MAHATMA GANDHI UNIVERSITY
of
MEDICAL SCIENCES & TECHNOLOGY
JAIPUR

Mahatma Gandhi Institute of Allied Health Sciences

Syllabus

Master of Science in Nuclear Medicine Technology

Program Code: MNM26

IV Semesters (2 Years) + 1 Year Residency

(M.Sc. NMT)

Principal
MG Institute of Allied Health Sciences
Jaipur

2026-2027

Dr. Bushra Fiza
Dean, Faculty of Allied and
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Recommended by the BOS in Allied Health Sciences at its meeting held on 8th April, 2026, the Faculty of Allied and Healthcare Professions at its meeting held on 28.7.2026 and approved by Academic Council at its meeting held on 03.08.2026

NOTICE

1. The university reserves the right to make changes in the syllabus /books/ guidelines, fee-structure or any other information at any time without prior notice the decision of the university shall be binding on all.

2. The jurisdiction of all court cases shall be Jaipur Bench of Hon'ble Rajasthan High Court only.

3. This syllabus is aligned with the NCAHP Curriculum dated 27.03.2026. Any subsequent amendments, revisions or corrigenda issued by the NCAHP shall automatically apply to the Rules, Regulations and Syllabus of MGUMST, Jaipur, and implemented accordingly.

References:

https://ncahp.abdm.gov.in/Curriculum/CurriculumNuclearMedicineTechnology.pdf

Rules and Regulations of
Master of Science in Nuclear Medicine Technology (M.Sc. NMT)
MNM26

1. **Title of the Program** – Master of Science in Nuclear Medicine Technology

2. **Duration of the Program** – 3 years [4 semesters or 2 Years of course work plus 1 Year mandatory Residency under clinically qualified Nuclear Medicine Technologist].

3. **Medium of Instruction** – English

4. **Eligibility for Admissions:**

- The Candidates must have passed Bachelor of Science (B.Sc) in Nuclear Medicine Technology or equivalent, B.Sc. in Physics, B.Sc. in Chemistry, or any B.Sc. degree that includes Physics, Chemistry, Radiation Physics, Biology, Zoology as one of the subjects, from a recognized university, with a minimum of 60% aggregate marks in the Bachelor's degree
- Post Graduate entrance criteria requires to be compulsory registered member of National Commission for Allied and Healthcare Professions (NCAHP)
- Admission to **Masters of Nuclear Medicine** course shall be made on the basis of eligibility and an entrance test to be conducted for the purpose at the State/ University/Institute level.
- Entrance test, to be conducted by the Institute/university/State government as per the syllabus.
- Successful candidates based on written test will be called for the interview and shall have to face an interview board.
- Medical fitness certificate is mandatory to submit and it is to be endorsed by Government medical officer.
- Foreign students admission process in post graduate (PG) –
    i. Foreign national students intending to study PG program in India, shall have to take equivalence certificate of eligibility certificate from respective State Allied and Healthcare Council.
    ii. For admission of Foreign National students, merit list will be based on University Entrance Exam
    iii. Verification of valid visa and valid visa duration of foreign national students to be verified by respective institution and University before enrolling students for programme.

- The admission criteria shall be updated by the Commission from time to time.
- Admission process shall be conducted by State/Union Territory/ University.

5. **Admission Process** – Selection shall be done by an admission board of the University/Rajasthan State Allied & Healthcare Council strictly on merit/written examination.

6. **Reservation Policy** – Reservation policy for admissions in post graduate programs shall be as per the state/ Centre Government norms.

7. Enrolment &/or Registration

- Every candidate who is admitted to the Master of Science in Nuclear Medicine Technology program in Mahatma Gandhi Institute of Allied Health Sciences shall be required to get himself/herself enrolled with the Mahatma Gandhi University of Medical Sciences & Technology (MGUMST) after paying the prescribed eligibility and enrolment fees.

- A candidate shall deposit enrolment fee along with tuition fees at the time of his/her admission to the program. Such a candidate who fails to submit, to the college principal, duly filled enrolment form along with original documents including migration certificate required for enrolment within prescribed period then after he/she shall pay late fee applicable at that time. No student will be allowed to appear in the End of Semester Examination without his/her enrolment.

8. **Introduction –**

Nuclear Medicine Technologists are pivotal in acquiring functional and metabolic images, offering unique insights into disease processes often invisible to anatomical scans. Their direct patient interaction, coupled with their commitment to radiation safety, ensures both diagnostic efficacy and patient well-being. Nuclear Medicine Technologists are the guardians of safe and effective radiation use, meticulously calibrating equipment and establishing stringent safety protocols. Their expertise in image reconstruction and data analysis enhances the diagnostic precision of nuclear medicine procedures.

a) Objectives/ Aim of the Program:

- Provide specialized training in the scientific principles of modern imaging sciences, radionuclide therapy, quality assurance, image analysis and the application of these principles in the field of nuclear medicine.
- Train students to be qualified, patient focused, compassionate, critical thinkers for the community who are engaged in lifelong learning.
    1. Students will be able to use their fundamental knowledge and clinical competence in Nuclear Medicine Science and Technology as and when required to achieve professional excellence.
    2. Students will demonstrate strong and well defined clinical and practical skills in Nuclear medicine diagnostic and therapeutic procedures, radiation safety, Nuclear medicine instrumentation, Radiochemistry and Radiopharmacy.
    3. Students will be able to practice the profession with highly professional and ethical attitude, strong communication skills,

and effective professional skills to work in an inter-disciplinary team.

4. Students will be able to use inter personal and collaborative skills to identify, assess and formulate problems and execute the solution.
5. Students will be able to imbibe the culture of research, innovation, entrepreneurship and incubation.
6. Students will be able to participate in lifelong learning process for a highly productive career and will be able to relate the concepts of Medicine, Biology, Radiobiology, Nuclear Physics and Radiochemistry towards serving the cause of the society.

b) Program Outcomes:

After successful completion of M.Sc. Nuclear Medicine Technology program, students will be able to:

POs	Attribute	Competency
PO 1	**Professional knowledge**	Possess and acquire **scientific knowledge** to work as a health care professional
PO 2	**Clinical/ Technical skills**	Demonstrate and possess **clinical skills** to provide quality health care services
PO 3	**Teamwork**	Demonstrate **team work skills** to support shared goals with the interdisciplinary health care team to improve societal health
PO 4	**Ethical value & professionalism**	Possess and demonstrate **ethical values and professionalism** within the legal frame work of the society
PO 5	**Communication**	**Communicate effectively** and appropriately with the interdisciplinary health care team and the society
PO 6	**Evidence based practice**	Demonstrate high quality **evidence-based practice** that leads to excellence in professional practice
PO 7	**Life-long learning**	Enhance knowledge and skills with the use of advancing technology for the **continual improvement** of professional practice
PO 8	**Entrepreneurship, leadership and mentorship**	Display **entrepreneurship, leadership, and mentorship** skills to practice independently as well as in collaboration with the interdisciplinary health care team

c) Expectation from the Future Postgraduates:

Upon successful completion of the postgraduate course, students will have developed a broad knowledge of the principles, technology, instrumentation, recent developments, and proper handling of the modern imaging equipment along with high technical specialization in quality assurance, quality control, and installation of various instruments and machines, radiopharmaceutical therapy dosimetry, image analysis, proper execution of the various scintigraphy procedures and be able to embark upon a successful career in their chosen direction of nuclear medicine science research.

- Perform and analyze quality assurance and NEMA quality control tests of equipment, and machine installation report.
- Designing imaging protocol for radionuclide therapy dosimetry and perform dosimetry analysis.
- Perform a range of nuclear medicine diagnostic and therapeutic procedures on patients to produce high quality images.
- Verifying informed consent, assuming responsibility for patient needs during procedures.
- Applying principles of ALARA to minimize exposure to patient, self, and others.
- Identifying, preparing, and dispensing of radiopharmaceuticals as prescribed.
- Evaluating images for technical quality, ensuring proper identification is recorded.
- Performing diagnostic scintigraphic procedures.
- Assist nuclear medicine physicians in complex examinations like PET guided biopsy.
- Record imaging identification and patient documentation quickly and accurately and observes protocols.
- Research and development of new techniques and imaging procedures as assigned.
- Promote effective working relationships and work effectively as part of a department / unit /team, inter- and intra-departmentally to facilitate the department/unit's ability to meet its goals and objectives.
- Follow established safety practices including biohazards, exposure control plan.
- Demonstrate respect and regard for the dignity of all patients, families, visitors and fellow employees to ensure a professional, responsible and courteous environment.
- Identifying and managing emergency situations.
- Perform ongoing quality assurance activities.
- Ensure safe custody of all the accessories of the Gamma Camera/SPECT/SPECT/CT, PET-PET/CT units of which he/she is in-charge.
- Understands and observes health and safety regulations/precautions and instruction for self and others protection. He/she should wear a dosimeter during duty hours.
- Attends all in service education program required as per hospital policy.
- Providing education and monitoring students and other health care providers.
- Orientation and teaching students and new employees.

- Learns new technologies and technologies as required by the professional bodies.
- Impart appropriate training to the students and other staff.
- Should have management and research skills.
- To exhibit keen interest, initiative & drive in the overall development of the Department and 'Leadership Qualities' for others to follow.
- He / She is expected to be confident and to perform all the duties diligently with utmost sincerity and honesty. Any other duty/task/work assigned by any higher authority like Director, Dean, Medical Superintendent, Head of the Department from time to time; either in "Public Interest" or in the interest of upkeep / development of the Department / Institutions.

9. Attendance –

- A candidate shall study in concerned department of the Institute for the entire period as a full-time student. No candidate is permitted to work in any other laboratory/college/hospital/pharmacy etc. while studying.
- A candidate who has a minimum of 80% attendance in theory and practical separately and 90% in clinical practices and who has fulfilled other requirements of the course shall be permitted to appear for the examination.
- A candidate having a shortage of attendance shall repeat the exam when it is offered next.

10. Minimum Instruction/ Teaching Days – Each academic semester shall consist of minimum 120 working days, including examinations.

11. Programme Structure (Semester I, II, III, IV…… Distribution of course semester wise)) –

M.Sc. Nuclear Medicine Technology

SEMESTER I

Course Code	Course Title	Credit Distribution (L, T, P, CL are hours/week)							
		Lecture (L)	Tutorial (T)	Practical (P)	Clinical Learning (CL)	Credits	IAC	ESE	Total
MNM 1101	Human Anatomy & Physiology for Nuclear Medicine	3	1	0	0	4	50	50	100
MNM 1102	Nuclear medicine Physics and Instrumentation	3	1	0	0	4	50	50	100
MNM 1103	Radiological Physics, Safety and Regulatory Planning of Facility	3	1	0	0	4	50	50	100
MNM 1104	Research publication ethics & pedagogy	2	1	0	0	3	50	50	100
MNM 1105	Practicum-I	0	0	4	0	2	50	50	100
MNM 1106	Clinical practice- I	0	0	0	9	3	50	50	100
Total		**11**	**4**	**4**	**9**	**20**	**300**	**300**	**600**

M.Sc. Nuclear Medicine Technology

SEMESTER II

Course Code	Course Title	Credit Distribution (L, T, P, CL are hours/week)							
		Lecture (L)	Tutorial (T)	Practical (P)	Clinical Learning (CL)	Credits	IAC	ESE	Total
MNM1201	Advanced Biostatistics and Research Methodology	2	1	0	0	3	50	50	100
MNM1202	Advanced Nuclear Medicine Instrumentation	2	1	0	0	3	50	50	100
MNM1203	SPECT & PET radiopharmaceuticals	2	1	0	0	3	50	50	100
MNM1204	Computers in Nuclear Medicine	2	1	0	0	3	50	50	100
MNM1205	Practicum-II	0	1	6	0	4	50	50	100
MNM1206	Clinical Practice- II	0	1	0	9	4	50	50	100
	Total	**8**	6	**6**	**9**	**20**	**300**	**300**	**600**

M.Sc. Nuclear Medicine Technology
SEMESTER III

Course Code	Course Title	Credit Distribution (L, T, P, CL are hours/week)							
		Lecture (L)	Tutorial (T)	Practical (P)	Clinical Learning (CL)	Credits	IAC	ESE	Total
MNM2301	Artificial Intelligence in Nuclear medicine	2	1	0	0	3	50	50	100
MNM2302	Clinical Nuclear Medicine Imaging	2	1	0	0	3	50	50	100
MNM2303	Image Analysis	2	0	0	0	2	50	50	100
MNM2304	Research Project-I	0	0	20	0	10	50	50	100
MNM2306	Clinical Practice-III	0	0	0	6	2	50	50	100
	Total	**6**	**2**	**20**	**6**	**20**	**250**	**250**	**500**

M. Sc. Nuclear Medicine Technology
SEMESTER-IV

Course Code	Course Title	Credit Distribution (L, T, P, CL are hours/week)							
		Lecture (L)	Tutorial (T)	Practical (P)	Clinical Learning (CL)	Credits	IAC	ESE	Total
MNM -2401	Radiation Dosimetry in Nuclear Medicine and Therapy Planning	2	1	0	0	3	50	50	100
MNM -2402	Therapeutic Radiopharmaceuticals	2	1	0	0	3	50	50	100
MNM -2403	Quality assurance and Quality control in Nuclear Medicine	0	1	2	0	2	50	50	100
MNM -2404	Research Project-II	0	0	20	0	10	50	50	100
MNM -2405	Clinical Practice-IV	0	0	0	06	2	50	50	100
	Total	**4**	3	**22**	**6**	**20**	**250**	**250**	**500**

12. Conduct of Continuous Assessment/ Internal Assessment –

It is essential to monitor the learning progress of each postgraduate candidate through continuous appraisal and regular assessments. It not only helps teachers to evaluate the students, but also students to evaluate themselves. The monitoring is done by the Nuclear Medicine Technologist of the department, based on participation of students in various teaching / learning activities

- There shall be periodic tests based on the pattern of university examination. Such tests may include written theory papers, practical, viva voce and clinical assessment. Records and marks obtained in such tests will be maintained by the HoD and shall be produced as and when called for.
- The assessment will be a combination of formative and summative assessments
- Theory, inter-departmental meeting
- Practical- clinical rounds and bed side evaluation and application.
- Learning Activities: Self Learning, use of computers and library
- Participation in departmental activities;
- Journal review meetings
- Seminars

- Clinical presentation
- Special clinics
- Inter departmental meetings
- Dissertation work
- Participation in national conferences/ presentation of paper -Minimum 1 in two years
- Participation in workshops /CME/symposium -Minimum 1 in two years
- Rotation and posting in other departments for learning hybrid technologies (2 weeks).

13. Dissertation/ Internship/ Project/ Clinical Postings

Dissertation/Thesis shall be submitted at least three months before the Theory and Clinical/Practical examination. The thesis shall be examined by a panel of two examiners; one internal (other than the main supervisor) and one external examiner.

One Year: Residency/Internship Training

All students are required to undergo one-year residency at **NCAHP/AERB** recognized institutes for successful completion of **M.Sc. Nuclear Medicine Technology** postgraduate course. This is a mandatory requirement for becoming the clinically qualified Nuclear Medicine Technologist in nuclear medicine.

14. Scheme of Examination – The end of semester examination for the program shall be conducted semester wise at the end of every semester.

Marks Distribution
M. Sc. Nuclear Medicine Technology
SEMESTER-I

Course Code	Course Title	Credits	IAC	ESE	Total
MNM1101	Human Anatomy & Physiology for Nuclear Medicine	4	50	50	100
MNM1102	Nuclear medicine physics and instrumentation	4	50	50	100
MNM1103	Radiological Physics, Safety and Regulatory Planning of Facility	4	50	50	100
MNM1104	Research publication ethics & pedagogy	3	50	50	100
MNM1105	Practicum-I	2	50	50	100
MNM1106	Clinical practice-I	3	50	50	100
Total		**20**	**300**	**300**	**600**

M. Sc. Nuclear Medicine Technology
SEMESTER-II

Course Code	Course Title	Credits	IAC	ESE	Total
MNM1201	Advanced Biostatistics and Research Methodology	3	50	50	100
MNM1202	Advanced Nuclear Medicine Instrumentation	3	50	50	100
MNM1203	SPECT & PET Radiopharmaceuticals	3	50	50	100
MNM1204	Computers in Nuclear Medicine	3	50	50	100
MNM1205	Practicum-II	4	50	50	100
MNM1206	Clinical Practice- II	4	50	50	100
Total		**20**	**300**	**300**	**600**

M.Sc. Nuclear Medicine Technology
SEMESTER III

Course Code	Course Title	Credits	IAC	ESE	Total
MNM2301	Artificial Intelligence in Nuclear Medicine	3	50	50	100
MNM2302	Clinical Nuclear Medicine Imaging	3	50	50	100
MNM2303	Image Analysis	2	50	50	100
MNM2304	Research Project-I	10	50	50	100
MNM2306	Clinical Practice-III	2	50	50	100
Total		**20**	**250**	**250**	**500**

M. Sc. Nuclear Medicine Technology
SEMESTER-IV

Course Code	Course Title	Credits	IAC	ESE	Total
MNM-2401	Radiation Dosimetry in Nuclear Medicine and Therapy Planning	3	50	50	100
MNM-2402	Therapeutic Radiopharmaceuticals	3	50	50	100
MNM-2403	Quality assurance and Quality control in Nuclear Medicine	2	50	50	100
MNM-2404	Research Project-II	10	50	50	100
MNM-2405	Clinical Practice-IV	2	50	50	100
	Total	**20**	**250**	**250**	**500**

15. Conduct of University Examination –

a) Appointment of Examiners and Paper Setters (Qualification of paper Setters and Examiners)

- All the examiners, paper setters, theory examination answer book evaluators, external and internal examiners for practical examinations shall be appointed by the respective university.
- One must be an Assistant professor/ Associate Professor/ Professor or have minimum of 3 years of teaching experience after post-graduation to be a recognized as PG teacher/Examiner of same elective/specialty.

- At least 50 % of total examiners in the last and final semester (IV semester) shall be externals (from other universities/Institutes).

b) Eligibility to appear for the Examination

- A student is required to have minimum 80% attendance in theory and practical separately and 90% in clinical practices of each semester to make him/her eligible to appear in the university semester examination.
- Candidates failing in one or more subjects (theory/practical) of semester will require to appear in failing subjects in the next examination of same semester.

c) Theory Examinations There shall be Theory papers in each semester of study.

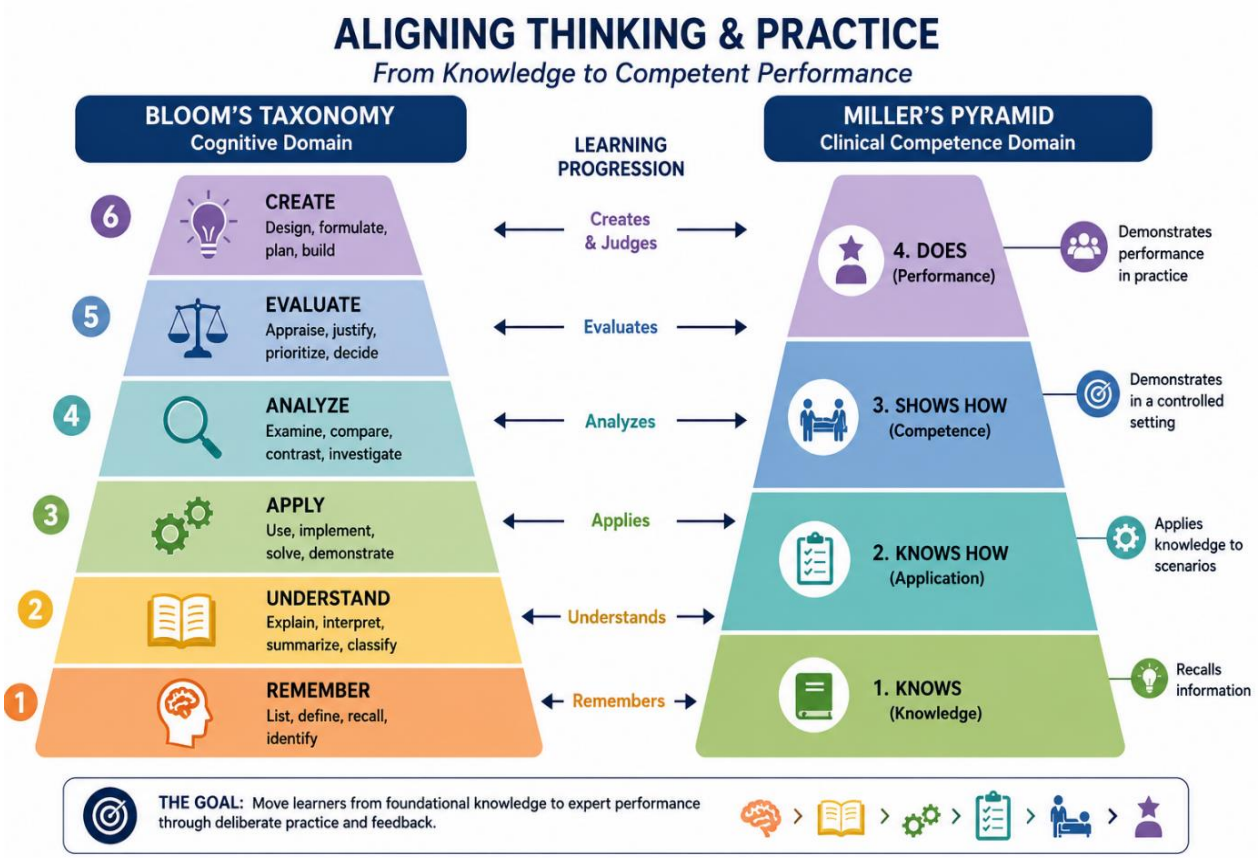
- Each Theory paper examination shall be of 2 hours duration and a maximum of 50 marks.
- Internal assessment (IA) shall be 50 marks for each Theory paper.
- The Paper Setter shall set the questions within the prescribed course of study of the concerned paper. There will be a set pattern of question papers duly approved by the Academic Council.

Proposed template of question papers –

MAXIMUM MARKS = 50		
TYPE OF QUESTION	NUMBER OF QUESTION	MARKS FOR EACH QUESTION
ESSAY TYPE	3 (to answer 2)	10
SHORT ESSAY TYPE	8 (to answer 6)	5

Passing Marks: A candidate will have to obtain at least 50% marks in each Theory paper including internal assessment to pass.

Bloom's Level: A blended approach—combining didactic methods, experiential laboratory training, problem-solving, clinical immersion, and research exposure—is essential in Nuclear Medicine Technology. When guided by educational frameworks such as Bloom's Level, these methodologies ensure that learners progress from acquiring foundational knowledge to demonstrating competence and ultimately practicing independently as professionals.



d) Practical Examinations and Viva Voce

i. At the end of each semester there shall be the practical and viva-voce examination. It shall be conducted after the Theory examination is over. A candidate will have to obtain at least 50% marks in the practical and viva-voce examination.

ii. For **First to Third Semester**: The practical examinations shall be conducted by a panel of two internal examiners.

iii. For **Fourth Semester**: The practical examination shall be conducted by a panel of two internal and two external examiners, out of which at least one should be from other institutions.

iv. Marks to be awarded separately by each examiner and an average shall be taken as the final marks awarded to the student in both practical as well as dissertation.

e) **Results:** A candidate has to score 50% each in theory and practical wherever applicable to be declared as pass. In case of fail, subsequently candidate has to reappear.

f) Supplementary Examination (MGUMST Rules)[@]

- Supplementary examination conducted by the University for unsuccessful candidates.
- Lower semester exams conducted along with current semester exams.
- Internal assessment can be improved before supplementary examination**.**

Grace Marks: The Award of grace marks shall be as per the policy governed by rules of MGUMST

g) **Revaluation/ Scrutiny@:** As per MGUMST rules

h) Promotion to the next Semester:

- The maximum period for completion of Masters course work is 4 years.
- If a candidate does not complete within the 4 years, he/she should leave the course.

16. Award of Degree[@]

The degree shall be awarded by the university only after receipt of course completion certificate and No Dues from the principal of the college**.**

17. Authority to issue transcript

The Controller of Examination of the University shall be the authority for issuing transcript after receiving the described fee from the candidate.

18. Logbooks and Clinical Records, if any

- Every candidate shall maintain a log book and record his/her participation in the training programs conducted by the department such as journal reviews, seminars etc.
- Candidates must also record research presentations and details of clinical research studies, if any.
- The log book shall be scrutinized and certified by the Nuclear Medicine Technologist of the department followed by Head of the Department (HoD) and presented in the university/Institute examination.

19. Any specific point/ rule/ regulation related to college/ institute – -N/A

20. Course wise Syllabus with Recommended Text Books

21. Model Paper- Attached

SEMESTER-I

Course Code	Course Title
MNM1101	Human Anatomy & Physiology for Nuclear Medicine
MNM1102	Nuclear medicine physics and instrumentation
MNM1103	Radiological Physics, Safety and Regulatory Planning of Facility
MNM1104	Research publication ethics & pedagogy
MNM1105	Practicum- I
MNM1106	Clinical practice-I

Human Anatomy & Physiology for Nuclear Medicine

Course Title	**Human Anatomy & Physiology for Nuclear Medicine**
Course Code	**MNM1101**
Academic Year	First
Semester	**I**
Number of Credits	4
Course Prerequisite	Basic knowledge of biology
Course Synopsis	This course also provides a comprehensive knowledge about anatomy and normal functions of the organ systems of the body

Course Outcomes (Cos):

CO No.	Course Learning Outcomes	Bloom's Level
CO1	Explain the General Anatomy of the human body (C2)	L1, L2
CO2	Explain the anatomy and physiology of respiratory, cardiovascular and digestive system (C2)	L2
CO3	Explain the anatomy and physiology of renal and reproductive system (C2)	L2

CO4	Explain the anatomy and physiology of endocrine, central nervous system and special senses (C2)	L2

Mapping of Course Outcomes (Cos) to program Outcomes (POs):

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1	**x**	**x**						
CO2	**x**	**x**						
CO3	**x**	**x**						
CO4	**x**	**x**						

Course Content:

Content	Competencies	Number of Hours (Theory):
SECTION A: HUMAN ANATOMY IN NUCLEAR MEDICINE		
Unit 1: General Anatomy, Locomotion and Support		
	• Define the Anatomical position and Anatomical terms (C1) • Explain the epithelium - types and functions (C2) • Explain the connective tissue–fibers and cells (C2)	4
	• Cartilage – types, examples and histology Bone – classification, examples and histology. Parts of long bone, names of all bones, vertebral column and intervertebral disc. Fontanel's of fetal skull (C2) • Joints – classification of joints with examples, typical synovial joint (in detail) (C2) • Muscular system – classification of muscular tissue and histology Important muscles of the body- Sternocleidomastoid, Trapezius, Muscles of tongue, Deltoid, Biceps brachii, Intercostal muscles, Thoracic diaphragm, Rectus abdominis, External oblique, Internal oblique, Transversus abdominis, Pelvic diaphragm, Gluteus maximus, Gluteus medius, Gluteus Minimus, Quadriceps femoris, Soleus(C2)	

Unit 2: Respiratory system		
	• List the parts of respiratory tract, nose, nasal cavity, paranasal air sinuses, larynx, trachea, lungs, pleura(C1) • Explain the trachea: Extent, Structure and nerve supply (C2) • Explain the diaphragm - attachments, nerve supply and actions (C2) • Explain the thoracic cage: thoracic wall, intercostal spaces and their contents (C2) • Explain the Lungs- gross anatomy, roots of the lungs, surface marking of pleura and lungs(C2) • Explain the pleura- parts, pleural cavity, pleural recesses, pulmonary ligament (C2)	4
Unit 3: Cardiovascular system		
	• Explain the heart - position, external features, right atrium internal features (C2) • Explain the right ventricle internal features, Blood supply to the heart (C2) • Explain the left atrium and left ventricle, nerve supply of heart (C2) • Explain the pericardium - Parts, blood supply, nerve supply and function(C2) • Explain the mediastinum - boundaries and contents (C2) • List and explain the arteries - Arch of aorta and descending thoracic aorta (extent course and branches) (C2) • Histology of heart (C2)	4
Unit 4: Digestive System		
	• List the parts of digestive system (C1) • Explain the tongue–gross anatomy, blood supply and nerve supply (C2) • Explain the salivary glands- Names and location (C2) • Explain the oesophagus- extent, parts, constrictions, blood supply, nerve supply and lymphatic drainage (C2) • Explain the stomach- position, relations, blood supply, nerve supply and lymphatic drainage (C1, C2) • Explain the duodenum- parts, important relations, blood supply and nerve supply (C2) • Explain the pancreas–position, parts, important relations, blood supply and nerve supply (C2) • Explain the small intestine–parts- duodenum, jejunum and ileum-blood supply and nerve supply (C1, C2) • Explain the large intestine–parts, position of each of the parts, extent, blood supply and nerve supply (C2) • List the differences between jejunum and ileum (C1)	5

	• List the differences between small intestine and **l**arge intestine (C1) • Explain the rectum and anal canal-position, blood supply, nerve supply and lymphatic drainage (C2) • Explain the liver- position, anatomical and physiological lobes, surfaces, relations, porta hepatis, blood supply and nerve supply (C1, C2) • Explain the extrahepatic biliary apparatus–gall • bladder and bile duct (C2)	
Unit 5: Renal System		
	• List the parts of urinary system (C1) • Explain the kidneys: position, external features, capsules, relations, macroscopic structure, blood supply and nerve supply (C2) • Explain the ureter- length, constrictions and blood supply (C2) • Explain the urinary bladder- position, external features, blood supply and nerve supply (C2) • Explain the urethra- female urethra, male urethra-parts (C2)	2
Unit 6: Reproductive System		
Male reproductive system	• List the parts of male reproductive system (C1) • List the spermatic cord- constituents and coverings (C1) • Explain the testes- position, coverings, gross structure, blood supply, nerve supply and lymphatic drainage (C2) • Explain the vas deferens- commencement, course and termination (C2) • Explain the prostate–position, external features, lobes and structure (C2) • Explain the seminal vesicles and ejaculatory ducts (C2)	2
Female reproductive system	• Name the parts of female reproductive system (C1) • Explain the uterus-position, parts, external features, relations, blood supply and lymphatic drainage (C2) • Explain the uterine tube- parts, blood supply and nerve supply (C2) • Explain the ovary – position and structure (C2)	2
Unit 7: Endocrine Gland and special senses		
Endocrine glands	• Name the endocrine glands (C1) • Explain the pituitary gland (Hypophysis cerebri)- position, parts, blood supply (C2) • Explain the suprarenal glands- position, relations, parts, blood supply and lymphatic drainage (C2)	2

	• Explain the thyroid gland- position, parts, blood supply and lymphatic drainage (C2) • Name the parathyroid glands-their position and blood supply (C1) • Recall the gross anatomy of the eye (C1) • Recall the gross anatomy of external, middle and internal ear (C1) • Recall the skin and its features (C1)	
Unit 8: Central Nervous system		
	• List the features and explain the spinal cord-position, external features, internal structure, brief note on important ascending and descending tracts (C2) • Name the parts of brain (C2) • Explain the cerebellum- functional lobes of the cerebellum and its functions (C2) • Explain the midbrain- external features and internal structure–in brief (C1) • Explain the cranial nerves (C2) • Explain the cerebral hemispheres–lobes, important sulci and functional areas (C2) • Explain the corpus callosum and internal capsule (C1, C2) • Explain the diencephalon- Thalamus and hypothalamus-position and functions (C2) • Explain the basal nuclei: Corpus striatum–parts and functions (C2) • Explain the blood supply to the central nervous system (C2) • Explain the ventricles (C2) • Define the CSF production and circulation (C1)	6

SECTION B: HUMAN PHYSIOLOGY FOR NUCLEAR MEDICINE		
Unit 1: Basic concepts and General physiology		
Blood	• Describe the Composition and functions of blood(C1) • Name the different types of plasma proteins and list their functions (C1) • Mention the morphology and functions of red blood cells (C1) • Mention the normal count of RBC and its variations (C1) • Describe the sites, stages and factors influencing erythropoiesis(C2) • Mention the normal value of hemoglobin concentration and its variations (C1) • Mention the functions of hemoglobin (C1) • Define anemia and describe the morphological classification of anemia (C2) • Classify White Blood Cells (WBC) (C2) • List the functions of WBCs(C1) • Mention the normal count of various types of WBCs (C1) • State Landsteiner's law (C1) • Describe the ABO and Rh systems of blood grouping(C2) • Explain the importance of blood grouping(C2) • Mention the hazards of blood transfusion(C1) • Explain the cause and clinical features of hemolytic disease of the newborn (erythroblastosis fetalis) (C2) • List the functions of lymph (C1)	3
Unit 2: Cardiovascular System		
	• Organization of cardiovascular system, greater and lesser circulation (C2) • Physiological anatomy of the heart, nerve supply, Junctional tissues of heart (pacemaker) (C2) • Cardiac cycle: Mechanical events, Heart sounds, causes, characteristics and significance (C2) • Normal ECG, clinical significance of ECG, Heart rate – Physiological variations (C2) • Cardiac output: Definitions, normal values, physiological variations (C1) • Arterial blood pressure: Definitions, normal values, physiological variations, factors maintaining blood pressure. (C2)	4

Unit 3: Respiratory System		
	• Respiratory and non-respiratory function of respiratory system (C1) • Physiological anatomy of respiratory system (C2) • Functions of respiratory tract, Respiratory membrane, Respiratory muscles, Surfactant: functions, respiratory distress syndrome (C1, C2) • Definitions of terms used in respiratory physiology: Eupnea, Hyperpnoea, Tachypnea, Apnea, Dyspnea (C1) • Mechanics of breathing – intrapulmonary and Intrapleural pressure changes during a respiratory cycle (C2) • Spirometry – Lung volumes and capacities. Vital capacity (C1) • Define pulmonary and alveolar ventilation and mention the normal values (C1) • Define anatomical dead space (C1) • Mention the normal value of anatomical dead space (C1) • Oxygen transport: Role of hemoglobin, factors affecting, oxygen carrying capacity. Carbon dioxide transport: forms, chloride shift (Hamburgers phenomenon) (C2) • Partial pressure of gases, Calculation of partial pressure of gasses in mixture. Arterial and venous blood gas concentrations and contents (C2) • Hypoxia: Types and effects Cyanosis, Asphyxia, Periodic Breathing, Acclimatization (C1)	**4**

