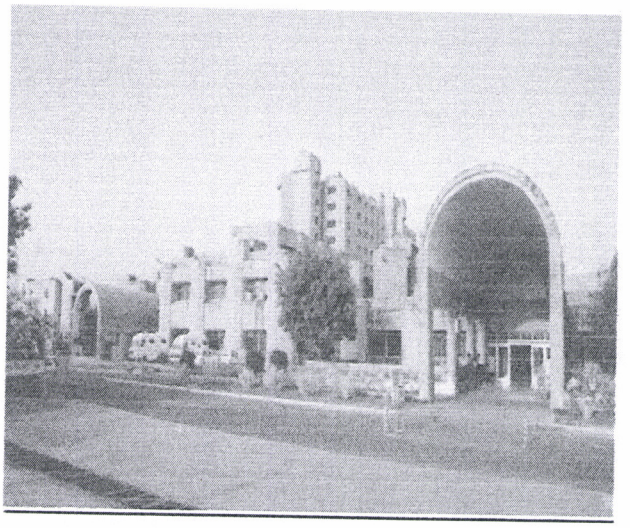
Colour Coding
Global GREEN
Regional BLUE
National ORANGE
Local (State) PINK



Curriculum

M. Sc. RadioPharmacy and Molecular Imaging

(M. Sc. RPh & MI)

College of Medical technology

Sanjay Gandhi Postgraduate Institute of Medical Sciences,

Rai-Berali Road, Lucknow

Dr. Manish Dixit
Additional Professor
Deptt. of Nuclear Medicine
S. G. P. G. I., Lucknow
Pin-226014 (INDIA)

M. Sc. RadioPharmacy and Molecular Imaging

(M. Sc. R. Ph & M. I.)

PREAMBLE

Nuclear Medicine is fast growing specialized branch of medicine which deals with the investigative support to specialists for treating the patients. It also involves many advanced technical procedures. Most of these procedures are highly technology intensive.

In India the Technical manpower currently available are with little or no exposure of working in current Nuclear Medicine technology environment. Well trained Technical manpower is crucial and core to understanding and adopting quality technical procedures for ensuring safety for the patients. This is also one of the main objectives of National Policy of India.

Department of Nuclear Medicine, SGPGIMS being one of the best centre in the country to start MD in Nuclear Medicine is in a unique position to start M. Sc. RadioPharmacy and Molecular Imaging (R. Ph & MI). The Department has adequate Infrastructure and technical expertise to train the candidates. MD and PDCC courses are already done by the department.

The existing short term training courses are insufficient to cater to the needs of Nuclear Medicine centers requirements hence the department proposes to start M Sc RadioPharmacy and Molecular Imaging (R. Ph & M. I) course.

VISION

To create RadioPharmacy experts with the ability for supporting the challenges of the nuclear medicine in terms of radiopharmaceutical production and application in pre-clinical and clinical studies and performing research on innovative radiopharmaceuticals development.

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Master of RadioPharmacy and Molecular Imaging ((M.Sc. RPh & MI)

NEED AND OUTCOME OF THE COURSE

The existing limited short term training courses are insufficient to eater to the needs of nuclear medicine centers requirements hence the department proposes to start M.Sc. (M.Sc. RPh & MI) course with following objectives:

1. To enable the students to have the understanding on the basics of the learning of radiopharmacy.
2. To impart the knowledge regarding the diagnostics, clinical aspects and related implications of radiopharmaceuticals and also understanding of new emerging technology includes the role of radionuclide as thernostics agent for emerging areas.
3. The identification is very essential for all the three line management -primary, secondary and tertiary managements and hence the systematic training course for the graduates at the university level is found to be very essential and urgent need.

DURATION OF THE COURSE:-

The duration of the course shall be on full time basis for a period of two years (Four Semesters).

The Rules and regulation for admission, examinations seats other academic proceeding as per the CMT & A. H. Sc rules and regulation documented in Information Boucher.

TEACHING FACULTY FOR COURSE

1. Faculty, Department of Nuclear Medicine, SGPGIMS, Lucknow.
   - i) Dr Sanjay Gambhir, Professor
   - ii) Dr Sukanta Barai, Professor
   - iii) Dr P K Pradhan, Professor
   - iv) Dr Amitabh Arya, Professor
   - v) Dr Manish Dixit, Additional Professor
   - vi) Dr Manish Ora, Associate Professor
   - vii) Dr Aftab H Nazar, Associate Professor

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vi) Dr Manish Ora, Associate Professor

vii) Dr Aftab H Nazar, Associate Professor

viii) Miss. Sarita Kumari, Medical Physicist

ix) Technical Staff and doctoral and Residents

2. Faculty, Department of Radioganosis, SGPGIMS, Lucknow.
   i) Dr Zafar Niyaz, Additional Professor
   ii) Dr Rajni kant, Assistant Professor
3. Faculty, Department of Molecular Medicine & Biotechnology, SGPGIMS, Lucknow.
   i) Dr Alok Kumar, Associate Professor
   ii) Dr. Lokendra K Sharma, Assistant Professor
4. Faculty, Department of Biostatistics & Health Informatics, SGPGIMS, Lucknow.
   i) Dr Prabhakar Mishra, Associate Professor
   ii) Dr Jai Kishun, Assistant Professor
5. Faculty, Stem cell centre, SGPGIMS, Lucknow
   i) Dr Jalaj Gupta, Assistant Professor
   ii) Dr Kulwant Singh, Assistant Professor
6. Faculty, Endocrinology, SGPGIMS, Lucknow
   i) Dr Rohit Sinha, Assistant Professor
7. Faculties, College of Medical Technology, SGPGIMS, Lucknow
8. Dr A. K Baranwal, Scientist, Animal House, SGPGIMS, Lucknow
9. Support faculty from Other Institutes/University:
   a. Faculty of King George Medical University, Lucknow
      i) Dr Satyendra K Singh, Associate Professor, Centre for Advance Research
   b. Department of Chemistry, IIT-Kanpur
      i) Dr. Ashish K. Patra, Associate Professor
   c. Guest faculty as and when required for specialized teaching.
10. Adjunct faculty as and when required for specialized teaching as per existing norms of the Institute.
    i) Dr Mukesh Pandey, Associate Consultant Research - Division of Nuclear Medicine, Department of Radiology, Mayo Clinic, Rochester, Minnesota.
    ii) Dr Subhash P Chauhan, Professor and Chairman, Department of Immunology and Microbiology Director, South Texas Centre of Excellence in Cancer Research School of Medicine, University of Texas Rio Grande Valley, Edinburg, TX

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11. Scientist from Central drug Research institute, Lucknow.
    i) Dr Prem Prakash Yadav, Principal Scientist
    ii) Dr Prem Narain Yadav, Principal Scientist
    iii) Dr Ajay K Srivastava, Senior scientist
12. Center for Biomedical Research, Lucknow
    i) Dr Dinesh kumar, Associate Professor
    ii)Dr Dharmendra k Tiwari, Assistant Professor

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TRAINING PROGRAMME

(A) Course of instruction

Details of theory & practical subjects and allotted hours are as detailed hereunder:

Table — I: Teaching subjects & distribution of teaching hours in respective Semester

Paper	Subject title	Teaching Hours/week	Teaching Hours/Academic Years	Marks 100 (External + Internal)
	SEMESTER 1			
RPMI-101	Fundamentals of Radiation Physics, protection and safety	3	86	80 +20
RPMI-102	Basic Radiochemistry and Radiopharmacy	5	130	80 +20
RPMI-103	Nuclear Medicine Instrumentation & Imaging Technology	4	104	80 +20
RPMI-P1	Practical Based on RPMI-101- RPMI-103	7	182	40 +60
	Total	**19**	**502**	**400**
	SEMESTER 2			
RPMI-204	Isotope Production and their chemistry	4	110	80 +20
RPMI-205	Basics of Human Biology & Laboratory animals in biomedical research	3	80	80 +20
RPMI-206	PET Radiochemistry	5	130	80 +20
RPMI-P2	Practical 2 of RPMI-104 - RPMI-106	7	182	40 +60
	Total	**19**	**502**	**400**
	SEMESTER 3			
RPMI-301	Nuclear pharmacy: design and regulations	2	92	80 +20
RPMI-302	Clinical application of radiopharmaceuticals: diagnostic and therapeutic	3	136	80 +20
RPMI-303	Computers, Bio-informatics, IPR and Biostatics in Nuclear Medicine	4	104	80 +20
RPMI-P3	Practical 1based on RPMI-101 to RPMI-103	7	138	40 +60
	Total	**16**	**470**	**400**

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	SEMESTER 4			
RPMI-401	Advancement in Radiopharmacy and its application	5	130	80 +20
RPMI-402	Principle of Molecular Targets and Imaging	5	130	80 +20
RPMI-P4	Practical 2 based on RPMI-104 to RPMI-106	4	104	40 +60
RPMI-403	Dissertation (Thesis, Record, viva Voice)	6	156	
	Total	**12**	**520**	**300**

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Specialized Training schedule for M. Sc R. Ph. & M.I

First Year Specialized Training	Duration	Second Year Specialized Training	Duration
Cyclotron Operation	Two months	**Cyclotron Operation**	Two months
PET Chemistry	Four months	**PET Chemistry**	Four months
SPECT Chemistry & QC analysis	Two months	**SPECT Chemistry & QC analysis**	Two months
Imaging Instrument and applications	Two months	**Imaging Instrument and applications**	Two months
Radiochemistry Automation and application	Two months	**Radiochemistry Automation and application**	Two months

POSTING AND TRAINING IN OUTSIDE CENTRES:

The Head/Principal of the College of Medical Technology should make necessary arrangements for the postgraduate students to undergo training in various skills in other centers within and outside the State or across the country if advanced facilities are not available in the institute.

