Program Name: Post Graduate Diploma in Nuclear Medicine Technology

Program Code: **PHY1111**

Offered jointly by Department of Physics, School of Basic and Applied Sciences, Adamas University and Netaji Subhas Chandra Bose Cancer Hospital, Kolkata

Duration: 1 Year

Academic Year: 2025-26

SEMESTER I

PHY11701: Fundamentals of Radiation Physics (Credit 4, 60 Lecture Hours)

Module I: Basics Physics: [10 L]

Elementary introduction to structure of matter, elements, compounds and mixtures, molecules and atoms. Atomic & Nuclear structures, atomic models, Periodic table, simple ideas of quantum mechanics, Mass energy equivalence, fluorescence, Phosphorescence, luminescence, electromagnetic spectrum. Electricity, Magnetism and Electromagnetic induction: Electricity in ionized gases-electric charges-electric induction- Coulomb law-unit of charge-resistance-ohms law electric power-Joules law. Magnetism-magnetic properties-electromagnetic effect-electrical instruments like Voltmeter, Ammeter & Multimeter. Transformer, transistor, rectifier, pre amplifier, pulse amplifier, power supply, circuits. Filters and their types.

Module II: Radiation Physics: [10 L]

Atomic number, mass number, isotopes, radioisotopes, radioactivity, specific activity, Stability of nuclides – binding energy, nuclear forces, Laws of radioactivity, Units of radioactivity, types of radioactive disintegrations, electron capture, characteristics of alpha, beta and gamma rays; energy of ionizing radiation, half-life (physical, biological), mean life, effective half-life, isomeric transitions, secular, transient and no-equilibrium, production of radioisotopes and X-rays (Characteristic and Bremsstrahlung), Cerenkov radiation, Auger effect, Metastable state and isomeric transition, internal conversion, neutron sources. Nuclear reactions, Nuclear reaction cross section, neutron activation with thermal neutrons, Nuclear isomerism, nuclear fission, fission products, nuclear reactors

Module III: Interaction of Electromagnetic Radiation with Matter: [6 L]

Gamma ray interactions - Excitation, ionization, photoelectric effect, Compton effect, pair production, annihilation radiations, specific ionization and linear energy transfer; Coherent Scattering, Attenuation of photon beams: attenuation, energy transfer and energy absorption, Half Value Thickness (HVT) and Tenth Value Thickness (TVT).

Module IV: Interaction of Charged Particles with Matter: [8 L]

Directly and indirectly ionizing particles, elastic and in-elastic collisions, Energy loss of charged particles (electron and heavy charged particles) in medium, Stopping power – Bethe Bloch Formula, Range energy relation – Bragg curve, Energy loss of electrons and positrons in matter collision and radioactive loss, range energy relation – Continuous slowing down approximation (CSDA). Dependence of Collision energy losses on the physical and chemical state of the absorber, empirical relations between range and energy, back scattering, Importance of these interactions in radiology and nuclear medicine

Module V: Interaction of neutrons with Matter: [2 L]

Elastic scattering, energy transfer, logarithmic energy decrement, inelastic scattering, dependence on E and Z, neutron induced reactions – neutron capture (n, p), (n, x) etc., neutron activation

Module VI: Principle and Working of X-ray Tube: [5 L]

Discovery - Production - Properties of X-rays - Characteristics and continuous spectra - Design of hot cathode X-ray tube - Basic requirements of medical diagnostic, therapeutic and industrial radiographic tubes - Rotating anode tubes - Hooded anode tubes, Rating of tubes - Safety devices in X-ray tubes – Ray proof and shock proof tubes - Insulation and cooling of X-ray tubes - Electric Accessories for X-ray tubes - Filament and high voltage transformers

Module VII: Radiation Quantities and Units: [4 L]

Activity (Becquerel & Curie), energy, exposure (C/kg & Roentgen), LET, charged particle equilibrium (CPE), linear and mass attenuation coefficients, mass stopping power, air kerma, Terma, absorbed dose (Gray & rad), radiation weighting factors (WR), tissue weighting factors (WT), equivalent dose (Sievert & rem), effective dose (Sievert & rem), collective Effective dose (Person Sv), Annual Limit of Intake {ALI} (Becquerel), Derived Air Concentration {DAC} (Becquerel/m3), personnel dose equivalent, committed dose.