Unit 4: Renal System		
	• Functions of kidneys. Nephrons – Juxta glomerular apparatus – functions, Steps in Urine formation – Ultrafiltration, Tubular Reabsorption, Tubular Secretion, GFR (C2) • Definition, normal values, factors affecting GFR, measurement of GFR, Renal threshold for glucose, tubular load for glucose(C2) • Role of aldosterone and ADH in urine formation, Micturition, Innervation of bladder (C1) • What is Diuresis (C1) • Mention Renal functions tests – Based on analysis of urine and analysis of blood, Skin: Functions of skin Sweat glands (C1)	2

Unit 5: Digestive System		
	• Introduction and structure of digestive tract (C1) • Describe the composition and function of alimentary canal, Saliva (C1) • Describe the composition and function of Stomach (C2) • Describe the composition and function of Pancreas (C1) • Describe the composition and function of Liver(C2) • Describe the composition and function of Gall bladder(C1) • Describe the composition and function of Succusentericus (C1) • Describe the composition and function of large intestine, Movements of small intestines(C2) • Describe Deglutition(C1)	3
Unit 6: Endocrine System		
	• Define and mention the functions of Major endocrine glands and their Hormone (C1) • Define Anterior pituitary: hormones and mention their functions, disorders like Giganitism, acromegaly, dwarfism(C1) • Define and mention Posterior pituitary: Hormones – diabetes insipidus(C1) • Define and mention Thyroid: Hormones, normal values, functions, role of TSH (C2) • What is simple goitre, myxoedema, cretinism, Grave's disease? (C1) • Define and mention Adrenal cortex: hormones, functions of cortisol and aldosterone. (C1) • explain briefly Addison's disease, Cushing's syndrome • Define and mention Adrenal medulla: actions of adrenaline and noradrenaline (C1) • Define and mention Endocrine pancreas: Insulin & glucagon, functions, Regulation of blood glucose level, diabetes mellitus (C1) • Define and mention Parathyroid: Functions of PTH **(C2)**	**3**
Unit 7: Nervous System		

	• What are Classification Organization of spinal cord (C1) • Mention the functions of Dorsal column and Spinothalamic tract (C1) • What are the functions of Corticospinal tract (C1) • What is Reflex Action (C1) • Definition, reflex arc (C1) • Mention the functions of Cerebellum, Basal ganglia, Thalamus, Hypothalamus, Cerebral cortex: Lobes & functions. (C2) • EEG – Definition and uses (C1) • what is Autonomic nervous system: Organization & functions (C2) • what is Cerebrospinal fluid: Composition and function (C2)	4

Unit 8: Special Senses		
	• Vision: Physiological anatomy of eye ball, rods & cones, Refractive errors: Myopia, hypermetropia, presbyopia & astigmatism (C1) • Audition: Functions of outer, middle & inner ear, cochlea, Deafness – types (C1) • Taste: Taste buds, primary taste sensation, Smell: Receptors, modalities of smell (C1)	2
Unit 9: Reproductive System		
	• Male reproductive system: functions of testes, puberty, spermatogenesis functions of testosterone, semen (C2) • Female reproductive system: Ovarian hormones functions – Menstrual cycle (C2) • Hormonal basis of changes in menstrual cycle (C1) • Enumerate the functions of placenta (C1) • Describe milk ejection reflex (C2) • Mention various contraceptive methods in males (C1) • Mention various contraceptive methods in females (C1) • Explain the mechanism of action of various contraceptive methods (C2)	2

Unit 10: Lymphatic system		
	• Explain the role of Lymphoid Tissue in Immune Surveillance (C2) • Describe the function of the secondary lymphoid organs (Spleen, MALT) as filters and sites of immune cell interaction (C2) • Detail the process of immune cell circulation and activation within the lymphatic network (C2) • Briefly explain the metabolic role of lacteals in fat absorption (chyle) (C2) • Explain the role of the Lymph Node as the Primary Filter (C2) • Describe the microanatomy of a lymph node (cortex, medulla, sinuses) and how it facilitates fluid filtration (C2) • Explain the physiological basis of lymph node enlargement (Lymphadenopathy) in response to infection or malignancy (C2) • Detail the entry and filtering of pathogens, cancer cells, and cellular debris (C2) • Explain the role of Lymphatic Physiology in Nuclear Medicine Imaging (C2) • Describe the physiological principle behind Lymphoscintigraphy: using lymphatic transport to guide radiotracer uptake and flow (C2) • Explain how the lymphatic drainage pathway is mapped to perform Sentinel Lymph Node (SLN) localization for cancer staging (C2) • Relate lymphatic failure to the clinical condition of Lymphedema (C2)	2

Learning Strategies, Contact Hours and Out of Class Engagement:

Learning Strategies	**Contact Hours**	**Out of Class Engagement**
Lecture	45	45
Seminar	11	11
Revision	2	2
Assessment	2	2
Total	60	60

Assessment Methods:

Formative	**Summative**
Unit Test	Mid Semester/ Sessional Exam (Theory)
Quiz	End Semester (Theory)
Assignment/ Presentation	

Mapping of Assessment with Cos:

Nature of Assessment	**CO1**	**CO2**	**CO3**	**CO4**
Mid Semester	x	x	-	
Quiz/Unit Test	x	x	**x**	x
Assignment/Presentations	x	x	**x**	x
End Semester Exam	x	x	**x**	x

Feedback Process:	**End-Semester Feedback**

Main References: Text Books:

1. Human Anatomy by Dr. B. D. Chaurasia (Vol 1,2,3,4)
2. Grays' Anatomy International edition 42e
3. Basics of Medical Physiology,4th edition, D.Venkatesh, H.H.Sudhakar
4. Guyton and Hall Textbook of Medical Physiology
5. Ross and Wilson Applied Anatomy and applied physiology

Additional References:

1. Chaurasia's handbook of human anatomy
2. Netter's Atlas

Nuclear Medicine Physics and Instrumentation

MNM 1102

Course Title	**Nuclear Medicine Physics and Instrumentation**
Course Code	**MNM1102**
Academic Year	First Year
Semester	**I**
Number of Credits	4
Course Prerequisite	Basic knowledge of physics and electronics at B.Sc. NM level
Course Synopsis	Upon completion of this course, students will gain a comprehensive understanding of non-imaging nuclear medicine instrumentation, cyclotron operations, and facility design. They will be able to perform routine instrumentation tasks, ensure safety through radiation monitoring and automation systems, and maintain regulatory standards in clinical and research environments.

Course Outcomes:

CO No.	Course Learning Outcomes	Bloom's Level
CO1	Apply advanced knowledge of radiation detection instruments—including dose calibrators, non-imaging probes, gamma spectrometers, survey meters, and liquid scintillation counters—to evaluate, optimize, and design quantitative nuclear medicine measurement protocols in compliance with quality control and regulatory standards (C6).	L1, L2
CO2	Identify and demonstrate structures of skeletal, respiratory, digestive, and urinary systems using models and specimens.	L2, L3

Mapping of Course Outcomes (Cos) to program Outcomes (POs):

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1	**x**	**x**						
CO2	**x**	**x**						

Course Content:

Content	Competencies	Number of Hours
Unit 1: Advanced Non-imaging Equipment in Nuclear Medicine		
Dose Calibrator	• Recall working principle of dose calibrator (C1). • Test a dose calibrator's performance by performing the Constancy, Linearity, Accuracy, and Geometry check procedures as per regulatory standards (C4). • Critique the results of a dose calibrator quality control (QC) test, judging if the device is fit for clinical use and recommending corrective actions for common failures (C5).	5
In-vivo probe	• Recall working principle of thyroid uptake probe (C1) • Explain working principle of intraoperative gamma probes (C2) • Compare the physical principles and clinical utility of intraoperative gamma probes vs. thyroid uptake probes, focusing on collimation, energy discrimination, and background subtraction techniques (C4). • Design a clinical protocol using a non-imaging probe (e.g., an external probe over the heart/thyroid) to acquire time-activity data for a basic pharmacokinetic study (e.g., effective half-life determination), and formulate a method for data processing (C6).	10
Gamma ray spectrometer	• Recall working principle of Gamma ray spectrometer (C1) • Explain properties of scintillation detectors: NaI (Tl), plastic scintillators, CZT etc. (C2) • Deconvolve complex multi-radionuclide spectra to accurately determine the activity of each component, distinguishing between true photopeaks and spectral artifacts (Compton scatter, escape peaks, summing) (C3). • Critique the suitability of NaI (Tl) vs. other scintillator detectors for specific radiopharmaceutical quality control assays, justifying the choice based on required energy resolution and efficiency (C4).	5

	• Derive and apply complex correction factors for volume and density variations (self-absorption) to achieve absolute activity quantification in varied sample matrices (e.g., blood, tissue) (C5). • Measure and correct for pulse pile-up effects at high count rates to maintain spectrum integrity and quantitative accuracy (C6).	
Geiger-Müller (GM) Counter	• Recall working principle of GM counter (C1). • Quantify the limitations of a GM survey meter at high and low exposure rates, using the dead time correction formula to convert observed count rates to true rates for high-activity areas.	5
Radiation survey equipment	• Recall working principle of survey meter (C1) • Select the appropriate radiation survey instrument (GM, ionization chamber, proportional counter) for tasks like high-level room survey, low-level surface contamination monitoring, and sealed source inventory, defending the selection based on dose rate response and energy dependence (C5).	5
Liquid Scintillation Counter	• Recall working principle of liquid scintillation counter (C1). • Differentiate the theoretical basis of major quench correction methods (e.g., t-SIE, Channel Ratio, TDCR), and correlate quench type (chemical vs. color) with its mechanism of energy loss (C4). • Design and validate a TDCR (Triple-to-Double Coincidence Ratio) measurement protocol for the absolute standardization of a pure beta emitter (Y-90 or Sr-89), eliminating the need for a traceable standard source (C5). • Compare and contrast LSC with Cherenkov counting for high-energy beta emitters (P-32, Y-90), assessing the trade-offs in efficiency, quench susceptibility, and sample preparation (C6).	5
Unit 2: Automation, Safety Systems, and Facility Design in Non-Imaging Nuclear Medicine		

	• Explain the basic operating principle of automated dose dispensers and synthesis modules, contrasting their use with manual methods (C2). • Illustrate how systematic workflow steps contribute to reproducibility in radiopharmaceutical preparation and describe the role of time-motion studies in workflow optimization (C2). • Describe the purpose of primary and secondary shielding in a hot lab and explain the principles guiding the separation of clean and contaminated zones in the room layout (C2). • Explain the mechanism by which negative pressure ventilation and specialized fume hoods prevent the spread of airborne and surface contamination (C2). • Summarize the essential function of safety interlocks and emergency shutdown systems in mitigating acute radiation risks (C2). • Understand the AERB/IAEA guidelines for facility design and regulatory compliance (C2).	10

Learning Strategies, Contact Hours and Out of Class Engagement:

Learning Strategies	Contact Hours	Out of Class Engagement
Lecture	45	45
Seminar	11	11
Revision	2	2
Assessment	2	2
Total	60	60

Assessment Methods:

Formative	Summative
Unit Test	Mid Semester/ Sessional Exam (Theory)
Quiz	End Semester (Theory)
Assignment/ Presentation	

Mapping of Assessment with Cos:

Nature of Assessment	CO1	CO2	CO3
Mid Semester	**x**	**x**	**-**
Quiz/Unit Test	**x**	**x**	**-**
Assignment/Presentations	**x**	**x**	**-**
End Semester Exam	**x**	**x**	**-**

Feedback Process:	**Mid-Semester Feedback**
	End-Semester Feedback

MAIN References: Text Books:

1. Physics in Nuclear Medicine – Simon Cherry, James Sorenson, Michael Phelps
2. Radiation Detection and Measurement – Glenn F. Knoll
3. Cyclotrons and Their Applications – John Livingood
4. IAEA Cyclotron Produced Radionuclides: Principles and Practice

Additional References:

1. Quality Assurance for Radioactivity Measurement in Nuclear Medicine – IAEA Technical Reports Series
2. Handbook of Radiopharmaceuticals: Radiochemistry and Applications – Michael J. Welch, Carol S. Redvanly
3. Practical Nuclear Medicine – Peter F. Sharp, Howard G. Gemmell, Alison D. Murray

Radiological Physics, Safety, and Regulatory Planning of Facility

MNM1103

Course Title	**Radiological Physics, Safety, and Regulatory Planning of Facility**
Course Code	**MNM1103**
Academic Year	First Year
Semester	**I**
Number of Credits	4
Course Prerequisite	Basic knowledge of radiation physics and radiation safety principles at at B.Sc. NM level
Course Synopsis	This course equips students with advanced knowledge and skills in radiological safety and nuclear medicine facility planning. By the end of the course, students will master ALARA optimization and risk assessment models, ensuring safe handling of radiopharmaceuticals like Tc-99m and Lu-177. They will gain expertise in designing hot labs, shielding for PET-CT suites, and cyclotron facilities, while adhering to AERB, IAEA, and ICRP regulations. The course emphasizes practical applications, such as managing Ga-68 DOTATATE spills, optimizing I-131 waste disposal, and planning sustainable PET facilities, therapy facilities, preparing students to implement robust safety protocols, emergency responses, and efficient facility operations in nuclear medicine practice.

Course Outcomes:

CO No.	Course Learning Outcomes	Bloom's
CO1	Explain radiation safety and survey principles (C2)	L1, L2
CO2	Design and evaluate the layout and safety systems of a nuclear medicine clinical facility in accordance with AERB/IAEA regulatory and radiological protection standards (C2)	L2, L3
CO3	Design and evaluate the layout and safety systems of a nuclear medicine clinical facility in accordance with AERB/IAEA regulatory and radiological protection standards (C2)	L2, L4

Mapping of Course Outcomes (Cos) to program Outcomes (POs):

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1	**x**	**x**						
CO2	**x**	**x**						
CO3	**x**	**x**						

Course Content:

Content	Competencies	Number of Hours
Unit 1: Radiation Protection and Safety Principles		
	• Explain Radiation protection philosophy: justification, optimization, dose limitation, ALARA principle (C2). • Explain Biological effects of ionizing radiation (C2) • Explain Occupational exposure limits and control measures (C2) • Explain shielding design and calculations for rooms and bunkers (C2) • Explain Primary and secondary barriers, occupancy factors, and workload estimation (C2)	3
Unit 2: Radiation Survey and Monitoring Techniques		
	• Explain the purpose and importance of radiation surveys in medical and research facilities (C2). • Classify radiation areas and survey requirements with explanation (C2). • Selection criteria based on radiation energy, type, and environment. Explain techniques for ambient dose rate and surface contamination assessment (C2). • Explain Routine monitoring in controlled areas: hot labs, patient rooms, storage (C2). • Discuss Wipe testing procedures and contamination action levels (C2). Explain Personnel Monitoring: Use of TLDs, OSLs, and digital dosimeters (C2). • Interpretation of dosimetry reports and dose investigation protocols (C4). • Calibration procedures, performance checks, and response verification (C3). • Maintenance logs, error tracking, and compliance documentation (C4).	15
Unit 3: Design of a Nuclear Medicine Clinical Facility		

	• Overview of nuclear medicine facility functions (diagnostic, therapeutic, radiopharmacy). • Layouts for hot lab, radiopharmacy, imaging rooms (SPECT/PET), injection/waiting areas, waste storage. • Unidirectional movement of staff, patients, and materials. • Shielding principles and material selection. • Shielding requirements for PET/CT, SPECT/CT, and isolation wards. • Design of walls, doors, viewing windows, and bunkers. • HVAC systems: negative pressure ventilation and fume hoods. • Safety interlocks, fire alarms, and emergency exits. • Automation: dose calibrators, synthesis modules, and automated dispensers. • AERB/IAEA guidelines for facility approval. • Documentation required for licensing (layout, shielding report, RSO nomination, QA plan). • Periodic audits and compliance requirements	20
Unit 4: Design of a Medical Cyclotron Facility		
	• Design and workflow of a cyclotron facility: vault, targetry, and radiochemistry lab (C2) • HVAC and negative pressure ventilation systems (C2) • Automation in dose dispensing and synthesis modules (C2) • Safety interlocks and emergency systems (C2) • Waste segregation and decay storage (C20 • National (AERB) and International (IAEA, NCRP, ICRP) regulations and standards (C2) • Licensing process for nuclear medicine and cyclotron facilities (C2) • Radiation safety officer (RSO) roles and responsibilities (C2) • Periodic inspection, record keeping, and audits (C2) • Transport and disposal of radioactive materials (C2)	20
Unit 5: Emergency Preparedness and Risk Management		

	• Handling contamination and spills (C2) • Decontamination procedures and monitoring (C2) • Emergency response planning for overexposure, fire, or equipment failure (C2) • Safety drills and reporting mechanisms (C2) • Case studies of radiological incidents in nuclear medicine or cyclotron settings (C2)	2

Learning Strategies, Contact Hours and Out of Class Engagement:

Learning Strategies	Contact Hours	Out of Class Engagement
Lecture	45	45
Seminar	11	11
Revision	2	2
Assessment	2	2
Total	60	60

Assessment Methods:

Formative	Summative
Unit Test	Mid Semester/ Sessional Exam (Theory)
Quiz	End Semester (Theory)
Assignment/ Presentation	

Mapping of Assessment with Cos:

Nature of Assessment	CO1	CO2	CO3
Mid Semester	**x**	**x**	**x**
Quiz/Unit Test	**x**	**x**	**x**
Assignment/Presentations	**X**	**x**	**x**
End Semester Exam	**x**	**x**	**x**

Feedback Process:	**Mid-Semester Feedback**
	End-Semester Feedback

Main References: Text Books:

1. Physics in Nuclear Medicine – Simon Cherry, James Sorenson, Michael Phelps
2. Radiation Detection and Measurement – Glenn F. Knoll
3. Cyclotrons and Their Applications – John Livingood
4. IAEA Cyclotron Produced Radionuclides: Principles and Practice

Additional References:

1. Quality Assurance for Radioactivity Measurement in Nuclear Medicine – IAEA Technical Reports Series
2. Handbook of Radiopharmaceuticals: Radiochemistry and Applications – Michael J. Welch, Carol S. Redvanly
3. Practical Nuclear Medicine – Peter F. Sharp, Howard G. Gemmell, Alison D. Murray

Research Publication Ethics and Pedagogy

MNM1104

Course Title	**Research Publication Ethics and Pedagogy**
Course Code	**MNM1104**
Academic Year	First Year
Semester	**I**
Number of Credits	3
Course Prerequisite	Basic knowledge of research publication ethics and pedagogy
Course Synopsis	This course equips students with advanced and research methodologies essential for nuclear medicine research. By the end of the course, students will master visualization, alongside expertise in designing clinical trials, observational studies, and systemic reviews.

Course Outcomes

CO No.	Course Learning Outcomes	Bloom's Level
CO1	To understand the principles of Bioethics (C2)	L1 & L2
CO2	To understand the principles of Research publication ethics (C2)	L2
CO3	To understand the different aspects of pedagogy (C4)	L2

Mapping of Course Outcomes (Cos) to program Outcomes (POs):

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1	**x**	**x**						
CO2	**x**	**x**		**x**				
CO3	**x**	**x**						
CO4	**X**	**x**						
CO5	**x**	**x**						

Course Content:

Content	Competencies	Number of Hours
Unit 1: Research and Publication Ethics		
	• Outline the history and evolution of bioethics (C2) • Explain the cardinal principles of bioethics (C2) • Apply national and international bioethical principles (C3) • Outline the principles of ethics in professional practice - clinical, research, academics, administrative domains (C2) Apply the principles of ethics in professional practice (C3) • Outline the general principles of ethics for conduct of research based on ICMR guidelines (C2) • Summarize the characteristics for responsible conduct of research (C2) • Identify potential ethical issues based on risk benefit analysis (C3) • Explain the components and procedures of informed consent process (C2) • Apply suitable methods in obtaining informed consent (C3) • Distinguish special considerations of informed consent process for waivers and proxy consent (C4) • Institutional Review Boards (IRBs): Protocol approval processes; applications in ensuring trial compliance. • Outline the process of ethical review of research proposals (C2) • Relate the types of review based on the research project proposals (C2) • Summarize the roles and responsibilities of IEC and its members (C2) • Define and explain the types of Vulnerability (C2) • Outline the characteristics of special and vulnerable population (C2) • Summarize the challenges for research in vulnerable population (C2) • Apply the ICMR guidelines for research in special and vulnerable population (C3) • Define and explain the types of Conflict of Interest (C2) • Identify and solve potential Conflict of Interest (C3) • List the importance of publishing scholarly works (C4) • Publication ethics: Avoiding plagiarism, authorship disputes; applications in nuclear medicine research. • Examine the criteria of authorship based on ICMJE guidelines (C4) • Test the publication for plagiarism (C4)	15
Unit 2: Pedagogy		

	• Relate 'Systems Approach' in education(C2) • Define and explain the components of curriculum (C2) • Outline the types of curricular frameworks(C2) • Identify the characteristics of curricular frameworks(C3) • Classify domains of learning (C2) Distinguish the levels of mastery for each learning domains (C4) • Outline the elements of specific learning objectives (C3) • Organize specific learning objectives based on domains of learning (C3) • Outline small group teaching methods (C3) • Explain the generic and specific methods of small group teaching (C3) Outline large group teaching methods (C3) • Explain the facilitation methods in large group lectures (C3) • Understand and perform microteaching (C4) • Outline the principles, characteristics and types of assessment (C3) • Identify/Apply appropriate tools for assessment. (C3) • Construct a blueprint of assessment for theory and practical exam (C3)	15

Learning Strategies, Contact Hours and Out of Class Engagement:

Learning Strategies	Contact Hours	Out of Class Engagement
Lecture	30	30
Seminar	11	11
Revision	2	2
Assessment	2	2
Total	45	45

Assessment Methods:

Formative	Summative
Unit Test	Mid Semester/ Sessional Exam (Theory)
Quiz	End Semester (Theory)
Assignment	

Mapping of Assessment with COs:

Nature of Assessment	CO1	CO2	CO3	CO4	CO5
Mid Semester	x	x	x		
Quiz/Unit Test	x	x	x		
Assignment/Presentations	X	x	x		
End Semester Exam	x	x	x		

Feedback Process:	Mid-Semester Feedback
	End-Semester Feedback

Main References: Text Books:

1. Designing Clinical Research – Stephen B. Hulley, Steven R. Cummings, Warren S. Browner, Wolters Kluwer; provides comprehensive research methodology.
2. Practical Statistics for Medical Research – Douglas G. Altman, Chapman & Hall; supports statistical applications in clinical studies.
3. Beauchamp and Childress, Principles of Biomedical Ethics, Fourth Edition. Oxford. 1994.
4. National Ethical guidelines for Biomedical and Health Research involving human participants. Indian Council of Medical Research. 2017.
5. ABC of Learning and Teaching in Medicine. Editor(s): Peter Cantillon, Diana Wood, Sarah Yardley. Ed: 3
6. Understanding Medical Education: Evidence, Theory, and Practice, Editor(s): Tim Swanwick Kirsty Forrest Bridget C. O'Brien. Ed 3

Additional References:

1. Principles of Medical Education. Editor(s): Tejinder Singh, Piyush Gupta, Daljit Singh. Jaypee Brothers. 2012. New Delhi.
2. Patricia A Marshall. Ethical challenges in study design and informed consent for health research in resource poor settings. World Health Organization. 2007.

Practical-I

MNM1105

Course Title	**Practical-I**
Course Code	**MNM1105**
Academic Year	First Year
Semester	**I**
Number of Credits	4
Course Prerequisite	Students should have foundational knowledge of calculus, differential equations, linear algebra, and basic nuclear physics. They should also be familiar with basic programming concepts (Python or MATLAB) and laboratory safety procedures. Prior exposure to Nuclear Medicine imaging concepts is beneficial of core nuclear medicine subjects and general hospital practices.
Course Synopsis	This course provides the student with hands-on competence in the advanced technical aspects of Nuclear Medicine physics, instrumentation, and safety. It covers essential mathematical and computational techniques for image processing and tracer kinetics (modeling), operational and quantification procedures for non-imaging detectors (calibrators), and the practical application of stringent radiation protection and facility design principles. The course emphasizes safe, accurate, and compliant clinical practices.

Course Outcomes

CO No.	Course Learning Outcomes	Bloom's Level
CO1	Perform the essential checks for the dose calibrator and GM counter, and set up the necessary equipment and source for conducting constancy and dead time and measurements (C4, P5)	L3
CO2	Set up non imaging devices to acquire and apply basic quenching correction or self-absorption correction factors to quantify activity in	L3

	samples. (C3, P3)	
CO3	Apply principles of ALARA, facility design (e.g. negative pressure), and regulatory guidelines (AERB/IAEA), and respond by checking the functionality of safety interlocks in a simulated hot lab environment. (C3,P4)	L4
CO4	Analyze the role of RSO and the proper procedure for contamination control, and respond actively and appropriately during a simulated spill drill by executing the established decontamination and monitoring steps.(C3,P3)	L4

Mapping of Course Outcomes (Cos) to program Outcomes (POs):

COs	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**
CO1	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**
CO2	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**
CO3	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**
CO4	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**
CO5	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**

Course Content

Content	Competencies	Number of Hours
Unit 1: Non-Imaging Detectors and Quantification		
	• Test the dose calibrator by performing and recording results for Constancy, Linearity, Accuracy, and Geometry checks using appropriate sources and standards (C4, P4) • Critique the results, identifying any failures, and recommending necessary corrective actions (e.g., adjustment, repair, or restricted use) (C5, P5) • Design and execute a simulated clinical protocol using a thyroid uptake probe to acquire time-activity data for effective half-life determination, including background subtraction techniques (C6, P5) • Deconvolve a prepared complex multi-radionuclide spectrum (e.g., Cs-137 + Co-60) to quantify the activity of each component, manually identifying and marking artifacts like Compton edges and summing peaks (C4, P4) • Derive and apply complex correction factors for self-absorption (volume/density variations) to achieve absolute activity quantification in phantom samples and Measure and correct for pulse pile-up effects at high count rates (C5, P5) • Operate the counter to measure background and known sources: Quantify the limitations at high count rates by measuring a high-activity source and applying the dead time correction formula to determine the true rate (C3, P4) • Given various scenarios (e.g., high-level therapy room, low-level bench contamination), select and use the appropriate survey instrument (GM, Ion Chamber, Proportional Counter), justifying the choice based on energy dependence and dose rate response (C5, P4) • Differentiate the effects of color vs. chemical quench on a spectrum. Apply a quench correction method to a quenched sample to determine the true disintegration rate (C4, P4) • Design and execute a TDCR (Triple-to-Double Coincidence Ratio) measurement protocol for the absolute standardization of a pure beta emitter (Y-90 or Sr-89), requiring no external standard (C6, P5)	15

Unit 2: Automation, Safety Systems, and Facility Design

	• Operate a simulated or real automated dose dispenser or synthesis module. Illustrate the systematic workflow steps, contrasting the reproducibility with a manual dispensing task (C4, P4) • Critically examine the layout of a provided hot lab floor plan. Describe the primary and secondary shielding placements and illustrate the separation of clean vs. contaminated zones, justifying the design based on guidelines (C5, P4) • Explain and verify the function of the negative pressure ventilation system and the specialized fume hood within the hot lab (e.g., by observing differential pressure gauges or flow indicators) (C4, P4) • Summarize the essential function of safety interlocks and emergency shutdown systems (e.g., power cutoff, ventilation shutdown) in a simulated high-activity scenario and Identify key regulatory compliance points (C4, P3) • Design a minor modification to an existing hot lab layout to accommodate a new therapeutic agent,ensuring safety and regulatory compliance (C6, P5)	15
Unit 3: Radiation Protection, Safety Principles, and Monitoring Techniques		
	• Calculate primary and secondary barrier thicknesses for a simulated SPECT room, given the isotope (99m-Tc), maximum workload, occupancy factor, and use factor (C3, P3) • Explain the principles of dose limitation and in the design (C2, P1) • Perform an area radiation survey in a simulated hot lab environment and classify the measured areas (controlled/supervised) and select the appropriate survey instrument (e.g., Ion Chamber for dose rate) based on the environment (C4, P4) • Execute standard wipe testing procedures for various surfaces in a radiopharmacy setting and calculate the removable contamination level in and compare the result to regulatory action levels (C3, P4) • Interpret provided simulated dosimetry reports and analyze a scenario of a high reading, initiating a dose investigation protocol and perform a simple performance check on a personal digital dosimeter (C4, P4) • Develop a maintenance log and schedule for survey meters and analyze historical maintenance records to document compliance with periodic co	15

Unit 4: Design of a Nuclear Medicine Clinical Facility		
	• Design a conceptual floor plan for a small Nuclear Medicine department (hot lab, SPECT/CT room, injection/uptake area). Illustrate the unidirectional movement of staff, patients, and materials to minimize cross-contamination (C6, P5) • Specify the required shielding materials and thicknesses for a PET/CT imaging room and a therapy isolation ward based on known source activities. Design the components of a shielded viewing window and door (C6, P5) • Analyze a provided schematic for a radiopharmacy to explain how negative pressure is maintained and where the air exhausts and identify the placement of safety interlocks (e.g., dose calibrator door interlock) (C6, P5) • Compile a simulated AERB/IAEA licensing documentation package, including the facility layout, a summary of the plan, and the designated Radiation Safety Officer roles and responsibilities (C6, P5)	5
Unit 5: Cyclotron Design and Emergency Preparedness		
	• Analyze a provided cyclotron facility floor plan (vault, targetry, chemistry lab) and describe the workflow for F-18 FDG production, focusing on the role of automated synthesis modules and waste segregation areas (C4, P4) • Summarize the 's primary responsibilities related to regulatory compliance (AERB/IAEA) and examine a case study of a violation and explain the necessary corrective actions and record-keeping requirements (C5, P3) • Conduct a simulated minor radioactive spill drill in the hot lab. Execute the including area and personnel monitoring, and the proper segregation of spill waste (C3, P4) • Develop a simplified emergency response plan for a major radiological incident (e.g., overexposure or a fire near the decay storage) and explain the safety drills, communication protocols, and reporting mechanisms to internal and external agencies (C6, P5)	10

Learning Strategies, Contact Hours and Out of Class Engagement:

Learning Strategies	Contact Hours	Out of Class Engagement
Small group Learning (SGD)	5	15
Problem Based Learning (PBL)	5	15

Case Based Learning (CBL)	5	15
Clinic	45	-
Total	60	45

Assessment Methods:

Formative	**Summative**
Unit Test	Mid Semester (Practical)
Quiz	Viva
Viva	Log book
Clinical assessment (OSCE, OSPE, WBPA)	End semester exam
Clinical/ practical Log book/ Record book	

Mapping of Assessment with COs:

Nature of Assessment	**CO1**	**CO2**	**CO3**	**CO4**	**CO5**	**CO6**
Mid Semester Examination	**x**	**x**	**x**	**x**	**x**	**x**
Quiz/Viva	**x**	**x**	**x**	**x**	**x**	**x**
Clinical/Practical Logbook/ Record Book	**X**	**x**	**x**	**x**	**x**	**x**
Clinical assessment (OSCE, OSPE, WBPA)	**x**	**x**	**x**	**x**	**x**	**x**

Feedback Process:	**Mid-Semester Feedback**
	End-Semester Feedback

Main References: Text Books:

1. Radiopharmaceuticals in Nuclear Medicine Pharmacy and Nuclear Medicine - Kowalsky, Richard J., and Steven W. Falen
2. Nuclear Medicine-The Requisites: Harvey A. Ziessman, JanisP.O'Malley, JamesH.Thrall

Additional References:

1. Radiopharmaceuticals and Hospital Radiopharmacy Practices - N. Ramamoorthy BRIT
2. Radiation safety in Nuclear Medicine –AERB Mumbai
3. Nuclear Medicine Technology: Procedures and Quick Reference–Pete Shackett

Clinical Practice-I

MNM1106

Course Title	**Clinical Practice-I**
Course Code	**MNM1106**
Academic Year	First Year
Semester	**I**
Number of Credits	4
Course Prerequisite	Students should have knowledge of core nuclear medicine subjects and general hospital practices.
Course Synopsis	This course will give training for the candidate to prepare & safely handle the radiopharmaceuticals for clinical applications in Nuclear Medicine department, expose them to the different imaging and non-imaging Nuclear Medicine procedures, to maintain documentations and stock inventory.