SYLLABUS

Course curriculum and Syllabi for the course shall be as prescribed by the Academic Board of the Institute from time to time. However to start with, a detailed and comprehensive syllabus in this regard is being annexed herewith.

METHOD OF TRAINING The training of student for M.Sc. shall be on a full time pattern with graded responsibilities and involvement in laboratory, experimental work and research studies. The participation of the students in all facets of educational process is essential. Every Candidate should take part in seminars, group discussions, case demonstrations, journal review meetings and other continuing medical education (CME) activities.

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Needs: Local : Pink, National : Orange, Regional: light blue, International : green

DISTRIBUTION OF INTERNAL ASSESSMENT MARKS IN SEMESTER 1 & II

Paper	Subject title	Theory	Practical
RPMI-101	Fundamentals of Radiation Physics, protection and safety	**20**	-
RPMI-102	Basic Radiochemistry and Radiopharmacy	**20**	-
RPMI-103	Nuclear Medicine Instrumentation & Imaging Technology	**20**	-
RPMI-201	Isotope Production and their chemistry	**20**	-
RPMI-202	Basics of Human Biology & Laboratory animals in biomedical research	**20**	-
RPMI-203	PET Radiochemistry	**20**	-
RPMI-P1	Practical 1based on RPMI-101 to RPMI-103 P=Practical (25), R=Record (10), VV= Viva-voice (15), A=Attendance (10)	-	**60** (P+R+VV+A)
RPMI-P2	Practical 2 based on RPMI-201 to RPMI-203 P=Practical (25), R=Record (10), VV= Viva-voice (15), A=Attendance (10)	-	**60** (P+R+VV+A)

DISTRIBUTION OF INTERNAL ASSESSMENT MARKS IN SEMESTER III & IV

Paper	Subject title	Theory	Practical
RPMI-301	Nuclear pharmacy: design and regulations	**20**	-
RPMI-302	Clinical application of radiopharmaceuticals: diagnostic and therapeutic	**20**	-
RPMI-303	Computers, Bio-informatics, IPR and Biostatics in Nuclear Medicine	**20**	-
RPMI-401	Advancement in Radiopharmacy and its application	**20**	-
RPMI-402	Principle of Molecular Targets and Imaging	**20**	-
RPMI-P3	Practical 1based on RPMI-301 to RPMI-303 P=Practical (25), R=Record (10), VV= Viva-voice (15), A=Attendance (10)	-	**60** (P+R+VV+A)
RPMI-P3	Practical 2 based on RPMI-401 to RPMI-402 P=Practical (25), R=Record (10), VV= Viva-voice (15), A=Attendance (10)		**60** (P+R+VV+A)
RPMI-403	**Dissertation** P=Practical (25), R=Record (5), VV= Viva-voice (15), A=Attendance (5)		**100**

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Note: A student must secure at least 50% of total marks fixed for internal assessment for a particular subject in order to be eligible to appear in University examination in that subject. The internal assessment marks will not be added to the marks obtained in the institute examination for declaration of pass.

(B) MAINTENANCE OF LOG BOOKWORK DIARY

1. Every Post Graduate Degree candidate shall maintain a record of skills Log Book he/she has acquired during the two years training period, certified by the various Heads of Department, where he/she undergone training including outside the institution.
2. The candidate should also be required to participate in the teaching and training program of post-graduate and intern-students.
3. In addition, the Course coordinator shall involve the Post- graduate degree course candidates in Seminars, Journal Clubs, Group Discussions and participation in other academic activities to enhance the professional skills of the candidates.
4. Every Post-graduate Degree course candidate should be encouraged to present short title papers in conferences and improve on it and submit them for publication in reputed journals. Motivation by the course co-coordinator is essential in this area to sharpen the research skills of the post-graduate candidates.
5. The Course coordinator shall scrutinize the Log Book once in every three months.
6. At the end of the course the candidates should summarize the content and the log book certified by the course coordinator.
7. The Log Book for each year should be submitted 2 months prior to the final semester examinations.

APPOINTMENT OF EXAMINERS (Annexure I)

1. Convener-Course Coordinator, SGPGIMS, Lucknow
2. Internal examiner-Faculty, Department of Nuclear Medicine, nominated by Dean, SGPGIMS, Lucknow
3. External examiner (02)-Shall be from the approved examiner list and will be nominated by the Dean, SGPGIMS, Lucknow on recommendation of the Chairman/Nodal Officer, College of Medical Technology, SGPGIMS, Lucknow.

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Detailed Syllabus

First Year

Semester I

RPMI-101

Fundamental of Radiation Physics, Protection and Safety **86 Hours**

1. Radiation Physics: **8 Hours**

Atom and sub atomic particles, Rutherford's atomic structure and its limitations, Bohr's atomic structure. Quantum numbers, Isotope, Isobar and Isotone, Periodic properties like atomic radius, ionic radius, Electro negativity, Ionisation potential, Electron affinity.

2. Radioactivity **10 Hours**

Discovery of Radioactivity, Radioactive Substances in Nature, Units and definition of Radioactivity. Laws of radioactivity, Periodic Table of the Elements, Isotopes and the Chart of the Nuclides, basis of radioactivity (N/Z ratio).Stability and Transmutation of Nuclides, Mass defect and Binding Energies of Nuclei, Nuclide Masses. Radioactive decay, Physical Half-Life, Activity, Decay Constant, Mode of radioactive decay, Types of radioactivity depending on N/Z ratio.

3. Radionuclides and their decay modes **10 Hours**

Alpha particle decay, Beta particle decay, Gamma ray, Proton-Decay and Other Rare Decay Modes, Decay Series, Law and Energy of Radioactive Decay, Radioactive Equilibrium, Secular Radioactive Equilibrium, Transient Radioactive Equilibrium, Half-life of Mother Nuclide Shorter than Half-life of Daughter Nuclide, Similar Half-lives, Branching Decay, Successive Transformations, Spontaneous Fission. X-ray emission, Theories of alpha, beta and positron emission; beta particle spectrum; K shell electron capture; Cerenkov radiation, characteristic radiation, Auger effect, Bremsstrahlung radiations, Meta stable state and isomeric

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transition, internal conversion. Nuclear reactions, Nuclear reaction cross section, neutron activation with thermal neutrons, Nuclear isomerism, nuclear fission, fission products.

Interaction of Radiation with matter **8 Hours**

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.

4. General principles of radiation protection **18 Hours**

Principles of radiation protection, specific factors involved in radiation protection time, distance, shielding. Quantities and units: Dose, roentgen unit of exposure, radiation sensitivity of biological materials, radiation absorbed dose (RAD, Gray), radiation weighting factor, Relative biological effectiveness (RBE), Quality factors, Roentgen Equivalent Man (REM), Sievert, equivalent dose, effective dose, collective equivalent dose, total effective dose equivalent, radiation dose limits, maximum permissible doses (IRCP recommendations) ICRP and National radiation safety standards. Natural radiation exposure, cosmic radiation, terrestrial radiation, nuclear fall outs, medical exposures. Basis for exposure limits for occupational exposure, ALARA, exposure of embryo /fetus, younger persons, occupational exposures, members of the public, dose limits for patients, risks associated with recommended limits. Deterministic and stochastic effects, the concept of comparative risk. Do's and Don'ts in radiation protection practice. Personal monitoring, film badges, TLD badge, use of survey meters and dose calibrators.

5. Radioactive decontamination and waste disposal **10 Hours**

Radioactive decontamination of labs, clothes, hands, glassware, gloves, metals, plastics, paints and bricks, decontamination of person, decontamination of room Radio isotopic 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.

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6. Regulatory Aspects & Licensing **12 Hours**

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 Medical physicist/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 and 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 and insuralce in the atomic energy field; ICRU and ICRP Recommendations; on Dose Limits, Protection Regulations, Basic Framework of Radiation Protection, Radiation Safety Program, Radiation Safety Officer and duties of Radiation. Safety Officer, Radiation Safety Committee, Personnel Monitoring, Responsibilities for Implementation of Basic Safety Standards Requirements. Relevant codes for X-ray and radiation therapy, licensing procedures under atomic energy (radiation protection) rules. Role of National and International Organizations like AERB, MCI, NMC, BRIT, BARC, IAEA, ICRP.