Module VIII: Statistics of Counting: [6 L]
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. Goodness of fit tests – Lexie's divergence coefficients Pearson's chi-square test.

Module IX: Reactor and Medical Cyclotron-Radionuclide Production: [4 L]

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

Module X: Basics of Nanotechnology: [2 L]

Concepts and its biomedical applications, liposomes, aerosols, nanoparticles, immuno-liposomes, drug delivery systems

Reference or Text Books:

1. Radiation Detection & Measurement" – Glenn F. Knoll, John Wiley & Sons Inc, 2004
2. "Concepts of Nuclear Physics" – Cohen, Bernard L., McGraw-Hill, 1971
3. "Atomic and Nuclear Physics" – S. N. Ghoshal, S Chand, 2001
4. "Radiation Safety in Nuclear Medicine" – Max H. Lombardi, CRC Publisher, 1st Edition
5. "Fundamentals of Nuclear Medicine Dosimetry" – Michael G. Stabin, Springer Publisher

PHY11702: Radiation Detection and Measurement (Credit 4, 60 Lecture Hours)

Module I: Digital Circuit System: [8 L]

Boolean algebra and logic gates: OR, AND, NOT, NOR, NAND and EXOR gates, Analog to digital converted and digital to analog converters. Power supplies and Regulated power supplies

Module II: Gas filled detector: [4 L]

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

Module III: Scintillation detectors (Organic and inorganic): [4 L]

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.

Module IV: Gamma Ray Spectrometry: [12 L]

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.

Module V: Semiconductor detectors: [4 L]

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 detectors.

Module VI: Liquid Scintillation Counters: [2 L]

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.

Module VII: Personnel Monitoring Devices: [5 L]

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. biodosimetry, extremity dosimeters.

Module VIII: Gamma Camera: [8 L]

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.

Module IX: Radiation Dosimetry: [3L]

Fundamentals of radiation dosimetry, types of radiation exposure (external and internal), dose estimation methods, specific absorbed fraction (SAF), internal dosimetry models (MIRD, ICRP), radiation dose from common PET and SPECT radiopharmaceuticals, optimization of dose in nuclear medicine, and regulatory guidelines for radiation dose assessment and monitoring, Patient-specific dosimetry, uncertainty analysis in dosimetry, and Monte Carlo simulations for radiation dose estimation.

Module X: QC of Radiation Protection Instruments: [10 L]

QC of - Ionisation chamber Type, Geiger-Muller Counter, pocket dosimeter, Dose calibrator, Scintillation type Gamma ray spectrometer, Zone monitors.

Reference or Text Books:

1. "Radiation Detection & Measurement" – Glenn F. Knoll, John Wiley & Sons Inc, 2004
2. "Radiological Protection and Safety: A Practitioner's Guide" – Pushparaja, Notion Press, 2019
3. "Radiation Safety in Nuclear Medicine" – Max H. Lombardi, CRC Publisher, 1st Edition
4. "Fundamentals of Nuclear Medicine Dosimetry" – Michael G. Stabin, Springer Publisher
5. "Physical Principles of Medical Imaging" – Perry Sprawls, Medical Physics Pub Corp

PHY11703: Radiopharmaceuticals (Credit 4, 60 Lecture Hours)

Module I: Radiopharmaceutical Chemistry: [10 L]

Fundamentals of inorganic, organic, and physical chemistry relevant to radiopharmaceuticals, Physicochemical properties of radioactive compounds, distinction between radionuclide, radiochemical, and radiopharmaceuticals, Carrier concepts (carrier-free, carrier-added, no-carrier-added), hydrolysis, redox reactions, concentration methods, and radiolytic decomposition, Chemistry and applications of key radionuclides: Tc-99m, I-131, Lu-177, F-18, P-32, Cr-51, Co-57, Fe-59, In-111, Tl-201, Y-90, Sr-89, Re-186, Sm-153, Xe-133, Kr-81m, and PET radionuclides (F, O, C, N, Cu, Rb, Ga)

Module II: Production of Radioisotopes, Radionuclide Generators: [8 L]

Reactor and accelerator-produced radionuclides, principles of radionuclide generation, parent-daughter equilibrium. Production and extraction of Fluorine-18 (^{18}F), Carbon-11 (^{11}C) for PET, Radionuclide generators: Mo-99/Tc-99m (solvent extraction, gel, and solid column), W-188/Re-188, Sn-113/In-113m, Ge-68/Ga-68, and ultra-short-lived generators like Sr-82/Rb-82, Rb-81m/Kr-81m.

