloxacin, ^{68}Gallium for detection of Infectious foci. Discussion of imaging preferences.

14. Salivary gland imaging **1 Lecture**

Imaging for parenchymal and obstructive diseases of salivary glands. Post Radiation Xerostomia evaluation.

15. Parathyroid Imaging **1 Lecture**

Dual isotope technique and Subtraction scans. ^{99m}Tc-MIBI wash out studies.

16. Bone marrow imaging **1 Lecture**

Imaging techniques for visualisation of Bone marrow infiltration

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.

The Atomic Energy Act, Rules issued under the Act, Surveillance procedures issued under the Rules, Notifications issued under RPR, 2004, AERB Safety Directive, Safety code for NM facility, Duties of RSO, Regulatory clearance-Approval of NM Lab, Physician & RSO, Regulatory consent, authorisation- for disposal of radioactive waste and safe transport of Radioactive materials. Radiation Safety Program, Radiation Safety Officer and duties of Radiation Safety Officer, Radiation Safety Committee, Responsibilities for Implementation of Basic Safety Standards Requirements, AERB Regulation Related to Medical Cyclotron and PET

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 activiy of the given unknown radioactive source.
7. Gamma ray spectrometry of ^{137}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}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.
3. Radiopharmacy procedure: Elution of generators and calculation of labelling efficiency.
4. To prepare ^{99m}Tc labeled radiopharmaceuticals involving the use of a single and a double vials preparations
5. Determination of ^{99}Mo breakthrough in ^{99m}Tc
6. Q.C. of radiopharmaceuticals by paper chromatography & to determine the Rf of ^{99m}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. Peform 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)