7. Transportation of radioactive substances **10 Hours**

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, trallsport emergencies, Regulations for different modes of transporting radioactive material including transport by post. All above guidelines will deals with PET, SPECT or alpha therapy radio nuclides transportation.

RPMI-102

Basic of Chemistry and Radio-pharmacy **130 Hours**

1. **Organic chemistry**: **40 Hours**

Reaction Intermediates Formation, structure, stability and reactions of Carbocation, Carbanions, Free radicals, Nitrenes, Carbenes, Benzynes. **Concept of Acids and bases** Hard and soft acids and bases, effect of structure and medium on strength of acids andbases. pH,

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pKa, pKb, Henderson- Hassenbelch equation, buffer solutions. **Organic reactions**: Substitution, Addition , Elimination reactions, Rearrangement; fries rearrangement, Schmidt rearrangement, Hofmann- martius aniline rearrangement, Favorskii rearrangement, Claisen Condensation and rearrangement, Suzuki, click reactions. Protection Deprotection of functional groups, Microwave reactions, and solid and solution phase chemistry., **Separation Techniques:** Chromatography: general principles, classification, chromatographic techniques, normal and reversed, phase bonded phase, column chromatography, , thin layer and, ion exchange chromatography, principle application and Instrumentation of Gas chromatography; Principal, applications, instrumentation of High pressure liquid chromatography,

2. Spectral analysis: **30 Hours**

(a) Ultraviolet, Visible and Optical spectroscopy: Introduction, energy levels, selection rules; Woodward Fieser, Fieser Kuhn and Nelson rule, Influence of substituent, ring Size and strain on spectra characteristics, solvent effect, methodology. Basic of Optical Spectroscopy with emphasis of florescence. Principle and properties of emission. Biochemical Applications of Nonlinear Optical Spectroscopy.

(b). Infrared Spectroscopy: Introduction, types of vibrations, characteristics regions of the spectrum, influence of substituent, ring size, hydrogen bonding, vibrational coupling, field effects on frequency, methodology, spectral interpretation with example.

(c). Nuclear Magnetic Resonance spectroscopy: Introduction, magnetic nuclear, chemical shift, shielding, relaxation process, chemical & magnetic non equivalence, local diamagnetic shielding and magnetic anisotropy, spin splitting, coupling constant, mechanism of coupling, quadrapoule broadening and decoupling. shift reagent, application of 1HNMR with some examples. Introduction to the following techniques would be covered to analyses the carbon, Nitrogen and fluorine spectra.

(d). **Mass Spectrometry:** Introduction, Essential components of a mass spectrometer, types of ions, molecular ion, fragment ion, rearrangement ion, metastable ion, Isotopic ions and their corresponding peaks, rules of fragmentation Introduction to FAB, LC-MS, GC-MS

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3. Co-ordination chemistry: Oragano-Metallic chemistry **25 Hours**

Introduction: monodentate, bidentate, and polydentate ligands, coordination sphere, coordination number, nomenclature of mononuclear and dinuclear complexes, chelate effect, Werner's theory and Sidgwick theory, EAN and formation of metal-metal bond in dimers, stability of complexes, determination of stability constants, Type of ligands and eighteen electron rule, transition metal carbonyl complexes, substitutes for carbonyl ligands, non-carbon ancillary ligands, ligand substitution reactions, ligand insertion reactions, carbene complexes, reaction mechanism involving substitution, elimination and addition concept, transition metal organometallics: square planar complexes, metal alkyls, metal alkylidenes, metal alkylidynes and metal arenes, Vaskas complex, isolobal analogy, fluxional properties of organometalic chemistry. Synthesis, structure, bonding and reactivity of transitional metal complexes with alkenes, cyclopentadienyl, cycloheptatriene, cyclooctatetraene etc.

4. Introduction to radio pharmacy **35 Hours**

General physicochemical properties of radioactive compounds: distinction between radionuclide, radiochemical and radiopharmaceuticals, carrier concept (carrier-free, carrier added, no carrier added). definition of a Radiopharmaceutical, ideal Radiopharmaceutical, Important characteristics of a radionuclide to be used in imaging and therapy, with example of ^{68}Ga, ^{177}Lu, ^{90}Y, ^{18}F, ^{99m}Tc, ^{131}I, ^{125}I etc., availability, short effective half-Life, particle emission, decay by electron capture or isomeric transition. Chemistry of tracer radionuclide metals: hydrolysis, reduction-oxidation, concentration methods, radiolytic decomposition High target to non-target activity ratio Isotope exchange reactions. Introduction of a foreign label. Bifunctional chelating agents. Biosynthesis. Efficiency and stability. The isotopic effect. Radiolysis. The importance of technetium. Oxidation states of technetium. Complexes with metal-nitrogen bonds. Oxo-complexes. Technetium complexes with low oxidation states. Radioisotopes of iodine: specific characteristics of ^{123}I, ^{124}I, ^{125}I and ^{131}I. Isotopic exchange, electrophilic substitution, nucleophilic substitution. Quality control protocols. Beta. Gamma, alpha and auger-electron emitting radio nuclides and their radiopharmaceuticals

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RPMI-103

Nuclear Medicine Instrumentation & Imaging Technology **104 Hours**

1. **Rectilinear scanner and Photography** **6 Hours**

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

2. **Gamma Camera** **12 Hours**

Basic principles of gamma camera, collimators parallel hole, divergent, convergent pinhole, fan beam, slant hole collimator. NaI (Tl) detector, position determining circuits, display. Gamma camera computer interface ADC/DAC. Performance characteristics and image quality. Criteria of installation of Gamma camera. Selection of gamma camera -specifications and other aspects, automatic acquisition of images. Purchasing and monitoring equipment performance, trouble shooting. νGamma 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

3. **SPECT (Single photon emission computerized tomography)** **20 Hours**

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, nonuniformity corrections, correction with combined SPECTCT system), effect of scatter & scatter correction, noise, partial volume effects. Performance characteristics

4. **Positron Emission Tomography** **20 Hours**

Introduction, PET and coincidence detection: Basic principles of PET imaging, Pet detector and scannerdesigns detectors -BGO, NaI (Tl), LSI; Attenuation correction with transmission sources –^{68}Ge, ^{137}Cs. Data corrections: normalization, uniformity correction, scatter correction, random correction. 2D and 3D reconstructions, performance characteristics of PET imagers.

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Daily, weekly and monthly Quality control of the PET/CT. PET v/s SPECT, Dedicated and hybrid PET systems. Performance characteristics, Modeling and quantification in PET.

5. Computed Tomography **10 Hours**

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.

6. MR/CT/Ultrasound imaging **10 Hours**

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

7. Fusion imaging **10 Hours**

Definition, introduction, Software and hardware fusion of images SPECT/ CT FusionImaging: Principles, applications, limitations and uses PET/CT Fusion Imaging:Principles, applications, limitations and usesUse of CT, PET and SPECT for imaging of small animals. Animal conditioning, dynamic studies andother applications of multimode PET+SPECT+ CT

8. **Probe Systems and dose calibrator** **10 Hours**

Gamma probe, Thyroid uptake probe, basic components, system setup and calibration, flat field collimator,isoresponse curve and working distance. QC of uptake probe. Principles and applications, QC of Dose calibrator

9. Instruments in Radiation Safety **10 Hours**

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

RPMI-201

Isotope Production and their chemistry **110 Hours**

1. Production of Radio-isotopes **10 Hours**

Principle of production, Research reactors for isotope production, Neutron energy and neutron flux, Cross-section, General consideration, different types of isotopes used in nuclear medicine, Radionuclide Considerations, Type and Energy of Emissions, Specific Activity, Chemical

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Properties, Economy and Production of radionuclides. Equation for radionuclide production in Reactors and charged particle accelerators, irradiation yields. Target consideration, Second order reactions, Specific activity, NCA. Compound nuclei, Energetics of Nuclear Reactions, Kinematics, Q value, Projectiles for Nuclear Reactions, threshold energy, Cross Sections of Nuclear Reactions, Yield of Nuclear Reactions, Production rates and cross-sections, Saturation factors and practical yields

1. Radionuclide Generators **20 Hours**

Need for Generator, Advantages of generator system, Definition, Properties of Ideal Generator, Basic Principle, Parent Daughter Growth –Decay Relationship, Parent Daughter Equilibrium, Transient Equilibrium, Secular equilibrium. The configuration of medically useful generators such as 99mMo/99mTc generator,

Types of radionuclide generator, column generator, solvent extraction generator, gel generator, sublimation generator, various generator systems, elution efficiency, Generator produced photon emitters, Generator produced positron emitters, Generator produced particle emitters for therapy.

(a) Gamma emitting radionuclidic generators: 99Mo - 99m Tc, 113Sn – 113mIn, Special emphasis on 99Mo - 99m Tc generator: Production of parent, Decay Scheme, Characteristics of Daughter Radionuclide, Types of generators – column generator, solvent extraction generator, gel generator, sublimation generator, various generator suppliers, Applications of Daughter Radionuclide

(b) Beta emitting radionuclide generators: ^{188}W /^{188}Re, ^{90}Sr / ^{90}Y, ^{132}Te /^{132}I. Production of parent, decay Scheme, characteristics of daughter radionuclides, generator suppliers, applications of daughter radionuclide.