Module III: Compartmental Analysis: [6 L]

Applications in nuclear medicine, modeling of radiopharmaceutical kinetics. Assumptions in compartmental models, single, two, and multi-compartment models, reversible and irreversible exchanges. Use of differential equations, mammary and catenary models, biological elimination processes.

Module IV: Development of radiopharmaceuticals: [4 L]

Empirical and rational approaches, impact of charge, size, solubility, stability, and bio-distribution. Structure-distribution relationships, biological properties, pharmacokinetics, metabolism, and excretion.

Module V: Modes of localisation: [5 L]

Specific localization: Substrate-specific mechanisms (enzyme inhibition, metabolic trapping, receptor binding, antibody-antigen interactions). Non-specific localization: Diffusion, compartmental trapping, capillary blockade, cell sequestration, phagocytosis, chemisorption.

Module VI: Methods of Radiolabeling: [8 L]

Isotope exchange, foreign label introduction, labeling with bi-functional chelating agents. Radiolabeling via biosynthesis, recoil labeling, excitation labeling. Principles and methods of radioiodination: Chloramine-T, Iodogen, monochloride, enzymatic, demetallation methods.

Radiolabeling of peptides, proteins, monoclonal antibodies (e.g., MIBG, amphetamines, orthoiodohippurate).

Module VII: Specific methods of labeling – Technetium labelling: [6 L]

Chemistry of Tc-99m, oxidation states, reduction methods, hydrolysis, re-oxidation, ligand exchange reactions. Formation of Tc-99m complexes, structure of radiopharmaceuticals, radiolytic decomposition, carrier effects. Tc-99m-based radiopharmaceuticals: DTPA, DMSA, MIBI, MAG3, MDP, phytates, ECD, EC, IDA compounds, sulfur colloid, and labeled particles. Tc-99m kit formulations, classification, stabilizers, preservatives, tricarbonyl core, nitrido compounds, HYNIC-TOC.

Module VIII: Therapeutic applications of Radionuclides: [8 L]

Selection of radionuclides for therapy (I-131, P-32, Sr-89, Sm-153, Re-186, Y-90, Lu-177). Radiopharmaceuticals for hyperthyroidism, thyroid carcinoma, bone metastasis, neural crest tumors, polycythemia vera, rheumatoid arthritis, hepatocellular carcinoma. Role of radiolabeled antibodies in targeted therapy, management of malignant effusions, pretargeted radioimmunotherapy of solid tumors.

Module IX: Quality control of Radiopharmaceuticals: [6 L]

Quality control procedures: pH, ionic strength, radionuclide purity, radiochemical purity, chemical purity, sterility, pyrogen testing. QC of radiopharmaceutical kits, chromatographic analysis, radioassay techniques. Breakthrough tests for Mo-99/Tc-99m, In-113m/Sn-113, Zr-based generators. QA techniques for PET radiopharmaceuticals: Thin-layer chromatography (TLC), High-Performance Liquid Chromatography (HPLC), Gas Chromatography (GC). QC in hospital radiopharmacy practices, aseptic techniques, good manufacturing practices (GMP), ISO & ISI standards for radiopharmaceuticals.