Course Outcomes:

At the end of the course, students should be able to:

CO No.	Course Learning Outcomes	Bloom's Level
CO1	Safely handle radioisotopes, practice radiation safety and regulatory norms (C4, P4, A4)	L4
CO2	Perform various quality control checks of equipment, radiopharmaceutical etc. and address trouble shooting (C4, P5, A5)	L4
CO3	Perform various clinical Nuclear Medicine procedures (C4, P5, A5)	L4
CO4	Maintain record keeping and stock inventory for diagnostic nuclear medicine. Learn the importance of effective communication, team work, ethical values and professionalism (C3, P4, A5)	L3
CO5	Apply the importance of effective communication, teamwork, ethical values and professionalism (C3, P3, A5)	L3

Mapping of Course Outcomes (Cos) to program Outcomes (POs):

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1	x	x	x	x	x	x	x	x
CO2	x	x	x	x	x	x	x	x
CO3	x	x	x	x	x	x	x	x
CO4	x	x	x	x	x	x	x	x
CO5	x	x	x	x	x	x	x	x

Course Content:

Content	Competencies	Number of Hours
Unit 1: Radiopharmacy Practices (SPECT and PET)		
	• To set Radiopharmacy (SPECT, PET) lab for daily activities (P3) • To identify and produce the inventory(C3) • To evaluate QC of dose calibrator (C3, P5) • To prepare and dispense radiopharmaceuticals (C3, P5) • To evaluate QC of radiopharmaceutical (C3, P5) • To express procedures to patient and to practice as per regulatory guidelines (C3, P4, A5) • Documentation and record keeping (C3)	50
Unit 2: Scintigraphy Practices		
	• To set imaging room (SPECT, PET) for daily activities (P3) • To practice and evaluate daily QC of imaging (SPECT, PET) and other accessory devices (C3, P4) • To take required patient history for the procedure (C3, A5) • To express procedures to patient and to practice as per regulatory guidelines (C3, A5) • To perform scans and processing techniques (C3, P4, A5) • Documentation and record keeping (C3)	50
Unit 3: CT and MRI Practices		
	• To set the imaging room for daily activities (P3) • To practice and evaluate daily QC of imaging and other accessory device (C3, P4) • To take required patient history for the procedure (C3, P4, A5) • To express procedure to patient and to practice as per regulatory guideline (C3, P4, A5) • To perform scan and processing techniques (C3, P4, A4) • Documentation and record keeping (C3)	35

Learning Strategies, Contact Hours and Out of Class Engagement:

Learning Strategies	Contact Hours	Out of Class Engagement
Small group Learning (SGD)	5	15
Problem Based Learning (PBL)	5	15
Case Based Learning (CBL)	5	15
Clinic	120	-
Total	135	45

Assessment Methods:

Formative	Summative
Unit Test	Mid Semester (Practical)
Quiz	Viva
Viva	Log book
Clinical assessment (OSCE, OSPE, WBPA)	End semester exam
Clinical/ practical Log book/ Record book	

Mapping of Assessment with COs:

Nature of Assessment	CO1	CO2	CO3	CO4	CO5	CO6
Mid Semester Examination	**x**	**x**	**x**	**x**	**x**	**x**
Quiz/Viva	**x**	**x**	**x**	**x**	**x**	**x**
Clinical/Practical Logbook/ Record Book	**x**	**x**	**x**	**x**	**x**	**x**
Clinical assessment (OSCE, OSPE, WBPA)	**x**	**x**	**x**	**x**	**x**	**x**

Feedback Process:	**Mid-Semester Feedback**
	End-Semester Feedback

Main References: Text Books:

1. Radiopharmaceuticals in Nuclear Medicine Pharmacy and Nuclear Medicine - Kowalsky, Richard J., and Steven W. Falen
2. Nuclear Medicine-The Requisites: Harvey A. Ziessman, JanisP.O'Malley, JamesH.Thrall

Additional References:

1. Radiopharmaceuticals and Hospital Radiopharmacy Practices - N. Ramamoorthy BRIT
2. Radiation safety in Nuclear Medicine –AERB Mumbai
3. Nuclear Medicine Technology: Procedures and Quick Reference–Pete Shackett

SEMESTER-II

Course Code	Course Title
MNM1201	Advanced Biostatistics and Research Methodology
MNM1202	Advanced Nuclear Medicine Instrumentation
MNM1203	SPECT & PET radiopharmaceuticals
MNM1204	Computers in Nuclear Medicine
MNM1205	Practicum- II
MNM1206	Clinical Practice- II

Advanced Biostatistics and Research Methodology
Course Code MNM1201

Course Title	**Advanced Biostatistics and Research Methodology**
Course Code	**MNM1201**
Academic Year	First Year
Semester	**II**
Number of Credits	3
Course Prerequisite	Basic knowledge of Biostatistics at B.Sc. NM level.
Course Synopsis	This course equips students with advanced biostatistical techniques and research methodologies essential for nuclear medicine research.

Course Outcomes:

CO No.	Course Learning Outcomes	Bloom's Level
CO1	Apply the concepts of probability distribution, hypothesis testing and other statistical tools to real world problems (C4)	L4
CO2	Explain the steps involved in a research process, epidemiology and observational study designs (C2)	L2
CO3	Apply statistical methods to conduct systematic reviews and metaanalysis (C4)	L4

Mapping of Course Outcomes (Cos) to program Outcomes (POs):

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1	**x**	**x**						
CO2	**x**	**x**						

CO3	**x**	**x**						

Course Content:

Content	Competencies	Number of Hours
Unit 1: Advanced Statistical Methods I		
Probability and Distributions	• Recall the basic concepts of Biostatistics (C1) • Explain the concepts of conditional probability and Bayes' theorem and apply them to evaluate the accuracy of diagnostic tests such as sensitivity and specificity (C3) • Analyze and interpret advanced probability distributions — Poisson, negative binomial, and log-normal — and apply them in modeling phenomena such as radioactive decay counts (C4) Explain the principles of sampling distributions and the central limit theorem, and compute confidence intervals to estimate population parameters (C3)	5
Hypothesis Testing and Power Analysis	• Explain the principles of parametric tests such as ANOVA, ANCOVA, and paired t-tests, and apply these methods to compare results across different imaging modalities (C3) • Differentiate and apply appropriate non-parametric tests such as Kruskal–Wallis and Wilcoxon signed-rank tests for analyzing non-normally distributed uptake data (C4) • Compute and interpret effect size and statistical power, and design suitable sample size calculations for clinical or PET imaging studies(C4)	5
Statistical Software	• Demonstrate proficiency in R programming for data manipulation and statistical modeling, and apply these techniques to analyze Standardized Uptake Value (SUV) data (C4) • Utilize SPSS or SAS software to perform advanced statistical analyses and interpret outputs from multicenter clinical trial data (C40 • Create effective data visualizations using tools such as G gplot2 and forest plots to present and communicate research findings (C4)	5
Applications in Nuclear Medicine	• Analyze diagnostic accuracy by constructing and interpreting ROC curves to evaluate the specificity and sensitivity of diagnostic imaging (C4) • Design imaging-based clinical trials by calculating and justifying appropriate sample sizes for PET-CT response studies (C4) • Generate and interpret boxplots using R programming to visualize SPECT cardiac uptake data (C4)	5

Unit 2: Advanced Statistical Methods II		
Regression Analysis	• Apply multiple linear regression techniques to adjust for confounding variables and predict Standardized Uptake Value (SUV) based on patient-specific factors (C4) • Develop and interpret logistic regression models to analyze binary outcomes such as tumor recurrence in PSMA PET studies (C4) • Construct and evaluate Cox proportional hazards models to perform survival analysis for therapy outcomes in Lu-177 clinical trials (C4)	5
Multivariate Methods	• Implement principal component analysis (PCA) to reduce dimensionality in high-resolution imaging datasets and extract meaningful radiomic features in PET data (C4) • Apply cluster analysis to identify and interpret distinct patient subgroups for tumor classification in nuclear medicine datasets (C4) • Use mixed-effects models to analyze repeated-measure data and interpret longitudinal trends in serial PET scans (C4)	5
Bayesian Statistics	• Explain the principles of Bayesian inference and apply prior and posterior probability distributions to update diagnostic probabilities in clinical imaging (C3) • Perform Markov Chain Monte Carlo (MCMC) simulations to model complex probabilistic systems in dosimetry estimation (C4) • Design and evaluate Bayesian adaptive clinical trials for optimizing decision-making in nuclear medicine research (C4) • Predict tumor response by applying logistic regression models to PET-CT outcome data (C4) • Classify neuroendocrine tumor (NET) profiles by applying PCA and clustering techniques to PET imaging datasets (C4) • Model and interpret survival outcomes using Cox regression to assess treatment efficacy in Lu-177 therapy trials (C4)	5
Unit 3: Research Design and Methodology		
Research Design and Methodology	• Explain the research process and describe various research designs with flowchart (C2) • Explain different methods of data collection and data sources (C2) • Define Epidemiology, Demography and Vital statistics (C1) • What are the sources of demographic data and vital statistics (C1) • Define and distinguish rate, ratio and proportion (C1) • Explain prevalence and incidence (C2) • Explain each measure of morbidity, mortality and fertility rates by stating the formula (C2)	5

	• Explain the observational study designs (case report, case series, case-control,cross-sectional, ecological) (C2) • Differentiate among various randomized controlled trial (RCT) designs such as parallel and crossover, and apply these designs to compare imaging modalities like SPECT and PET (C4) • Design and evaluate adaptive clinical trials incorporating interim analyses and sample size re-estimation for theranostic nuclear medicine studies (C4) • Interpret and apply the CONSORT guidelines to ensure standardized and transparent reporting of nuclear medicine clinical trials (C4) • Explain and differentiate prospective and retrospective cohort study designs, and apply them to evaluate long-term PET imaging outcomes (C3) • Construct and analyze case-control studies using matching and odds ratio estimation to assess radiation exposure risks (C4) • Implement STROBE guidelines to promote transparency and improve the reporting quality of observational imaging studies (C4)	
Systematic Reviews and Meta-Analysis, Data Management	• Conduct comprehensive literature searches using PubMed, Scopus, and PRISMA protocols to synthesize evidence from PET-CT studies. (C4) • Compute and interpret effect sizes using fixed and random-effects models for meta-analysis of diagnostic accuracy studies (C4) • Assess heterogeneity across studies by calculating and interpreting I^2 and Q statistics to evaluate variability in nuclear medicine research (C4) • Design and implement relational databases using SQL queries to organize and manage imaging trial datasets efficiently (C4) • Apply data cleaning techniques to identify, handle, and rectify issues such as missing values and outliers to ensure the integrity of PET datasets (C4) • Explain and apply FAIR data principles and utilize data repositories to enable secure and interoperable data sharing in multicenter nuclear medicine studies (C3)	5

Learning Strategies, Contact Hours and Out of Class Engagement:

Learning Strategies	Contact Hours	Out of Class Engagement
Lecture	30	30
Seminar	11	11
Revision	2	2
Assessment	2	2
Total	45	45

Assessment Methods:

Formative	Summative
Unit Test	Mid Semester/Sessional Exam (Theory)
Quiz	End Semester (Theory)
Assignment/Presentation	-

Mapping of Assessment with COs:

Nature of Assessment	CO1	CO2	CO3
Mid Semester Examination	**x**	**x**	**-**
Quiz/Viva	**x**	**x**	**x**
Assignments/Presentations	**x**	**x**	**x**
End Semester Exam	**x**	**x**	**x**

Feedback Process:	Mid-Semester Feedback
	End-Semester Feedback

Main References: Text Books:

1. Biostatistics: A Foundation for Analysis in the Health Sciences – Wayne W. Daniel, Chad L. Cross, Wiley; covers advanced statistical methods for medical research.
2. Designing Clinical Research – Stephen B. Hulley, Steven R. Cummings, Warren S. Browner, Wolters Kluwer; provides comprehensive research methodology.
3. Practical Statistics for Medical Research – Douglas G. Altman, Chapman & Hall; supports statistical applications in clinical studies.

Additional References:

1. Medical Statistics: A Textbook for the Health Sciences – Michael J. Campbell, David Machin, Stephen J. Walters, Wiley; detailed guide to biostatistics.
2. Systematic Reviews in Health Care: Meta-Analysis in Context – Matthias Egger, George DaveySmith, Douglas G. Altman, BMJ Books; covers meta-analysis techniques.
3. R for Data Science – Hadley Wickham, Garrett Grolemund, O'Reilly; supports statistical programming for research

Advanced Nuclear Medicine Instrumentation

Course Code MNM1202

Course Title	**Advanced Nuclear Medicine Instrumentation**
Course Code	**MNM1202**
Academic Year	First Year
Semester	**II**
Number of Credits	3
Course Prerequisite	Basic knowledge of Nuclear medicine instrumentation at B.Sc. NM level.
Course Synopsis	This course provides an in-depth understanding of advanced nuclear medicine instrumentation, focusing on imaging systems critical for diagnostic and therapeutic applications.

Course Outcomes:

CO No.	Course Learning Outcomes	Bloom's level
CO1	To understand working and recent advances in gamma camera, SPECT and PET camera (C2)	L2
CO2	To understand working and recent advances in CT and MRI (C2)	L2
CO3	To understand and compare hybrid imaging systems (C4)	L4

Mapping of Course Outcomes (COs) to Program Outcomes (POs):

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1	**x**	**x**						
CO2	**x**	**x**						
CO3	**x**	**x**						

Course Content:

Content	Competencies	Number of Hours
Unit 1: Imaging Instrumentation I		
Planar Gamma Camera	• Overview of clinically relevant non-ionizing radiation-based imaging (C1) • Overview of planar gamma cameras (C1) • Historical evolution from Hal Anger's design to digital systems (C1) • Explain principle and working of gamma imaging (C2) • Explain the role of position logic circuit and event localization in gamma camera image formation (C2) • Discuss different types of collimators (C2) • Evaluate the factors affecting resolution of gamma camera (C5) • Discuss different types of collimators (C2) • Discuss image artifacts (C2) • Apply correction techniques for corrections of image artifacts in gamma camera (C3)	5
SPECT Systems	• Overview of SPECT systems (C1) • Discuss attenuation effects in SPECT imaging (C2) • Apply attenuation correction methods to counter attenuation effects (C3) • Discuss scatter effects in SPECT imaging and apply its correction (C3) • Discuss partial volume effects in SPECT imaging and apply its correction (C3) • Historical evolution from early tomography (1970s) to CZT-based systems (2000s) (C2) • Discuss principles of solid-state detection for 3D imaging components.	7
Positron Emission Tomography (PET)	• Overview of PET systems (C1) • Recall working principle of PET (C1) • Discuss silicon photomultipliers (SiPMs) and digital photon counting (C2) • Discuss application of monolithic and semi-monolithic crystals in PET (C2) • Discuss recent improvements such as TOF PET (C2) • Discuss total-body/long axial field of view systems (C2) • Discuss newer scintillator materials and hybrid materials for PET imaging (C2)	5

Unit 2: Imaging Instrumentation II		
Computed Tomography (CT)	• Review of CT principles and generations (C1). • Discuss advances in tube design (C2) • Discuss advances in detector technologies (C2) • Discuss advances in gantry, geometry and mechanics (C2) • Analyse methods for radiation dose optimization in CT (C4)	**5**
Magnetic Resonance Imaging	• Review evolution and working principle of MRI (C1) • Discuss advances in Magnet technology (C2) • Discuss advances in gradient coil system (C2) • Discuss advances in RF coil systems (C2) • Discuss advances in data acquisition and reconstruction (C2) • Discuss integration of AI and Smart instrumentation with MRI (C2)	5
Unit 3: Imaging Instrumentation III		
SPECT-CT Systems	• Overview of SPECT-CT; historical evolution from standalone to hybrid systems (1990s) (C1) • Discuss the Design of hybrid gantries (C2) • Discuss the registration and calibration between SPECT and CT (C2) • Discuss advantages of solid-state (CZT/CdTe) detectors (C2) • Discuss calibration methods, standardization and correction methods (C2) • Discuss image fusion algorithms and software packages (C2)	**7**
PET-CT Systems	• Overview of PET-CT; historical evolution from separate to integrated systems (2000s) (C1) • Compare PET vs PET/CT (C4) • Discuss CT based corrections in PET (C2) • Discuss registration and fusion algorithms for PET/CT (C2) • Discuss work flow optimization and radiation dose • management (C2)	6
PET-MRI Systems	• Overview of PET-MRI; historical evolution (C1) • Compare PET/CT vs PET/MRI (C4) • Discuss MRI architecture and integration with PET, challenges (C2) • Discuss registration and fusion algorithms for PET/MRI (C2) • Discuss roles of MRI in motion correction and attenuation accuracy (C2)	5

Learning Strategies, Contact Hours and Out of Class Engagement:

Learning Strategies	Contact Hours	Out of Class Engagement
Lecture	30	30
Seminar	11	11
Revision	2	2
Assessment	2	2
Total	45	45

Assessment Methods:

Formative	Summative
Unit Test	Mid Semester/Sessional Exam (Theory)
Quiz	End Semester (Theory)
Assignment/Presentation	
Feedback Process:	Mid-Semester Feedback
	End-Semester Feedback

Main References: Text Books:

1. Nuclear Medicine Physics: The Basics – Ramesh Chandra, Wolters Kluwer
2. Nuclear Medicine and PET/CT: Technology and Techniques – Paul E. Christian, Kristen M. Waterstram-Rich, Mosby
3. Physics in Nuclear Medicine – Simon Cherry, James Sorenson, Michael Phelps, Elsevier

Additional References:

1. Molecular Imaging: Principles and Practice – Ralph Weissleder, Brian D. Ross, Alnawaz Rehemtulla, BC Decker
2. Practical Nuclear Medicine – Peter F. Sharp, Howard G. Gemmell, Alison D. Murray, Springer
3. Handbook of Nuclear Medicine and Molecular Imaging – E. Dana Dana, Beckman, Dong-Soo Lee, Ukihide Tateishi, Biomedical
4. NEMA Standards Publication NU 2-2018: Performance Measurements of Positron Emission Tomographs – National Electrical Manufacturers Association

SPECT & PET Radiopharmaceuticals

Course Code MNM1203

Course Title	**SPECT & PET Radiopharmaceuticals**
Course Code	**MNM1203**
Academic Year	First Year
Semester	**II**
Number of Credits	3
Course Prerequisite	Basic knowledge of chemistry and radiopharmacy for Nuclear medicine instrumentation at B.Sc. NM level.
Course Synopsis	By the end of this course students will gain a comprehensive understanding of the principles and practices involved in SPECT & PET radiopharmaceuticals, including the production, radiolabelling, and quality control of clinically used agents. This module will prepare the students to contribute effectively in both clinical and research environments.

Course Outcomes

CO No.	Course Learning Outcomes	Bloom's Level
CO1	Understand and explain about various gamma emitting radio pharmacy and Radiopharmaceuticals used in nuclear medicine (C2)	L2
CO2	To understand synthesis of PET radiopharmaceuticals (C2)	L2
CO3	To understand Drug Development and Trials for nuclear medicine (C2)	L3

Mapping of Course Outcomes (COs) to Program Outcomes (POs):

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1	**x**	**x**						
CO2	**x**	**x**						
CO3	**x**	**x**					**X**	**X**

Course Content

Content	Competencies	Number of Hours
Unit 1: 99mTc- labelled Radiopharmaceuticals		
99mTc-labelled Radiopharmaceuticals	• Explain Technetium Chemistry (C2). • Explain Labeling with 99mTc- Sodium pertechnetate (C2) • Outline Evolution of 99mTc-labelled Radiopharmaceuticals (C2). • Explain Coordination Chemistry of commonly used 99mTc-labelled Radiopharmaceuticals (C2) • Infer monographs for 99mTc-labelled Radiopharmaceuticals (C1)	**05**
Radioiodine-labelled radiopharmaceuticals	• Explain radio Iodine Chemistry (C2) • Describe the production, physical and chemical characteristics, biological behavior of different isotopes of Iodine (C2) • Compare and identify merits and demerits of various radio-iodination methods (C3) • Describe synthesis, quality control and clinical applications of Iodine labelled radiopharmaceuticals (C2)	**05**
Unit 2: PET Radiopharmaceuticals		
	• To understand the designing of PET radiopharmacy as per the regulatory guidelines (C2) • To explain packaging and transportation of cyclotron produced radioisotopes/radiopharmaceuticals (C2) • To understand production of F-18, C-11, N-13 and O-15 (C2) • To understand radiochemistry of PET radiopharmaceuticals - F-18, C-11, N-13 and Oxygen-15 etc. (C2) • To explain about various F-18 labelled radiotracers of clinical uses like F-18 FDG, F-18 FLT, F-DOPA. (C2) • To understand automated synthesis Modules, need, description, design, and applications, miniaturized automatic radio synthesis modules. (C2) radiopharmaceuticals, Cu-64 and Zr-89 labelled radiopharmaceuticals. (C2) • To know description of PET radionuclide generators, elution efficiency and QC, Rb-82, Ga-68 chemistry, Ga-68 labelled various radiopharmaceuticals, Cu-64 and Zr-89 labelled radiopharmaceuticals. (C2) • To outline processes in the release of produced PET radiopharmaceuticals, Outline of tools &techniques for PET radiopharmaceuticals. TLC, HPLC, gas chromatography methods; Waste disposal and radiation safety procedures (C2) • To understand the task specific safe handling of PET	**20**

	radiopharmaceuticals. (C2)	
Unit 3: Drug Development and Trials		
	• Overview of radiopharmaceutical drug development: From concept to clinical use • Preclinical studies: In vitro assays, animal biodistribution, dosimetry • Phases of clinical trials: Phase 0 (microdosing), Phase I (safety), Phase II (efficacy), Phase III (large-scale efficacy), Phase IV (post-marketing) • Regulatory frameworks: AERB, CDSCO, FDA, EMA guidelines for radiopharmaceuticals • Good Clinical Practice (GCP): Ethical considerations, informed consent, IRB approval • Clinical trial design in nuclear medicine: Randomized controlled trials, diagnostic accuracy studies • Case studies: Development of Tc-99m sestamibi, Ga-68 PSMA, Lu-177 PSMA • Challenges in radiopharmaceutical trials: Short half-lives, radiation safety • Post-approval monitoring: Pharmacovigilance, adverse event reporting • Emerging trends: Theranostics, personalized radiopharmaceuticals	**15**

Learning Strategies, Contact Hours and Out of Class Engagement:

Learning Strategies	Contact Hours	Out of Class Engagement
Lecture	30	30
Seminar	11	11
Revision	2	2
Assessment	2	2
Total	45	45

Assessment Methods:

Formative	Summative
Unit Test	Mid Semester/Sessional Exam (Theory)
Quiz	End Semester (Theory)
Assignment/Presentation	-

Mapping of Assessment with COs:

Nature of Assessment	CO1	CO2	CO3	CO4
Mid Semester Examination	**X**	**-**	**-**	**-**
Quiz/Viva	**X**	**X**	**X**	**X**
Assignments/Presentations	**X**	**X**	**X**	**X**
End Semester Exam	**X**	**X**	**X**	**X**

Feedback Process:	Mid-Semester Feedback
	End-Semester Feedback

Main References: Text Books:

1. Nuclear Medicine and Molecular Imaging: The Requisite by Janis P. O'Malley, Harvey A. Ziessman, and James H. Thrall

2. Essential Nuclear Medicine Physics by Rachel A. Powsner and Edward R. Powsner

3. Nuclear Medicine Physics: The Basics by Ramesh Chandra

4. FOOD & DRUG ADMINISTRATION, FDA Guidance for Industry: Medical Imaging Drug and Biological Products, Part 1: Conducting Safety Assessments, (2004).

5. SIEGEL, J.A., et al., MIRD pamphlet no. 16; Techniques for quantitative radiopharmaceutical biodistribution data acquisition and analysis for use in human radiation dose estimates, J Nucl Med 40 2 (1999) 37S-61S.

Additional References:

1. STABIN, M.G., MIRDOSE: personal computer software for internal dose assessment in nuclear medicine, J Nucl Med 37 3 (1996) 538-46.

2. STABIN, M.G., SIEGEL, J.A., Physical models and dose factors for use in internal dose assessment, Health Phys 85 (2003) 294- 310.

3. Software manuals: OLINDA/EXM, IDAC-Dose 2.1INTERNATIONAL COMMISSION ON RADIATION UNITS AND MEASUREMENTS, Absorbed-dose specification in Nuclear Medicine, ICRU Rep. 67, Bethesda, MD (2002). Morrison, R.T. & Boyd, R.N. Organic Chemistry, Pearson, 2010.

Computers in Nuclear Medicine

Course Code MNM1204

Course Title	**Computers in Nuclear Medicine**
Course Code	**MNM1204**
Academic Year	First Year
Semester	**II**
Number of Credits	3
Course Prerequisite	Basic knowledge of Computers at B.Sc. NM level.
Course Synopsis	This course provides students with advanced mathematical and computational skills tailored for nuclear medicine applications. By the end of the course, students will master linear algebra, calculus, differential equations, and stochastic processes, enabling precise modeling of tracer kinetics and image reconstruction. They will gain proficiency in programming languages (e.g., Python, MATLAB) and nuclear medicine software (e.g., 3D Slicer, GE Xeleris) for image processing, dosimetry, and workflow automation. The course emphasizes practical applications, such as reconstructing F-18 FDG PET images using SVD, simulating Lu-177 dose distributions with Monte Carlo methods, and automating SPECT quality control with Python scripts, equipping students with the technical expertise to enhance imaging accuracy and research efficiency in nuclear medicine.

Course Outcomes

Course Learning Outcomes	Bloom's level
To apply Computational Algorithms in Nuclear Medicine (C3)	L3
To use Programming and Software Tools relevant to nuclear medicine (C3)	L3
To use computer algorithms for evaluating tracer kinetics in Nuclear Medicine (C3)	L3

Mapping of Course Outcomes (COs) to Program Outcomes (POs):

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1	**x**	**x**				**x**		

CO2	**x**	**x**				**x**		
CO3	**x**	**x**				**x**		

Course Content

Content	Competencies	Number of Hours
Unit 1: Computational Algorithms in Nuclear Medicine		
Image Processing Algorithms	• To apply Edge detection: Sobel, Canny filters; in segmenting PET tumor boundaries (C3). • To apply morphological operations: Dilation, erosionin refining SPECT organ contours (C3). • To apply registration algorithms: Rigid, non-rigid transformations in aligning PET-CT datasets (C3).	3
Numerical Methods for Imaging	• To apply Iterative solvers: Conjugate gradient for large systems in SPECT reconstruction (C3). • To apply regularization techniques: Tikhonov, total variation in reducing PET noise artifacts(C3). • To apply interpolation methods: Bilinear, spline interpolation in resampling PET-MRI images (C3).	3
Simulation Techniques	• To apply Monte Carlo simulations: GATE, Geant4 for radiation modeling in simulating Tc-99m scatter(C3). • To apply Finite element methods: Solving PDEs for tracer diffusion in modeling Lu-177 distribution (C3). • To apply Parallel computing: GPU-based algorithms in accelerating PET reconstruction (C3).	2
Applications in Nuclear Medicine	• To Segment tumors using edge detection for PET in neuroendocrine tumors (C3). • To simulate therapy doses using Geant4 for Lu-177 dose distribution.	2
Unit 2: Programming and Software Tools		
Programming Languages	• To apply Python: NumPy, SciPy in processing PET data. • To apply MATLAB: Image Processing Toolbox in analysing SPECT images (C3). • To apply C++, High-performance computing in optimizing PET reconstruction.	3
Software Development	• To understand code optimization: Vectorization, memory management applications in speeding up image processing (C2). • To understand Version control: Git, GitHub for collaborative coding applications in managing research scripts (C2).	4

	• To understand Debugging: Profiling, error handling applications in ensuring robust dosimetry programs (C2).	
Nuclear Medicine Software	• To apply DICOM processing: Pydicom, ITK for image handling, applications in managing PET-CT datasets (C3). • To use Open-source tools: 3D Slicer, ImageJ; in visualizing images (C3). • To use Vendor-specific software: GE Xeleris, Siemens Syngo in processing SPECT data (C3). • To process PET images: Using Python to analyze uptake in oncology scans. • To visualize SPECT data and apply 3D Slicer for lung perfusion images (C3). • To optimize algorithms using C++ to accelerate PET reconstruction (C3).	3
Unit 3: Computational Applications in Nuclear Medicine		
Tracer Kinetic Modeling:	• Use of computers in Compartmental analysis: One-, two-compartment models; applications in quantifying F-18 FDG metabolism (C3). • Use of computers for Non-linear fitting: Levenberg-Marquardt algorithm; applications in fitting uptake curves (C3). • Use of computers for Parametric imaging: Voxel-wise kinetic parameters; applications in brain PET studies (C3).	**3**
Dosimetry Computations	• Use of computers for Dose estimation: MIRD formalism implementation; applications in calculating I-131 thyroid doses(C3). • Use of computers for Voxel-based dosimetry: S-value calculations; applications in Lu-177 therapy planning. • Software tools: OLINDA/EXM, IDAC-Dose; applications in estimating organ doses (C3).	**4**
Workflow Automation	• To apply Batch processing for Automating image analysis and in processing multiple PET-CT scans (C3). • To apply Data integration: Combining imaging and clinical data; applications in multicenter trial analysis (C3). • To apply Scripting workflows: Bash, Python scripts in streamlining SPECT QC analysis, renogram data sets etc. (C3).	**3**

Learning Strategies, Contact Hours and Out of Class Engagement:

Learning Strategies	Contact Hours	Out of Class Engagement
Lecture	30	30
Seminar	11	11
Revision	2	2
Assessment	2	2
Total	45	45

Assessment Methods:

Formative	Summative
Unit Test	Mid Semester/Sessional Exam (Theory)
Quiz	End Semester (Theory)
Assignment/Presentation	-

Mapping of Assessment with COs:

Nature of Assessment	CO1	CO2	CO3
Mid Semester Examination	**X**	-	-
Quiz/Viva	**X**	**X**	**X**
Assignments/Presentations	**X**	**X**	**X**
End Semester Exam	**X**	**X**	**X**

Feedback Process:	Mid-Semester Feedback
	End-Semester Feedback

Main References: Text Books:

1. Mathematics for Medical Imaging – Chandra K. Chui, Springer; covers advanced mathematical methods for imaging.
2. Computational Nuclear Medicine – Michael Ljungberg, CRC Press; provides computational techniques for nuclear medicine.
3. Numerical Methods for Engineers – Steven C. Chapra, Raymond P. Canale, McGraw-Hill; supports numerical algorithms.

Additional References:

1. Introduction to Scientific Computing with MATLAB – Ian Gladwell, James G. Nagy, Warren E. Ferguson, SIAM; supports programming for imaging.
2. Monte Carlo Calculations in Nuclear Medicine – Michael Ljungberg, Sven-Erik Strand, CRC Press; covers simulation techniques.
3. Image Processing and Analysis – Richard A. Robb, Oxford University Press; supports computational image processing.
4. Python for Data Analysis – Wes McKinney, O'Reilly; supports programming for nuclear medicine data

Practical-II

Course Code MNM1205

Course Title	**Practical-II**
Course Code	**MNM1205**
Academic Year	First
Semester	**II**
Number of Credits	4
Course Prerequisite	Students should have knowledge of core nuclear medicine subjects and general hospital practices
Course Synopsis	This course will give training for the candidate to prepare & safely handle the radiopharmaceuticals for clinical applications in Nuclear Medicine department, expose them to the different imaging and non-imaging Nuclear Medicine procedures, to maintain documentations and stock inventory.

Course Outcomes

CO No.	Course Learning Outcomes	Bloom's level
CO1	Evaluate the performance of NaI(Tl) detection systems by quantitatively measuring the effects of electronic settings and external fields (magnetic) on energy resolution (FWHM) and signal stability (C5, P4)	L5
CO2	Design and implement a deconvolution algorithm to analyze complex, composite gamma-ray spectra, accurately quantifying the activity of multiple components while correcting for interfering factors (C6, P5)	L6
CO3	Design a comprehensive protocol for an emerging radiopharmaceutical (e.g., Ga-68 PSMA), and model the decomposition kinetics of a Tc-99m agent over time to establish a rigorous, validated shelf-life (C6, P5)	L6
CO4	Evaluate Mo-99/Tc-99m generator performance under varied conditions, and design an experiment to determine and model the energy dependence of linear attenuation coefficients across different materials (C6, P5)	L6
	Formulate and assess the performance of an in house cold kit, and	

CO5	develop a formalized protocol for the safe dispensing and administration of a high-activity therapeutic radiopharmaceutical (Lu-177) including patient specific considerations (C6, P5)	L6

Mapping of Course Outcomes (COs) to Program Outcomes (POs):

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**
CO2	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**
CO3	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**
CO4	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**
CO5	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**

Course Content

Content	Competencies	Number of Hours
Unit 1: Radiation Detection Physics, Signal Processing, and Quantitative Spectroscopy		
	• Design and execute a study to evaluate the effects of varying linear amplifier gain and shaping time on the energy resolution (FWHM) and signal-to-noise ratio (SNR) of a NaI(Tl) spectrum (Cs-137), determining the optimal setting for spectroscopy (C5, P4) • Acquire the composite gamma-ray energy spectrum of a mixture (e.g., Ba-133+ Cs-137) and develop and implement a matrix-based deconvolution algorithm to accurately quantify the activity of each component, correcting for Compton scattering interference (C6, P5) • Design a protocol to determine the absolute intrinsic efficiency of NaI(Tl) the detector as a function of gamma-ray energy, using multiple certified standard sources and derive the efficiency curve (C6, P5) • Design a practical experiment to quantitatively measure the degree of photomultiplier tube (PMT) signal degradation (gain shift, FWHM broadening) caused by a known external magnetic field and evaluate the effectiveness of passive magnetic shielding materials (e.g., mu-metal) in mitigating this effect (C5, P4) • Determine the half-life of a clinical isotope (). Apply non-linear	**45**

	least-squares fitting techniques to the decay data to extract the half-life and its uncertainty (C4, P4) • Design an experiment to determine the linear attenuation coefficients for a single high-Z material and a single low-Z material across three distinct gamma-ray energies (C6, P5) • Determine the **System Spatial Resolution** (FWHM) and **Sensitivity** of a SPECT collimator (e.g., LEHR) using a pinpoint source (e.g., 99m-Tc) and **derive the Iso-Response Function (IRF)** by mapping the across the FWHM detector face, analyzing uniformity and linearity (C5, P4)	
Unit 2: SPECT and PET Radiopharmacy		
	• Assess and model the secular/transient equilibrium of the Mo-99/Tc-99m generator system. Predict and verify the Tc-99m activity yield at various time points post-elution using decay equations and compare predicted vs. measured values (C5, P4) • Evaluate the quantitative performance of a Mo-99/Tc-99m generator by determining Elution Efficiency and Elution Profile under varied conditions (e.g., changes in elution volume or time) and critique the results to establish optimal operating parameters for a specific (C5, P4) • Design and execute a stability study for a single complex Tc-99m radiopharmaceutical (Tc-99mMIBI or Tc-99mEC) and model the decomposition kinetics over time and under thermal stress, using or advanced to establish a quantitatively rigorous shelf-life and stability profile (C6, P5) • For a clinically emerging radiopharmaceutical (e.g. Ga-68 PSMA or Cu-64 DOTATATE), design a comprehensive Quality Control (QC) protocol and include quantitative methods for determining Radiochemical purity (RCP), Radionuclide purity (RNP), and sterility/endotoxin testing (C6, P5) • Develop and participate in a formalized dispensing and administration protocol for a therapeutic radiopharmaceutical (C4, P3) • Formulate a cold (DTPA or MDP simplified kit) from raw chemical components. Assess the performance of the reconstituted product by evaluating its and its susceptibility to reducing agent and metal ion contamination, establishing formulation optimization parameters (C6, P5)	**60**

Learning Strategies, Contact Hours and Out of Class Engagement:

Learning Strategies	Contact Hours	Out of Class Engagement
Small group Learning (SGD)	5	15
Problem Based Learning (PBL)	5	15
Case Based Learning (CBL)	5	15
Clinic	90	-
Total	**105**	45

Assessment Methods:

Formative	Summative
Unit Test	Mid Semester (Practical)
Quiz	Viva
Clinical assessment (OSCE, OSPE, WBPA)	End Semester Exam
Clinical / practical Logbook/ Record book	-

Mapping of Assessment with COs:

Nature of Assessment	CO1	CO2	CO3	CO4	CO5	CO6
Mid Semester Examination	x	x	x	x	x	x
Quiz/Viva	x	x	x	x	x	x
Clinical/Practical Logbook/Record Book	x	x	x	x	x	x
Clinical assessment (OSCE, OSPE, WBPA)	x	x	x	x	x	x

Feedback Process:	Mid-Semester Feedback
	End-Semester Feedback

Main References: Text Books:

1. Radiopharmaceuticals in Nuclear Medicine Pharmacy and Nuclear Medicine - Kowalsky, Richard J., and Steven W. Falen
2. Nuclear Medicine-The Requisites: Harvey A. Ziessman, Janis P.O'Malley, James H.Thrall

Additional References:

1. Radiopharmaceuticals and Hospital Radiopharmacy Practices - N. Ramamoorthy BRIT
2. Radiation safety in Nuclear Medicine –AERB Mumbai
3. Nuclear Medicine Technology: Procedures and Quick Reference–Pete Shack

Clinical Practice-II

Course Code: MNM1206

Course Title	**Clinical Practice-II**
Course Code	**MNM1206**
Academic Year	First Year
Semester	**II**
Number of Credits	4
Course Prerequisite	Students should have knowledge of core nuclear medicine subjects and general hospital practices
Course Synopsis	This course will give training for the candidate to prepare & safely handle the radiopharmaceuticals for clinical applications in Nuclear Medicine department, expose them to the different imaging and non-imaging Nuclear Medicine procedures, to maintain documentations and stock inventory.