(c) Positron emitting radionuclide generators: $^{68}Ge/^{68}Ga$, $^{82}Sr/^{82}Rb$: Production of parent, Decay Scheme, Characteristics of Daughter Radionuclide, Various generator suppliers, Applications of Daughter Radionuclide.

(d) Alpha emitting radionuclide generators and Complex Systems: ^{225}Ac / ^{213}Bi, $^{212}Pb/^{212}Bi$

2. Medical cyclotron: **15 Hours**

Basic working principles and instrumentation of cyclotron, type of cyclotron, Magnet Power Supply, Principles of RF generation and measurement, Extraction System, Targetry (Solid, Liquid and Gas), advantages and limitations, Target Maintenance, Cooling Systems, Transmission Lines, Ion Sources, Vacuum Pumps, Vacuum Gauges, Temperature transducer and loops, Pressure Measurement, Flow measurement, Conductivity and humidity measurement, Air compressors, Linear and Rotary Motion Transducers, Feedback Control

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Systems. cyclotron generated radionuclides, cyclotron shielding, neutron detection and other quality control procedures.

Responsibility of Cyclotron Operator, Safety Regulations and Guidelines, Safety Checks, Checklists and Recordkeeping, Machine and Personnel Safety Interlocks, Cyclotron Shielding Principles, Radiation Detection and Monitoring in Cyclotron, Waste Management (Liquid, Solid and Gaseous Waste), Gas supplies and other Consumables

3. Production of medically useful radioisotopes in Cyclotron **12 Hours**

Choice of an accelerator, Comparison of cyclotrons with other accelerators, Radioisotope yield considerations, Characteristics of commercial cyclotrons, Operating costs, Maintenance.

PET isotopes: Production ^{18}F, ^{11}C, ^{13}N, ^{15}O, ^{68}Ga using liquid targets, production other PET isotopes (^{124}I, ^{64}Cu, ^{68}Ga, ^{45}Ti, ^{44}Sc, ^{86}Y, ^{89}Zr etc) using solid and gaseous targets

SPECT isotopes: ^{67}Ga, ^{123}I, ^{111}In. Production, separation & purification

Therapeutic isotopes: Alpha emitters ^{211}At, ^{225}Ac

4. Development of radiopharmaceuticals and ^{99m}Tc- chemistry **38 Hours**

Definition of a Radiopharmaceutical, ideal Radiopharmaceutical, Important characteristics of a radionuclide to be used in imaging and therapy, with example of ^{68}Ga, ^{177}Lu, ^{90}Y, ^{18}F, ^{99m}Tc, ^{131}I, ^{125}I etc., availability, short effective half-Life, particle emission, decay by electron capture or isomeric transition. High target to non-target activity ratio.

Design of new Radiopharmaceuticals. General considerations. Factors influencing the design of new radiopharmaceuticals. 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.

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.

^{99m}Tc-chemistry: Core structures of various common ^{99m}Tc- radiopharmaceuticals, labelling techniques, importance of 99mTc-kit components, 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 $9^{9m}Tc$: formation of ^{99m}Tc- complexes by ligand exchange, structure of ^{99m}Tc-complexes.

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oxidation states of ^{99m}Tc in radiopharmaceuticals and kits for ^{99m}Tc-labeling-: DTPA, GSA, GHA, DMSA, MIBI, MAG3, MDP, 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.

Kit formulation of radiopharmaceuticals and their classification. Additives, stabilisers and preservatives.

5. Quality control of Radiopharmaceuticals **15 Hours**

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, breakthrough test. Breakthrough of methyl ethyl ketone, alumina. 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 bio-distribution of radiopharmaceuticals, iatrogenic alterations in the bio-distribution of radiopharmaceuticals. Regulations, ethics and registration of radiopharmaceuticals

RPMI-202

Basics of Human Biology and Laboratory animals in biomedical research

Basics of Human biology **50 Hours**

1. Cell Pathology: Different type of cells, cell membrane Physiology, and development of action Potential, impulse transmission, cardiac and skeletal muscles electrophysiology, cell stimulation and neuronal functions. Tissues: Epithelial, connective, muscular and nervous tissues, their types and characteristics. Bones and joints; structure and functions of skeleton and joints. Blood and Lymph: Composition and functions of blood including their disorders. Blood grouping and its significance, mechanism of coagulation, bleeding and clotting disorders, formation of lymph and its composition.

2. Cardiovascular system: Anatomy and physiology of heart, blood circulation-systemic, Hepatic pulmonary, fetal and circle of Willis, cardiac cycle, heart rate, blood pressure and its regulation, ECG and heart sounds. Cardiovascular diseases: Atherosclerosis, Ischemic Heart disease, Myocardial infection, hypertension, Cardiac failure, peripheral vascular diseases.

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3. Digestive system: Gross anatomy of the Gastrointestinal system and its physiology with special reference to liver, pancreas ant stomach. Respiratory system: Anatomy of respiratory tract, mechanism of respiration, lungs volume, transport of oxygen and carbon dioxide. Special focus on related disease such as Tuberculosis, Asthma.

4. Urinary system: Structure and function of kidney and urinary tract. Endocrine system: Basic anatomy and physiology pituitary, thyroid, parathyroid, adrenal and pancreatic hormones and disorders of these glands. Central nervous system: Structure and function of brain and spinal cord. Function of cerebellum, vital centers of medulla oblongata, cerebral ventricles, cranial nerves and their function. Reflex arc cerebrospinal fluid and its functions, meninges, Motor and sensory pathways. And related diseases such as Neurological Disease: Cerebro vascular Accident, Parkinsonism, Spinal Cord Injury, Multiple sclerosis, Cerebral Palsy.

Laboratory animals in biomedical research **30 Hours**

1. Basics of Laboratory animal

Introduction to the laboratory animals, Need of animals for research, National & International Bodies for Animal Research, guideline of CPCSEA and its rules and regulation, India, role of IAEC, SGPGIMS, Principle of 3Rs, Species Specific Identification for individual experiments, Laboratory Animal Housing & Environment, Laboratory Animal Feeding and Handling, mice, Rats etc. Laboratory Animal Breeding, Animal Health Monitoring Wearing PPEs & SOP writing, How to decide about animal disease model. route of administration of drugs, restraining and blood collecting methods, methods of anaesthetising animals and methods of euthanasia

2. Bio-distribution and internal dosimetry study

Target organ isolation, collection of different body fluids, processing of the biological samples, analysis of radioligands in different body fluids and target organs. Dosimetry calculations: Measurement time points, measurement volumes, measurement activities, measurement of standard deviation, measurement of Time Integrated Activity Coefficient, Calculation methods, software, weighing factor, reporting

3. Disease modeling and imaging studies

Pharmacological Screening models of dementia (scopolamine induced amnesia, streptozotocin/amyloid beta/aluminum chloride induced dementia), seizures

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(pentylenetetrazole/NMDA/Picrotoxin induced seizures, kainic acid induced status epilepticus, Lithium-pilocarpine induced spontaneous recurrent seizures) and tumours (dimethylbenz(a)anthracene (DMBA) induced skin/breast tumor, nitrosomethyl urea induced tumors), hepatotoxicity (Cyclophosphamide/acetaminophane/paclitaxel/5-fluoro uracil/ heavy metals induced hepatotoxicity), nephrotoxicity (cadmium/lead/methotrexate/gentamicin/ cyclosporine/cisplatin induced nephrotoxicity).

Use of suitable radiotracers for disease diagnosis, analysis, interpretation of findings, and generation of report.

RPMI-203

PET Radio Chemistry **130 Hours**

1. PET radionuclides and their role in Nuclear medicine **5 Hours**

What are PET radio nuclides, Advantages and Characteristics of different PET radioisotopes used in NM, Specific radiochemical considerations, Specific radio pharmacological considerations, Ideal Positron-Emitting Radionuclides.

2. PET radio Pharmaceuticals **30 Hours**

What is a PET radiopharmaceuticals, The role of radiopharmaceuticals in PET, Advantages of PET over SPECT, Vehicle molecules, Pharmacological prerequisites for PET ligands, Development of PET Radiopharmaceuticals: Biochemical Basis, PET tracers mainly reflecting energy utilization, Glucose Metabolism: ^{18}F-FDG, Bone Metabolism: ^{18}F-Fluoride, Proliferation markers, ^{18}F-Fluorothymidine(FLT), Membrane Lipid Synthesis: ^{18}F-Fluorocholine (FCH) and ^{18}F-Acetate, Amino Acid (AA) Transport and Protein Synthesis: ^{18}F-FDOPA, PET tracers for tumor hypoxia: ^{18}F-Fluoromisonidazole (FMISO), ^{18}F-FAZA, Estrogen Receptor Binding: ^{18}F-Fluoroestradiol (FES), Specific target interactions (enzymes, transporters, receptors), ^{68}Ga-DOTA based peptides, ^{68}Ga-PSMA and other ^{68}Ga PET RPhs. Other important PET tracers. The Role of FDA, Current Good Manufacturing Practices (cGMPs).