Reference or Text Books:

1. "Radiopharmaceuticals in Nuclear Pharmacy and Nuclear Medicine" – Richard J. Kowalsky, Steven W. Falen, American Pharmacists Association, 4th Edition
2. "Radiopharmaceutical Chemistry" – Jason S. Lewis, Albert D. Windhorst, Brian M. Zeglis, Springer Nature, 1st Edition
3. "PET and PET/CT: A Clinical Guide" – Eugene C. Lin, Abass Alavi, Thieme Medical Publishers Inc, 3rd Edition
4. "Nuclear Medicine and PET/CT: Technology and Techniques" – Kristen M. Waterstram-Rich, Paul E. Christian, Mosby, 6th Edition
5. "Fundamentals of Nuclear Medicine Dosimetry" – Michael G. Stabin, Springer Publisher

PHY11704: Instrumentation and Medical Imaging Technique (Credit 4, 60 Lecture Hours)

Module I: Collimator and Probe: [10 L]

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. Thyroid uptake probe, basic components, system set-up and calibration, flat field collimator, iso-response curve and working distance. Emerging designs and considerations of Multicrystal Gamma Camera ad Intraoperative probes. Discussions on Standards and Quality Control. Small animal imaging systems.

Module II: Rectilinear scanner: [8 L]

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.

Module III: Application of Computers in Nuclear Medicine: [10 L]

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.

Module IV: Tomography: [15 L]

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) 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. Positron emitters and radiochemistry to produce, 18F-Sodium Fluoride, 18F-Fluorodeoxyglucose (FDG), 18F-Fluorodopa, 18F-Fluorothymidine (FLT), 18F-MISO, 18F-FAZA, 18F-FET, 18F-FBA, 11C-Sodium Acetate, 13NH3 and H215O.

Module VI: Medical Informatics: [4 L]

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

Module VII: Biomedical Ultrasound: [2 L]

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

Module VIII: Magnetic Resonance Imaging (MRI): [2 L]

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

Module IX: Radiological Instrumentation - CT scanner: [4 L]

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's between conventional single slice, multislice, spiral and electron beam CT. Comparison of patient radiation doses and effects of slice thickness.

Reference or Text Books:

1. "Physical Principles of Medical Imaging" – Perry Sprawls, Medical Physics Pub Corp
2. "PET and PET/CT: A Clinical Guide" – Eugene C. Lin, Abass Alavi, Thieme Medical Publishers Inc, 3rd Edition
3. "Nuclear Medicine and PET/CT: Technology and Techniques" – Kristen M. Waterstram-Rich, Paul E. Christian, Mosby, 6th Edition
4. "Radiological Protection and Safety: A Practitioner's Guide" – Pushparaja, Notion Press, 2019
5. "Radiation Detection & Measurement" – Glenn F. Knoll, John Wiley & Sons Inc, 2004

PHY12705: Fundamental Physics and Radiation Physics Lab (Credit 2, 120 Lecture Hours)

1. To measure Half Value Layer of γ emitters / β emitters and determine linear mass absorption coefficients
2. To study the statistics of radioisotope measurements and observe the effects of backgrounds on the counting statistics
3. To study characteristics of G.M. Tube: operating voltage, slope, efficiency and resolving time of G.M. tube
4. Identification of unknown radionuclide through Gamma Ray Spectrometer
5. Determination of energy spectrum of the give radionuclide using Gamma Ray Spectrometer
6. To study absorption characteristics of β particles and find out the range using Feather method
7. Determination of backscatter of β particles using Lead material
8. To study the bremsstrahlung of β particles
9. To determine the radiation response of TLD
10. To measure AC voltage signal and its frequency using an oscilloscope and to study NPN and PNP transistor and characteristics of multivibrator
11. OPAMP circuits: inverting, non-inverting amplifiers, integrator and differentiator circuit
12. To study linearity of Gamma Ray Spectrometer
13. To determine the half-life of radioactive isotope
14. To study basics of MATLAB

Optional for Advanced Learners:

15. Introduction to Monte Carlo Simulations and Geant4 Framework.
16. Understanding GATE and Its Application in Medical Imaging.
17. Design and Simulation of PET, SPECT, and CT Systems.
18. Radiotherapy Dosimetry and Treatment Planning Simulations

SEMESTER II

PHY11706: Radiation Biology (Credit 4, 60 Lecture Hours)

Module I: General Cell Biology & Cellular Physiology: [8 L]

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.