Course Outcomes

CO No.	Course Learning Outcomes	Bloom's level
CO1	Safely handle radioisotopes, practice radiation safety and regulatory norms (C4, P4, A4)	L4
CO2	Perform various quality control check of equipment, radiopharmaceutical etc. and address trouble shooting for therapeutic nuclear medicine procedures (C4, P5, A5)	L4
CO3	Perform various clinical therapeutic nuclear medicine procedure (C4, P5, A5)	L4
CO4	Maintain recordkeeping and stock inventory for therapeutic nuclear medicine. Learn the importance of effective communication, team work, ethical values and professionalism (C3, P4, A5)	L3
CO5	Apply knowledge of patient care, safety protocols and quality assurance (C4, P4, A4) (C3, P3, A5)	L4

Mapping of Course Outcomes (COs) to Program Outcomes (POs):

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1	x	x	x	x	x	x	x	x
CO2	x	x	x	x	x	x	x	x
CO3	x	x	x	x	x	x	x	x
CO4	x	x	x	x	x	x	x	x
CO5	x	x	x	x	x	x	x	x

Course Content

Content	Competencies	Number of Hours
Unit 1: Radiopharmacy Practices (Therapy)		
	• To set Radiopharmacy (therapy) lab for daily activities (P3) • To identify and produce the inventory(C3) • To evaluate QC of dose calibrator (C3, P5) • To prepare and dispense radiopharmaceuticals (C3, P5) • To evaluate QC of radiopharmaceutical (C3, P5) • To take required patient history for the procedure (C3, A5) • To express procedures to patient and to practice as per regulatory guidelines (C3, P4, A5) • To produce radiation exposure records (C3) • Documentation and record keeping (C3)	50
Unit 2: In-vitro Nuclear Medicine Practices		
	• To locate and identify to check inventory(C3) • To evaluate QC of various non-imaging and radiation monitoring equipment (C3, P5) • To perform in-vitro procedures (C3, P5, A5) • To operate various non-imaging and radiation monitoring equipment (C3, P5) • To produce radiation surveillance reports (C3, P4) • Documentation and record keeping (C3)	50
Unit 3: CT and MRI Practices		

	• To set the imaging room for daily activities (P3) • To practice and evaluate daily QC of imaging and other accessory device (C3, P4) • To take required patient history for the procedure (C3, P4, A5) • To express procedure to patient and to practice as per regulatory guideline (C3, P4, A5) • To perform scan and processing techniques (C3, P4, A4) • Documentation and recordkeeping (C3)	50

Learning Strategies, Contact Hours and Out of Class Engagement:

Learning Strategies	**Contact Hours**	**Out of Class Engagement**
Small group Learning (SGD)	5	15
Problem Based Learning (PBL)	5	15
Case Based Learning (CBL)	5	15
Clinic	90	-
Total	**105**	45

Assessment Methods:

Formative	**Summative**
Unit Test	Mid Semester (Practical)
Quiz	Viva
Viva	Logbook
Clinical assessment (OSCE, OSPE, WBPA)	End Semester Exam
Clinical / practical Logbook/ Record book	-

Mapping of Assessment with COs:

Nature of Assessment	**CO1**	**CO2**	**CO3**	**CO4**	**CO5**	**CO6**
Mid Semester Examination	**x**	**x**	**x**	**x**	**x**	**x**

Quiz/Viva	**x**	**x**	**x**	**x**	**x**	**x**
Clinical/Practical Logbook/Record Book	**x**	**x**	**x**	**x**	**x**	**x**
Clinical assessment (OSCE, OSPE, WBPA)	**x**	**x**	**x**	**x**	**x**	**x**

Feedback Process:	Mid-Semester Feedback
	End-Semester Feedback

Main References: Text Books:

1. Radiopharmaceuticals in Nuclear Medicine Pharmacy and Nuclear Medicine - Kowalsky, Richard J., and Steven W. Falen
2. Nuclear Medicine-The Requisites: Harvey A. Ziessman, Janis P.O'Malley, James H.Thrall

Additional References:

1. Radiopharmaceuticals and Hospital Radiopharmacy Practices - N. Ramamoorthy BRIT
2. Radiation safety in Nuclear Medicine –AERB Mumbai
3. Nuclear Medicine Technology: Procedures and Quick Reference–Pete Shacke

SEMESTER-III

Course Code	Course Title
MNM2301	Artificial Intelligence in Nuclear Medicine
MNM2302	Clinical nuclear medicine
MNM2303	Image Analysis
MNM2304	Research project-I
MNM2305	Clinical Practice-III
MNM2301	Artificial Intelligence in Nuclear Medicine

Artificial Intelligence in Nuclear Medicine

Course Code: MNM2301

Course Title	**Artificial Intelligence in Nuclear Medicine**
Course Code	**MNM2301**
Academic Year	Second
Semester	**III**
Number of Credits	3
Course Prerequisite	Fundamentals of computer science and understanding of computer programming
Course Synopsis	This course equips students with advanced computational and artificial intelligence (AI) skills tailored for nuclear medicine applications. By the end of the course, students will master data preprocessing, machine learning, and deep learning techniques, enabling automated analysis of PET, SPECT, and hybrid imaging data. They will gain proficiency in high-performance computing (e.g., GPU, cloud) and AI tools (e.g., CNNs, YOLO) for lesion detection, radiomics, and theranostic planning. The course emphasizes practical applications, such as segmenting Ga-68 PSMA PET tumors, predicting Lu-177 therapy outcomes, and integrating AI into PACS for streamlined workflows, preparing students to leverage cutting-edge technologies for precise diagnostics, ethical AI deployment, and enhanced clinical decision-making in nuclear medicine.

Course Outcomes

CO No.	Course Learning Outcomes	Bloom's level
CO1	To apply advanced computational technique in Nuclear medicine(C3)	L4
CO2	To apply Machine Learning Fundamentals for Nuclear Medicine(C3)	L4
CO3	To apply AI in Diagnostics and Theranostic Nuclear Medicine (C3)	L4
CO4	To understand and apply Ethical consideration in AI (C3)	L3

Mapping of Course Outcomes (COs) to Program Outcomes (POs):

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1	**x**	**x**						
CO2	**x**	**x**						
CO3	**x**	**x**						
CO4	**x**	**x**		**x**				

Course Content:

Content	Competencies	Number of Hours
Unit1: Advanced Computational Techniques in Nuclear Medicine		
General Introduction	Data Preprocessing and Integration: • DICOM processing: Parsing, standardizing imaging data; applications in managing image datasets (C3). • Data normalization: Scaling, harmonization across scanners; applications in multicenter studies (C3). • Multi-modal integration: Combining PET, CT, MRI data; applications in hybrid imaging analysis (C3). Computational Image Processing: • Advanced filtering: Anisotropic diffusion, non-local means; applications in denoising SPECT images (C3). • Segmentation: Watershed, active contours; applications in delineating tumors (C3). • o Feature extraction: Texture, shape features; applications in preparing data for AI models. (C3)	**10**

	High-Performance Computing: • Parallel processing: GPU acceleration with CUDA; applications in speeding up PET image analysis (C3). • Cloud computing: AWS, Azure for scalable processing; applications in handling large-scale imaging trials (C3). • Distributed computing: Apache Spark for big data; applications in analyzing multi-site SPECT data (C3). • Applications in Nuclear Medicine: • Standardizing PET data: Normalizing PET-CT datasets for oncology trials (C3). • Segmenting neuroendocrine tumors: Using active contours for PET images (C3). • Accelerating analysis: Implementing GPU-based processing (C3).)	
Unit 2: Machine Learning Fundamentals for Nuclear Medicine		
	Supervised Learning: • Classification: Support vector machines, random forests; applications in classifying PET tumor malignancy (C3). • Regression: Ridge, lasso regression; applications in predicting SUV from patient covariates (C3). • Model evaluation: ROC curves, cross-validation; applications in validating diagnostic models (C3). Unsupervised Learning: • Clustering: K-means, hierarchical clustering; applications in grouping cardiac uptake patterns (C3). • Dimensionality reduction: t-SNE, UMAP; applications in visualizing PET radiomics data (C3). • Anomaly detection: Isolation forests; applications in identifying abnormal scans (C3). Machine Learning Pipelines: • Feature selection: Recursive feature elimination; applications in optimizing PET-CT feature sets (C3). • Hyperparameter tuning: Grid search, random search; applications in improving model performance (C3). • Workflow automation: Scikit-learn pipelines; applications in streamlining F-18 FDG analysis (C3). Applications in Nuclear Medicine: • Classifying tumors: Using random forests for PET-CT lung cancer diagnosis (C3). • Clustering uptake patterns: Applying K-means to scans (C3). • Detecting anomalies: Using isolation forests for PET quality control(C3).	**08**

Deep Learning in Nuclear Medicine	Convolutional Neural Networks (CNNs): • Architecture: Layers, kernels, pooling; applications in detecting lesions in PET-CT (C3). • Transfer learning: Pre-trained models (e.g., ResNet); applications in tumor segmentation (C3). • 3D CNNs: Volumetric analysis; applications in analyzing SPECT cardiac data (C3). Advanced Deep Learning Models: • Recurrent neural networks (RNNs): LSTM for time-series; applications in dynamic F-18 FDG PET analysis (C3). • Generative adversarial networks (GANs): Synthetic image generation; applications in augmenting datasets (C3). • Attention mechanisms: Transformer-based models; applications in focusing on PET tumor regions (C3). Training and Optimization: • Loss functions: Cross-entropy, Dice loss; applications in optimizing PET segmentation models (C3). • Optimization algorithms: Adam, RMSprop; applications in training CNNs for SPECT analysis (C3). • Overfitting prevention: Dropout, data augmentation; applications in improving model robustness (C3). Applications in Nuclear Medicine: • Detecting lesions: Using CNNs for F-18 FDG PET-CT oncology imaging (C3). • Segmenting tumors: Applying transfer learning for Ga-68 PSMA PET prostate cancer (C3). Analyzing dynamic scans: Using LSTMs for F-18 FDG PET brain kinetics (C3).	**08**
Unit4: AI Applications in Diagnostics and Theranostic		
	• AI-Driven Diagnostics: • Automated lesion detection: YOLO, Faster R-CNN; applications in identifying Tc-99m MDP bone scan metastases (C3). • Disease classification: Deep learning for dementia; applications in F-18 florbetapir PET-MRI diagnosis (C3). • Predictive modeling: Survival prediction; applications in Lu-177 PSMA therapy outcomes (C3). • Radiomics and Theranostics • Radiomic feature extraction: Pyradiomics for texture analysis; applications in Ga-68 DOTATATE PET prognosis (C3). • AI in dosimetry: Predicting organ doses; applications in	**10**

	I-131 therapy planning (C3). • Theranostic integration: AI for patient selection; applications in Lu-177 therapies (C3). • Clinical Decision Support • Decision trees: Rule-based systems; applications in PET report generation (C3). • Natural language processing (NLP): Report summarization; applications in structuring F-18 FDG PET-CT reports (C3). • Explainable AI: SHAP, LIME for model transparency; applications in validating Tc-99m MIBI diagnostics (C3). • Applications in Nuclear Medicine: • Detecting metastases: Using YOLO for Tc-99m MDP bone scan analysis (C3). • Predicting therapy outcomes: Applying AI models for Lu-177 PSMA survival analysis. (C3) • Generating reports: Using NLP to summarize F-18 FDG PET-CT findings (C3).	
Unit5: Ethics, Validation, and Workflow Integration		
	Ethical Considerations in AI: • Bias mitigation: Ensuring diverse datasets; applications in equitable PET diagnostics (C3). • Patient privacy: GDPR, HIPAA compliance; applications in securing imaging data. Transparency: Ethical AI deployment; applications in explaining AI results (C3). AI Model Validation: • Regulatory frameworks: FDA/EMA AI guidelines; applications in validating PET-CT AI tools (C3). • Performance metrics: Sensitivity, specificity, AUC; applications in assessing models (C3). • Clinical validation: Prospective trials; applications in deploying PET AI systems (C3). Workflow Integration: • PACS integration: Embedding AI in imaging systems; applications in streamlining image analysis (C3). • Clinical workflow optimization: AI for scan prioritization; applications in managing PET schedules (C3). • Interoperability: HL7, FHIR standards; applications in integrating PET AI with EHRs (C3) • Applications in Nuclear Medicine: • Ensuring equitable diagnostics: Mitigating bias in PET-CT AI models (C3). • Validating AI tools: Conducting trials for PET tumor	

	detection algorithms (C3). • Optimizing workflows: Integrating AI for scan prioritization (C3).	

Learning Strategies, Contact Hours and Out of Class Engagement:

Learning Strategies	**Contact Hours**	**Out of Class Engagement**
Lecture	30	30
Seminar	11	11
Revision	2	2
Assessment	2	2
Total	**45**	**45**

Assessment Methods:

Formative	**Summative**
Unit tests	Mid Semester (Theory)
Quiz	End Semester (Theory)
Assignments/presentations	

Mapping of Assessment with COs:

Nature of Assessment	**CO1**	**CO2**	**CO3**	**CO4**
Mid Semester Examination	**x**			
Quiz/Viva	**x**	**x**	**x**	**x**
Clinical/Practical Logbook/Record Book	**x**	**x**	**x**	**x**
Clinical assessment (OSCE, OSPE, WBPA)	**x**	**x**	**x**	**x**

Feedback Process:	Mid-Semester Feedback
	End-Semester Feedback

Main References: Text Books:

1. Artificial Intelligence in Medical Imaging – Erik R. Ranschaert, Sergey Morozov, Paul R. Algra, Springer; covers AI applications in nuclear medicine.
2. Deep Learning for Medical Image Analysis – S. Kevin Zhou, Hayit Greenspan, Dinggang Shen, Academic Press; provides deep learning techniques for imaging.
3. Computational Nuclear Medicine – Michael Ljungberg, CRC Press; supports computational methods for nuclear medicine.

Additional References:

1. Machine Learning in Medicine – Ton J. Cleophas, Aeilko H. Zwinderman, Springer; supports machine learning applications.
2. Radiomics and Radiogenomics – Ruijiang Li, Lei Xing, Sandy Napel, CRC Press; covers radiomics for nuclear medicine.
3. Artificial Intelligence in Healthcare – Adam Bohr, Kaveh Memarzadeh, Springer; addresses ethics and validation.
4. Python for Data Science – Wes McKinney, O'Reilly; supports programming for AI applications

Clinical Nuclear Medicine Imaging

Course Code MNM2302

Course Title	**Clinical nuclear medicine imaging**
Course Code	**MNM2302**
Academic Year	Second
Semester	**III**
Number of Credits	3
Course Prerequisite	Basic understanding of Clinical nuclear medicine at B.Sc. NM level.
Course Synopsis	By the end of this course students will gain a comprehensive understanding of routine clinical SPECT and PET protocols. The course aims to enhance skills in analyzing clinical nuclear medicine studies, identifying and minimizing sources of error, and developing optimized protocols for accurate patient dosimetry estimation.

Course Outcomes

CO No.	Course Learning Outcomes	Bloom's Level
CO1	To create Protocols for routine clinical SPECT and PET Procedures (C6)	L6
CO2	To analyse clinical studies and sources of error (C5)	L5
CO3	To develop and optimize clinical protocols for the estimation of patient dosimetry	L6

Mapping of Course Outcomes (COs) to Program Outcomes (POs):

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1	**x**	**x**	**x**					
CO2	**x**	**x**	**x**					
CO3	**x**	**x**	**x**					
CO4	**x**	**x**	**x**					

Course Content:

Content	Competencies	Number of Hours
Unit1: Protocols for routine clinical SPECT Procedure		
	• To prepare protocol for Cardiac Studies: static blood pool imaging, Rest/stress myocardial imaging, infarct imaging, MUGA, gated blood pool study, first pass study (shunt detection), Tl-201 imaging (C6) • To prepare protocol for Brain perfusion imaging (C6)	15
Unit 2: Protocols for routine clinical PET Procedure		
	• Overview of kinetic modelling and Standardized Uptake Value (SUV) (C1) • Clinical application and methods for performing PET/CT procedures in Neurology (FDOPA, FLT) and Oncology (F-18 FDG, Ga-68-TATE/PSMA), Infection imgaing (F-18 FDG WBC Scan) (C3) • To prepare Gated PET/CT studies (respiratory and cardiac gating) (C6) • To use F-18 FDG and N-13 NH3 for cardiac studies (C6). • To use PET in treatment planning and to study treatment response (C6).	15
Unit 3: Analysis of clinical studies and sources of error		
	• Overview of types of studies performed on SPECT, PET, and Planar imaging system (C1) • To Define classify and evaluate errors in terms of radiopharmaceutical preparation, patient preparation, instrumentation: collimators, PMTs, detectors, software and reconstruction artifacts (Filter settings, matrix size, scatter correction) (C5) • To evaluate Motion Artifacts, Attenuation correction artifacts (misregistration, CT noise) (C5) • Introduction to error impact on image interpretation (C2) • Pattern recognition and error tracing in common scans, interpreting normal vs technical abnormal patterns (C5) Importance of QC, SOPs, Error documentation and log maintenance (C2)	10
Unit 4: Developing and optimization of clinical protocols for the estimation of patient dosimetry		
	• Overview of imaging protocols and quantitative methods for patient-specific dose estimation (C1) • Components of dosimetry protocol-Image acquisition, timing, and quantification (C2) • Factors affecting protocol optimization: Patient related, instrumentation related, and radiopharmaceutical related (C4) • Designing and validating new protocol (C6)	5

Learning Strategies, Contact Hours and Out of Class Engagement:

Learning Strategies	Contact Hours	Out of Class Engagement
Lecture	30	30
Seminar	11	11
Revision	2	2
Assessment	2	2
Total	**45**	**45**

Assessment Methods:

Formative	Summative
Unit tests	Mid Semester/Sessional Exam
Quiz	End Semester Exam
Assignments/presentations	

Mapping of Assessment with COs:

Nature of Assessment	CO1	CO2	CO3
Mid Semester Examination	**x**		
Quiz/ Unit Test	**x**	**x**	**x**
End Semester Exam	**x**	**x**	**x**

Feedback Process:	Mid-Semester Feedback
	End-Semester Feedback

Main References: Text Books:

1. Nuclear Medicine and Molecular Imaging: The Requisite by Janis P. O'Malley, Harvey A. Ziessman, and James H. Thrall

2. Essential Nuclear Medicine Physics by Rachel A. Powsner and Edward R. Powsner

3. Nuclear Medicine Physics: The Basics by RameshChandra

Additional References:

1. FOOD & DRUG ADMINISTRATION, FDA Guidance for Industry: Medical Imaging Drug and Biological Products, Part 1: Conducting Safety Assessments, (2004).

2. SIEGEL, J.A., et al., MIRD pamphlet no. 16: Techniques for quantitative radiopharmaceutical biodistribution data acquisition and analysis for use in human radiation dose estimates, J Nucl Med 40 2 (1999) 37S-61S.

3. INTERNATIONAL COMMISSION ON RADIATION

4. UNITS AND MEASUREMENTS, Absorbed-dose specification in Nuclear Medicine, ICRU Rep. 67, Bethesda, MD (2002)

Image Analysis

Course Code MNM2303

Course Title	**Image Analysis**
Course Code	**MNM2303**
Academic Year	Second
Semester	**III**
Number of Credits	2
Course Prerequisite	A foundational understanding of nuclear medicine, digital signal processing (DSP), and linear algebra is required to comprehend the mathematical and physical principles of image formation and reconstruction algorithms.
Course Synopsis	This course provides a comprehensive study of nuclear medicine image reconstruction and analysis, covering the theoretical basis of analytic and iterative reconstruction techniques (FBP, OSEM, MLEM), quantitative analysis methods (SUV, kinetic modeling),

Course Outcomes

CO No.	Course Learning Outcomes	Bloom 's Level
CO1	Explain the fundamental principles of image formation models and analytic reconstruction techniques, including the Radon transform, filtered back projection (FBP), and the Central Slice Theorem, as applied in SPECT and PET imaging systems (C2)	L2
CO2	Apply iterative reconstruction algorithms (e.g., MLEM, OSEM) and regularization techniques (e.g., Total Variation, Penalized Likelihood) to enhance image quality by optimizing the balance between noise reduction and resolution in various nuclear medicine scans (C3)	L3
CO3	Analyze quantitative metrics (e.g., SUV, TLG) and kinetic modeling techniques (e.g., Patlak, Logan plots) from nuclear medicine images, and evaluate the diagnostic utility of image registration and fusion for multi-modal imaging (PET-CT/MRI) (C4)	L4

Mapping of Course Outcomes (COs) to Program Outcomes (POs):

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1	x	x	x	x	x	x	x	x
CO2	x	x	x	x	x	x	x	x
CO3	x	x	x	x	x	x	x	x

Course Content:

Content	Competencies	Number of Hours
Unit 1: Fundamentals of Image Reconstruction		
	Image Formation Models: (C2) • Forward projection: Radon transform, system matrix; applications in modeling PET photon detection. • Back projection: Filtered back projection (FBP) principles; applications in SPECT image formation. • Noise models: Poisson statistics in nuclear imaging; applications in optimizing reconstructions. Analytic Reconstruction: (C2) • FBP algorithms: Ramp, Hann filters; applications in reconstructing SPECT images. • Fourier-based methods: Central slice theorem; applications in fast PET reconstruction. • Limitations: Streaking, noise amplification; applications in evaluating PET quality. System Response Modeling: (C2) • Point spread function (PSF): Detector resolution effects; applications in PET image sharpening. • Collimator response: Geometric efficiency in SPECT; applications in image accuracy. • Attenuation and scatter: Modeling photon interactions; applications in PET corrections. Applications in Nuclear Medicine: (C3) • Reconstructing SPECT images: Using FBP for cardiac imaging. • Modeling PET data: Applying PSF for PET oncology scans. • Correcting scatter: Simulating photon interactions in PET reconstructions. ·	20
Unit 2: Iterative Reconstruction Techniques		

	Iterative Algorithms: (C2) • Maximum likelihood expectation maximization (MLEM): Statistical modeling; applications in PET image clarity. • Ordered subset expectation maximization (OSEM): Accelerated convergence; applications in PET-CT. • Bayesian reconstruction: Prior-based methods; applications in reducing Tc-99m SPECT noise Regularization Techniques: (C2) • Total variation (TV): Edge-preserving smoothing; applications in PET denoising. • Penalized likelihood: Quadratic, Huber penalties; applications in balancing noise and resolution. • Sparse regularization: L1-norm for compressed sensing; applications in low-dose PET imaging. Advanced Corrections: (C3) • Attenuation correction: CT-based, MRI-based maps; applications in accurate SUV for PET. • Scatter correction: Single scatter simulation; applications in improving PET contrast. • Motion correction: Respiratory, cardiac gating; applications in nuclear medicine scans. Applications in Nuclear Medicine: (C3) • Enhancing PET images: Using OSEM for PET oncology imaging. • Reducing SPECT noise: Applying TV regularization for cardiac scans. • Correcting motion: Implementing gating for PET neuroendocrine imaging.	20
Unit 3: Quantitative Image Analysis		
	Region of Interest (ROI) and Volume of Interest (VOI) Analysis: (C2) • Manual segmentation: Defining ROIs/VOIs; applications in quantifying PET tumor uptake. • Automated segmentation: Thresholding, region growing; applications in prostate cancer analysis. • Quantitative metrics: SUV mean, max, peak, total lesion glycolysis (TLG); applications in therapy response assessment. Kinetic Modeling: (C2) • Compartmental models: One-, two-compartment analysis; applications in PET brain metabolism. • Non-linear fitting: Patlak, Logan plots; applications in quantifying kinetics. • Parametric imaging: Voxel-wise rate constants; applications in nuclear medicine image analysis	20

	Image Registration and Fusion: (C3) • Rigid registration: Translation, rotation; applications in aligning PET-CT datasets. • Non-rigid registration: Deformable models; applications in PET-MRI brain imaging. • Multi-modal fusion: Combining PET, CT, MRI; applications in enhancing diagnostic accuracy. Applications in Nuclear Medicine: (C3) • Quantifying tumor uptake: Measuring SUV for PET-CT in lung cancer. • Modeling renal function: Using Patlak plots for renogram kinetics. • Fusing PET-MRI: Aligning PET with MRI for neuroendocrine tumors.	

Learning Strategies, Contact Hours and Out of Class Engagement:

Learning Strategies	**Contact Hours**	**Out of Class Engagement**
Lecture	5	15
Seminar	5	15
Revision	5	15
Assessment		-
Total	**60**	**60**

Assessment Methods:

Formative	**Summative**
Unit tests	Mid Semester
Quiz	End Semester Exam
Assignments/presentations	

Mapping of Assessment with COs:

Nature of Assessment	**CO1**	**CO2**	**CO3**
Mid Semester Examination	**x**	**x**	**x**

Quiz/ Unit Test	**x**	**x**	**x**
End Semester Exam	**x**	**x**	**x**

Feedback Process:	Mid-Semester Feedback
	End-Semester Feedback

Main References: Text Books:

1. Quantitative Analysis in Nuclear Medicine Imaging – Habib Zaidi, Springer; covers advanced image analysis techniques.
2. Image Reconstruction in Radiology – J.A. Seibert, CRC Press; provides comprehensive reconstruction methods.
3. Medical Image Analysis – Atam P. Dhawan, Wiley; supports quantitative and radiomics analysis.

Additional References:

1. Nuclear Medicine Physics: The Basics – Ramesh Chandra, Wolters Kluwer
2. Quality Control in Nuclear Medicine – James A. Ponto, Society of Nuclear Medicine
3. Nuclear Medicine and PET/CT: Technology and Techniques – Paul E. Christian, Kristen M. Waterstram-Rich, Mosby

Research Project-I

Course Code: MNM2304

Course Title	**Research Project-I**
Course Code	**MNM2304**
Academic Year	Second
Semester	**III**
Number of Credits	10
Course Prerequisite	Training in research methodology, research ethics and statistics ethics. Knowledge of various clinical And research domains of nuclear medicine
Course Synopsis	The course will help students learn, the approach to identify a research problem, frame hypothesis, understanding its disciplinary or interdisciplinary nature and learn to work independently or as part of a team. They will be mentored in preparing appropriate research protocols and methods to answer research questions, analyzing findings and drawing conclusions. The students will know how to clearly present, communicate and defend their study to critical evaluators and experts.

Course Outcomes

CO No.	Course Learning Outcomes	Bloom's Levels
CO1	Understand the process and get trained in designing, drafting, executing are search study(C1, P1, A1)	L1
CO2	Understand regulatory aspects involved in research (C3,P3,A2)	L3
CO3	Conduct research experiments relevant to their study (C3,P3,A2)	L3

Mapping of Course Outcomes (COs) to Program Outcomes (POs):

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1	**x**	**x**	**-**	**-**	**-**	**-**	**-**	**-**

CO2	**x**	**-**	**-**	**x**	**-**	**-**	**-**	**-**
CO3	**x**	**-**	**x**	**-**	**-**	**-**	**-**	**-**

Course Content:

Content	**Competencies**	**Number of Hours**
Unit1		
	Understand research domains and techniques in Nuclear Medicine (C1, P1, A1)	100
Unit2		
	Identify research problem through literature survey, design research protocol and present for study approval (C3, P3, A2)	100
Unit3		
	Plan and organize research under supervision (C3, P3, A2)	100

Learning Strategies, Contact Hours and Out of Class Engagement:

Learning Strategies	**Contact Hours**	**Out of Class Engagement**
Lecture	0	0
Practical		300
Total		**300**

Assessment Methods:

Formative	**Summative**
Quiz/Viva	Mid Semester/Sessional Exam (Presentation)
Any others: WPBA	End Semester Exam-NA
Assignments/presentations	

Mapping of Assessment with COs:

Nature of Assessment	**CO1**	**CO2**	**CO3**

Mid Semester/ Sessional Examination	**x**	**x**	**x**
Quiz/ Viva	**-**	**x**	**x**
Assignments/Presentations	**x**	**x**	**x**
Any others: WPBA	**x**	**x**	**x**

Feedback Process:	Mid-Semester Feedback
	End-Semester Feedback

Main References:

- Research journals, Scientific literatures

Clinical Practice-III

Course Code MNM-2305

Course Title	**Clinical Practice-III**
Course Code	**MNM-2305**
Academic Year	Second
Semester	**III**
Number of Credits	2
Course Prerequisite	Students should have knowledge of core nuclear medicine subjects and general hospital practices.
Course Synopsis	This course provides an in-depth, case-based study of advanced clinical interpretation, radiopharmaceutical quality control correlation, hybrid imaging analysis, and theranostic management for expert hospital nuclear medicine practice.

Course Outcomes

CO No.	Course Learning Outcomes	Bloom's Level
CO1	Critically analyze radiopharmaceutical quality control data, correlate failures with resulting image artifacts or biodistribution errors, and troubleshoot complex clinical cases involving non-pathological tracer uptake anomalies (C5, P6, A4)	L5
CO2	Master the advanced interpretation of multi-modal fusion images (SPECT/CT, PET/CT), accurately apply and interpret quantitative metrics (SUV, LVEF, Perfusion Quantification), and systematically recognize and mitigate complex image artifact (C5, P6, A4)	L5
CO3	Apply principles of patient-specific dosimetry and clinical criteria to select, plan, and manage radionuclide therapy (theranostics), and analyze post-therapy imaging to assess treatment response and manage adverse events (C4, P5, A3)	L4

Mapping of Course Outcomes (COs) to Program Outcomes (POs):

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1	x	x	x	x	x	x	x	x
CO2	x	x	x	x	x	x	x	x
CO3	x	x	x	x	x	x	x	x

Course Content:

Content	Competencies	Number of Hours
Unit 1: Advanced Radiopharmacy Quality Control and Clinical Correlation		
Radiopharmaceutical Analysis and Pitfalls	• To analyse in-depth and interpret radiochemical purity testing results (e.g., chromatography, TLC) and correlate with potential clinical image artifacts or biodistribution errors (C4, P4, A3) • To analyse clinical significance and management of radiopharmaceutical contaminants (breakthrough, free pertechnetate) (C5, P5, A4) • To interpret advanced Quality Assurance (QA) for PET radiopharmaceuticals (e.g., ^{18}F –labeled agents) including sterility, checks, and endotoxin testing, and the clinical implications of QC failures (C5, P6,A4)	15
Dose Administration and Patient-Specific Considerations	• Pharmacokinetics and Dosimetry: To Clinically apply MIRD formalism and patient-specific dosimetry calculations, especially for therapeutic agents (^{131} I, ^{177}Lu, ^{90} Y) (C3, P5, A3) • Factors affecting biodistribution and image quality: To analyse drug interactions, patient condition (renal/hepatic impairment), and technical administration errors and troubleshoot cases of abnormal tracer uptake due to non-pathological causes (C4, P6, A4)	10
Unit 2: Scintigraphy: Multi-Modal Imaging Analysis and Reporting		

Integrated Image Interpretation (SPECT/CT, PET/CT, PET/MR)	• To interpret advanced fusion images, focusing on the synergistic role of the anatomical (CT/MR) and functional (SPECT/PET) components (C4, P5, A4) • Artifact Recognition and Correction: to perform detailed analysis of complex image artifacts (patient motion, attenuation correction errors, scatter, septal penetration) and methods for correction or mitigation (C5, P6, A4) • Quantification Techniques: In-depth understanding and calculation of quantitative parameters: Standardized Uptake Value (SUV), Total Lesion Glycolysis (TLG), and Perfusion Quantification (e.g., • Myocardial Perfusion Reserve) (C3, P5, A3)	05
System-Wise Clinical Case Analysis	• Oncology: To analyze complex PET/CT cases for response assessment (e.g., PERCIST, Lugano criteria) and differentiation of viable tumor from post-therapy changes. Interpretation of non-FDG tracers (-PSMA, -DOTATATE) (C5, P5, A4) • Cardiology: Advanced interpretation of Gated-SPECT/PET for wall motion, thickening, and Left Ventricular Ejection Fraction (LVEF) calculation. Analysis of viability protocols (C4, P5, A3) • Neurology: To interpret neuro-receptor imaging (e.g., DaTscan) and brain perfusion/metabolism studies for dementia and seizure focus localization (C4, P4, A3) • Infection/Inflammation: Differential interpretation of infection-specific tracers (, 346abelled WBC) in prosthetic infections, osteomyelitis, and fever of unknown origin (C5, P5, A4)	15
Unit 3: Therapeutic Nuclear Medicine (Theranostics) Practice		
Pre-Therapy Analysis and Selection	• Clinical decision-making for radionuclide therapy: Patient selection criteria, contraindications, and appropriate radiopharmaceutical choice (, -PSMA, -DOTATATE) (C5, P5, A4) • Pre-Therapy Dosimetry: Calculation and interpretation of absorbed dose estimates using quantitative SPECT/CT or PET/CT for personalized treatment planning (C4, P5,A3)	10
Post-Therapy Clinical Management and Interpretation	• Monitoring and Follow-up: Analyze post-therapy whole-body scans and correlate findings with serum markers and other imaging modalities (CT/MRI).	15

	Interpret expected versus unexpected treatment response (C5, P4, A4) • Adverse Event Management: Clinical protocols for managing immediate and long-term adverse effects (e.g., bone marrow suppression, xerostomia) and their relation to administered activity and dosimetry (C5, P6, A5) • Radiation Safety for Therapeutic Patients: In-depth knowledge of discharge criteria, patient and family instructions, and regulatory compliance for high-dose treatments (e.g., ICRP/local authority • guidelines) (C4, P5, A5)	
Unit 4: Clinical Practice Management and Professionalism		
Clinical Quality Improvement and Auditing	• To design and implement departmental Quality Assurance (QA) and Quality Improvement (QI) programs related to radiopharmaceutical production, imaging protocols, and patient safety (C6, P6, A5) • Role of the technologist in clinical audit and accreditation processes (e.g., recommendations) (C4, P5, A4)	05
Evidence-Based Practice and Research	• Critical analysis of nuclear medicine literature and integration of new tracers/protocols into clinical service (C5, P6, A4) • Formulating research questions, applying biostatistical methods for data analysis, and ethical considerations in clinical nuclear medicine research (C6, P5, A5)	05
Communication and Consultation Skills	• To effectively communicate complex technical information and potential image limitations to the Nuclear Medicine Physician and other referring clinicians (C4, P7, A5) • To educate patient, consent protocols for high-risk diagnostic and therapeutic procedures (C5, P5, A5)	10

Learning Strategies, Contact Hours and Out of Class Engagement:

Learning Strategies	Contact Hours	Out of Class Engagement
Small group Learning (SGD	5	15
Problem Based Learning (PBL)	5	15

Case Based Learning (CBL)	5	15
Clinic	75	-
Total	**90**	**45**

Assessment Methods:

Formative	**Summative**
Unit Test	Mid Semester (Practical)
Quiz	Viva
Viva	Logbook
Clinical assessment (OSCE, OSPE, WBPA)	End Semester Exam
Clinical / practical Logbook/ Record book	

Mapping of Assessment with COs:

Mid Semester Examination	**CO1**	**CO2**	**CO3**	**CO4**	**CO5**	**CO6**
Quiz/Viva	**x**	**x**	**x**	**x**	**x**	**x**
Clinical/Practical Log Book/ RecordBook	**x**	**x**	**x**	**x**	**x**	**x**
Clinical assessment (OSCE, OSPE,WBPA)	**x**	**x**	**x**	**x**	**x**	**x**

Feedback Process:	Mid-Semester Feedback
	End-Semester Feedback

Main References:

1. Radio pharmaceuticals in Nuclear Medicine Pharmacy and Nuclear Medicine – Kowalsky, Richard J., and Steven W. Falen

2. Nuclear Medicine-The Requisites: Harvey A. Ziessman, Janis P.O'Malley, James H. Thrall

Additional References:

1. Radio pharmaceuticals and Hospital Radio pharmacy Practices – N. Ramamoorthy BRIT
2. Radiation safety in Nuclear Medicine –AERB Mumbai
3. Nuclear Medicine Technology: Procedures and Quick Reference–Pete Shackett

Semester IV

Course Code	Course Title
MNM2401	Radiation Dosimetry in Nuclear Medicine and Therapy Planning
MNM2402	Therapeutic Radiopharmaceuticals
MNM-2403	Quality Assurance in Nuclear Medicine
MNM2404	Research Project-II
MNM2405	Clinical Practice- IV

Radiation Dosimetry in Nuclear Medicine and Therapy Planning

Course Code MNM2401

Course Title	**Radiation Dosimetry in Nuclear Medicine and Therapy Planning**
Course Code	**MNM2401**
Academic Year	Second Year
Semester	**IV**
Number of Credits	3
Course Prerequisite	Basic of dosimetry in nuclear medicine at B.Sc. NM level.
Course Synopsis	This course deals with the internal radiation dosimetry and treatment planning for nuclear medicine therapy.