3. Radiochemistry of ^{18}F-Labeled Radiopharmaceuticals **45 Hours**

HOT cell, Handling of gaseous radioisotopes, Synthesis Modules and Automation in the synthesis of PET RPhs, Micro-reactors for PET Tracer Labelling, ^{18}F Labelling methods,

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Details of steps involved in general nucleophilic radio fluorination, ^{18}F labelling of small molecules, ^{18}F-labelling of Peptides and Proteins, microwaving in ^{18}F Chemistry, Radio synthesis of ^{18}F-Fluorodeoxyglucose (FDG), ^{18}F-Fluorodopa, ^{18}F-Fluorothymidine (FLT), ^{18}F-FAZA, ^{18}F-T807, ^{18}F-T-808, ^{18}F-NaF. Newer methods of radiolabeling of ^{18}F- using diazonium salt, boronic acid based precursors.

4. Radiochemistry of ^{11}C, ^{13}N and ^{15}O-Labeled Tracers **25 Hours**

Synthesis and quality control of the following tracers will be explore ^{11}C-Chloine, ^{11}C-Methionine , ^{11}C-PiB, ^{11}C-PK1195, Introduction of ^{11}C via urea based scaffolds, Loop technology for insertion of ^{11}C radionuclide, synthesis of ^{11}C-methyl iodide and ^{11}C-methyl triflate as methylating agent. $^{13}NH_3$ and $H_2{}^{15}O$. n-^{15}O-Butanol, ^{13}N-Ammonia.

5. Radiochemistry of ^{68}Ga, ^{64}Cu and ^{89}Zr-labelling **25 Hours**

Generator Production of ^{68}Ga, performance parameters of $^{68}Ge/^{68}Ga$ generators, ^{68}Ge breakthrough, different $^{68}Ge/^{68}Ga$ column generators, Coordination chemistry of Ga, $^{68}Ge/^{68}Ga$ Generator Eluate Quality and Subsequent Labelling Chemistry, different methods of purification of ^{68}Ga, different methods of ^{68}Ga radiolabelling, role of buffers in radiolabelling, stability of Ga complexes, radio-synthesis of ^{68}Ga-PSMA, ^{68}Ga-DOTA peptides and other ^{68}Ga based RPhs. $^{64}Cu/^{89}Zr$ production protocols, preparation of solid targetry for bombardment, purification of solid target and radiolabeling with chelators/biomolecules and their QC.

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List of Practicals Semester I-II

Practical (RPMI 101-RPMI-103)
1. Perform quality control of Dose Calibrator. 2. Determine the half-life of a radionuclide with the help of a Dose Calibrator. 3. To determine the half-life of a radioactive material. 4. Radiation exposure: effect of distance, Shielding and time.
5. Performance of organic reactions, purification and characterization of isolated product using analytical tool. 6. Separation techniques and characterization (TLC, column, distillation, crystallization, GC etc.) Organic synthesis: Representative reaction to be covered Esterification and saponification, Oxidation, Reduction, Nucleophilic substitution, Condensation reactions, Aromatic electrophilic substitution, Heterocyclic synthesis, Solid phase synthesis
7. Determine the Intrinsic uniformity of Gamma Camera. 8. Determine the extrinsic uniformity of Gamma Camera for the given collimator. 9. Perform the total performance test on the SPECT gamma camera. 10. Perform experiment to calibrate PET/CT 11. Devise an experiment to measure the pixel size for 128X128 and 256X256 matrix size of the Gamma Camera.
Practical (RPMI 201-RPMI-203)
1. To perform Radiation survey around the cyclotron and Radioiodine therapy Ward. 2. Demonstration of ^{99}Mo-^{99m}Tc column generator and quality control of Generator 3. Demonstration of cyclotron and Perform preconditioning of cyclotron. 4. Determine the dead time by two sources method and determine count rate at 20 % count loss.
5. Demonstration of methods of acquisition of PET/CT procedures in cardiology, Neurology and Oncology. 6. To study the formation of MAA and study its bio-distribution.
7. Prepare single or double vial kit preparation of radiopharmaceutical. 8. Perform the wipe test on the floor and determine the level of contamination on the floor. 9. Demonstration of transport of radioactive materials.

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Semester III

RPMI-301

Nuclear pharmacy: design and regulations **92 Hours**

1. Radiation Safety regulations in Nuclear Medicine **20 Hours**

Layout of Nuclear Medicine Laboratory, Design of radiation labs, types of labs,Security of Sources and radioactive cautions signs and labels, 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, responsibilities for implementation of Basic Safety Standards Requirements 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 Committee, Guidance level for diagnostic administration, misadministration and preventive measures, reporting of misadministration. Radiation emergency in NM and preparedness. Rules and regulation of Institutional bio-safety committee.

2. Design of Radio pharmacy laboratory: **20 Hours**

Regulatory requirements, pharmaceutical aspects, radiation safety aspects, local constraints, designof 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 and procurement of radiopharmaceuticals. Trace of delayed shipments, surveys, wipe tests, packaging, disposal, storage requirements, and record keeping logs.

3. Regulatory Requirements & Guidelines for Medical Cyclotron Facility 20 Hours

Consenting process, medical cyclotron facility design, operation and maintenance, roles and responsibilities (Employer, Licensee, Radiological Safety Officer, Radiation Workers, Student/Trainee, Medical Cyclotron Operators, Radiochemist), Unusual Incidences & Reporting, operational radiation protection, labelling, marking, packaging and distribution, security aspects, emergency preparedness, decommissioning

4. Regulatory aspects of Radiopharmaceuticals **20 Hours**

Radiation Regulations for Radiopharmaceuticals, Role of RPC, Role of DCGI, GMP aspects of Radiopharmaceuticals, Rules for importing and exporting RPhs (AERB)

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Good manufacturing practice (GMP), ISO and ISI standards in radiopharmaceuticals. Regulations, ethics and registration of radiopharmaceuticals

5. Documentation **12 Hours**

Record keeping of RPhs, transporting of radioactive materials, radiation surveillance records, personal dose records, unusual incidence reporting/recording and preparation of SOP's for filling regulatory approvals.

RPMI-302

Clinical application of radiopharmaceuticals: diagnostic and therapeutic **136 Hours**

1. Thyroid studies **12 Hours**

Anatomy and Physiology of thyroid, RPhs for thyroid studies, Diagnostic agents: ^{131}I NaI-Capsules and Solutions, ^{99m}TcO4-, Thyroid imaging and uptakes (^{99m}Tc and ^{131}I), Perchlorate discharge test, T_3/T_4suppression test, TSH stimulation test. ^{131}I whole-body imaging. Post Therapy Scans. Therapeutic agents: ^{131}I NaI.

2. Lungs Imaging **12 Hours**

Anatomy and Physiology of Lungs, RPhs for Lung imaging, Ventilation 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 studies, perfusion imaging using MAA, Microsphere, and pulmonary embolism.

3. Liver-spleen imaging **15 Hours**

Anatomy and Physiology, Liver imaging R. Phs, 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.

4. Hepatobiliary imaging **15 Hours**

RPhs for hepatobiliary imaging, ^{99m}Tc-HIDA derivatives, ^{99m}Tc-Disofenin, ^{99m}Tc-Mebrofenin Hepatobiliary imaging protocols, Neonatal hepatitis versus Biliary atresia, Gall bladder dynamic studies using IDA compounds. Deconvolution analysis, Hepatic Extraction Fraction, Interventional methods. Bile leak studies.

5. Gastrointestinal studies **12 Hours**

Conventional imaging modalities used for GI studies. Advantages and disadvantages of these modalities over scintigraphy. Oesophageal transit time studies, Gastric oesophageal reflux,

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gastric emptying time, Duodena-gastric reflux, Meckel's diverticulum imaging, GI bleeding with ^{99m}Tc-RBC, ^{99m}Tc-Sulphur Collide. Advantages and disadvantages of each method.

6. Cardiac studies **10 Hours**

Radiopharmaceuticals Phs for heart imaging, Perfusion Imaging: ^{201}Tl, ^{99m}Tc- MIBI, ^{99m}Tc-Tetraphosmin, ^{82}Rb Chloride, ^{13}N Ammonia, Metabolic Imaging: ^{18}F-FDG, ^{13}N-Amino Acid (GLUTAMIC ACID), Myocardial Infarct Imaging : ^{99m}Tc-PPi, ECG, First pass study (shunt detection), Importance of Electrocardiogram (ECG),gated blood pool study, MUGA, Ejection fraction, Wall motion analysis, Infarct avid imaging, Rest / Stress myocardial imaging, Gated SPECT, Pharmacological stress, Bulls Eye analysis, Severity scores. Use of ^{201}Tl, ^{18}F-FDG and $^{13}NH_3$ for cardiac studies.