Module II: Anatomy, Physiology and Pathology: [12 L]

Anatomy and physiology as applied to radiodiagnosis and radiotherapy - Structure & function of organs and systems & their common diseases: Skin, Lymphatic system, Bone and muscle, Nervous, Endocrine, Cardiovascular, Respiratory, Digestive (Gastro-Intestinal), Urinary, Reproductive, Eye and ear. Anatomy of human body, nomenclature & Surface anatomy, Radiographic Anatomy (including cross sectional anatomy - identify the different organs/ structures on plain xrays, CT scans and other available imaging modalities. Normal anatomy & deviation for abnormalities.

Module III: Introduction to Immunology: [6 L]

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.

Module IV: Introduction to Biology of cancer: [4 L]

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

Module V: Basic Medical Terminology: [6 L]

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

Module VI: Radiation Biology: [12 L]

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

Module VII: Radiolabeling of Cells: [8 L]

Methods of labeling for blood pool studies and detection of gastrointestinal blooding - Tc-99m red blood cells (i.e. In-vitro, Invivo and modified In-vivo), Tc-99m RBC's (denatured) for splenic 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).

Reference or Text Books:

1. "Basic Anatomy and Physiology" – A. K. Jain, Arya Publications, 2020 (3rd Edition)
2. "Radiation Biology" – Eric J. Hall, Amato J. Giaccia, Lippincott Williams & Wilkins
3. "Radiopharmaceutical Chemistry" – Jason S. Lewis, Albert D. Windhorst, Brian M. Zeglis, Springer Nature, 1st Edition
4. "Radiopharmaceuticals in Nuclear Pharmacy and Nuclear Medicine" – Richard J. Kowalsky, Steven W. Falen, American Pharmacists Association, 4th Edition
5. "Nuclear Medicine and PET/CT: Technology and Techniques" – Kristen M. Waterstram-Rich, Paul E. Christian, Mosby, 6th Edition

PHY11707: Radiation Protection and Regulatory Aspects (Credit 4, 60 Lecture Hours)

Module I: Planning of Nuclear Medicine (NM) Facilities: [10 L]

Classification and general features of NM laboratories (site, typical floor plans, ventilation, surface, walls, floor and ceiling, work surfaces, containment systems, fume-hood, glove box etc.), planning of NM laboratories, such as diagnostic and high dose therapy, PET-CT and medical cyclotron installation, shielding evaluation of NM laboratories and medical cyclotron, model layouts of various NM laboratories.

Module II: Introduction Common hospital practices: [4 L]

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

Module III: Transport of radioactive material: [4 L]

Regulatory aspects of transport of radioactive material, introduction, terms used (e.g. Competent Authority, A1&A2 values, transport index (TI) etc.), transport scenarios (routine, normal & accident), variety of packages covered under the transport regulations, general requirement of all packaging, requirements for transport of radioactive material in liquid form, preparation, marking, labelling of packages, preparation of transport documents (Consignors Declaration, TREM Card, Instructions to the Carrier & Emergency in Writing) and general instructions.

Module IV: Basic Radiation Protection and Regulatory Aspects: [10 L]

Types and sources of radiation (natural and artificial), radiation dose measurement units (Gray, Sievert), concept of occupational risk, philosophy of radiation protection, system of dose limitation, ALARA principle, radiation protection strategies (time, distance, shielding), dose limits to radiation workers and general public, AERB/ICRP recommendations, dose constraints for comforters of patients, personal protective equipment (PPE), safe handling of radiopharmaceuticals, occupational exposure limits, patient safety measures, radiation monitoring devices (Geiger counters, dosimeters), waste disposal and decay-in-storage, emergency procedures for radiation spills, regulatory frameworks (IAEA, ICRP, AERB), licensing, and compliance with radiation safety standards in nuclear medicine.

Module V: Radiation Hazard Evaluation and Control: [8 L]

Internal and external radiation hazards and their perspective, evaluation and control of hazard due to external radiation, individual and workplace monitoring, application of time, distance and shielding; specific gamma ray constant, external radiation monitoring, survey meters, internal hazard evaluation and control, protective measures for handling of unsealed sources (e.g. fume-hood, glove box), environmental control, protective clothing, contamination

monitoring (direct and indirect), air contamination monitoring, personnel contamination monitoring and decontamination procedures, surface decontamination procedures.