Course Outcomes:

CO No.	Course Learning Outcomes	Bloom's level
CO1	To recall Fundamentals of Radiation Dosimetry (C1)	L1
CO2	To apply Internal Dosimetry and MIRD in nuclear medicine (C3)	L3
CO3	To apply Internal Dosimetry and MIRD in nuclear medicine (C3)	L3

Mapping of Course Outcomes (COs) to Program Outcomes (POs):

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1	**x**	**x**						
CO2	**x**	**x**						

CO3	**x**	**x**						

Course Content

Content	Competencies	Number of Hours
Unit 1: Fundamentals of Radiation Dosimetry		
	Recall Concepts and Quantities (C1): • Absorbed dose, exposure, kerma, LET, fluence, and their interrelations. • Equivalent dose, effective dose, dose rate; tissue and radiation weighting factors. Units and Measurement: • SI and non-SI units: Gray, Sievert, rad, rem; calibration and conversions. • Use of ICRU and ICRP definitions and dosimetric standards. Recall Dosimetric Models (C1): • Point source, distributed source, reference man, and MIRD schema overview. • Calculation of cumulated activity and residence time.	10
Unit 2: Internal Dosimetry and MIRD Formalism		
	To apply Internal Dose Calculation (C3): • MIRD equation, S-values, time-integrated activity. • Organ-level dosimetry, source-target concepts. • Biological and Physical Decay Considerations: • Physical vs. biological vs. effective half-life. • Integration of activity curves and dynamic modeling. • To use Tools and Software (C3): • OLINDA/EXM, IDAC-Dose, and related internal dosimetry software. • Case-based learning for diagnostic and therapeutic isotopes (I-131, Lu-177, Ac-225).	15
Unit 3: Treatment Planning in Nuclear Medicine Therapy		
	To understand and apply Personalized Therapy Approaches (C3): • Pre-therapy imaging and dosimetry (e.g., with Lu-177, I-131, Y-90). • Patient-specific planning for optimal tumor-to-normal tissue dose ratios. • Role of imaging-based dose planning (SPECT/CT and PET/CT).	15

	To understand and apply Therapy Protocols (C3): • Protocols for I-131, Lu-177-DOTATATE, Lu-177-PSMA, Y-90 microspheres. • Redosing and fractionation approaches. • Predictive and Response Assessment: • Tumor dosimetry and correlation with treatment response. • Biokinetics and toxicity prediction	
Unit 4: Advanced Techniques and Emerging Concepts		
	To understand and apply 3D Dosimetry and Voxel-Based Techniques (C3): • Voxel dosimetry using SPECT/CT or PET/CT-based models. • DPK-based approaches and voxel S-values. • Software platforms (OLINDA/EXM,PLANET Dose, MIRD cell). • DICOM-RT, Monte Carlo methods, and image-based segmentation. To understand and apply Radiobiological Modeling (C3): • BED (Biologically Effective Dose) and EQD2 concepts in radionuclide therapy. • Tumor control probability (TCP) and normal tissue complication probability (NTCP). • Alpha therapy dosimetry (e.g., Ac-225, Bi-213), theranostics. • AI-assisted segmentation and dosimetry automation. • Use of radiomics and radiogenomics in personalized therapy planning. • Research and Innovations, Clinical trial frameworks for new therapeutic agents.	5

Learning Strategies, Contact Hours and Out of Class Engagement:

Learning Strategies	**Contact Hours**	**Out of Class Engagement**
Lecture	30	30
Seminar	**11**	11
Revision	**2**	**2**
Assessment	**2**	**2**
Total	**45**	**45**

Assessment Methods:

Formative	**Summative**
Unit Test	Mid Semester/Sessional Exam (Theory)
Quiz	End Semester (Theory)

Assignments/presentations	

Mapping of Assessment with COs:

Nature of Assessment	**CO1**	**CO2**	**CO3**
Mid Semester Examination	**x**	**x**	
Quiz/ Unit Test	**x**	**x**	**x**
End Semester Exam	**x**	**x**	**x**

Feedback Process:	Mid-Semester Feedback
	End-Semester Feedback

Main References:

1. Radiation Dosimetry: Physical and Biological Aspects – Otto G. Raabe
2. Nuclear Medicine Physics – Ramesh Chandra
3. MIRD Primer for Absorbed Dose Calculations – Society of Nuclear Medicine

Additional References:

1. Handbook of Radiopharmaceuticals – Michael J. Welch, Carol S. Redvanly
2. Quantitative Analysis in Nuclear Medicine Imaging – Habib Zaidi
3. Radiopharmaceutical Therapy – Frank Rösch, Springer

Therapeutic Radiopharmaceuticals

Course Code MNM2402

Course Title	**Therapeutic Radiopharmaceuticals**
Course Code	**MNM2402**
Academic Year	Second Year
Semester	**IV**
Number of Credits	3
Course Prerequisite	Basic of dosimetry in nuclear medicine at B.Sc. NM level.
Course Synopsis	

Course Outcomes

CO No.	Course Learning Outcomes	Bloom's level
CO1	To recall radiopharmaceuticals used in therapy (C1)	L1
CO2	To critically review PRRT and Targeted Radionuclide Therapy (C5)	L3
CO3	To critically review Target Alpha Therapy (C5)	L3

Mapping of Course Outcomes (COs) to Program Outcomes (POs):

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1	**x**	**x**						
CO2	**x**	**x**						
CO3	**x**	**x**						

Course Outcomes:

Content	Competencies	Number of Hours
Unit 1: Introduction to Therapeutic radiopharmaceuticals		

	· Recall principle of radionuclide therapy (C1) · Understand selection of radionuclides for therapy procedure (C2) · Understand characteristics and decay characteristics of therapeutic radionuclides (C2) · Understand production of clinically used radionuclides for therapy (e.g. Lu-177, Ra-223, Ac-225, At-211, Cu-67) (C2)	**10**
Unit 2: Iodine Radiopharmaceuticals		
	·Recall Iodine isotopes and method of production, methods of radioiodination, mechanism of iodine uptake and retention (C1) ·Recall I-131 NaI for thyrotoxicosis and thyroid cancer: patient preparation, radiopharmaceutical dose, dispensing and regulatory requirements (C1) · Recall Other I-131 based therapy MIBG, Radioimmunotherapy (C1)	**5**
Unit 3: PRRT and Targeted Radionuclide Therapy		
	· Discuss radiolabeling with Lu-177, non-carrier added and carrier added Lu-177 and radiopharmaceutical preparation (DOTATATE and PSMA) · Critically review therapy protocol for Lu-177 DOTATATE and PSMA-617: patient preparation and dose administration. Regulatory Requirements (C5) · Critically review therapy protocol for Bone pain palliation: Radiopharmaceutical used and its QC, mode of administration, dose and regulatory requirements (C5) · Critically review selective intra-arterial radionuclide therapy (SIRT), TARE (Transarterial radionuclide embolism): Radiopharmaceutical used, mode of administration, dose and regulatory requirements (C5) · Critically review Patch Therapy with Re-188: Radiopharmaceutical used, mode of administration, dose and regulatory requirements (C5) · Critically review Radio synovectomy: Radiopharmaceutical used, mode of administration, dose and regulatory requirements (C5)	15
Unit 4: Targeted Alpha Therapy		

	· Discuss characteristics of alpha particles, their radiobiological effects (C2) · Compare alpha with beta emitters and auger electrons and rationale behind using alpha particles (C4) · Discuss properties of clinically important alpha emitters: currently in use and emerging (C4) · Discuss chelation chemistry and challenges with alpha emitter with major focus of Ac-225, handling, storage and waste management (C2) · Critically review clinical Application of (C5): Ra-225 RaCl2, Ac-225 DOTATATE, Ac-225 PSMA-617 dose calculation, formulation, mode of administration and regulatory requirements	15

Learning Strategies, Contact Hours and Out of Class Engagement:

Learning Strategies	**Contact Hours**	**Out of Class Engagement**
Lecture	30	30
Seminar	11	11
Revision	2	2
Assessment	2	2
Total	45	45

Assessment Methods:

Formative	**Summative**
Unit Test	Mid Semester/Sessional Exam (Theory)
Quiz	End Semester (Theory)
Assignments/presentations	

Mapping of Assessment with COs:

Nature of Assessment	**CO1**	**CO2**	**CO3**
Mid Semester Examination			
Quiz/ Unit Test			
End Semester Exam			

Feedback Process:	Mid-Semester Feedback
	End-Semester Feedback

Main References:

1. Radiopharmaceutical Chemistry: Jason S. Lewis, Albert D. Windhorst, Brian M. Zeglis
2. Targeted Radionuclide Therapy: Tod W. Speer (Lippincott Williams & Wilkins)
3. Nuclear Medicine Therapy: LaleKostakoglu and Ora Israel (Springer, 2014)
4. Theranostic Radiopharmaceuticals (IAEA-TECDOC Series)
5. Alpha Emitting Radionuclides and Radiopharmaceuticals for Therapy (IAEA-TECDOC series)
6. Nuclear Medicine in Oncology: Molecular Imaging and Target Therapy:Gang Huang, Xiaoyuan (Shawn) Chen (Springer, 2021)
7. Recent Reviews in Journal: Journal of Nuclear Medicine (JNM), European Journal of Nuclear Medicine and Molecular Imaging (EJNMMI), Theranostics (Open access)
8. Targeted Radiopharmaceuticals and Imaging: Development Challenges and Opportunities (Royal Society of Chemistry 2025) https://doi.org/10.1039/9781837677139

Quality Assurance and Quality Control in Nuclear Medicine

Course Code MNM2403

Course Title	**Quality Assurance and Quality Control in NuclearMedicine**
Course Code	**MNM2403**
Academic Year	Second Year
Semester	**IV**
Number of Credits	2
Course Prerequisite	A foundational understanding of nuclear medicine equipment is required to comprehend the mathematical and physical principles of QA algorithms.
Course Synopsis	This course provides a comprehensive study of nuclear medicine quality assurance and the practical implementation of NEMA and AERB compliant acceptance testing and routine QA for SPECT, PET,and hybrid imaging systems.

Course Outcomes (COs):

CO No.	Course Learning Outcomes	Bloom's level
CO1	Explain the fundamental principles of Quality assurance and quality control of the various equipment (C2)	L2
CO2	Evaluate the performance of nuclear medicine imaging equipment (Planar Gamma Camera/SPECT, PET/PET-CT/PET-MRI) by conducting acceptance tests based on NEMA standards and AERB requirements, specifically those related to spatial resolution, sensitivity, and co-registration accuracy (C4)	L4
CO3	Develop and manage a comprehensive Quality Assurance (QA) program by implementing routine daily, weekly, and annual QA protocols, and troubleshooting common non-uniformity or misalignment issues to ensure regulatory compliance (AERB, NEMA) and clinical reliability (C6)	L6

Mapping of Course Outcomes (COs) to Program Outcomes (POs):

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**
CO2	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**

CO3	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**

Course Content

Content	Competencies	Number of Hours
Unit 1: Acceptance Testing and NEMA Standards for Imaging Equipment		
	• Planar Gamma Camera/SPECT: (C3) • Acceptance tests: Intrinsic uniformity (Tc-99m differential/integral), spatial resolution (bar phantoms), energy resolution (FWHM for Tc-99m, I-131, Ga-67), count rate performance, sensitivity, collimator penetration, center-of-rotation alignment • AERB requirements: Radiation safety, uniformity ≤5% for Tc-99m • PET/PET-CT: (C4) • Acceptance tests: Spatial resolution (transaxial/axial FWHM at 1 cm, 10 cm), sensitivity (F-18 counts), scatter fraction, noise equivalent count rate (NECR), image quality (contrast recovery), TOF accuracy (<400 ps), CT-based attenuation correction. • AERB requirements: Leakage radiation, image quality verification. • PET-MRI and SPECT-CT: (C4) • Acceptance tests: Co-registration accuracy (≤2 mm for PET-CT/MRI, SPECT-CT), CT Hounsfield unit accuracy, MRI SNR, B0 homogeneity, SPECT uniformity, PET scatter fraction. • AERB requirements: Hybrid system alignment, radiation safety. • Applications in Nuclear Medicine: • Validating Tc-99m SPECT uniformity for cardiac imaging. • Ensuring F-18 PET-CT resolution for oncology scans. • Confirming PET-MRI alignment for brain tumor imaging.	**20**
Unit 2: Routine Quality Control for Imaging Equipment		
	Daily QA Protocols: • Planar Gamma Camera/SPECT: Uniformity (Tc-99m flood source), center-of-rotation check (C3) • PET/PET-CT: Sensitivity, uniformity (F-18 phantom), CT noise checks (C3) • PET-MRI: MRI SNR, PET uniformity, CT alignment	**20**

	verification (C3) • SPECT-CT: SPECT uniformity, CT Hounsfield unit calibration (C3) Weekly/Monthly QA Protocols: • SPECT: Spatial resolution (bar phantom), energy peaking (Tc-99m), NEMA phantom for image quality (C3) • PET: Scatter fraction, NECR, monthly phantom tests (F-18 ACR phantom) (C3) • PET-MRI/SPECT-CT: Co-registration accuracy, CT noise, MRI distortion checks (C3) Quarterly/Annual QA: • SPECT: Collimator integrity, full system performance (resolution, sensitivity) (C3) • PET: TOF stability, annual NEMA phantom tests for F-18 (C3) • Hybrid Systems: Comprehensive stability, attenuation correction accuracy (C3) • AERB audits: Compliance with safety and performance standards (C3) Applications in Nuclear Medicine: • Daily Tc-99m SPECT QC for reliable myocardial perfusion imaging (C4) • Monthly F-18 PET-CT phantom tests for oncology accuracy (C4) • Annual PET-MRI QA for consistent brain imaging performance (C4)	
Unit 3: Regulatory Compliance and QA Program Management		
Communication and Consultation Skills	• Regulatory Frameworks: • AERB SC/MED-2: Mandatory QA tests, frequency, documentation for all instruments. • IAEA TECDOC-602/1859: International QA standards for non-imaging and imaging systems. • NEMA Standards (NU 1/2-2018): Performance benchmarks for SPECT, PET. • QA Program Implementation: • Protocol development: Standardized SOPs for dose calibrators, SPECT, PET-CT. • Record-keeping: Digital logs for AERB audits, equipment performance tracking. • Staff training: Competency assessments for QA procedures (e.g., Tc-99m uniformity tests). • Troubleshooting and Corrective Actions: • Non-imaging: Addressing dose calibrator linearity drift, HPLC peak tailing.	**20**

	• Imaging: Correcting SPECT non-uniformity, PET-CT misalignment. • Root cause analysis: Identifying equipment failures, implementing fixes. • Applications in Nuclear Medicine: • Developing QA SOPs for Ga-68 PET-CT imaging. • Training staff on I-131 thyroid probe QC protocols. • Troubleshooting Tc-99m SPECT image artifacts for clinical reliabilit	

Learning Strategies, Contact Hours and Out of Class Engagement:

Learning Strategies	**Contact Hours**	**Out of Class Engagement**
Lecture	5	15
Seminar	5	15
Revision	5	15
Assessment		-
Total	**60**	**60**

Assessment Methods:

Formative	**Summative**
Unit Test	Mid Semester/Sessional Exam (Theory)
Quiz	End Semester (Theory)
Assignments/presentations	

Mapping of Assessment with COs:

Nature of Assessment	**CO1**	**CO2**	**CO3**
Mid Semester Examination	**x**	**x**	**x**
Quiz/ Unit Test	**x**	**x**	**x**
Clinical/Practical Logbook/Record Book	**x**	**x**	**x**
Clinical assessment (OSCE, OSPE, WBPA)	**x**	**x**	**x**

Feedback Process:	Mid-Semester Feedback
	End-Semester Feedback

Main References:

1. Quality Control in Nuclear Medicine – James A. Ponto, Society of Nuclear Medicine
2. Nuclear Medicine Physics: The Basics – Ramesh Chandra, Wolters Kluwer

Additional References:

1. Nuclear Medicine and PET/CT: Technology and Techniques – Paul E. Christian, Kristen M. Waterstram-Rich, Mosby

Research Project -II

Course Code MNM2404

Course Title	**Research Project -II**
Course Code	**MNM2404**
Academic Year	Second Year
Semester	**IV**
Number of Credits	2
Course Prerequisite	Training in basic research techniques with deep understanding of dissertation topic and the methodology involved in conducting the research. Knowledge and experience in handling related research material and equipment
Course Synopsis	The course is aimed to develop in students, interest and motivation for research which, with advanced training and involvement can be translated into competency and reasoned points of view in their area of interest.

Course Outcomes

CO No.	Course Learning Outcomes	Bloom's level
CO1	Execute research experiments independently or as part of a team (C3,P3, A5)	L3
CO2	Explain, analyse, present, and defend the research findings (C4, P5, A4)	L4
CO3	Explain, analyse, present, and defend the research findings (C4, P5, A4)	L6

Mapping of Course Outcomes (COs) to Program Outcomes (POs):

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1	**x**	**-**	**x**	**-**	**-**	**-**	**-**	**-**
CO2	**x**	**x**	**-**	**-**	**x**	**-**	**-**	**-**
CO3	**-**	**-**	**-**	**-**	**x**	**-**	**x**	**-**

Course Content

Content	Competencies	Number of Hours
Unit1.		
	1.Execute research investigations (C3, P3, A5)	240
Unit2		
	2. Plan, organize and analyze research findings (C4, P5, A4) 3. Summarizing compiling thesis and research article (C6, P3, A4)	60

Learning Strategies, Contact Hours and Out of Class Engagement:

Learning Strategies	Contact Hours	Out of Class Engagement
Lecture	0	0
Seminar	300	300
Revision	0	0
Assessment	0	0
Total	**300**	**300**

Assessment Methods:

Formative	Summative
Unit Test	Mid Semester/Sessional Exam (Theory)
Quiz	End Semester (Theory)
Assignments/presentations	

Mapping of Assessment with COs:

Nature of Assessment	CO1	CO2	CO3
Mid Semester Examination	**x**	**x**	**x**
Quiz/ Unit Test	**x**	**x**	**x**
Clinical/Practical Logbook/Record Book	**x**	**x**	**x**
Clinical assessment (OSCE, OSPE, WBPA)	**x**	**x**	**x**

Feedback Process:	Mid-Semester Feedback
	End-Semester Feedback

Main References:

1.Research journals, Scientific literatures

Clinical Practice-IV

Course Code MNM2405

Course Title	**Clinical Practice-IV**
Course Code	**MNM2405**
Academic Year	Second Year
Semester	**IV**
Number of Credits	2
Course Prerequisite	Students should have knowledge of core nuclear medicine subjects and general hospital practices.
Course Synopsis	This course covers advanced analytical skills in radiopharmacy, image quantification and artifact mitigation, theranostic decision-making and dosimetry, and the design of clinical programs for expert hospital service.

Course Outcomes

CO No.	Course Learning Outcomes	Bloom's level
CO1	Critically analyze documentation and patient factors to troubleshoot radiopharmaceutical failures and non-pathological biodistribution anomalies, including dose calculation for therapeutic agents (C5, P6, A4)	L5
CO2	Systematically analyze and mitigate complex artifacts in hybrid imaging () and accurately calculate and interpret advanced quantitative metrics (etc.) (C4, P5, A3)	L5
CO3	Analyze pre- and post-therapy scans to determine patient eligibility, calculate absorbed dose using quantitative methods, and manage treatment response and adverse events for a range of theranostic applications (C6, P6, A5)	L6
CO4	Design and implement a full-scale departmental and program, ensuring strict compliance with national and international radiation safety standards for high-dose patients and incident management (C6, P6, A5)	L6
CO5	Critically appraise nuclear medicine research to integrate new protocols, formulate research questions, and compose concise, clinically relevant reports that address differential diagnosis (C6, P5, A5)	L6

Mapping of Course Outcomes (COs) to Program Outcomes (POs):

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**
CO2	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**
CO3	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**
CO4	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**
CO5	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**

Course Content

Content	Competencies	Number of Hours
Unit 1: Advanced Radiopharmacy and Clinical Correlation: Troubleshooting and Analysis		**Error**
Radiopharmaceutical Quality Management	• In-depth analysis of QC failure cases (e.g., high free pertechnetate, colloidal particles) and their specific image-based consequences (e.g., gastric uptake in bone scan, liver uptake in brain scan) (C4, P6, A4)	5
Clinical Pharmacokinetics & Dosimetry	• Critical analysis of patient-specific factors (renal function, hydration, drug interactions) that necessitate dose or protocol modifications (C5, P6, A4) • Principles and calculation of absorbed dose for therapeutic agents (C3, P5, A3)	5
PET Radiochemistry and Production	• Interpretation of final QC documentation for short-lived PET tracers (), focusing on regulatory compliance (GMP/GLP) and impact of minor impurities on clinical use (C5, P4, A4)	15
Unit 2: Integrated Scintigraphy and Hybrid Imaging Analysis		
Advanced Artifact and Pitfall Interpretation	• To Systematically analyze the complex artifacts in SPECT/CT and PET/CT (metal artifacts, motion, misregistration, truncation) and strategies for image reprocessing and mitigation (C5, P6, A4)	5

Quantitative Nuclear Medicine	• To calculate and interpret the quantitative metrics (e.g., SUVmax, SUVmean, SUVpeak, LVEF, GFR/ERPF) and understanding their variability and limitations across different scanners and software (C5, P5, A4)	5
Clinical Correlation and Reporting	• To correlate of NM findings with other modalities (MRI, CT, Ultrasound) and practice in formulating concise, clinically relevant reports that address the differential diagnosis and guide patient management (C6, P5 A5)	5
Unit 3: Molecular and Theranostic Applications: Clinical Decision-Making and Management		
Neuroendocrine and Prostate Theranostics	• In-depth interpretation of pre-therapy scans (68Ga-DOTATATE, 68Ga-PSMA) for eligibility and dosimetry. Post-therapy analysis of treatment response and complication management (e.g., 177Lu therapy) (C5, P6, A5)	5
Radioiodine Therapy (I-131)	• To analyze the diagnostic/post-therapy whole-body scans for differentiated thyroid cancer, focusing on residual disease vs. distant metastases. Management of dose calculation and adverse effects (C5, P5, A4)	15
Emerging Theranostic Agents	• To analyze the role of newer agents for pain palliation, synovectomy, and other emerging areas (C4, P3, A3) 15 To analyze the role of newer agents for pain palliation, synovectomy, and other emerging areas (C4, P3, A3)	15
Unit 4: **Clinical Practice Management and Professional skills**		
Advanced Radiation Safety and Waste Management	• To analyze the clinical scenarios involving radiation incidents (e.g., contamination, dose extravasation) and protocols for high-dose patient discharge and compliance with national/international safety standards (ICRP, /local equivalent) (C5, P5, A5)	5
Quality Assurance (QA) and Auditing	• To design a full-scale QA program for a hospital Nuclear Medicine department, including instrumentation QA, process QC, and clinical outcome auditing (C6, P6, A5)	5

Research Methodology and Evidence-Based Practice	• To critically appraise randomized controlled trials in Nuclear Medicine and apply biostatistics and research ethics to clinical practice and service improvement (C6, P5, A5)	5

Learning Strategies, Contact Hours and Out of Class Engagement:

Learning Strategies	Contact Hours	Out of Class Engagement
Small group Learning (SGD)	5	15
Problem Based Learning (PBL)	5	15
Case Based Learning (CBL)	5	15
Clinic	75	-
Total	**90**	**45**

Assessment Methods:

Formative	Summative
Unit Test	Mid Semester (Practical)
Quiz	Viva
Clinical assessment (OSCE, OSPE, WBPA)	End Semester Exam
Clinical / practical Logbook/ Record book	

Mapping of Assessment with COs:

Nature of Assessment	CO1	CO2	CO3	CO4	CO5	CO6
Mid Semester Examination	x	x	x	x	x	x
Quiz/ Unit Test	x	x	x	x	x	x
Clinical/Practical Logbook/Record Book	x	x	x	x	x	x
Clinical assessment (OSCE, OSPE, WBPA)	x	x	x	x	x	x

Feedback Process:	Mid-Semester Feedback
	End-Semester Feedback

Main References:

1. Radiopharmaceuticals in Nuclear Medicine Pharmacy and Nuclear Medicine - Kowalsky, Richard J., and Steven W. Falen
2. Nuclear Medicine-The Requisites: Harvey A. Ziessman, JanisP.O'Malley, JamesH.Thrall

Additional References:

1. Radiopharmaceuticals and Hospital Radiopharmacy Practices - N. Ramamoorthy BRIT
2. Radiationsafety in Nuclear Medicine –AERB Mumbai
3. Nuclear Medicine Technology: Procedures and Quick Reference–Pete Shackett

Residency/Internship Clinical Training

Residency/Clinical Training of Nuclear Medicine Technologist

II. Program Philosophy and Core Objective

Objective: The primary objective of the clinical training program for Nuclear Medicine Technologist is to produce an independent practitioner who is a lifelong learner and who can work unsupervised within a multi-disciplinary team at a safe and highly professional standard.

This objective is achieved through a structured program designed to transition the trainee from theoretical knowledge (gained in an academic **Bachelor/Master of Science in Nuclear Medicine Technology** program) to practical, hands-on clinical competency. The core pillars of the independent practitioner are:

1. **Clinical Competency:** The ability to perform all Nuclear Medicine Practice tasks accurately and safely.
2. **Safety and Professionalism:** Adherence to national and international radiation safety regulations and the highest ethical standards.
3. **Team Integration:** Effective collaboration and communication within the multi-disciplinary healthcare team (Nuclear Medicine Physicians, Radiopharmacists, Technologists, Nurses, etc.).
4. **Lifelong Learning:** Developing the critical thinking and scientific inquiry skills necessary to adapt to rapid technological advancements.

Eligibility

Candidate who have successfully completed the M.Sc. Nuclear Medicine academic program

III.Program Structure and Supervision

Training & Assessment: The training will be conducted in **practicing facilities/ hospitals (attached to allied and healthcare institutes)** that possess the full spectrum of modern Nuclear Medicine facilities, including but not limited to Gamma Cameras, SPECT, SPECT/CT, PET/CT, and a dedicated Radiopharmacy or hot lab facilities for diagnostic and therapeutic nuclear medicine. The assessment of NMT shall be conducted in accordance with Appendix B.

Supervision: Training will be under the **direct supervision of a Clinically Qualified Nuclear Medicine Technologist***, who serves as the Program Director/Faculty/Radiological Safety Officer

Clinically Qualified Nuclear Medicine Technologist – The healthcare professionals who are registered as Nuclear Medicine Technologist in NCAHP and actively working in the clinical Nuclear Medicine Department

1. **Direct Supervision:** Initially, the trainee works under the immediate guidance of the supervisor for all tasks until a pre-defined competency milestone is achieved.

2. **Graduated Responsibility:** As competency grows, supervision transitions to indirect oversight, where the trainee independently performs routine tasks but has immediate access to the supervisor for consultation on complex cases and decision-making.
3. **Mentorship:** The supervisor also functions as a mentor, guiding the trainee's professional development, participation in research, and teaching activities.