7. Bone imaging **12 Hours**

Bone imaging agents ^{85}Sr, ^{99m}Tc- PPi, ^{99m}Tc- HEDP, ^{99m}Tc-MDP, 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.

8. Renal imaging studies **10 Hours**

Anatomy and Physiology, Renal imaging Agents, GFR Agent: ^{99m}Tc - DTPA, Iothalamate, Tubular Secretion Agents : ^{99m}Tc- MAG3 , ^{99m}Tc- EC, ^{131}I OIH, Renal cortical agents : ^{99m}Tc GHA, ^{99m}Tc-DMSA, 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 and indirect radionuclide cystourethrography, Cortical Renal Scans using ^{99m}Tc-GHA & ^{99m}Tc-DMSA, Differential function by Geometric Mean.

9. Brain imaging **12 Hours**

Anatomy and Physiology, RPS for brain Imaging – Non diffusing Agents: ^{99m}TcO4- , ^{99m}Tc-DTPA, ^{99m}TcGH, Diffusing Agents: ^{123}I –HIPDM, ^{99m}Tc- HMPAO, ^{99m}Tc- ECD, metabolic agents: ^{18}F FDG, Cerebral blood flow dynamic studies, Blood Brain Barrier imaging, Perfusion Imaging, Brain SPECT, Interventional methods, Cisternography, CSF leak, PET brain imaging.

13. Tumour Imaging: **8 Hours**

^{18}F-FDG PET Scans for Oncologic Staging and Evaluation of Post therapy status. Imaging for Medullary Carcinoma of Thyroid, Neural Crest Tumours, Apoptotic Imaging. Post Therapy Scans. Organ specific (cold spot, hot spot), nonspecific (^{67}Ga- Citrate, ^{131}I MIBI, ^{99m}Tc

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Tetrofosmine, ^{18}F-FDG), Tumor type specific (^{131}I for papillary and follicular carcinoma, ^{131}I MIBG (adrenal cortex), ^{99m}Tc Mebrofenin for hepatocellualar Ca, Antibody (^{99m}Tc CEA, ^{111}In Prostascint, , peptide (^{111}In Octreotide, ^{68}Ga DOTATATE). ^{99m}Tc-HYNICTOC.

14. **Gastrointestinal studies** **15 Hours**

Conventional imaging modalities used for GI studies. Advantages and disadvantages of these modalities over scintigraphy. Oesophageal transit time studies, Gastric oesophageal reflux, gastric emptying time, Duodena-gastric reflux, Meckel's diverticulum imaging, GI bleeding with ^{99m}Tc-RBC, ^{99m}Tc-S. Collide. Advantages and disadvantages of each method

Parathyroid Imaging **3 Hours**

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

RPMI-303

Computers, Bio-informatics, IPR and Biostatics in Nuclear Medicine **104 Hours**

1. **Computers In Nuclear Medicine**: **26 Hours**

Computers 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 Normalization methods, Automated ROI's and Computational methods. 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. demonstration in MTLAB and Mathematical software packages;

2. **Mathematics** **24 Hours**

Numbering system, Accuracy and Precision, Significant figures, Matrices, Mathematical Constants. Linearand Polynomial Equations, Linear and Quadratic Equations and Identities, Slope, Roots, Relation between Roots and Coefficients. Logarithms; Definition, Laws of Logarithms, Rule for Change of Base, Common and Natural Logarithms, Permutations and Combinations, Probability, Factorials. Calculus; Relations and functions, Limits, Definition of Derivative, Physical Significance, Differentiation of Simple Functions, Differential Equations, integration and Summation, Definition of Trigonometric Functions, Identities. Introduction to Mathematical Transformation: Fourier Transform, Laplace transforms.

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3. Biostatistics **20 Hours**

Basic Concepts: Probability, a Priori and posteriori Probabilities. Statistical significance of probabilities Sample and Population, Variables, Classification of Variables, Nominal, Ordinal, interval and Ratio, Fixed and Random, Population Distributions: Binomial distributions and Poisson distributions -their properties, parameters and applications. Normal and't' distributions -Population and Sample Parameters. Measures of central tendency, measures of dispersion, Variance, degrees of freedom, confidence limits and intervals. Probability of occurrence – use of Z and t tables. Sampling, Estimates and Hypothesis testing: Sampling methods, Random sampling and estimates of population parameters from samples. Sample statistics, Hypothesis testing. Drawing inferences and confidence limits. P values. Student's t test for comparing means. General and paired t tests. Special cases where Variances are unequal. Central Limit Theorem. Analysis of Variance- F- Distribution, Test for Homogeneity of Variance One Way ANOVA, Comparison of Means of Multiple Groups By Partitioning of the total Sum of Squares as within and between Sum of Squares, Assumptions in ANOVA, Missing Values, Two Way ANOVA; Design of Experiments. Correlation and Regression: Pearson's Product Moment Correlation Coefficient, comparison of Correlation Coefficients, Partial and Multiple Correlation, Linear Regression Analysis Interpretation of Regression Coefficients. Application of Correlation and Regression in Method Comparison and Evaluation. Nonparametric Statistics: Spearman's Coefficient of Rank Correlation, Chi Square Test. Nonparametric Methods for Hypothesis Testing Based on Ranks. Mann Whitney U Test, Wilcoxon Signed Rank test, T Test. Clinical Statistics: Cohort Studies, Case Control Studies, Sample Size calculations, Clinical Trials, Meta analysis. Demonstration of application Software's in Statistics

4. Introduction of Bio-molecular modelling **18 Hours**

Introduction of Molecular Modelling-Protein structure prediction-Structure-based drug design-Docking Virtual Screening-Molecular Dynamics-Protein folding prediction-Ligand-based drug design (CoMFA, CoMSIA, HypoGen)-Scoring functions and weight rules.

5. Drug Regulatory Affairs, Intellectual Property and Patenting **16 Hours**

Harmonization of regulatory requirements including ICH activity. Regulatory requirements of different regions applicable to pharmaceutical developments, manufacturing, quality control on finished products, extended release products, biopharmaceutical and bioequivalence assessment and good clinical practices and Comparison with regulation in India. Filing of

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INDA, NDA and ANDA for approval and registration. Role of Central Drugs Standard Control Organisation, USP, EUP, DGCI.

Concepts and fundamentals of Intellectual property protection (IPP) and Intellectual property Rights (IPR). Economic importance, important mechanism for protection of Intellectual property. Patents, Industrial and layout designs, Copyrights, Trademarks, Trade secrets, factors affecting IP protection, Penalties for violation or infringement. Trade related aspects of IPR. Concepts behind GATT, WTO, TRIPS, TRIMS and GATS. Salient features of Indian Patent act 1970, 1999, 2003, amendments and rules.

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Semester IV

RPMI-401

Advancement in Radiopharmacy and its application: **92 Hours**

1. Nanotechnology **14 Hours**

Concepts and its biomedical applications, liposomes, aerosols, nanoparticles, immuno-liposomes, drugdelivery systems. Introduction to Nanotechnology and their application in nuclear medicine for diagnostic and therapeutic purposes. Different types of drug delivery nanocarriers for diagnostic and therapeutic purposes (Liposomes, micelles, phytosomes, Chitosan Nanoparticles etc.) and their advantages over present drug delivery systems. Methods of preparation of Nano carriers and quality control procedures. Mechanism of localisation of nanodrug delivery systems. Future applications in Nuclear Medicine.

2. Therapeutic applications of radionuclides **22 Hours**

Radionuclide therapy (RNT), definition, Problems for development of therapeutic RP, Uptake mechanisms of therapeutic radiopharmaceuticals, types of preparation, Properties of ideal therapeutic radiopharmaceuticals, selection of appropriate radionuclides includes particle emission, half-life, Specific Activity, decay characteristics, characteristics of the ideal therapeutic radiopharmaceutical. Ranges ofemitted particle radiation in the tissue: Beta particle emitting radionuclides: Response of beta particleradiation on tumor, classification of b-particles, Alpha particle emitting Radionuclides, Auger-electrons emitting radionuclides, properties of Auger-electron-emitting radionuclides. Dosimetry in therapy by Radiopharmaceuticals: Absorbed radiation dose, Patient Specific Dosimetry

3. Theranostic and Personalized Nuclear Medicine **16 Hours**

Concept and prospects of theranostic in nuclear medicine. Theranostic radiopharmaceuticals, Personalized Nuclear medicine, Theragnosis in personalizing treatment regime. Different theranostic radioisotopes usedin nuclear medicine. Theranostic in the treatment of neuroendocrine tumor. Theranostic in the treatment ofprostate cancer. Targeted radiotherapy: Radioimmunotherapy (Rituximab). Antibodies, antigens, RIT- Advantages of RIT,selection of Antibodies & antigens treatment of non-Hodgkin's, B-cell lymphomaPeptide Receptor Radionuclide Therapy: Introduction, amino acids, peptides, proteins, PRRT for NETPRRT studies with [^{111}In-DTPA]-octreotide, Somatostatin receptor Radiotherapy -with ^{90}Y-DOTATA

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TOC, ^{90}Y- DOTA TATE, and ^{177}Lu-DOTA TATE, Bombesin peptides analog, ViP analog, CCK analogy, neurotensin peptide analogy. PRRT for prostate cancer with ^{177}Lu- PSMA.