Module VI: Overview of Whole body counting system: [8 L]

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.

Module VI: Radiological emergency: [4 L]

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.

Module VII: Radioactive waste management: [5 L]

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 (Iodine-131, Lutetium-177, etc).

Module VIII: Regulatory Aspects for Nuclear Medicine Laboratories: [6 L]

Regulations with respect to nuclear medicine laboratories, relevant regulatory documents such as Act, Rules, Code, Standards and Guides, responsibilities of employer, licensee, Radiological Safety Officer (RSO), technologist and radioisotope supplier, Safety and security of radioactive sources during transport and storage, inventory control, security provisions: administrative and technical measures, graded approach in security provision, physical protection system. Regulatory requirements for import/export, procurement, use, handling, transfer and disposal of radioisotopes; inventory control, Radiation Protection Program (RPP).

Module IX: Design of Radiopharmacy laboratory: [6 L]

Regulatory requirements, Pharmaceutical aspects, Radiation protection aspects, Local constraints, Design of hospital pharmacy, stocking of consumables and labels, disposable materials. Laminar airflow 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.

Reference or Text Books:

1. "Radiological Protection and Safety: A Practitioner's Guide" – Pushparaja, Notion Press, 2019
2. "Radiation Safety in Nuclear Medicine" – Max H. Lombardi, CRC Publisher, 1st Edition
3. "Radiopharmaceuticals in Nuclear Pharmacy and Nuclear Medicine" – Richard J. Kowalsky, Steven W. Falen, American Pharmacists Association, 4th Edition
4. "Nuclear Medicine and PET/CT: Technology and Techniques" – Kristen M. Waterstram-Rich, Paul E. Christian, Mosby, 6th Edition
5. "Fundamentals of Nuclear Medicine Dosimetry" – Michael G. Stabin, Springer Publisher

PHY11708: Clinical Applications of Nuclear Medicine (Credit 4, 60 Lecture Hours)

Module I: Non-imaging applications of radionuclides: [8 L]

51Cr labeled RBC's for blood volume, red cell volume measurement, spleen uptake, red cell survival studies. Schilling's test using 58Co/57Co for vitamin B12 absorption, applications of 14C radiorespirometry for H.Pylori ulcers, Ferrokinetic studies using radioisotopes of Iron.

Module II: Imaging I – Thyroid, Lung, Liver-Spleen, Hepatobiliary: [12 L]

Thyroid imaging and uptake (99mTc and 131I), Perchlorate discharge test, T3/T4 suppression test, TSH stimulation test. 131I whole-body imaging. Post Therapy Scans. Ventilation lung imaging studies using gases (133Xe, 81mKr), Inhalation imaging using aerosols, aerosols generators, mucociliary clearance, COPD, Pulmonary permeability using DTPA, perfusion imaging using MAA, Microsphere, pulmonary embolism. 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 Perrectal Scintigraphy. Hepatobiliary imaging protocols, Neonatal hepatitis versus Biliary atresia, Gall bladder dynamic studies using IDA compounds. Deconvolution analysis, Hepatic Extraction Fraction, Interventional methods. Parathyroid Imaging: Dual isotope technique and Subtraction scans. 99mTc-MIBI wash out studies

Module III: Imaging II: Bone, Renal, Brain, Tumour: [10 L]

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, 18F-Fluoride Bone Scans. 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. Cerebral blood flow dynamic studies, Blood Brain Barrier imaging, Perfusion Imaging, Brain SPECT, Interventional methods, Cisternography, CSF leak. 18F-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.