IV. Core Areas of Detailed Training (Competencies)

The training curriculum is typically divided into modules covering the complete Nuclear Medicine workflow:

MODULE 1- CLINICAL AWARENESS	
Objective	**To provide the resident with clinical knowledge and experience related to Nuclear Medicine**
Expected Duration	5% of total time
Sub-Modules	1.1 Essential anatomy and physiology for the Nuclear Medicine Technologist 1.2 Basic principles of radiation biology and epidemiology 1.3 Clinical activities and factors that affect patient care

Module 1 – Clinical Awareness	
Sub-module 1.1 – Essential Anatomy and Physiology for the Nuclear Medicine Technologist	
Objective	To gain sufficient knowledge of anatomy and physiology to be able to communicate effectively with medical personnel
Prerequisite	None
Competencies Addressed	An understanding of (a) anatomy and physiology as seen on nuclear medicine images and in dynamic studies. (b) basic knowledge of anatomy and physiology as seen on other types of medical images The ability to discuss with nuclear medicine specialist the important features of diagnostic images
Core Knowledge	• Identify difference in image forming processes needed to produce various medical images • Typical anatomy and physiology related to nuclear medicine static, SPECT, whole body and dynamic imaging, PET (where available) • Typical anatomy on radiology images or other dynamic imaging modalities, e.g., echocardiography and blood flow in MRI

Recommended Elements of Training	• Discuss anatomy and physiological aspects of static, SPECT, whole body and dynamic nuclear medicine images with nuclear medicine specialist • Discuss various aspects of anatomy and physiology in medical images with medical staff including, but not limited to, Nuclear Medicine Physician Radiologists, Oncologist and other physicians. • Identify anatomy in other medical images. • Display nuclear medicine images and dynamic examinations properly • Appreciate physiological function in other dynamic imaging modalities, e.g., echocardiography and blood flow in MRI

Module 1- Clinical Awareness	
Sub-module 1.2 Basic Principles of Radiation Biology and Epidemiology	
Objective	To understand the basic radiation biology underpinning nuclear medicine imaging
Pre Requisites	None
Competencies Addressed	An understanding of the basic principles of radiation biology and epidemiology**.**
Core knowledge	Radiation biology • Basic cell biology • Track structure, LET and absorbed dose • RBE and Quality Factors • Equivalent dose and Radiation Weighting Factors • Effective dose and Tissue Weighting Factors • Cellular responses, DNA repair and cell survival/death • Oxygen effect • Stochastic and deterministic effects • Acute and late biological responses • Risk models and quantitative radiation risks • Doses and risks in nuclear medicine • LNT and uncertainties at low doses • Non-targeted effects (bystander responses & genomic instability) Epidemiology • Epidemiologic studies: case control and cohort studies • Odds ratio, relative risk ratio

Recommended Elements of Training	• Demonstrate understanding of factors affecting relative biological effect of different types of radiation • Demonstrate an understanding of mechanisms of radiation induced damage on the cell • Demonstrate an understanding of the terms used in epidemiology • Demonstrate an understanding of different dose-risk models • Demonstrate an understanding of the terms used in risk assessment

Module 1 Clinical Awareness	
Sub-module 1.3: Clinical Activities and Factors that Affect Patient Care	
Objective	To provide the resident with broad patient-related experiences and an understanding of the role of multidisciplinary professionals involved in or requesting nuclear medicine services.
Prerequisite	None
Competency addressed	An understanding of the factors that affect patient care An ability to discuss clinical activities and their relation to patient care in the following areas: • Nuclear medicine • Radiology • Radiation oncology • Other areas.
Core Knowledge	• Need for patient care, rapport, privacy, and confidentiality during patient related experiences. • Appropriate professional conduct and ethical attitudes
	• Appropriate hygiene and infection control procedures • Effect of diagnostic imaging and radiotherapy on patient quality of life • Patient-staff interactions • Patient – Nuclear Medicine Technologist interaction • Interactions, roles, and responsibilities of multi-disciplinary professionals involved in patient management.
Recommended Elements of Training	**Nuclear medicine** • Exposure to the following patient-related clinical experiences: • Nuclear medicine imaging procedures • Preparation and administration of radiopharmaceutical • Radionuclide therapy During this time, the resident should: • Understand the patient work flow for a nuclear medicine procedure • Attend preparation of radiopharmaceutical

	• Attend reporting sessions in nuclear medicine over a number of weeks covering related modalities • Attend at least two clinical review meetings covering each of a number of organ systems (case review) • Attend some common diagnostic nuclear medicine procedures. • Demonstrate an understanding of the purpose of the typical procedures. • Note the reasons for the patient's admission and their conditions • Attend administration of radionuclide for therapy • Prepare a patient case study for a complex procedure such as a cardiac procedure • Study local and national regulations on confidentiality and handling of patient information. **Radiation Oncology** • Attend all phases of the radiotherapy process from a simulation through to patient treatment. • Examine the roles of imaging used in this above process (diagnosis, simulation, and treatment) whether the imaging modality is situated within radiation oncology or elsewhere. • Discuss the key differences in the application of identified imaging modalities in therapy compared to nuclear medicine **Radiology** • Observe some common diagnostic radiology procedures including interventional procedures •Discuss the role of CT in nuclear medicine imaging Discuss the differences between, and relative advantages of, nuclear medicine and x-ray imaging • Discuss the dosimetry and protection differences between nuclear medicine and radiology (patient and staff) • Study the QC procedures used in radiology **Ultrasound** • Observe ultrasound imaging procedures (where ethically possible), including Doppler imaging • Discuss the differences between, and relative advantages of ultrasound and nuclear medicine **MRI** • Observe MRI procedures including functional studies • Discuss the difference between, and relative advantage of nuclear medicine and MRI **Other areas** • Discuss the problems and restrictions when nuclear medicine is used in operating theatre or ward • Study local regulations on hygiene and infection control

MODULE 2- RADIATION PROTECTION	
Objective	To develop key skills in radiation protection practice in a nuclear medicine department It should be noted that the tasks defined in this module, with the exception of 2.2, 2.3 and 2.6 may be also carried out by a Radiation Protection Officer (RPO). Local circumstances will dictate actual working arrangements
Expected Duration	15 % of total time
Sub-Modules	2.1 Monitoring radiation levels including personnel monitoring 2.2 Exposure from unsealed sources and the risk of contamination 2.3 ALARA and Radiation Safety Precautions in Nuclear Medicine 2.4 Risk assessment and advice to staff, patients and others regarding radiation risk 2.5 Areas designated for the use of unsealed radioactive material 2.6 Radiation shielding considerations in the design of new facilities 2.7 Regulatory controls and other guidance on the safe use of ionizing radiation in nuclear medicine

Module 2: Radiation Protection	
Sub-module 2.1: Monitoring Radiation Levels Including Personnel Monitoring	
Objective	To be able to identify sources of radiation, to monitor radiation levels and analyze potential hazards
Prerequisite	None
Competencies Addressed	An understanding of (a) The principles of operation of equipment used for monitoring radiation levels in nuclear medicine. (b) The purpose, principles and operation of a personnel dosimetry program Ability to measure radiation levels and to perform quantitative measurement of contamination
Core Knowledge	· Identify external and internal radiation hazards · Quantify radiation hazards using survey meters, contamination monitors and wipe testing. · Identify radionuclides by type of emission, energy and half-life. · The theory, principles of operation, and limitations of personal monitoring • The basic operational quantities and their relationship to effective dose

	• Advise on the requirements for safe handling and storage of unsealed radioactive materials.
Recommended Elements of Training	• Read, and be reasonably familiar with, the resource material recommended for this competency • Awareness of the local regulatory guideline on radiation protection in nuclear medicine • Prepare a protocol for a contamination survey, including: what is wiped, materials used, areas wiped, how are they measured, limits of action. • Prepare a protocol for an external exposure survey, including: where and when measurements are made, what instrument(s) are used, limits of action. • Carry out a radiation survey of a laboratory, including: o Inventory of the types and amounts of radio-isotope and radio-pharmaceutical entering the lab and any relevant properties (e.g. iodine is volatile) o Inventory of available radiation measuring instruments. Note the applications and limitations of each instrument. o Inventory of sealed sources, handling, storage and location o Use of personal monitors: type, location, frequency of changing o Handling and storage of unsealed sources Generate a written radiation survey report with appropriate recommendations. Prepare material for information to staff.

Module 2: Radiation Protection	
Sub-module 2.2: Exposure from unsealed Sources and the Risk of Contamination	
Objective	To demonstrate knowledge on the reduction of exposure from unsealed sources and how to handle spills and accidents
Pre Requisites	Awareness of the local regulatory guideline on radiation protection in nuclear medicine Sub-module 1.1 Clinical Awareness
Competencies Addressed	An understanding of methods to reduce exposure. The ability to (a) safely handle unsealed radioactive sources. (b) handle accidents and spills

Core Knowledge	• Identify locations or practices where radiation exposure could reasonably be reduced. • Estimate dose rates near patients and influence of patterns of close contact. · Implement measures to reduce non-essential contact with radioactive patients and other sources. · Decontaminate staff, machine and premises after a spill of radioactive material. · Estimate organ doses after contamination · Assess the level of contamination remaining after decontamination. • Implement measures to reduce exposure due to residual contamination. · Analyse misadministration's, make estimates of absorbed dose and provide guidance on improvement of practices. • Generate a written incident report.
Recommended Elements of Training	• Review the workflow of the Department from a radiation safety point of view. This should include: o receipt, storage and disposal of radioactive material o preparation and dispensing of radiopharmaceuticals o patient injection or administration procedures o patient movements before and after injection o patient scanning procedures • Conduct a radiation survey of the various areas in the Department (hot lab, patient waiting areas, scanning rooms etc.), noting in particular: o the availability and use of shields o whether the layout allows adequate distance from sources o whether work procedures allow minimal time near sources · Propose and justify reasonable changes to procedures, layout or shielding to reduce the radiation dose to staff, patients or members of the public. · Prepare general instructions for Department staff for contaminating and decontaminating following a spill. Describe additional tasks to assess residual contamination and formulate recommendations for remedial action (e.g. taping plastic over the contaminated floor area, replacing contaminated equipment etc.). · Review literature on procedures to estimate organ doses from contamination. · Note radiopharmaceuticals for which extra steps would be required, because of long half-life, increased likelihood of uptake or adverse biological characteristics. In each case, specify and justify the required steps. · Devise a system for maintaining an overview of spill incidents, including contributing factors and measures to prevent further incidents · Prepare a hypothetical incident report for: a major spill of iodine in the

	Hot Lab; a minor spill of gallium in a camera room.

Module 2: Radiation Protection	
Sub-module 2.3: ALARA and Radiation Safety Precautions in Nuclear Medicine	
Objective	To demonstrate knowledge on how to apply ALARA and radiation protection regulations in nuclear medicine clinical practice
Prerequisite	Sub -Module 2.1 Monitoring radiation levels including personnel Monitoring Sub- Module 2.2 Exposure from unsealed sources and the risk of contamination
Competency addressed	An understanding of the application of the ALARA principal Ability to apply radiation protection regulations in clinical nuclear medicine practice
Core Knowledge	• Basic radiation protection Principle: Time, Distance, Shielding • Demonstrate knowledge of dose limits for occupational and public exposures and of typical radiation doses to health care workers and others in a well-managed practice • Design workflow and procedures so as to minimize the radiation dose to staff, patients, carers at home and members of the public. • Identify situations when extra precautions may be advisable, such as a breastfeeding patient or when the mother of a pediatric patient is pregnant • Develop precautions for a new procedure • Prepare local routines and Information sheets for patients/carers for specific clinical applications, addressing such issues as periods of close contact with children, breast feeding and urinary incontinence.
Recommended elements of training	• Be reasonably familiar with the resource material recommended for this competency • Review the potential exposures from diagnostic nuclear medicine to staff in the Department, including Hot Lab staff, nurses, porters, technologists and medicos, and in the hospital. Also note the exposures to members of the public, including accompanying persons and other patients, including travel home by car or public transport. • Write a report from your observations with recommendations to reduce exposure. For any possible modifications which reduce dose, consider the disadvantages. Is the reduction in dose achieved by 'reasonable' means?
	Choose a procedure involving ^{99m}Tc. Write out the workflow, including radiopharmaceutical dispensing, patient preparation and injection, scanning and patient movements. Estimate the dose rate for each occasion

	of exposure. This can be done by reading the literature or by taking some measurements. Inpatients, outpatients, accompanying persons, staff and members of the public should all be considered. • For each workflow step, describe and justify reasonable practices to minimize radiation dose, indicating who is being protected (e.g. technologist, nurse, patient, accompanying person). • Produce an Information Sheet for the patient and/or carers with recommendations for practices to minimize radiation dose. • Compare your conclusions with current recommendations (e.g. in the Department's Radiation Safety and Protection Plan). Comment on any differences. • Review recommendations from international organizations on handling of breast-feeding women.

Module 2: Radiation Protection	
Sub-module 2.4: Risk Assessment and Advice to Staff, Patients and Others Regarding Radiation Risk	
Objective	To demonstrate knowledge on how to apply radiation protection regulations in nuclear medicine clinical practice
Prerequisite	Sub-Module 3.1 Clinical Awareness Sub-Module 3.1 Monitoring radiation levels including personnel monitoring Sub-Module 3.2 Exposure from unsealed sources and the risk of contamination
Competency addressed	An understanding of: (a) The methods for estimating effective dose to the patient from diagnostic nuclear medicine scans. (b) knowledge of the risks associated with radiation exposure. (c) The procedures for risk assessment. Ability to communicate risk or lack of risk in the context of dose, justification and relevant non-radiation risks
Core knowledge	• Relate occupational exposures in nuclear medicine to other occupational risks and to variations in natural background. • Assess the risk and recommend precautions for women who wish to continue working in nuclear medicine while pregnant • Determine the risks to patients of any age from the radiation exposure associated with their diagnostic nuclear medicine procedures, and relate these to other clinical risks • Able to communicate risk or lack of risk in context of dose, justification and optimization

Recommended Elements of Training	• Read, and be reasonably familiar with, the resource material recommended for this competency
	• Review material on risk assessment and communication of risk.
	• Write a formal response to the following requests for information. In each case, provide an estimate of effective dose, the corresponding risk, and one or more examples of a comparable exposure and/or a comparable risk.
	  • for a concerned parent, whose 9-year-old child has been referred for a renal scan (dose to the child).
	  • for a pregnant mother, whose 5-year-old child has been referred for a bone scan (dose to the mother/fetus)
	  • for a pregnant registrar who is concerned about working in the stress room
	  • for an ultra-sonographer who is concerned about scanning a nuclear medicine patient
	  • for a patient who had a diagnostic nuclear medicine procedure when she was unaware that she was pregnant at the time, including comment on the fetal dose, any likely consequences and comparison with the normal risks of pregnancy.

Module 2: Radiation Protection	
Sub-module 2.5: Areas Designated for the Use of Unsealed Radioactive Material	
Objective	To demonstrate knowledge about the general design requirements of the department
Prerequisite	Sub-module 2.1 Monitoring radiation levels including personnel monitoring
Competency Addressed	Familiarity with (a) The designation of areas of the workplace associated with protection from unsealed radioactive material (b) The different radionuclide decay processes. Ability to manage a radioactive waste store for the sources used in a nuclear medicine department
Core Knowledge	• Grade a laboratory area depending on the radionuclides, activity and operations according to the respective regulatory body. • Design areas and specify construction requirements suitable for o Preparation, dispensing and administration ofradiopharmaceuticals o A radioactive waste store o CT installations in combination with radionuclide imaging • Understand the difference in requirements for Controlled and Supervised areas.

Recommended Elements of Training	· Be familiar with the resource material recommended for this competency. · Determine the grading of a NM Facilities as High, Medium or Low, from the maximum quantities of radionuclides and the operations as per the regulatory rules. Assume both diagnostic (including some FDG for PET) and therapy radiopharmaceuticals will be used. · Prepare a set of specifications for the hot lab, including o Surface finishes o Airborne contamination o Segregation of radionuclide and paper work o Security of access and stores o Local shielding o Any other features you think would be required
	· Estimate the lead thickness required for the walls and door of a 1x1x1m cupboard to be used for soiled linen contaminated with up to 5 GBq of I-131. The cupboard is immediately behind an area occupied by office staff. The door opens onto a corridor.

Module 2: Radiation Protection	
Sub-module 2.6: Radiation Shielding Considerations in Design of New Facilities	
Objective	To acquire knowledge on facility design for radiation protection
Pre-requisites	Sub-Module 3.2 Exposure from unsealed sources and the risk of contamination Sub-Module 3.5 Areas designated for the use of unsealed radioactive material.
Competency Addressed	An understanding of the principles and requirements of shielding design for radionuclides energies being used for diagnostic Nuclear Medicine purposes. Familiarity with shielding requirements for PET, SPECT installations in combination with other imaging (e.g. CT) modalities The ability to design satisfactory radiation shielding for all types of nuclear medicine equipment
Core Knowledge	• Principles o Radiation dose units and metrics applicable to shielding design o Primary Radiation; attenuated and un-attenuated o Secondary Radiation; scatter and leakage o Transmission of primary and secondary radiation through patients, imaging components and barriers • Regulatory Requirements and Guidelines o Local legislation and guidance applying to the design of Nuclear Medicine facilities o Designation of controlled and supervised areas o Dose limits for workers and members of the public o Dose constraints and shielding design goals

	• Shielding concepts
	  ○ Concepts of primary and secondary barriers
	  Concepts of workload including effect of technique factors, effect of patient numbers, effect of future changes in workload, equipment design, and usage, e.g., change from gamma camera room to a PET/ CT room which need specific shielding for 511 keV.
	  ○ Concepts of occupancy and impact of the occupancy of surrounding areas on shielding design
	  ○ Concept of cross-talk between equipment and other disturbances of measurement due to radioactivity in surrounding rooms.
	• Materials
	  ○ Attenuation properties of materials
	  ○ Substitute materials and impact on shielding effectiveness
	  ○ Common building materials and techniques
	• Shielding Requirements
	  ○ Determination of radiation dose at barrier from workload data
	  ○ Calculation of required transmission
	  ○ Specification of required materials
	• Assessment of shielding
	  ○ Visual monitoring during construction
	  ○ Use of radionuclides
	  ○ X ray measurement (for SPECT/CT, PET/CT)

Recommended Elements of Training	• Carry out workload assessment – taking into account both examination technique & patient numbers
	• Determine occupancy of surroundings of a PET/CT room
	• Perform the shielding calculation and assumptions for the establishment of PET/CT. Depending on the situation, a PET/CT system may require moderate to heavy shielding. Hot lab and injection rooms should have appropriate shielding
	• Assess the effect on shielding options of equipment location and orientation
	  · Assess the effectiveness of shielding and errors in measurements.
	  · Document effect of changes in workload, equipment usage, equipment orientation or equipment design on shielding requirements
	• · Do an assessment of shielding, visual monitoring during construction. Perform Documentation of complete assumptions, design, and specifications for future reference, and maintenance.

Module 2: Radiation Protection	
Sub-module 2.7 Regulatory Controls and Other Guidance on the Safe Use of Ionizing Radiation in Nuclear Medicine	
Objective	To understand and advise on all aspects of regulatory compliance
Prerequisites	Sub-module 2.3: ALARA and Radiation Safety Precautions in Nuclear Medicine
Competency Addressed	An understanding of the local regulatory requirements for Nuclear Medicine The ability to advise on local, regional, and national radiation protection and safety legislation
Core Knowledge	· The regulatory controls on the safe use of ionizing radiation in nuclear medicine in the trainee's own location · Create and maintain radiation records for a Nuclear Medicine Dept. that conform with regulatory requirements and usual standards of practice including o Personnel dose o Radiation licenses and registrations o Radiation incidents o Radioactive materials including wastes. · Apply the guidelines relevant to nuclear medicine as issued by the local regulatory authority and professional organization · Assess and report on the Radiation Safety Program in the trainee's institution
Recommended Elements of Training	• Read, and be reasonably familiar with, the resource material recommended for this competency • Summarize the radiation control legislative requirements in your location including: o Responsibilities of employers and employees including information on radiation safety o Licensing and supervision for anyone working in nuclear medicine including physicians, registrars, technologists/ trainees, service engineers, scientists and postgraduate students. o Include any requirements relating to the use of hybrid CT imaging systems o Limits on radiation dose resulting from working with radiation, working near radiation, or as a member of the general public o Radiation monitoring of persons working in nuclear medicine o Area monitoring o Calibration of radiation monitoring devices

	○ Registration of nuclear medicine facilities, radioactive sources whether sealed or unsealed, x ray apparatus including hybrid CT ○ Purchase of radioactive material ○ Disposal, loss or theft of radioactive material ○ Investigation and reporting of radiation accidents ○ Exposure to humans for research purposes ○ Contamination of the environment ○ Maintaining or destroying radiation records ○ Discharge of radioactive material to air or sewer ○ Transport of radioactive materials • In your own Department, review the current record keeping system related to: ○ personnel dosimetry ○ licensing for use of radioactive materials ○ incident reporting ○ inventory control and waste disposal of radioactive material
	• For each of these areas, consider possible improvements. If necessary, design and implement an appropriate system which will facilitate identification of potential problems such as lost sources, repeated spills, excessive dose to a particular person, etc. • Write a report on the record system • In your own Hospital, report on the radiation safety program including: ○ Description of any committees and duties of anyone who has a radiation safety role. Draw a diagram of lines of management and reporting ○ How are radiation accidents reported and investigated ○ What would be a 'high' dose reading on a personal dosimeter in nuclear medicine and what would be done about it ○ How are staff informed about radiation safety ○ How are safety rules drawn up and enforced

MODULE 3 - RESEARCH, DEVELOPMENT AND TEACHING	
Objective	To develop key skills in research, development and teaching in Nuclear Medicine Physics.
Expected Duration	5% of overall time.
Sub-Modules	3.1. Research and Development 3.2. Teaching

Module 3 - Research, Development and Teaching	
Sub-module 3.1-Research and Development	
Objective	To develop the ability to perform research in an area of relevance to nuclear medicine practice either individually or as a member of a multi- disciplinary research team.
Pre-requisites	None
Core Knowledge	(1)Understanding of · The role of ethics in research involving human and animal subjects including radiation related subjects.

Module 3 - Research, Development, and Teaching	
Sub-module 3.2 - Teaching	
Objective	To develop the skills required to be an effective educator and mentor in nuclear medicine practice.
Prerequisites	None
Competencies Addressed	An understanding of the general principles of effective teaching Ability to teach principles and methods of nuclear medicine physics.
Core Knowledge	Understand the general principles of effective teaching including: · teaching method and strategies appropriate to the group size, needs, interests, and backgrounds of the audience · mechanisms of student feedback and assessment strategy · provision of necessary instructional material for the student · preparation of teaching material review of teaching processes

Recommended elements of training	• Attend a general course (often available at national or international nuclear medicine meetings) on how to teach • Attend refresher courses at the SNM, ARCCNM and EANM meetings to observe both Nuclear Medicine Technologist and nuclear medicine physicians teaching various topics • Teach medical physics, technology, and radiation topics (including radiation safety) to different audiences. Suggested examples include: • Teaching to Nuclear Medicine Technologist, junior Nuclear Medicine Technologist, or other technically orientated staff • Teaching to nuclear medicine staff and residents • Teaching radiation safety to nurses or other paramedical staff (e.g., departmental secretaries) • Teaching technologists to carry out quality control of a • specific nuclear medicine equipment

MODULE 4 – PROFESSIONAL DEVELOPMENT AND MANAGEMENT	
Objective	To develop knowledge and competencies relating professional aspects of the Nuclear Medicine Technologist roles and responsibilities.
Expected Duration	5% of total time
Sub-Modules	4.1 Professional Awareness 4.2 Communication 4.3 Quality Management 4.4 Clinical audit

Module 4 – Professional Development and Management	
Sub-module 4.1: Professional Awareness	
Objective	To demonstrate an understanding of, and participate in (if possible), activities related to professional awareness.
Prerequisite	None
Competencies Addressed	Demonstrate an understanding of professional issues. Contribution to professional body activities.
Core Knowledge	• An understanding of departmental staff structure and local career opportunities for Nuclear Medicine Technologist. • An appreciation of the structure and activities of the local professional medical physics organization, and its relationship to overseas peak bodies. • An understanding of the ethical, legal and intellectual property issues faced in the workplace by the Nuclear Medicine Technologist • An understanding of the term CPD and how it operates.
Recommended Elements of Training	• **Career Planning** • Achieve an understanding of the scope of practice and career structure of Nuclear Medicine Technologist. • Achieve an understanding of the opportunities and restrictions in career progression. • Draw a tree diagram summarizing your department's staff structure, including your position. • Define your own career plan.

	Professional Organization Activities • Demonstrate an awareness of your professional organization including its aims, structure, key office bearers and administrative staff. • Attend and actively participate in professional activities. • Regularly review websites of medical physics professional organizations world-wide • Demonstrate an awareness of topical issues affecting your profession and your professional organization. • Demonstrate an awareness of other allied organizations (e.g. Nuclear medicine physicians and nuclear medicine technologists) and locate the relevant websites. • Demonstrate of the awareness of international agencies and professional bodies as related to nuclear medicine physics. • Demonstrate an awareness of important professional journals in and related to medical physics and nuclear medicine, and regularly read relevant papers. **Professional Issues** **(i) Ethics** • Demonstrate an understanding of your professional organization's and hospital's policies and procedures on professional and clinical ethics. • Demonstrate an awareness of the code of conduct and mission statement for your professional organization and hospital. • Understand the local and/or national requirements for ethics clearance for clinical research projects. • Understand the requirements of privacy of staff and patient information. **(ii) Legal Issues** • Outline the objectives, definition and requirements of/for legal issues at your institution/s (e.g. hospital and university if relevant) and in your state and country as related to Nuclear Medicine Technologist. This should include the policies on conflict of interest and legislation and regulatory matters. • Outline local and/or national requirements of radiation incident reporting. • Awareness of data protection legislation. **(iii) Intellectual Property** · Understand the types of intellectual property. · Outline the objectives, definition and requirements of/for intellectual property at your institution/s (e.g. hospital and university if relevant). · Outline ownership of material produced as a result of your research at your institution.

	· Demonstrate an awareness of vendor intellectual property requirements in the workplace, including software licensing and warranties. **Continual Professional Development (CPD)** · Demonstrate an awareness of the objective of CPD. · Demonstrate an awareness of legislation and/or professional organization requirements for CPD.

Module 4 – Professional Development and Management	
Sub-module 4.2: Communication	
Objective	• To be a good communicator within a multi-disciplinary team, with • patients and the general public.
Prerequisites	None
Competencies Addressed	• Demonstrate a high level of oral and written communication and interpretation skills • The ability to communicate with clinicians and apply physical • principles to clinical problems
Core Knowledge	How to communicate effectively within a multidisciplinary team, both orally and in writing.
Recommended Elements of Training	**Oral Skills** •Attend a course on o Oral presentation competencies, o Mentoring competencies, and/or o Conducting professional meetings. •Actively participate in physics department meetings (chair a meeting if possible). •Actively participate in Department technical meetings. o Scientific presentation at meeting of Nuclear Medicine Technologist, multi- disciplinary professionals or an audience containing members of the general public.
	• Medical Physics tutoring for other Nuclear Medicine professionals. Examples include Radiation Safety lectures and tutorials to Nuclear Medicine Registrars. • Actively participate in project progress meetings during equipment commissioning. • Presentation of research results at a national and/or international conference/meeting. • Provide accurate, clear, clinical medical physics advice regarding optimization of nuclear medicine procedures to other Nuclear Medicine Professionals.

	Written Skills • Demonstrate understanding of professional issues such as legal consequences of information documented and forwarded via email, confidentiality, sensitivity and permission to use data. • Demonstrate understanding of appropriate format and style of professional written communication, including email, memos and letters. • Keep a logbook • Write an example of a professional letter, email and memo that you could send to a key manager in the Nuclear Medicine Department addressing a medical physics issue. • Write a brief technical report on the optimization of a diagnostic procedure. • Write a business case to management regarding the case for new or a replacement of nuclear medicine equipment. • Write or review a protocol (new or revised) for a quality control process in the Department. • Write a progress and/or final report for commissioning of a new item of nuclear medicine equipment in a Nuclear Medicine Department. **Comprehension Skills** • Participate in department meetings to review journal papers • Present a review of an international technical protocol to Physics Department **Communication** · Investigate the roles of other medical and allied health professions in the health system, and especially where those professions involve imaging. · Talk with work colleagues, to understand their point of view, and to help them understand yours. **Consultation and Support** · Communicate with the clinician in terms they can understand in their specialty · Listen to a non-nuclear medicine problem posed by a clinical colleague · Use your general physics background to problem-solve · Think laterally, including outside the nuclear medicine context · Research a problem and postulate a solution, keeping in mind the boundaries of your understanding and ability · Enlist the help of others with relevant skills

Module 4 – Professional Development and Management	
Sub-module 4.3: Quality Management	
Objective	To provide the resident with understanding of the organization and implementation of a comprehensive system for quality management
Prerequisite	Module 4.1: Professional awareness
Competencies Addressed	Understanding of the structure of a quality system. Ability to implement and maintain the physics aspects of the quality system.
Core Knowledge	· Basic knowledge of quality management standards. · Understanding of the terms used such as: quality assurance, quality control, quality audit, risk management, human resources management. · Knowledge of the national regulations. · Understanding of all elements needed in a quality system. · Basic knowledge of how a quality system is adapted to the nuclear medicine practice. · Basic knowledge of the maintenance of a quality system.
Recommended Elements of Training	• Study a suitable standard on quality management. • Explain the meaning of relevant terms such as: quality assurance, quality control, quality audit, risk management, human resources management, and traceability. • Describe the role of all professionals in the quality system. • Review which parts of the standard that has been implemented in the nuclear medicine department. • Give recommendations on how the quality system for the nuclear medicine department could be improved. • Describe the role of the Nuclear Medicine Technologist in the Quality system. • Check if the existing quality documents are properly updated • Check if the existing quality documents are used in clinical practice. • Study an entire patient procedure and describe how different parts of the quality system influences the quality of the procedure. • **Describe which role the quality system plays during the "lifecycle" of nuclear medicine equipment.**

Module 4 – Professional Development and Management	
Sub-module 4.4: Clinical Audit	
Objective	To demonstrate an understanding of the purpose, conduct and analysis of a clinical audit.
Prerequisite	None

Competencies Addressed	An understanding of nature, purpose and importance of clinical audit in the nuclear medicine setting. The ability to effectively contribute as a member of a multidisciplinary team to a nuclear medicine clinical audit.
Core Knowledge	· The purpose of clinical audit in nuclear medicine. · The role of the Nuclear Medicine Technologist in clinical audit. · Familiarity with local legislative requirements for clinical audits.
Recommended Elements of Training	• Acquire an understanding of the purpose of clinical audit and what it involves from the provided knowledge sources. • Become familiar with any local legislative requirements for clinical audit. • Identify practical examples of clinical audit in Nuclear Medicine. • Consult relevant audit documents and other sources to ascertain the acceptable standards for medical physics in a nuclear medicine department. • Demonstrate ability to assemble departmental information on medical physics activities in a department (e.g. QA and calibration documentation) prior to the commencement of an audit visit. • Demonstrate practical aspects of medical physics activities in a department (e.g. in QA and calibration) at the request of an audit team member during an audit visit. • Respond to suggestions to change of work practice as a result of an audit visit.

MODULE 5 - EQUIPMENT PROCUREMENT, ACCEPTANCE TESTING AND COMMISSIONING	
Objective	To acquaint the resident with procedures for acquiring new equipment, acceptance, reference testing and commissioning.
Expected Duration	10% of the entire time
Sub-Modules	5.1 Acquisition and life cycle of nuclear medicine equipment 5.2 Dose calibrator acceptance testing 5.3 Scintillation probe and well counter acceptance testing 5.4 Gamma camera, SPECT and CT acceptance test and commissioning 5.5 PET and CT acceptance test and commissioning

Module 5 - Equipment Procurement, Acceptance Testing and Commissioning	
Sub-module 5.1: –Acquisition and Life Cycle of Nuclear Medicine Equipment	
Objective	To develop the competency necessary to prepare specifications for new equipment and to assist in the management of nuclear medicine equipment.
Prerequisite	Sub-module 2.5 Areas Designated for the Use of Unsealed Radioactive Material Sub-module 2.6 Radiation Protection Considerations in Design of New Facilities
Competencies Addressed	To understand the procedures for acceptance testing and equipment maintenance as well as verification of equipment performance after maintenance. The capability to make budgetary requests, prepare the specifications and acquire suitable equipment through a tendering process
Core Knowledge	· Knowledge of issues relevant to equipment selection (e.g. Equipment technology, functionality, performance, compatibility, training, maintenance service, building and building services, delivery and installation, and local purchasing procedures). · Familiarity with current products, key differences in available technologies. · Prepare a project and budget proposal
	• Principles of Equipment Planning o Creation of the business plan o Clinical consideration o Technical considerations including power supply and earthing/grounding o Maintenance planning

	○ Equipment limitations ○ Workflow and limitations ○ Room layout ○ Workload and radiation shielding • Principles of Equipment Acquisition ○ Specification ○ Tender ○ Selection of vendors • Principles of Equipment Installation, Acceptance Testing and Commissioning ○ The need for oversight of the installation process ○ The role of acceptance testing ○ The role of commissioning • Principles of equipment oversight ○ Quality control programmes ○ Equipment service and maintenance • Principles of Equipment Disposal • Concept of equipment life cycle
Recommended Elements of Training	• Demonstrate an understanding of the process involved in equipment requisition and acquisition • Review and report on department needs on: ○ Equipment technology ○ Functionality ○ Performance ○ Compatibility ○ Training ○ Maintenance service ○ Building and building services ○ Delivery and installation • Perform: ○ Market research on equipment technology Technology assessment
	• Review of procurement documentation • Submit project proposal and budgetary request • Prepare/perform within a multidisciplinary team ○ Tender specification ○ Tender evaluation ○ Tender recommendation • Equipment business plan and draft of a tender document • Equipment Planning ○ Development of room layout ○ Establish workload and radiation shielding requirements

	• Equipment Acquisition
	  ○ Development of specifications based on needs analysis
	  ○ Selection of primary vendors
	  ○ Selection of final vendor
	  ○ Negotiation with vendors to optimize equipment and price
	• Supervise and mentor technical staff to successfully complete a project on schedule.
	• Attend a course on
	  ○ Time management
	  ○ Conflict resolution
	  ○ Performance management
	• Oversight of equipment maintenance
	• Supervise the maintenance of nuclear medicine equipment, such as:
	  ○ Participate in trouble-shooting equipment faults for a period of time.
	  ○ Assume responsibility for different items of equipment for a period of time, including being a contact point for equipment faults and liaising with engineers.
	  ○ Write a report and/or present to the physics department case studies outlining the equipment fault, its cause and required verification measurements required to ensure accurate dose delivery.

	• Understand differences between units from different manufacturers.
	  ○ Perform appropriate testing after maintenance, calibration, and software upgrades to assure image quality and patient safety
	• Principles of Equipment Disposal
	  ○ Assist in planning for equipment replacement and disposal
	  ○ Negotiate for beneficial arrangements for equipment removal
	• Ensure appropriate disposal considering hazardous materials in the equipment

Module 5 - Equipment Procurement, Acceptance Testing and Commissioning	
Sub-module 5.2 - Dose Calibrator Acceptance Testing	
Objective	Become familiar with the procedure for acceptance testing of a new dose calibrator.
Prerequisite	Sub-module 5.1 Acquisition and life cycle of Nuclear Medicine Equipment Familiarity with basic principles of dose calibrator functions and operation Familiarity with hot lab procedures and radiation safety measures required to handle the sources associated with the experimental work.

Competencies Addressed	An understanding of the procedure for initial acceptance of a dose calibrator Ability to perform dose calibrator acceptance testing
Core Knowledge	· Principles of operation of the dose calibrator · Factors affecting dose calibrator accuracy o Background activity o Source geometry o Source position o Sample activity o Isotope measured · Use of certified radioactive sources · 'Precision' and 'accuracy' · Criteria for acceptable performance · Appropriate action if equipment fails acceptance testing · Understand the reference test as part of the QC
Recommended Elements of Training	Perform the following tests on a dose calibrator: · Physical Inspection · Precision and Accuracy · Linearity of Activity Response · Background test · Dose calibrator geometry test

Module 5 - Equipment Procurement, Acceptance Testing and Commissioning	
Sub-module 5.3 – Scintillation probe and Well Counter Acceptance Testing	
Objective	Become familiar with the procedure for acceptance testing of a new scintillation probe or well counter.
Prerequisite	Familiarity with basic principles of scintillation probe or well counter functions and operation. Familiarity with hot lab procedures and radiation safety measures required to handle the sources associated with the experimental work.
Competencies Addressed	An understanding of the procedure for initial acceptance testing of a scintillation probe or well counter. Ability to perform acceptance testing of a scintillation probe or well counter.
Core Knowledge	· Components and principles of operation of the o scintillation probe system o well counter · Chi squared test · Recommended acceptance tests · Understand the reference test as part of the QC.

Recommended Elements of Training	Perform the following tests on the scintillation probe and well counter systems as the acceptance test and the annual basis as the reference test: · Physical inspection · Test of function of scaler - timer/rate meter · Test of energy calibration · Test of energy resolution (% FWHM) · Test of sensitivity · Test of counting precision (Chi squared test) · Test of linearity of energy response
	· Test of integral background count rate · Test of linearity of activity response · Test of preset analyzer settings.