4. Molecular Imaging probes: Target specific radiopharmaceuticals **12 Hours**

Basics of molecular imaging, methodology of molecular imaging, Classification of radiopharmaceuticals, blood flow/membrane transport radiopharmaceutical, metabolism-based radiopharmaceutical. Receptor &transport mediated radiopharmaceutical. Receptors, receptor binding, design of radiopharmaceutical.

5. New development in therapeutic agents; **12 Hours**

Nano technology based therapeutic agents, Liposomes, Therapeutic Radiopharmaceuticals for Bone Pain Palliation: Introduction, commercial agents ^{186}Re-HEDP, $^{89}SrCl_2$, ^{153}Sm-EDTMP, New Agents - ^{188}ReHEDP, ^{188}Re(V) DMSA, ^{177}Lu-EDTMP.Radioimmuno scintigraphy & therapy Radionuclide Synovectomy: Introduction, Advantages, Selection of RN, Radiopharmaceuticals for treatment of primary and metastatic Hepatic Cancer Balloon therapy.

6. Alpha emitting Radioisotopes for therapy **8 Hours**

^{223}Radium-: Alpharadin, (Generator prod. RP ^{227}Ac - ^{223}Ra), ^{212}Bismuth, (^{212}Bi is produced by chemistry generator from ^{224}Ra), ^{213}Bismuth (^{213}Bi is produced by chemistry generator from ^{225}Ac), ^{211}Astatium: (cyclotron produced RP. ^{209}Bi (α, 2n) ^{211}At), ^{225}Actinium: Cyclotron produced RP. ^{226}Ra (p, 2n) ^{225}Ac. Production and physical characteristics, uptake and bio-kinetic properties.

7. New Development in Cyclotron and Radiochemistry Modules **8 Hours**

ECR ion sources, Super Conducting Cyclotrons, Hadron Therapy, Boron Neutron Capture Therapy, Microfluidics based Radiochemistry.

RPMI-402

Principle of Molecular Targets and Imaging **138 Hours**

Drug Design **30 Hours**

Analogue synthesis versus rational design, discovery of lead compounds, pharmacophore identification, structure modification, physicochemical alterations, prodrug approach, quantitative structure activity relationship, molecular modeling, combinatorial chemistry and high throughtput screening. kinetic ADME studies (absorption, distribution, metabolism, and excretion) are required so as to determine the fate of these agents as an indicator of efficacy and toxicity.

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Structure of Cell Membrane **15 Hours**

Membrane lipids, membrane proteins, membrane carbohydrates, passage through membrane and drug action that effects the structure of cell membranes (antifungal, antibacterial and local anaesthetics).

Receptors **16 Hours**

Drug receptor interaction, G-protein coupled receptors, ion channel linked receptors. ligand gated ion channels (LGICs). Ligand-receptors theories: Clarks occupancy theory, rate theory, induced fit theory, macromolecular perturbation theory and activation aggregation theory.

Enzymes **15 Hours**

Introduction, kinetics, enzyme kinetics in drug action, mechanism of enzyme catalysis; electrostatic catalysis and desolvation, covalent catalysis, acid-base catalysis, strain/distortion in enzyme catalysis, coenzyme catalysis. Example based on hemoglobin, theories of enzyme inhibition and inactivation, enzyme activation of drugs-pro-drugs.

Introduction to Immunology: **15 Hours**

Structure and function of immune system, cells of the Immune system, humoral and cell-mediated immune response– primary and secondary responses and their applications, polyclonal and monoclonal antibodies ,basic characteristics of antigens/antibodies, structure and classification of antibodies, antigen-antibody interactions, methods of estimation of Ag, Ab and their relevance in disease detection, production and purification of polyclonal antibodies, primary & secondary immune response, disadvantages of using polyclonal antibodies, Hybridoma & other techniques for production of monoclonal antibodies and their fragments, in vitro applications in diagnostics, in vivo applications of monoclonal antibodies & fragments, conjugated antibodies, radiolabelled monoclonal antibodies, production, isotopes used, mechanism of localization, factors effecting localization, implications in imaging & therapy, new generation antibodies,Cells & important cytokines, host directed immune therapies, immunobiology of cancer

Biochemistry and Molecular biology **20 Hours**

Introduction to Biochemistry includes carbohydrates, proteins, nucleic acids, enzymes, lipids. Protein structure and protein 3-dimensional shape, structure-function relationship, proteins purification, Importance of Amino acids in Nuclear Medicine, Nature of enzyme catalysed reactions, their regulation, inhibition and mechanisms. Structure and function of carbohydrates and their importance in central metabolism. Importance of Enzymes – Clinical Biochemistry, Structures and nature of fatty acids and lipids found in biological membranes. Introduction to

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Molecular Biology, Nucleic Acids and Biological Information Flow. PCR and Recombinant Technology for cloning of important Human proteins. Related Biochemical and molecular biology techniques. Aptamers with radiolabelled aptamers for nuclear imaging and therapy.

Modes of localisation: **12 Hours**

Localisation of radiopharmaceuticals in organ of interest for diagnostic and therapeutic purposes. Various Mechanism of localisation with respect to each radiopharmaceutical.Ideal characteristic of RP for modes of localisation: Active and passive modes of localisation. Substrate specific radiopharmaceutical localization, Receptor mediated biochemical, metabolic trapping, enzyme substrate, antibodies to tumor associated antigens. Filtration, Phagocytosis, Cell Sequestration, Capillary blockade, ion Exchange, Chemisorption, Cellular migration.

Compartmental Analysis **15 Hours**

Compartmental analysis and its applications in Nuclear Medicine, Assumptions in Compartmental model, Single compartment model, The Continuously stirred tank reactor (CSTR); Single Compartment model: The Charged Capacitor; Single Compartment model: Discrete time analogues for two compartment systems; Occupancy theorem. Application of Differential equations, Open and closed models, Single compartment, two compartment and multi compartment models, reversible and irreversible exchanges, Mammary and Caternary models, Problems on radioactive generators, biological elimination processes of radiopharmaceuticals. Distributed Models

RPMI-403

Dissertation/Thesis: Dissertation topic will be allotted to the student at the beginning of second year, and shall be supervised by supervisor. The dissertation shall be submitted by the student before the course work of fourth Semester is completed and will be evaluated as a part of Grand Viva-Voce in the fourth Semester examination.

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List of Practicals Semester III-IV

Practicals (RPMI-301-RPMI-303)
1. To prepare layout plan for different types of nuclear medicine laboratories 2. Designing of a PET department depending upon number of patients per week 3. Calculation of shielding for a given radionuclide
4. Preparation of PET Radiopharmaceuticals and its QC 5. Q.C. of PET radiopharmaceuticals. 6. Radiolabeling of ^{11}C-based tracers such as ^{11}C -Choline, ^{11}C -Methionine, ^{11}C-PiB. 7. To perform Renogram study (using DTPA/EC) 8. Preparation of ^{99m}Tc -Radiopharmaceuticals and its QC 9. Metal Target Preparation, target purification and QC
Practicals (RPMI-401-RPMI-402)
1. Demonstration of methods of acquisition of PET/CT procedures in cardiology, Neurology and Oncology. 2. Demonstration of SPECT/ CT Fusion Imaging principles. 3. Demonstration of PET/CT Fusion Imaging principles 4. To set a protocol for PET imaging for Oncology patient, 5. To set a protocol for PET imaging for cardiac viability study 6. To perform Bone scan (3phase, whole body and statics) 7. To perform MPI. 8. Demonstrations regarding determination of target to non target ratios for various SPECT and PET radiopharmaceuticals in experimental models.
9. Radioisotope production in Medical cyclotron. 10. Radiolabeling of ^{18}F based RPs ^{18}F-Fluorodeoxyglucose (FDG)/^{18}F-Fluorothymidine (FLT)/^{18}F-Fluroestradiol (FES) other 18F-Tracers etc. 11. Radiolabeling of ^{68}Ga-DOTA/PSMA-11/FAPI & its QC. 12. Solid target Preparation for production of ^{64}Cu, $^{124/123}Iodine$, or ^{89}Zr 13. To perform Lung perfusion study 14. To perform DMSA scan

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Suggested Books and Reference Texts