Module IV: Advanced Imaging: [8 L]

Lymphoscintigraphy & Sentinel Node Scintigraphy, Use of Labelled Leukocyte, 99mTc-Ciprofloxacin, 68Gallium for detection of Infectious foci. Discussion of imaging preferences. Imaging for parenchymal and obstructive diseases of salivary glands. Post Radiation Xerostomia evaluation. Imaging techniques for visualisation of Bone marrow infiltration Lymphoscintigraphy & Sentinel Node Scitigraphy. Scrotal Imaging, Dacryoscintigraphy,

Scintimammography: Early and Delayed Imaging. Special Positions and Restraining means. Hysterosalphingography

Module V: Molecular Imaging probes: [6 L]

Basics of molecular imaging, methodology of molecular imaging, Various receptor imaging agents, ligands and labelling of molecules. 111In-penteterotide, 68Ga-DOTA. Conventional labeling of proteins, oligodeoxynucleotide antisense probes, reporter genes for imaging, gene therapy, gene delivery

Module VI: Contrast Agents: [6 L]

Types & Administration: Oral, IV (ionic/non-ionic), rectal, intrathecal contrast, catheter-based administration. Iodinated Contrast: Properties, solubility, hydrophilicity, osmolality (HOCM vs. LOCM), viscosity, calcium binding, iodine concentration, adverse reactions. Alternative Contrast Media: Barium-based vs. iodinated oral contrast, indications for steroid premedication, contraindications.

Module VII: Diagnostic In-vitro Techniques: [8 L]

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 T3, T4, TSH, free hormones, thyroid antibodies and thyroglobulin, other hormones and drugs.

Reference or Text Books:

1. "Nuclear Medicine and PET/CT: Technology and Techniques" – Kristen M. Waterstram-Rich, Paul E. Christian, Mosby, 6th Edition
2. "Radiopharmaceuticals in Nuclear Pharmacy and Nuclear Medicine" – Richard J. Kowalsky, Steven W. Falen, American Pharmacists Association, 4th Edition
3. "Radiopharmaceutical Chemistry" – Jason S. Lewis, Albert D. Windhorst, Brian M. Zeglis, Springer Nature, 1st Edition
4. "PET and PET/CT: A Clinical Guide" – Eugene C. Lin, Abass Alavi, Thieme Medical Publishers Inc, 3rd Edition
5. "Fundamentals of Nuclear Medicine Dosimetry" – Michael G. Stabin, Springer Publisher

PHY12709: Nuclear Medicine Lab I (Credit 2, 120 Lecture Hours)

1. Determination of ^{99}Mo – ^{99m}Tc column generator and to determine the efficiency of extraction
2. Quality Control of Gamma Camera – intrinsic and extrinsic uniformity, spatial resolution and linearity of Gamma Camera
3. To prepare single vial / double vial / triple vial kit preparation of radiopharmaceutical
4. To perform whole body bone scan (3 phase and static)
5. To perform Myocardial Perfusion Imaging (MPI)
6. To perform Lung perfusion
7. To perform dynamic and static renal scans (using DTPA / EC / DMSA)
8. To prepare solid meal for Gastric Empty Time study
9. To perform Gated Blood Pool scintigraphy (MUGA scan)
10. To perform salivary scintigraphy
11. To perform GER
12. To perform Liver scan using Sulphur Colloid
13. To perform Brain SPECT study
14. To perform Thyroid scan
15. To perform ParaThyroid scan
16. To perform Quality Control of Dose Calibrator

PHY12710: Nuclear Medicine Lab II (Credit 2, 120 Lecture Hours)

1. To perform whole body Iodine-131 scan
2. Demonstration of transport of radioactive materials
3. Monitor the given item for contamination, Perform decontamination using contamination monitor
4. To perform the wipe test on the floor and determine the level of contamination
5. To perform Radiation survey of the department including Radio-iodine therapy ward
6. To perform the Radiochemical purity of the given radiopharmaceutical using paperchromatography
7. To demonstrate weighted CTDI (body and head) using ion chamber for QA testing of CT machine
8. To perform experiment to calibrate PET-CT
9. Demonstration of methods of acquisition of PET-CT procedures in cardiology, Neurology and Oncology
10. Demonstration of SPECT / CT Fusion Imaging principles
11. Demonstration of PET-CT Fusion Imaging principles
12. To set a protocol for PET Imaging for Oncology patient
13. To set a protocol for PET imaging for cardiac viability study
14. To demonstrate Iodine-131 therapy in a Thyroid cancer patient
15. To demonstrate monitoring and discharge from the word of a high dose Iodine-131 patient
16. To demonstrate and monitor Iodine therapy for thyrotoxicosis
17. Demonstration of Cyclotron, synthesis of 18 FDG and its beam targeting