Module 5 - Equipment Procurement, Acceptance Test and Commissioning	
Sub-module 5.4 - Gamma Camera/SPECT and CT Acceptance Testing and Commissioning	
Objective	Be able to demonstrate familiarity with the processes involved in acceptance testing of gamma cameras/SPECT and CT.
Prerequisite	Familiarity with all aspects of gamma camera/SPECT and CT design and performance, both hardware and software Familiarity with hot lab procedures and radiation safety requirements for handling the sources required for the acceptance tests
Competencies Addressed	An understanding of the procedure for acceptance test of the gamma camera/SPECT and CT systems Ability to perform acceptance testing of the gamma camera / SPECT systems.
Core Knowledge	· Standards for gamma camera/SPECT acceptance testing · Manufacturer specifications of system performance · Interpretation of acceptance test results · Criteria for acceptable performance · Appropriate action if equipment fails acceptance testing · Basic understanding of CT acceptance test. · Understand the reference test as part of the QC
Recommende Elements of Training	• Read, and be reasonably familiar with, the resource material recommended for this competency. • Design a set of acceptance tests to be performed on a gamma camera system following its commissioning which determine whether the camera meets required performance specifications. • Perform acceptance testing on a SPECT system

	○ Mechanical inspection ○ Pixel size ○ Centre Of Rotation (COR) ○ Tomographic uniformity ○ Tomographic resolution (air) ○ Tomographic resolution (scatter) ○ Slice thickness ○ Rotational sensitivity uniformity ○ Total performance study • Produce a report which shows the results of the acceptance tests, flagging any non-compliances (based on your original minimum performance specifications) and indicating whether the system should be accepted for routine clinical imaging. • Obtain the relevant specifications from the vendors of currently available gamma cameras, SPECT and compare them to the specification document. • Prepare a document detailing acceptance test to be performed on a gamma camera system capable of SPECT. • Write a report detailing the results of the acceptance tests. Flag any non-compliances (based on your criteria from the previous step) and indicate whether the system should be accepted for routine clinical imaging. • Discuss whether the camera meets any local national standards for gamma camera performance (if available). • Perform the reference test at the annual basis. Compare the results to the acceptance test to see any changes or deteriorations. • Observe the acceptance test of CT

Module 5 - Equipment Procurement, Acceptance Testing and Commissioning	
Sub-module 5.5 – PET and CT Acceptance Testing and Commissioning	
Objective	Be able to demonstrate familiarity with the processesinvolved in acceptance testing of PET/CT.
Prerequisite	Familiarity with basic principle of the PET /CT function and operation
Competencies Addressed	An understanding of NEMA procedures for PET acceptance testing Ability to perform ○ PET acceptance testing and commissioning ○ SUV calibration and check SUV calibration accuracy
Core Knowledge	· Standards for PET system acceptance testing such as NEMA NU 2- 2007. · Manufacturer specifications of system performance · Interpretation of acceptance test results · Criteria for acceptable performance

	· Appropriate action if equipment fails acceptance testing · Basic understanding of CT acceptance test.
Recommended Elements of Training	• Prepare a report comparing the various technologies used for PET coincidence imaging for whole body PET studies. • The comparison should include the following technologies: o Gamma camera based coincidence system o GSO, LySO PET systems (e.g. Philips Gemini) o BGO based systems (e.g. GE Discovery Series) o LSO (e.g. Siemens Biograph,) o PET scanners vs. PET/CT hybrid scanners • Perform PET acceptance test according to the NEMA Nu-2 2007 • The following aspects of performance should be covered o Count rate performance o Spatial Resolution o Corrections applied and quantitative accuracy o 3D vs. 2D acquisitions in terms of sensitivity, injected activity and effect of activity outside field of view. o Relative merits of CT vs. non-CT based attenuation correction o Appropriate NEMA standard to evaluate performance for whole body studies (NEMA 2001) o Activity injected into patient and uptake period o Throughput of studies and relative cost of systems · Observe the acceptance test of CT. · The SUV is a quantitative index and hence requires activity concentration in the patient to be estimated in absolute terms with the PET scan. o Describe each of the corrections and calibrations which have to be performed to achieve quantitative values • How does this impact on the routine QC of the PET scanner • Design and describe an experiment to verify that the PET scanner provides accurate activity concentration values and all corrections and calibrations are appropriately applied.

MODULE 6 - RADIOACTIVITY MEASUREMENTS AND INTERNAL DOSIMETRY	
Objective	To provide the resident with clinical knowledge and skills to measure radioactivity and perform internal dosimetry calculations.
Expected Duration	10% of overall time
Sub-Modules	6.1 Use of traceable standards for radioactivity measurements 6.2 Formalism and application of internal dosimetry 6.3 Absorbed dose from diagnostic nuclear medicine radiopharmaceuticals 6.4 Quantitative nuclear medicine imaging 6.5 Patient-specific dosimetry

Module 6 - Radioactivity Measurements and Internal Dosimetry	
Sub-module 6.1: Use of Traceable Standards for Radioactivity Measurements	
Objective	To acquire the knowledge and skills to be able to perform and understand quality assurance principles for radioactivity measurement in nuclear medicine.
Prerequisite	Sub-module 7.2: QC for Dose calibrator Sub-module 7.3: QC for Scintillation probe and well counter
Competencies Addressed	An understanding of the traceability chain for radionuclide activity measurements in the nuclear medicine setting. The ability to apply quality assurance principles and estimate the uncertainties involved in radioactivity measurements in the clinical setting.
Core Knowledge	· Traceability to primary standards. · Uncertainties involved when measuring the clinical vials c.f., the standard source(s). · Methods for cross-calibrations. · Inter-comparisons.
Recommended Elements of Training	· Perform decay corrections to reference time. · Investigate the volume dependence for activity meter measurements. · Review established constancy tests for activity meters by repeat measurements of the check source and record the decay-corrected results on a constancy graph. Note any deviations or trends. · Prepare an uncertainty analysis for measuring the radionuclide activity used in the clinic.

	· Perform cross-calibrations with instruments available in the clinic, e.g. gamma-well counters, gamma probes, solid-state detectors. Discuss the uncertainties in each measurement. · Participate in inter-comparison of standard sources with other institutes. · Review or set up an appropriate quality assurance program for radioactivity measurements.

Module 6 - Radioactivity Measurements and Internal Dosimetry	
Sub-module 6.2: Formalism and Application of Internal Dosimetry	
Objective	To acquire the knowledge and skills of applying established formalisms for internal dosimetry calculations.
Prerequisite	Sub-module 1.2: Basic principles of radiation biology and epidemiology
Competencies addressed	An understanding of the formalism established for internal dose calculations, including its limitations. Ability to calculate absorbed dose to organs according to the MIRD formalism as well as to derive the effective dose.
Core Knowledge	· Identifying the physical and biological parameters for absorbed dose calculation. · Choosing the proper methods of data collection. · Identifying the factors affecting the absorbed dose to particular organs. · Understanding biokinetic analysis and modelling and the fundamentals of compartment analysis. · Understanding the MIRD formalism so that calculation of absorbed and effective dose can be made for different clinical investigations. · Understanding the uncertainties involved in the various steps. · Estimating the absorbed dose to fetus. Fundamental understanding of cellular dosimetry (optional).
Recommended Elements of Training	• Review the definitions of absorbed dose, equivalent dose and effective dose. • Choose various nuclear medicine procedures, including pediatric procedures. Describe the measurements required to calculate organ cumulative activity for this procedure. Describe how these measurements could be performed using equipment available in your department. Describe the uncertainties involved. • Using measured or published biokinetic data, calculate the cumulative activity for the important source organs, in the chosen procedure. Compare the results with the dose information provided by the distributing company for that radiopharmaceutical. • Search the literature for examples of papers where individual dosimetry has been done. Note the methods for data acquisition.

	• Evaluate how clinical examinations with a scintillation camera can be designed in order to constitute the basis for an absorbed dose estimate. What data and how many measurements are needed? What other sources can be useful to support the acquired data? • Study the available literature on estimates of fetal dose from different radiopharmaceuticals, based on standardized kinetic models. Specifically investigate the case of a fetal thyroid dose after the radioiodine (I-131) administration to a woman in a different period of gestation. Search also the literature to explore how the above dose assessment changes in hyperthyroid or a thyroid patient.

Module 6 - Radioactivity Measurements and Internal Dosimetry	
Sub-module 6.3: Radiation dose from Diagnostic Nuclear Medicine Radiopharmaceuticals	
Objective	To acquire the knowledge and skills to use look-up tables for estimating absorbed and effective dose from diagnostic nuclear medicine procedures
Prerequisite	Sub-module 6.2: Formalism and application of internal dosimetry
Competencies Addressed	An understanding of the underlying methods for the derived tables available for internal dose estimations, including the uncertainties expected for different patients. The ability to use established tables for estimating absorbed dose and effective dose to the patient.
Core Knowledge	(1) Quantities and units · Understand the concepts of absorbed dose, equivalent dose and effective dose listed in ICRU60, ICRP60 and ICRP103. · Understand the appropriate applications of the different quantities (e.g. equivalent dose for whole organs, effective dose only for low- dose stochastic effects). (2) Dose estimates · Importance of appropriate biokinetic data in determining internal dose. · Variations in biokinetic data with age, gender and physiology/pathology, and appreciate how this affects internal dose · Reliable sources of generic radiopharmaceutical dosimetry data.
Recommended Elements of Training	• Read, and be reasonably familiar with, the resource material recommended for this competency • Estimate the effective absorbed dose, and the equivalent dose to specific organs and tissues, for three of the procedures commonly used in the practice or institution where the resident works. • For one of the procedures, comment on - changes in absorbed dose with the weight and age of the patient. - the dose to the embryo/fetus in pregnant patients as a function of stage of gestation. - the effect of non-standard physiology such as impaired renal clearance on

	the absorbed doses received - the estimated doses with reference dose levels and the doses given in the "package insert" for the radiopharmaceutical used. • Prepare a basic dosimetry report for the chosen procedure

Module 6 - Radioactivity Measurements and Internal Dosimetry	
Sub-module 6.4: Quantitative Nuclear Medicine Imaging	
Objective	To acquire the knowledge and skills to be able to derive quantitative information from nuclear medicine images.
Prerequisite	Sub-modules 5.2, 5.3, 5.4, 7.1, 7.4, (Dose calibrator, Scintillation probe and well counter, Gamma camera and SPECT, Operation of a clinical acquisition and processing/reviewing workstation, Computer image processing techniques)
Competencies Addressed	An understanding of the main factors affecting quantitative measurements in nuclear medicine Ability to acquire quantitative measures from planar, SPECT and PET studies
Core Knowledge	· Fundamentals of image analysis · Patient, physical and technical factors affecting accurate activity quantification: anatomic, physiological, time dependent, instrumentation and image processing factors. · Estimation of activity from planar images. · Common approaches for quantitative SPECT studies. · SPECT quantification and activity/cross calibration factor
Recommended Elements of Training	(1) Validation of methods for activity estimation from planar images. The work could include • Review of methods given in the literature and selection of appropriate method • Validation of the method using a phantom which simulates activity in the lungs and in the liver, including simulation of the lower density of the lungs. (2) Perform SPECT activity quantification calibration and evaluation • Review methods for SPECT activity quantification and select method which can be implemented with the equipment you have in the department. • With a uniform phantom, calibrate the SPECT system to provide a calibration factor which can convert SPECT counts per voxel to activity per mL (e.g. kBq/mL). • With a uniform phantom which is different from the calibration phantom and which contains a known activity concentration, validate the method you have devised for absolute activity estimation with SPECT. (3) Investigate the effect of acquisition parameters (e.g. time per projection, matrix size, number of projections on the activity calibration factor).

	(4) Design and carry out a phantom experiment which demonstrates the effect of partial volume on activity quantification (can be demonstrated either for planar o SPECT studies).

Module 6 - Radioactivity Measurements and Internal Dosimetry	
Sub-module 6.5 – Patient-Specific Dosimetry	
Objective	To acquire the knowledge and skills to understand when patient- specific dosimetry is required and how to perform it.
Prerequisites	Sub-modules 6.2, 6.4. (Formalism and application of internal dosimetry, Quantitative nuclear medicine imaging)
Competencies Addressed	An understanding of the tools and requirements needed for performing patient-specific internal dosimetry. The ability to calculate patient-specific dosimetry from repeat images and uptake measurements.
Core Knowledge	• Situations when there is a need for patient-specific dosimetry • Tools available for individual dosimetry • Uncertainties involved and methods available to reduce them (tracer studies, repeat imaging, sampling etc.) • Process by which research proposals are evaluated and approved • Comparison of the absorbed dose from novel and established diagnostic procedures to dose constraints for exposures for research purposes • Realize how to suggest recommendations on referral to the regulatory authority or review by independent Nuclear Medicine Technologist as appropriate.
Recommended Elements of Training	• Practice to advice on and perform internal dosimetry for therapeutic procedures • Explain to a research applicant the dose constraints and other recommendations in e.g. the national Code of Practice on Exposure of Humans to Ionizing Radiation for Research Purposes (ARPANSA, 2004/2005) • Independently verify and document an estimate of radiation dose to a subject, in a research study from established diagnostic radiopharmaceutical procedures including dual modality imaging • Other radiological imaging procedures in the study (preferably by consulting the MP specialized in diagnostic radiology) • Novel diagnostic or therapy radiopharmaceutical procedures • Prepare dosimetry reports for pregnant patients

	• Read one of the publications on patient-specific dosimetry from the suggested reading list and prepare a short summary of the methodology utilized to estimate the absorbed dose

MODULE 7 – QUALITY CONTROL OF NUCLEAR MEDICINE EQUIPMENT	
Objective	To acquaint the resident with procedures for the Quality control of nuclear medicine equipment
Expected Duration	15% of total time
Sub-Modules	7.1 Design and supervision of a routine QC program 7.2 Dose calibrator 7.3 Scintillation probe and well counter 7.4 Gamma camera and SPECT 7.5 PET 7.6 Display and Hardcopy Devices 7.7 BMD

Module 7 – Quality Control of Nuclear Medicine Equipment	
Sub-module 7.1 – Design and Supervision of a Routine QC Program	
Objective	To understand and manage all aspects of a routine nuclear medicine quality control programme
Prerequisite	Module 4.2: Communication
Competencies Addressed	An understanding of the methods for the clinical implementation and supervision of a quality control programme The ability to manage a QC programme including the appropriate use of instrumentation, test selection and test frequency
Core Knowledge	· Principles of quality control · Regulatory requirements o Roles and responsibilities of staff involved in the QC programme o Which staff groups are required to perform different types of tests o Supervision requirements o Training needs and delivery o Reporting and record keeping

	· Quality Control tests o Types of tests o Complexity of differing tests o Applicability of tests o Appropriate frequencies for performance of different tests o Use of control charts including operating levels, upper and lower control limits
Recommended Elements of Training	• Participation in the training of staff to perform QC tests • Establishment of o operating levels o control limits o control charts o record keeping • Implement QC program to include o Dose calibrator o Scintillation probe and well counter o Gamma camera o SPECT camera o PET scanner o CT scanner o BMD
	• Carry out periodic review of quality control program with other staff o Perform Nuclear Medicine Technologist level quality control tests o Develop quality control program o Monitor technologist's quality control tests

Module 7 – Quality Control of Nuclear Medicine Equipment	
Sub-module 7.2 – QC of a Dose Calibrator	
Objective	To be competent in all dose calibrator quality control procedures needed to ensure accurate measurements of radioactivity
Prerequisite	Sub-module 5.2: Dose calibrator acceptance testing
Competencies Addressed	An understanding of the effect of geometry, energy and type of emissions on radioactivity measurements. The ability to perform basic dose calibrator QC including constancy, background, linearity and accuracy checks and set appropriate action levels.

Core Knowledge	• The meaning of the terms linearity of response, constancy, accuracy, geometry dependence. • How to perform the following QC checks o Physical inspection o High voltage visual inspection check o Zero check and adjustment o Background check

Module 7 – Quality Control of Nuclear Medicine Equipment	
Sub-module 7.3 – QC of a Scintillation Probe and Well Counter	
Objective	To become competent in quality control procedures for the scintillation probe and well counter
Prerequisite	Familiarity with hot lab procedures and radiation safety measures for the safe handling of radioactive sources.
Competencies Addressed	An understanding of the principles of operation of a scintillation probe and well counter and relevant QC procedures. The ability to perform basic QC procedures for non-imaging scintillation systems
Core Knowledge	• Familiarity with basic principles of scintillation probes and well counters • How to perform the following quality control checks: o Physical Inspection o Function of Scaler-timer/Rate meter o Energy Calibration o Energy Resolution (% FWHM) o Sensitivity o Counting Precision (Chi squared test) o Linearity of Energy Response o Integral Background Count Rate o Linearity of Activity Response o Preset Analyzer Settings • Limits of acceptability • Setting action levels • Recommended frequency of checks • Importance of record keeping • Creating a control chart
Recommended Elements of Training	• Read, and be reasonably familiar with, the resource material recommended for this competency • Critically review a department's QC procedures for scintillation probe and well counter • Perform the following QC tests with reference to IAEA TECDOC 602:

	○ Physical Inspection ○ Function of Scaler-timer/Rate meter ○ Energy Calibration ○ Energy Resolution (% FWHM) ○ Sensitivity ○ Counting Precision (Chi squared test) ○ Linearity of Energy Response ○ Integral Background Count Rate ○ Linearity of Activity Response ○ Preset Analyzer Settings • Analyze data obtained in the above tests and determine whether the results fit within acceptable limits • Propose appropriate corrective action if test results are unsatisfactory • Record results • Create control chart

Module 7 – Quality Control of Nuclear Medicine Equipment	
Sub-module 7.4 – QC of a Gamma Camera and SPECT	
Objective	To become competent to perform and evaluate SPECT QC procedures.
Prerequisite	• Familiarity with basic principles of gamma camera design and the principles of SPECT image acquisition and reconstruction • Familiarity with the gamma camera/computer system used in the trainee's department and ability to acquire and reconstruct SPECT studies • Familiarity with hot lab procedures and radiation safety requirements for handling the sources required for the experiments
Competencies Addressed	An understanding of QC procedures for planar and SPECT devices. The ability to perform and evaluate typical · Planar QC procedures including: spatial resolution and uniformity (integral and differential), · SPECT QC procedures including: spatial resolution, uniformity (integral and differential), COR, spatial resolution SPECT uniformity and tomographic image quality

Core Knowledge	· The ability to setup and carry out the required experiments. · The ability to generate a report, including description and presentation of experimental setup, results and conclusions from the results. · An understanding of the necessity and limitations of the QC procedures. · Knowledge of the underlying physical principles responsible for the experimental observations.
Recommended Elements of Training	• Read, and be reasonably familiar with, the resource material recommended for this competency. • Critically review the department's gamma camera QC protocols with respect to the recommendations made in a national recommendations document such as the ANZSNM Technical Standards Subcommittee (TSS) document "Minimum quality control requirements for nuclear medicine equipment". o Write a report on your findings, including recommendations required to achieve compliance with the recommended minimum QC requirements. • Perform and write up the following planar QC tests using local national recommendations or the ANZSNM TSS document: o Quantitative high-count uniformity • Examine the effects of total counts and matrix size on differential and integral uniformity o Intrinsic spatial resolution o Use a bar phantom and ^{99m}Tc point source. An estimate of the resolution in terms of Full Width at Half Maximum (FWHM) should be made from the measurement. o As an alternative to using a bar phantom, if a slit phantom is available, intrinsic resolution FWHM may be measured with the slit phantom. • Perform and write up the following SPECT QC tests: o Centre of Rotation measurement as specified by the manufacturer o SPECT spatial resolution as a function of the radius of rotation (ROR) o Perform 2 SPECT acquisitions of a line source at the minimum ROR and at 20cm ROR. o Collect planar views at each ROR. o Reconstruct the SPECT acquisitions and calculate SPECT spatial resolution as a function of ROR. o Compare the SPECT resolution with the static resolution for each ROR • SPECT Uniformity o Perform a SPECT acquisition of a uniform phantom filled with 99mTc o Reconstruct the data with attenuation correction.

- Assess the reconstructed phantom uniformity. Describe any artefacts seen and provide quantitative estimates of the non- uniformities in the reconstructed slices.

- Tomographic image quality
  - Perform a SPECT acquisition of a Jasczcak phantom filled with 99mTc.
  - Compare reconstructed images with previous studies of the same phantom to check that the system has maintained its capabilities for clinical imaging in terms of tomographic uniformity, contrast, and spatial resolution.

Reports

- Formal reports are to be written for each of the tasks performed as part of this competency. The reports should be properly structured and should contain as a minimum:
  - Methods section describing your experimental setup used, including details of phantoms, activity used, camera setup, collection parameters etc. Where appropriate, justification should be provided for your experimental method (e.g. why you selected particular matrix/pixel size, use of non-standard phantom etc.). Pictures or diagrams of your experimental setup are also encouraged.
  - Image processing and data analysis methods used to include justifications for e.g. type of reconstruction filter, smoothing etc.
  - Presentation of the results of the experiment. The results should be properly compiled and summarized to provide a picture of the performance of the gamma camera for this test.
  - The results of your experiments should be fully discussed, including comparison with previous test results if available (e.g. acceptance test results), effect of not following e.g. NEMA protocol exactly, effect of different imaging conditions on results (e.g. radius of rotation on SPECT resolution), limitations of your experimental setup etc. Discussion should be supported by appropriate references. Conclusions should also be drawn regarding the suitability of the gamma camera for clinical use based on your measurements.
  - It is important that you convey an understanding of the purpose, underlying principles, and limitations of the tests in your report to demonstrate your competency.
  - Use of a note book is recommended for recording experimental details and results for later use when writing the report.
  - While you are expected to research and devise appropriate methodology for the experiments, it is worthwhile to check

	your proposed experimental methods with your supervisor, particularly for tests with which you are unfamiliar. • Specific Items to be addressed in your reports: ***Review of QC Procedures:*** • There might be valid differences between the procedures used in your department and the national recommendations, and in fact tests carried out might even be more appropriate for your particular equipment. If tests differ from local national or TSSC recommendations, but are considered appropriate, then this should be stated and reasons given why the current tests and procedures should not be changed. ***Quantitative High-Count Uniformity:*** · Based on the results from the effects of total counts and matrix size on uniformity, discuss whether your current procedure uses appropriate matrix size and total counts. If not, what changes are required? ***Intrinsic Spatial Resolution:*** · Discuss whether the measured resolution is acceptable for this type of gamma camera. · If a bar phantom is used to estimate resolution, discuss the limitations of this method for estimating FWHM. ***SPECT QC Tests:*** · Indicate whether the centre of rotation measurements is outside the limits specified by the manufacturer for this camera. · Indicate what is an acceptable degradation in resolution between SPECT and planar measurements at the same distance/ROR. Discuss whether your measurement indicates that the camera meets this requirement. If not, what could cause the greater degradation in resolution seen with SPECT.
	SPECT Uniformity: · Would you expect a high-count uniform phantom SPECT collection to be completely free of uniformity artefacts? · What level of non-uniformities would be acceptable? · Discuss the effect of noise on non-uniformity artefacts with relation to your high-count phantom studies compared to lower count, high noise clinical studies. · Use the information in the reading material and your specific gamma camera manuals as guides for planning and performing the measurements. **Phantoms and Sources** · Unless otherwise specified, ^{99m}Tc should be used for all measurements. · The amount of activity used should be appropriate for the test. Guidance for activity to be used and count rates for tests can be found in the reading material. Proper radiation safety procedures must be followed to avoid contamination of personnel and equipment.

- Place phantoms/sources on protective covers (e.g. incontinence pads) to avoid contamination of equipment.
- Make sure that phantoms do not leak – check with non-radioactive liquid first!
- Make sure you are aware of and follow any local radiation safety guidelines.
- Store phantoms/sources in appropriately shielded areas until decayed.

· If phantoms such as a bar phantom or slit phantoms are not available in your department it may be possible to borrow them from other departments. Check this with your supervisor.

· Some improvisation may be required if appropriate phantoms are not available:

- For SPECT uniformity a cylindrical plastic bottle with a screw top seal would be suitable.
- For SPECT resolution, any tubing with small internal diameter (< 2mm) may be used, providing it can be filled and sealed. Examples are:
- Disposable 1 mL pipettes or hematocrit tubes filled and sealed at both end with plasticine.
- Thin extension tubing taped to a ruler.

Quantitative Uniformity

· Review the NEMA specification for measurement of integral and differential uniformity.

· Review camera manuals to see if software is provided to perform quantitative flood field uniformity assessments:

- if available, is it done using NEMA methodology?
- NEMA specifies a particular pixel size and minimum count in the centre pixel for the uniformity test. As part of this exercise, you are required to also investigate the effects of matrix size and total counts on the measured uniformity value.
- Investigate whether the software will be suitable for investigating the variation of uniformity with matrix size (for instance some software will not analyze an arbitrary image matrix size, or will always collapse the image matrix to a 64x64 pixel size prior to analysis).
- If software is not available or unable to perform the type of measurement required, the ImageJ QC plugins that can analyze images for uniformity are available – consult the plugin notes on the ImageJ website (http://rsbweb.nih.gov/ij/) for further information.

SPECT Uniformity

- Sufficient counts should be collected to avoid masking of non-uniformities by noise – consult reading material for appropriate activity in phantom and collection times.

	• The data should be reconstructed with attenuation correction – uniform attenuation within the phantom may be assumed. Attenuation correction should be available on all clinical SPECT systems – if not available on your system, consult with your supervisor. • Some experimentation with reconstruction filters will be required to provide best trade-off between noise and detection of non-uniformities. It is suggested that filters with a sharp roll-off (e.g. high order Butterworth filter) and resolution recovery filters are not used for this experiment. A Hann filter would be suitable. **SPECT Spatial Resolution** • Review effects of acquisition parameters such as pixel size and number of steps on the spatial resolution of reconstructed images. Plan acquisition parameters accordingly (spatial resolution is likely to be 6- 8 mm FWHM for high resolution, low energy collimators at the minimum radius of rotation). • SPECT resolution is to be measured without scatter. Thus, line source should be suspended in air rather than placed on the patient SPECT bed. This can be achieved by taping the line source to the end of the bed or head holder. • Line up the line source with the axis of rotation. • Review principles of SPECT image reconstruction using filtered back projection and consider the most appropriate reconstruction filter to use for assessment of spatial resolution. • Spatial resolution of line and point source images can be assessed by measuring FWHM of a profile drawn through the image. Consult your camera to see if tools for FWHM measurement are provided. If none are available, the ImageJ QC plugins provide a FWHM tool that may be useful - consult the plugin notes on the ImageJ website (http://rsbweb.nih.gov/ij/) for further information.
	Tomographic image quality · Compare uniformity, contrast and spatial resolution of the study with a similar study acquired previously (if possible, at time of scanner installation). Comment on any differences in these parameters.

Module 7 – Quality Control of Nuclear Medicine Equipment	
Sub-module 7.5 – QC of PET/CT Systems	
Objective	To become competent in routine quality control procedures for PET/CT systems.

Prerequisite	Sub-module 2.2 Exposure from sealed and unsealed sources and the risk of contamination, Sub-module 9.1 Operation of a clinical acquisition and processing/reviewing workstation Sub-module 9.6 Image reconstruction, registration and fusion, and tracer kinetic modelling
Competencies Addressed	Familiarity with routine PET/CT QC procedures. The ability to perform routine QC procedures on a PET/CT system and to initiate appropriate corrective action when QC results reveal problems with the PET/CT system performance.
Core Knowledge	An understanding of the QC procedures required to maintain a PET/CT system in optimal operating condition.
Recommended Elements of Training	• Read and become reasonably familiar with the recommendedreading material. • Summarize in writing the procedures in place at the trainee's department for routine PET/CT quality control.
	• Comment in writing on any differences between these procedures and those specified in the IAEA document 'Quality Assurance for PET and PET/CT Systems'. • Perform all scheduled routine PET/CT QC procedures in the department for a period of at least two weeks, under supervision. Write a report containing, for each procedure: o the purpose of the procedure. o the steps involved in performing procedure, including mention of any phantoms and how they are positioned o what parameters are evaluated and how o the frequency with which it is performed o where results are stored and how they can be accessed for review o what results were obtained during the period. o how results are interpreted. o what values are specified as acceptable by themanufacturer. o what actions should be taken when results fall outside the acceptable range.

Module 7 – Quality Control of Nuclear Medicine Equipment	
Sub-module 7.6 – QC of Display and Hardcopy Devices	
Objective	Understand factors affecting image quality on display monitors and hard copy devices.
Prerequisite	None

Competencies Addressed	· An understanding of quality control procedures for display and hard copy devices. · Knowledge of film and other hard copy properties and calibration · Ability to perform QC for display and hard copy devices.
Core Knowledge	Familiarity with factors affecting image quality on display monitors and hard copy devices including: · Film and other hard copy properties and calibration · Display calibration · Test patterns used for display and hard copy testing and calibration · The effects of display window settings and grey scale maps on image display
Recommended Elements of Training	• Read, and be reasonably familiar with, the resource material recommended for this competency. • For each Nuclear Medicine workstation in the department display a suitable monitor test pattern (such as an SMTPE or TG18-QC test pattern) and o Follow the steps recommended in Resource 6 "Quality Assurance of Display Monitors" to assess monitor performance. Produce a suitable record sheet for each monitor assessed to summarize results. o If a densitometer is available, print the test pattern and measure the optical densities of grey scale squares on the hard copy of the test pattern. Comment on the linearity of optical density versus known intensity. o If paper hardcopy and/or films using a laser imager are normally produced, comment on o Loss of grey scale levels and range on hard copy compared to displayed image o Differences in color (if color printer) between hard copy and screen display o Experiment with the printer driver settings – can hard copy be improved by changing printer settings? (Note: record original printer settings prior to any changes so that original settings can be easily restored after you completed this task). • On a Nuclear Medicine clinical workstation Investigate the effect of choosing different grey scale maps (e.g linear, exponential, logarithmic, different gamma factors) and of altering display window settings (lower window level, upper window level) on a monitor test pattern image and on a variety of clinical images o Choose a clinical study that is normally displayed in color (e.g. cardiac or brain) and display the images with the color map your department uses normally. Investigate the effect of using different color maps (including greyscale) on the image appearance. o Write a brief report on your findings.

	• Using the information, images and tools provided on the website given in resource 5, carry out the procedures described for Setting up your monitor on a PC computer to which you have access (Note: do NOT do this on a PC based gamma camera workstation). Preferably download the QuickGamma software and use it to investigate the interaction between its gamma adjustment and the black level adjustment on your monitor. o Write a brief report on your experiences including an estimate of the gamma for the monitor. **Reports** • Reports to be written for each of the tasks in this competency may be less formal than those required in other competencies. Inclusion of worksheets to summarize monitor performance, summaries in point form concerning the effects of gamma corrections on image, etc. are acceptable. However, the written materials should still make clear the tasks that were performed and demonstrate your understanding of the areas covered in this competency

Module 7 – Quality Control of Nuclear Medicine Equipment	
Sub-module 7.7 – QC of DXA Systems	
Objective	To acquire the knowledge and skills to be able to perform QC tests on dual- energy X ray absorptiometry (DXA) units.
Prerequisite	None
Competencies Addressed	An understanding of the theory and operation of DXA equipment and the importance of QC and calibration in the accurate use of normal ranges the ability to perform QC of DXA equipment.
Core Knowledge	· The principles of general radiography · Dual energy x-ray absorptiometry principles. · Bone mineral densitometry concepts · DXA equipment components · Basic introduction to osteoporosis, bone physiology and risk factors · Radiation safety – shielding and patient dose. · Scan acquisition modes · Phantom calibration
	· Normal range, precision and reproducibility · Procedures for AP Spine, Femur/Dual Femur, Total Body, Forearm and LVA/Lateral spine.

Recommended Elements of Training	· Read and be reasonably familiar with items of core knowledge. · Perform a radiation survey of a DXA unit. · Perform routine QC on a bone mineral densitometer. · Perform calibration of a bone mineral densitometer.

MODULE 8 - RADIONUCLIDE THERAPY USING UNSEALED SOURCES	
Objective	To develop skills in the practical issues of individual radiopharmaceutical treatment and appropriate radiation safety requirements depending on the radionuclide used in therapy
Expected Duration	10% of total time
Sub-Modules	8.1 Understanding the principles of radionuclide therapy 8.2 Facility Design for radionuclide therapy 8.3 Treatment procedures 8.4 Selection of Radiopharmaceuticals for Nuclear Medicine Therapy 8.5 Dosimetry for radionuclide therapeutic procedure 8.6 Radiation safety precautions for therapy using unsealed radionuclide sources

Module 8 - Radionuclide Therapy Using Unsealed Sources	
Sub-module 8.1: Understanding the principles of radionuclide therapy	
Objective	To acquire understanding the principles of radionuclide therapy
Pre-requisites	Module 2 Radiation Protection
Competency Addressed	An understanding of the principles of radionuclide therapy
Core knowledge	• Principles o Radiopharmaceuticals uptake and retention o Quantity of radiopharmaceuticals o Retention of radiopharmaceuticals o Consideration of Physical half-life o Tissue factors affecting radiopharmaceuticals uptake o Radionuclides for therapy · Alpha emitter · Beta emitter o Auger and Coster-Kronig electron emission processes · Regulatory Requirements and Guidelines o Local legislation and guidelines to be applied for the radionuclide therapy
Recommended Elements of Training	· List side effects from radioiodine treatment of thyroid diseases. · Classify into groups on the basis of the range of principal radiation emitted by the radionuclides. · Study the Local legislation and guidelines and compare them with the recommendations by ICRP, MIRD for radionuclide therapy · Describe physical characteristics (benefits and drawbacks) of one alpha emitter, one beta emitter and one radionuclide

	emitting Auger electrons used for therapy applications

Module 8 - Radionuclide Therapy Using Unsealed Sources	
Sub-module 8.2: Facility Design for Radionuclide Therapy	
Objective	To acquire knowledge on facility design for therapy using unsealed sources
Pre-requisites	Module 1 Clinical Awareness Module 2 Radiation Protection
Competency Addressed	An understanding of the principles of shielding design for the different radionuclide energies being used for therapeutic purposes The ability to design satisfactory radiation shielding for the different radionuclide energies used for therapeutic purposes
Core Knowledge	• Principles o The expected effective half life o Basic radiation protection Principle: Time, Distance, Shielding • Regulatory Requirements and Guidelines o Local legislation and guidelines to be applied to the design of radionuclide therapeutic facilities • Physical Design o Location e.g. the facility should be away from the public area and use of external wall can reduce the radiation shielding requirements o The expected length of hospital stay of the patient and the expected radiation dose rate from the patient o The design of excretory pathways o The target design dose in accessible areas (e.g. the need for a dedicated shower/toilet for each room and a waste storage) o Dose constraints and shielding design goals, e.g. a constraint of 0.2 is often used for medical radiation workers o Attenuation of possible shielding materials for the radionuclide being used • Waste management o Management of patient's waste by "Delay and decay" method, e.g., the radioactive waste is held in storage until sufficient radioactive decay has taken place to allow safe discharge into the general environment o Waste discharge from the hospital to sewage at a point where the specific activity is acceptable to the regulatory authority

Recommended Elements of Training	· Determine occupancy of surroundings of a radionuclide therapy room · Specify protective barriers i.e. walls, windows, doors, floors, ceilings, protective screens & shields for radionuclide therapy · Specify the shielding requirements for other penetrations, e.g. plumbing, electrical sockets · Specify correct warning signs at appropriate location · Document the management of a therapy patient. · Determine the maximum expected activity, e.g. the maximum expected number of patients per year in the treatment room. · Documentation of all assumptions, design, and specifications for future reference, and maintenance.