1. Cell & Molecular Biology by De Robertis, Wolters Kluwer India Pvt. Ltd.; 8th Edition 2010.
2. Molecular Biology of the Cell by Alberts, Bray, Lewis, Raff, W. W. Norton & Company; 6th Edition 2014.
3. Molecular Biology of Gene by James D. Watson, 7th Edition, 2013.
4. Text Book of Medical Physiology by Guyton, John .E. Hall, Elsiever, 13th Edition 2016.
5. Physiology by Chatterjee, CBS Publishers & Distributors; 11th Edition 2016.
6. Biochemistry by Lehninger, WH Freeman; 7th Edition 2017.
7. Biochemistry by Stryer, W. H. Freeman & Co Ltd; 5th Edition 2002 .
8. Basic Medical Biochemistry by Smith Marks & Libermann, Lippincott Williams & Wilkins, 2nd Edition 2004.
9. Handbook of Laboratory Animals. Washington, DC: The National Academies Press, 2013.
10. Guide for the Care and Use of Laboratory Animals, 2017
11. Methods in Biostatistics by Mahajan, Jaypee Brothers Medical, 8th Edition 2015.
12. Methods of Biostatistics by Bhaskararao, Mahajans, Jaypee Brothers Medical, 9th Edition 2018.
13. Statistical and Mathematical Techniques in NM by GS Pant, Wiley-Blackwell; 1st Edition, 2016.
14. Biostatistics: A foundation for the analysis in the Health Sciences by Wayne W. Daniel, John Wiley, John Wiley & Sons, 11th Edition 2019.
15. Object Oriented Programming with C++ by E. Balaguruswamy, McGraw Hill Education, 7th Edition 2017.
16. A First Course in Computers by Sanjay Saxena, Pearson; 3rd Edition 2013.
17. Calculus (Pearson Education, 2003) by G. B. Thomas and R. L. Finney, Pearson, 3rd Edition 2002.
18. Introduction to Mathematical Physics by Harper (Prentice Hall of India), Prentice Hall India Learning Private Limited, 1st Edition 1978.
19. Mathematical Models in Biology –An Introduction by Allman & Rhodes, Cambridge University Press, 1st Edition, 2003.
20. Radiation detection by Knoll, Wiley, 4th Edition 2010.
21. Handbook of Health Physics and Radiological Health by Shleien,Slaback, Birkey, Wolters Kluwer; 4th Edition 2011.
22. Physics and Radiobiology of Nuclear Medicine by Gopal Saha,Springer; 4th Edition, 2012.
23. Elements of Radiobiology by Selman, Charles C Thomas, 1st Edition, 1983.
24. The essential Physics of Medical Imaging by Bushberg, Seibert, Leidholdt, Lippincott Williams and Wilkins; Third, North American, 1st Edition 2011.
25. Physics in Nuclear Medicine by Cherry, Sorenson, Phelps, LWW; 7th edition, 2011.
26. Medical Imaging Physics by William R. Hendee, Saunders, 4th Editions, 2012.
27. Advances in Diagnostic Medical Physics by Pant GS, Medical Physics Pub Corp; 1st Edition, 2008.
28. Quality Controls of NM Instrumentation by Pant GS, Jones & Bartlett 2nd Edition, 2013.
29. Radiation Safety for unsealed Sources by Pant GS, Wiley; 1st Edition 2009.
30. Radiation Dosimetry by Attix, Poesch, Wiley-VCH; 1st Edition 1991.
31. Fundamentals of Nuclear Pharmacy by Gopal Saha, Springer; 6th Edition 2010.
32. Radiopharmaceuticals by Gopal Subramaniam, American Pharmacists Association (APhA); 4th Edition, 2020.
33. Text Book of Radiopharamcy by Sampson, CRC Press, 3rd Edition, 1999.
34. Radio immunoassay Principles & Practices by Pillai & Bhandarkar, Palgrave Macmillan; 1st Edition 1991.
35. Nuclear Medicine in Vitro by B. Rothfield, E. R. Powsner, 1st Edition 1975 radiology.
36. Basics of PET Imaging by Gopal Saha , Springer; 2nd Edition , 2014.
37. Nuclear Medicine Technology and Techniques by Bernier, Christian, Langan, Mosby; 8th Edition 2016.
38. PET and PET/CT in Oncology by Pehr, Biersack, Coleman, Springer, 1st Edition, 2011.

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39. Nuclear & PET Techniques by Christian, Mosby; 8th Editions, 2016.
40. Organic Chemistry 6th Edition by Robert Morrison, Robert Neilson, Prentice Hall; 6th Edition, 1992.
41. Concise Inorganic chemistry 5th Edition by J. D. Lee, Oxford University Press, 5th Edition 2008.
42. Principles of Inorganic Chemistry by Puri , Sharma, Kalia, Wiley-Blackwell, 1st Edition 2015.
43. Principles of Physical Chemistry by Hans Kuhn, Horst-Dieter Försterling, David H. Waldeck, Wiley-Interscience; 2nd Edition, 2009.
44. Spectroscopy of Organic Compounds by P. S. Kalsi, NEW AGE; 6th Edition 2006.
45. Elementary Organic Spectroscopy by Y. R. Sharma, S. Chand, 4th Edition 2013.
46. Organic chemistry 2nd Edition by Jonathan Clayden, Nick Greeves, Oxford University Press; 2nd Edition, 2014.
47. Cell biology and molecular biology by G. Karp, Bruce Alberts, John Wiley & Sons Inc, 5th Edition 2006.

List of Referred Journal

1. European Journal of Nuclear Medicine & Molecular Imaging (Eup. J. Nucl. Med. Mol. Imag.)
2. Journal of Nuclear Medicine (J. Nucl. Med.)
3. Journal of Organic Chemistry (J Org. Chem.)
4. Journal Medicinal Chemistry (J. Med. Chem.)
5. Inorganic Chemistry (Inorg. Chem.)
6. Bioorganic Chemistry (BioOrg. Chem.)
7. Applied Reactions Isotopes (Appl. Radiat. Isot.)
8. Nuclear Medicine & Biology (Nucl. Med. Biol.)
9. Indian Journal of Nuclear Medicine (Ind. J. Nucl. Med.)

Safety Code

1. AERB Safety Manual and AERB Safety Guide
2. AERB Safety Code (Nuclear Medicine Laboratories)
3. AERB Safety Code (Transport of Radioactive Materials)
4. AERB Safety Guide (Standards of Safety in Transport of Radioactive Material)
5. AERB Safety Guide (Procedure for Forwarding, Transport, Handling and Storage of Radioactive Consignments)
6. IAEA activities in Nuclear Safety by IAEA

Recommended Links

- http://www.w3.org/IPR
- http://www.wipo.int/portal/index.html.en
- http://www.ipr.co.uk/IP_conventions/patent_cooperation_treaty.html
- www.patentoffice.nic.in
- http://www.cbd.int/biosafety/background

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Board of Studies meeting held to be held on March 20th 2023 at Department of Nuclear Medicine, SGPGIMS via virtual mode in the presence of committee members for the course of M. Sc. RadioPharmacy and Molecular Imaging (M. Sc. RPh & MI) at College of Medical technology (CMT), SGPGIMS, Lucknow

Committee members as follows

1.	Dean, SGPGI	Chairman
2.	Prof. S. Gambhir	Head, Department of Nuclear Medicine
3.	Dr. Sandip Basu	External Expert, BARC-Mumbai
4.	Dr. Jaya Shukla	External Expert, PGIMER, Chandigarh
5.	Dr Ruchi Gupta	Nodal Officer, CMT & A. H Sc
6.	Prof. Siddhart Rai	Addl. Nodal Officer, CMT & A. H. Sc
7.	Dr. Manish Dixit	Course Coordinator
8.	Prof. P K Pradhan	Member,
9.	Dr. Sukanta Barai	Member
10.	Dr Amitabha Arya	Member
11.	Dr Manish Ora	Member
12.	Dr Afatab H Nazar	Member

This course was started at College of Medical technology and Allied Health Science (CMT & H. Sc), SGPGIMS, Lucknow from academic year 2022-23 with intake of five students every year. The agenda for today Board of study meeting are as follows:

1. Conversion of academic year into semester system
2. Updating the list of teaching faculties
3. Adaptation of common rules and regulation regarding admission process, examination pattern such as pattern of intermediate/exist examinations, criteria for promotion and leave.
4. Course syllabus, duration and annual intake will remain same as earlier approved by Governing Body.

Dr Manish Dixit (Course co-coordinator)

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Annexure 1

List of External Examiners

1. **Dr Anil Mishra**, Scientist-G, Head and Additional director, INMAS, Defence Research and Development Organisation, New Delhi. Mobile # 9999892866
2. **Dr. Jaya Shukla,** Additional Professor, Department of Nuclear Medicine, PGIMER Chandigarh.
3. **Dr. Rubel Chakravarty**, Ph. D, Scientific Officer E, Isotope Production and Applications Division Bhabha Atomic Research Centre, Mumbai, India; mobile # 9869848214
4. **Dr. Sudipta Chakraborty,** Ph. D, Scientific Head, Radiopharmaceuticals Division, Bhabha Atomic Research Centre, Mumbai, India
5. **Dr. Anupam Mathur**, Ph. D, Scientific Officer E, Board of Radiation and Isotope Technology, Mumbai
6. **Dr Puja Panwar Hazari,** Scientist-E, INMAS, Defence Research and Development Organisation, New Delhi.
7. **Dr. Anjani Kumar Tiwari,** Associate Professor, Department of Chemistry, BBAU Central University, LUCKNOW-226025, India

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