Module 8 - Radionuclide Therapy Using Unsealed Sources	
Sub-module 8.3: Treatment Procedure	
Objective	To understand the treatment protocols and rationale of the therapy
Pre-requisites	Module 1 Clinical Awareness Module 2 Radiation Protection Module 6 Radioactivity Measurements and Internal Dosimetry
Competency Addressed	An understanding of the purpose, principles and operational procedures of the radionuclide therapy Ability to manage patients appropriately from a radiation safety perspective both pre and post administration of the radionuclide
Core Knowledge	• Principles o Mechanisms of different types of radiopharmaceutical uptake used in therapy o Bio-distribution of radiopharmaceutical o Different types of radionuclide treatment and characteristics of specific radiopharmaceuticals for radionuclide therapy o Physical characteristics of radionuclide o Understand the concepts of absorbed dose, equivalent dose, cumulative absorbed dose and effective dose o Radiation protection principles (justification, optimization and limitation) • Procedures to be followed prior to treatment o Advise the patient and their attendance about preparations to follow before the treatment, during the treatment at home or in hospital and when discharged o Determine whether the treatment can be given as an inpatient or outpatient, where the dose should be

	administered and assess which ward/s are suitable for admission of patients for each type of treatment available o Ensure correct radiopharmaceutical and activity is ordered for the specific patient o Arrange for appropriate equipment, survey instruments, personal protection and dosimeters to be provided for the purpose of treatment o Assist the nuclear medicine physician to prepare information on the benefits and risks of the procedure for the patient to give his/her informed consent • Treatment procedures o Pre-treatment management o Protocols and procedures o Form of radionuclide to be administered to patient for therapy o Patient dose preparation and administration o Dose planning for treatment o Dose calculation of the appropriate radionuclide to be administered to the patient for therapy o Radionuclide therapy of distant metastases o Postoperative management of radionuclide therapy o Prepare a check-list of the whole procedure • Discharge o Safety of family members following discharge o Determination of the time frame when the patient can return to work or move in public environment o Discharge to a non-home environment • Long term advice o On future pregnancy. o Carcinogenesis e.g. the patient's follow-up and post treatment care issues. o Other probable complications or events/ symptoms to be aware of and be watchful of.

Recommended Elements of Training	• Read, and be reasonably familiar with, the resource material recommended for this competency If Instructions, Information and Protocols for the tasks below already exist locally you should critically review them in comparison to national and international recommendations. • Make a list of radionuclide therapies routinely performed in your department. Briefly summarize three examples: one each by oral administration, intravenous infusion and intra-articular injection. Comment on rationale of the therapy, biodistribution of the radiopharmaceutical, radionuclide properties, therapeutic efficacy and possible adverse effects. • Prepare a protocol for nuclear medicine staff to unpack, dispense, label and administer a therapy dose to a patient for a therapy performed in your institution. • Prepare instructions for nursing staff caring for an elderly patient undergoing treatment with I-131 for thyrotoxicosis as an inpatient in a single room in a geriatric ward. Include observations, medication, patient hygiene, management of linen, meals, waste, access by visitors and other hospital staff, requests for medical tests, spills or episode of incontinence, use of electronic personal radiation dosimeter and significance of dosimeter readings. • In consultation with a nuclear medicine physician, prepare an Information pamphlet for patients having I-131 therapy for thyroid cancer. Include preparation for admission, what to do in hospital and what precautions to observe after discharge including return to work or planning a pregnancy.

Module 8 - Radionuclide Therapy Using Unsealed Sources	
Sub-module 8.4: Selection of Radiopharmaceuticals for Nuclear Medicine Therapy	
Objective	To acquire knowledge on the fundamental principles of individual radiopharmaceutical treatment
Pre-requisites	Module 2 Radiation Protection Module 6 Radioactivity Measurements and Internal Dosimetry
Competency Addressed	An understanding of the common indications and radiopharmaceuticals used for therapy in nuclear medicine Familiarity with the wide range of diseases in which radionuclide therapy is being used and the selection of the appropriate radionuclide for the specific patient

Core Knowledge	• Principles
	  ○ General principles of radionuclide therapy
	  ○ Physical half-life, biological half-life (clearance)
	  ○ Radiation quantities and units
	  ○ Effective dose, equivalent dose, absorbed dose rate
	• Selection of a therapeutic radionuclide for therapy
	  ○ Half – life
	  ○ Locally absorbed radiations
	  ○ Specific activity and chemical form
	• Concept of radionuclide therapy
	  ○ Optimization of radiation dose and dose rate for ablation therapy
	  ○ Criteria for therapeutic administration of radionuclide
	  ○ Calculation of ablation dose
	• Selection of therapeutic radionuclide for different types of diseases
	  ○ Thyroid cancer therapy with I-131
	  ○ Therapy for thyrotoxicosis with I-131
	  ○ I-131 MIBG therapy
	  ○ I-131 Lipiodol therapy
	  ○ Y-90 Microspheres
	  ○ P-32 therapy for Myeloproliferative therapy
	  ○ Radionuclide therapy for painful bone metastases
	  ○ Radiation Synovectomy for the knee with Y-90 silicate
	  ○ In-111 Octreotide therapy
	  ○ Monoclonal antibody therapy
	  ○ Other therapeutic procedures

Recommended Elements of Training	· Carry out the clinical overview of each treatment procedure · Review the technical aspects of patient preparation and patient management · Assess the dose administration for different type of radionuclide therapy · Determine the benefits and side effects of therapy · Determine the risks associated with radionuclide therapy by considering the effects of radiation

Module 8 - Radionuclide Therapy Using Unsealed Sources	
Sub-module 8.5: Dosimetry for Radionuclide Therapeutic Procedure	
Objective	To acquire knowledge on the estimation of radiation absorbed doses for therapy procedures involving radionuclide
Pre-requisites	Module 1 Clinical Awareness Module 2 Radiation Protection Module 6 Radioactivity Measurements and Internal Dosimetry

Competency Addressed	An understanding of the principles of internal dosimetry An ability to calculate the activity of the administered dose for therapy in nuclear medicine
Core Knowledge	General considerations of bio-kinetics and dosimetry o Selection of radionuclides o Selection of organs and tissues for dose calculation Other considerations o Maximum safe administered dose o Standard fixed dose • The ablation dose • Therapy and pregnancy e.g., the patient must be reassured both as to the effect of therapy on fetus and as to the effect of pregnancy upon the course of her diseases
Recommended Elements of Training	· Read, and be reasonably familiar with, the resource material recommended for this competency. · Calculate the activity of 131I to be administered in thyroid. by using the data for the thyroid uptake (for the particular patient) and from available clinical data.
	· Describe step by step the procedures for a patient undergoing treatment for hyperthyroidism. · Determine occupancy of surroundings of a radionuclide therapy facility. · Carry out calculations for patient who are to be treated by considering uptake and biological half-life.

Module 8 - Radionuclide Therapy Using Unsealed Sources	
Sub-module 8.6: Radiation Safety Precautions for Therapy Using Unsealed Radionuclide Sources	
Objective	To be able to perform audit on radiation safety of unsealed radionuclide sources used in therapy
Prerequisite	Module 1 Clinical Awareness Module 2 Radiation Protection Module 6 Radioactivity Measurements and Internal Dosimetry

Competency Addressed	Familiarity with · All legislations, guidelines and international best practices to ensure radiation safety, before, during and after administration of radionuclide therapy · The chemical forms of therapy radiopharmaceuticals and how this would affect their distribution in the environment when excreted by the patient or if spilt from a container Ability to · Apply radiation protection regulations to personnel, patients and members of the public associated with radionuclide therapy · Communicate with the patient, staff and public about the risks associated with handling of high activity unsealed sources
Core Knowledge	Principles o Fundamentals of safety principles Regulatory requirements and guidelines o Local legislation and guidelines applied for the radionuclide therapy Radiation safety for radionuclide therapy o Advise the patient about preparations to follow before the treatment, during the treatment at home or in hospital and when discharged o Radiation monitoring and radiation safety precautions o Instruct ward staff on monitoring the patient, managing contaminated linen, food waste and other items and responding to medical emergencies o Explain to ward staff the precautions to be observed for their own personal safety and the safety of other health care employees and visitors o Instruct catering staff, cleaners and maintenance engineers who service therapy bedrooms and bathrooms o Dispense the radiopharmaceutical to within ±10% of the prescribed activity and monitor its safe administration to the patient by the physician or technologist o Determine when the patient may be discharged from hospital with respect to the radioactivity remaining in the body o Radiation protection for workers and members of the public o Dose limits for workers and members of the public o Radiation monitoring and documentation associated in the procedure o Ability to manage disused sources and waste o Inventory control and waste management of radioactive material

Recommended Elements of Training	• Read, and be reasonably familiar with, the resource material recommended for this competency. • Document the safety issues and precautions aspects for the patients, staff and public. • Make a list of therapy in the treatment of thyroid cancer and thyrotoxic patients being used by 131I. Also list the other radionuclide which are used for therapy. • Make a radiation safety manual of the above procedures.
	• Prepare a protocol for nuclear medicine staff to unpack, dispense, label and administer a therapy dose to a patient for a therapy performed in your institution. • Relate occupational exposures differences in different therapeutic radionuclide implementations. • Assess the risk and recommend precautions for pregnant women, children and staff who will be attending the patient. • Assess the risk of radiation from the patients undergoing radionuclide therapy to the members of the public. • Write a formal response to the following requests for information (for therapy with I-131). In each case, provide an estimate of effective dose, the corresponding risk, and one or more examples of a comparable exposure and/or a comparable risk. • For a parent who is undergoing radionuclide therapy, who has a 5- year old child. • For a pregnant mother, who has to undergo therapy (dose to the mother/fetus). • For a pregnant registrar who is concerned about working with therapy patients • For a nurse attending a patient who undergoes radionuclide therapy.

MODULE 9 - CLINICAL COMPUTING AND NETWORKING	
Objective	To gain adequate knowledge and necessary skills to operate, upgrade and maintain clinical computer system including networks, and to effectively manipulate, analyze and process medical image data in different formats.
Expected Duration	10% of time.
Sub-Modules	9.1. Operation of a clinical acquisition and processing/reviewing workstation. 9.2. Computer system administration management. 9.3. First line computer system troubleshooting. 9.4. Computer image processing techniques. 9.5. Image analysis in a high-level programming language (optional). 9.6. Image reconstruction, registration and fusion, and tracer kinetic modelling. 9.7. Standard image file formats used in nuclear medicine. 9.8. Computer networking, PACS, RIS and HIS. 9.9. Software validation: computer simulations, phantoms and clinical data.

Module 9 - Clinical computing and networking	
Sub-module 9.1 - Operation of a Clinical Acquisition and Processing/Reviewing Workstation	
Objective	To gain knowledge and skills required to operate clinical acquisition and reviewing/processing workstations (WS) to ensure their consistent and efficient use.
Prerequisite	• Basic familiarity with hardware components and architecture, principles underlying the design, functional features and implementation of a modern computer operating system. • Understanding of the role of a computer system for data acquisition and data processing/reviewing in a nuclear medicine service.
Competencies Addressed	An understanding of the basic characteristics of workstation operating systems and clinical software for image acquisition and processing.
	The ability to effectively use a workstation operating system and nuclear medicine clinical software to perform simple image display tasks, define scan protocols, acquire different type of scans, perform basic manipulation, analysis and processing of the common types of clinical data, transfer and archive clinical data.

Core Knowledge	• Understanding the essential hardware components of a workstation and effective use of a mouse, keyboard, windows, menus, shortcuts, utilities and help resources. • Operational knowledge of the available operating system(s) (e.g. Windows, Unix, Linux, Mac OS): design and implementation issues, working with files and directories, partitions, booting the system, analysis of a process, multiprocessing, multithreading, memory management techniques, process scheduling. • Understanding the underlying principles necessary to design clinical imaging protocols: static, dynamic, dual-isotope and multiple energy windows, gated, WB, SPECT, PET. • Understanding of basic image display and manipulation tasks: brightness and contrast adjustment, layout design, color table choice, interpolation, resizing, cropping, padding, shifting, annotating, frame grabbing etc. • Operational knowledge and practical skills in image analysis and processing- ROI definition and manipulation, curve plotting and analysis, general spatial and temporal filtering, geometric transformations (operators), tomographic image reconstruction with appropriate selection of parameters: - essential features of processing WS. • Basic procedures related to data transfer and short/midterm image data archiving.
Recommended Elements of Training	• Read the resource material on the WS operating system, user instructions, manuals, guidance or other documentation accompanying the available WS-s. • Get accustomed to image display variables and ways of their altering.
	• Get familiarized with different image acquisition /processing protocols and obtain an adequate understanding of the meaning of different acquisition parameters that can be adjusted through the graphical user interface (GUI-s). • Generate a tree diagram of the workstation menu interface to get an overview of the workstation capabilities. • Explore and exercise clinical data transfer and archiving. • Work through the tasks listed in the competencies section above, referring to manuals and/or experienced users as required, until able to demonstrate familiarity with each task.

Module 9 - Clinical Computing and Networking	
Sub-module 9.2 – Computer System Administration Management	
Objective	To achieve competence in performing necessary system administration tasks relevant for reliable functioning of the clinical nuclear medicine computer systems.
Prerequisite	Sub-module 9.1: Operation of a clinical acquisition and processing/reviewing workstation
Competencies Addressed	An understanding of computer system administration responsibilities and the essential commands, tools and utilities important for ensuring a consistent operation of clinical computer systems. The ability to perform necessary system administration tasks such as planning, installing, supporting, and maintaining the computer hardware, operating systems, clinical software and networking.
Core Knowledge	• Identification of the system hardware components and advanced understanding of their functioning and role: processor type and specification, motherboard, I/O cards, bus slots, RAM, disks and disk partitions, peripherals, power supply etc.
	• Working knowledge of different software types and versions: operating system, clinical software and network related issues. Documenting the configuration of the system. • Correct installation and customization of the operating system, proper start-up and shutdown procedures, identifying CPU and memory usage of individual processes, checking available disk space, disc error checking, clean up and de-fragmentation. • Understanding and effective using of administrator privileges, adding or editing users/groups, ownership and permissions concepts and user preferences. • Effectively determining the space occupied by individual files and folders, identifying recently created or modified files, compressing and decompressing files and folders. • Understanding of the procedures to check basic network connectivity. • Installing, setting up and troubleshooting a printer. • Performing system backup and restore, image data retrieval and recovery. • Creation of hard copies.

Recommended Elements of Training	• Read the essential reference material on computer system administration that applies to the available computer system. • Obtain details on system hardware and software configuration and prepare the report with a structured description. • Discuss with the system administrator each of the following tasks, read related reference material and after either independent or supervised performance of the tasks, prepare a short document for selected three (3) of the following tasks: 1. Computer system start-up and shutdown; 2. Install and update operating system or fine-tune it for specific clinical software requirements; 3. Learn about account/groups creation/removal and maintaining; 4. Study system rescue and repair; 5. Access system and in-house documentation; 6. Access system administrator privileges and privileges of a user belonging to a certain group; 7. Explore installation/removal of peripheral devices; 8. Understand parameters of a printer configuration; 9. Study system backup and restore; 10. Install/configure/update virus protection software.
	• Consult resources above (or the system administrator if no information can be found) for information about each of the tasks in the list. Perform tasks and document the procedure followed in each case: 1. Check available disk space and perform clean up (defragmenting, squeeze); 2. Determine space occupied by individual files and folders; 3. Identify recently created/modified files; 4. Determine CPU and memory usage of individual processes; 5. Understand and interpret system log files; 6. Connect from a remote computer; 7. Study procedure to check basic network connectivity and means of diagnosing the network (e.g. ping, traceroute). • Prepare a short report that summarizes the extent of the duties of a system administrator in a given organization (NM service, section or department), and which demarcates between hers/his representative duties and the duties linked to a network/security administrator (analyst/specialist) and database administrator tasks. • Prepare a technical document describing the procedures used for backup and recovery of computer systems in the trainee's nuclear medicine department. • Discuss advantages and limitations of the above system backup procedures, with reference to alternative procedures and technologies that could offer advantages in terms of convenience, efficiency or cost over the existing procedures.

	• Prepare a report that shows knowledge of an available script language and describes the chosen operating system and scripting language, typical uses for scripts, syntactic and lexical rules,

Module 9 - Clinical Computing and Networking	
Sub-module 9.3: First-line Computer System Troubleshooting	
Objective	To expand the acquired knowledge on computer basics and system administration tasks with an ability to successfully eliminate common computer problems.
Prerequisite	Sub-module 9.1: Operation of a clinical acquisition and processing/reviewing workstation, Sub-module 9.2: Computer system administration management
Competencies Addressed	An understanding of the possible causes of a computer system malfunction. The ability to o Rapidly recognize and troubleshoot common computer hardware, software and networking related problems. o Design, schedule and implement computer system preventive maintenance
Core Knowledge	• Knowledge and adoption of important maintenance measures for the operating system and data, clinical software and hardware. • Consistent identification and differentiation between the above-mentioned categories of computer problems. • Recognizing the signs of developing hardware problems. • Following appropriate instructions and protocols to diagnose and resolve each of the above classes of problem, involving other staff and external service providers as appropriate. • Familiarity with the weaknesses and strengths of common operating systems and applications software. • Accessing and interpreting system log files and error messages to aid diagnosis. • Use of a built-in documentation and diagnostic tools and utilities. • Utilization of the internet support resources to access bug reports and obtain and install patches and software updates. • Obtain updated information about computer viruses and use this information to implement appropriate virus protection measures, and respond effectively to virus occurrences.
Recommended elements of training	• Locate the sources of documentation and help facilities (on-line, manuals, guides, web-based sources, hardcopies etc.) for the various departmental computer systems and prepare a list of these sources, including URLs for web-based sources.

	• Research, using above reference material and other documentation sources, or asking your supervisor, the possible methods of diagnosing and counteract the following problems on each of the department's computer platforms: o Hard disk errors; o Slowly running or frozen computer; o Inability to start an application; o Unusual behavior of the software; o Network errors, problems with connectivity and slow response.

Module 9 - Clinical Computing and Networking	
Sub-module 9.4 - Computer Image Processing Techniques	
Objective	To understand the underlying principles of image processing techniques applied to nuclear medicine images and be able to write and test the image processing routines in interactive programming environment and effectively apply them to selected clinical problems.
Prerequisite	Sub-module 9.1: Operation of a clinical acquisition and processing/reviewing workstation Sub-module 9.2: Computer system administration management
Competencies Addressed	• An understanding of the underlying algorithms and programming language mandatory for developing simple image analysis/processing programs in an interactive programming environment. • The ability to develop, test and document efficient image processing routines/applications in a high-level programming environment and to utilize macro routines in the vendor's provided computer systems (environments), for selected clinical tasks.
Core Knowledge	• Thorough understanding of the data formats, constants, variables, array and structure, functions, subroutines, declarations, program decisions and loops employed in the available high level programming environment. (Note: A high-level programming environment, such as IDL, MATLAB and Mathematica, as opposed to a high-level programming language, refers here to the software packages or environments designed for data analysis, visualization and cross/platform application development having a major advantage of compactness and large flexibility.) • Writing and testing of the program code for 2D static and dynamic image data processing tasks by using the existing range of available functions/subroutines specific for the chosen programming environment: data read/write, display, normalization, color tables, point operators, neighboring operators, geometric operators, Fourier domain operations, curve and surface plotting routines. Thorough understanding of basic image enhancement functions typically applied in nuclear medicine imaging: contrast enhancement, noise suppression, general linear and nonlinear filtering and their

	properties. • Understanding of an image restoration concept and application of common filters such as Metz and Wiener. • ROI creation, manipulation and statistics, motion correction, time activity curve creation and analysis, curve smoothing, interpolation, function fitting. • Understanding of the environment in which the code should be written: starting and ending the macro program, windows, commands, macro language syntax, operators, data types, variables, program execution. • Basic understanding of the macro language statements to manipulate image data and curves: open/close, load, save, new data, plot/display statements.
Recommended Elements of Training	• Read, and be reasonably familiar with, the resource material recommended for this competency. • Become acquainted with a set of common image analysis and processing routines described and implemented in programming environments such as MATLAB, IDL, Mathematica or applications like ImageJ (Java) • Write a program to initialize necessary arrays, open and display image(s), perform simple addition, subtraction or multiplication with a constant, and display the final result of the operation. • Explore computer codes for interpolation and write code to perform interpolation of the opened and displayed image (e.g. 64 x 64) to 128 x128 pixels; investigate different properties of interpolation schemes (e.g. nearest neighbor, linear (bilinear), cubic (bicubic), B-spline, interpolation by convolution) • Read the literature and become reasonable familiar with different forms of contrast enhancement techniques; e.g. explore the histogram equalization, design the algorithm, write the program in the chosen environment and test it with images having different levels of contrast. • Design a generalized scheme to perform low-pass filtering in spatial domain; test the variable dimension of a symmetric filtering kernel; implement different ways of handling the image edge (e.g. image padding: constant values, closest pixel value, mirrored values, wrapping-periodical repeating). • Identify in the literature the methods to measure MTF of the gamma camera system. Find out which analytical expressions for the MTF have been used for the construction of a Metz filter. • Search the literature for the description of the different linear and non-linear curve fitting algorithms; write a short program to fit the supplied time-activity curve representing the washout of activity from a: i) lung ventilation dynamic study or, ii) washout from a kidney following the administration of Lasix; describe different techniques of weighting the data points and estimate the uncertainties of the fit parameters.

	• Use macro utility to create the procedure to open file/image(s) (e.g. flood correction matrices, line source for estimating spatial resolution), customize screen display, color bar and controls, reposition and resize window, define ROI(s), calculate important ROI parameters, create profile(s) and save numerical results and profiles in newly opened file. Learn procedures to create, write, run and debug the macro.

Module 9 - Clinical Computing and Networking	
Sub-module 9.5 – Image Analysis in a High-Level Programming Language (optional)	
Objective	To achieve competency in developing simple computer programs for numerical data and curve manipulation, image analysis and processing in a high-level language.
Prerequisite	Sub-modules 9.1, 9.2 and 9.4. (Operation of a clinical acquisition and processing/reviewing workstation, Computer system administration management, Computer image processing techniques)
Competencies Addressed	An understanding of the programming flowcharts and pseudo code, and the transition from this conceptual approach to a development of actual programs in a high-level language. The ability to write simple, readable and efficient programs in a high level (procedural) language, to test new software and properly document the code.
Core Knowledge	• Familiarity with a concept of the commonly used tools that help developing and documenting program logic: flowcharts and pseudo code. • Understanding and efficient use of a chosen programming language: writing code, compiling and running, making code readable, batch execution, designing functions and procedures, program control, components of the language, debugging and error control, GUI building.
Recommended Elements of Training	• Choose a high-level programming language which is available in the department. • Read, and be particularly familiar with, the reference material on: data types, variables, constants, operators: arithmetic, logical; comparison, concatenation etc., subroutine and functions, program control statements, error handling, arrays and collections, accessing array elements, sorting, strings, decision making, loops, basic input output of the data - all related to the chosen language. • Develop a basic algorithm and necessary data I/O steps in an illustrative form, to perform (i) a cubic spline interpolation for a given set of 1D data or (ii) an integration of a function by Gaussian quadrature's or Simpson rule.

	• Implement the above algorithm in the chosen language, write a source program, compile it and run. • Perform test runs and check the results with altered input data and parameters that can be adjusted. • Write a program in the chosen language that reads in a nuclear medicine image from a file (e.g. raw binary data), makes a transpose of a matrix representing the image, extracts and displays a sub-matrix and stores the sums of all the rows and all the columns in separate 1-dimensional arrays. This program should also find the maximum and minimum pixel values, total number of counts in the image, average and standard deviation. Consider defining and extracting the variable width line profile from the image. Enable writing of the data (image statistics and profile data) to a file that can be later opened and processed by a spread sheet program. (Not all of the functions should be implemented and tested). Comment and compare your small application with the typical NM tools in commercial programs for analyzing image data.
	• Write a program that will open a flood image and do the calculation of the common integral and differential uniformity following the NEMA specifications. Consider UFOV and CFOV definitions, 9-point smoothing and histogram representation of a distribution of the differential non-uniformity parameter.

Module 9 - Clinical Computing and Networking	
Sub-module 9.6 – Image Reconstruction, Registration and Fusion and Tracer Kinetic Modelling	
Objective	To understand and to be able to perform complex nuclear medicine image processing techniques including image reconstruction, registration and fusion, compensation for different physical factors degrading reconstructed image quality, and fundamentals of tracer kinetic modelling.
Prerequisite	Sub-modules 6.2, 9.1, 9.4 (Formalism and application of internal dosimetry, Operation of a clinical acquisition and processing/reviewing workstation, Computer image processing techniques)
Competencies Addressed	An understanding of the algorithms implemented in the software routinely used in the resident's department to perform image reconstruction, registration, fusion and various compensation schemes for physical factors affecting the quality of SPECT and PET images. The ability to · Perform image reconstruction and registration in clinical studies, and to propose, design and optimize/evaluate new reconstruction approaches and compensation schemes for different image degrading factors. · Apply models for the analysis of the tracer kinetics

Core Knowledge	• Understanding basic concepts, terms and definitions related to analytical and iterative reconstructions: Radon transform, central slice theorem, frequency distance principle, Fourier re-binning, maximum likelihood expectation maximization (ML-EM) reconstruction, OSEM and other acceleration schemes in statistical iterative reconstructions, regularization etc.
	• Understanding differences, advantages and disadvantages of analytical and iterative (statistical/algebraic) reconstruction techniques. • Awareness of the different scatter, attenuation and depth dependent resolution correction schemes applicable to the analytical and iterative reconstruction techniques, their impact on reconstructed image quality and their importance and limitations in quantitative volume and activity measurements. • Knowledge of the practical implementation of software for merging anatomic and functional imaging: computer algorithms for image registration (feature and volume based), accuracy validation of the registered images (external markers, stereotactic frames, volume-based SPECT to CT image registration, deliberate misalignment and realignment), visualization techniques and clinical applications. • Acquaintance with a typical fusion display techniques-color or alpha blending, side by side reviewing of the original images with synchronized cursors, interlaced pixel display, fused 3D data display, volume and surface rendering, 3D volume images and superimposed 2D orthogonal or oblique out-planes to show the functional information. • Understanding of single and multiple compartmental models, fitting of kinetic models, Patlak and Logan plots. • Understanding the concept of SUV values and factors which influence their values (partial volume effect, glucose level, choice of ROI, etc.)
Recommended Elements of Training	• Read and be reasonably familiar with papers and other sources of documentation describing these algorithms in detail. • Write a report describing the algorithms (e.g. filtered back projection (FBP), maximum likelihood expectation maximization (ML-EM, OSEM), including sufficient detail to demonstrate a clear understanding of the algorithms, underlying assumptions and their strengths and weaknesses compared to the alternative available algorithms. • Study the FBP algorithm (e.g. its implementation in DONNER library) and based on the FORTRAN computer code in translate and test the code in the chosen high-level environment/language.
	• Explore properties and parameters of the built-in radon/iradon function for Radon transform in MATLAB and test its behavior with the provided Shep-Logan phantom: study the influence of the number of projections, matrix size, filter kernel, interpolation schemes and addition of noise, on the quality of reconstructed images; model your

	own 2D phantom with the available head phantom image and test radon/iradon function. • Following the literature develop algorithmically Chang attenuation or Sorenson attenuation correction scheme and consider how it can be implemented in the FBP reconstruction program previously developed in the environment such as IDL, MATLAB or Mathematica. • Study the most frequently applied SPECT scatter correction schemes; chose one scheme (e.g. triple energy window, dual energy window); investigate different acquisition possibilities with the available camera systems and try to design a program in IDL, MATLAB or Mathematica which would analytically reconstruct the scatter corrected data. Comment different approaches in scatter correction schemes employed in analytical and statistical reconstruction techniques. • In the chosen programming environment consider developing and testing a program that performs alpha blending of a background image with a selected foreground image. • Study tracer modelling and calculations of myocardial and/or cerebral blood flow in PET studies for different tracers, like O-15, Rb-82, NH3-N-13.

Module 9 - Clinical Computing and Networking	
Sub-module 9.7 – Standard Image File Formats Used in Nuclear Medicine	
Objective	To be able to routinely use and manipulate medical image data in a range of image formats and to demonstrate an understanding of the relative advantages and disadvantages of the different image formats for specific applications.
Prerequisite	Sub modules 9.1, 9.2 (Operation of a clinical acquisition and processing/reviewing workstation, Computer system administration management)
Competencies Addressed	· An understanding of the structure and properties of image file formats commonly utilized in nuclear medicine. · The ability to read, display and manipulate medical image data provided in commonly used formats (Interfile 3.3, DICOM 3.0).
Core Knowledge	· Understanding of the significance of storage format options for integer, float, textual and other data. · The structure and characteristics of image file formats regularly used in nuclear medicine. · Definition and features of some standard bit-mapped image file formats, their strengths and weaknesses. · Awareness of the most commonly used digital image compression techniques. JPEG, fractal and wavelet compression.

Recommended Elements of Training	• Read and be reasonably familiar with the reference material recommended for this competency. • Study thoroughly the major characteristics of a DICOM and Interfile • 3.3 format; explore the available modules /programs to convert from one image format to another (IDL, MATLAB, Mathematica) • Write a report which demonstrates an understanding of common file formats by including a detailed description of the most common formats used in medical imaging; contrasts their main features, advantages and disadvantages.

Module 9 - Clinical Computing and Networking	
Sub-module 9.8 – Computer Networking, PACS, RIS and HIS	
Objective	To become familiar with the basic concept of PACS, its components, architecture, and implementation in a nuclear medicine environment and to become acquainted with the essentials of a radiology information system (RIS) and integrated hospital information system (HIS) to store, manipulate, and distribute patient data and images.
Prerequisite	Sub-module 9.1, 9.2, 9.3 (Operation of a clinical acquisition and processing/reviewing workstation, Computer system administration management, First line computer system troubleshooting)
Competencies Addressed	An understanding of PACS technology and acceptance testing procedures as well as the essentials of RIS and HIS. The ability to • Participate in the maintenance of computer hardware and software that comprise a computer network, including the use, configuration and monitoring of active network equipment, • contribute to competent decisions related to selection of PACS that best meets the NM department needs based on its key characteristics and features. • The ability to effectively use NM workstations, servers and PACS linked to the local RIS or HIS and those linked to an external PACS system.

Core Knowledge	• Understanding of the essential network concepts: layers, models and architectures, types and sizes of networks, performance issues and concepts, network standards. • Essential network hardware components: physical media of connectivity-cabling, hubs, switches, bridges, routers, gateways, repeaters, protecting with firewalls. • Learning network features: file and printer sharing, application services, remote access, e-mail, network security
	• Understanding of the 7-layer OSI networking model and how data travels through the layers. • Understanding network communication protocols: TCP, UDP, TCP/IP, IP packets and IP addresses, sub netting, subnet masks • Other application layer common network applications encountered at the user level: DHCP, DNS, HTTP, Mail, FTP, Telnet, SMTP, NFS etc. • Knowledge of securing the network: account security, permissions, external threats, viruses and malicious software • Utilizing clinical networks to provide support for fast and efficient clinical report delivery to referring physician and to other authorized users involved in the patients' care taking into account patient data confidentiality. • Good understanding of the PACS infrastructure important for connectivity, reliability and security. • Understanding of the essential physical components of the PACS chain in NM department such as acquisition systems/cameras, network, intermediate computers, database servers and archival. • Sufficient knowledge to tailor the archiving system to the needs and specifications of an individual nuclear medicine service (procedural volume, data per study type, capacity, performance and cost). • Acceptance testing of PACS: network operation, installation and configuration, functionality under load, image quality and fault tolerance. • Basic acquaintance with requirements for the distribution of diagnostic images throughout the health enterprise: film replacement, timing performance, scalability and cost effectiveness, image quality, integration of the electronic medical record and security. • Understanding of the RIS features such as: ○ User access control, • Patient consent; • Patient demographics, update and relation to HIS; • Booking and scheduling, • Work lists and folders

	○ Reporting; ○ RIS integration, integration between RIS and NM modalities, RIS and PACS, RIS and workstations. • Understanding of the functional requirements that RIS/HIS must possess to ensure the functionality and connectivity to NM modalities
Recommended Elements of Training	• Locate appropriate resource material and read the literature to be able to write briefly about the basics of each of the hardware components and protocols listed above for this competency. Read also about network management and network security. • Write a report on the ways which the network in a specific nuclear medicine department utilizes these hardware components and protocols, and comment on network management and security issues/vulnerabilities of the network. • Based on the studied literature and assistance provided by local IT specialists and Nuclear Medicine Technologist, identify the current network infrastructure, make an assessment on the future network needs assuming potential growth of the service (e.g. new SPECT-CT system or 1-2 dedicated gamma cameras) and describe it in a report. • Study PACS system in the NM department and prepare a technical documentation that describes its major components and features. • Based on the available literature, design a short guidance that could serve as a reference document for performing acceptance testing of the PACS - recognize specific requirements and assign roles for different professionals. • Get acquainted with available PACS in the NM department, prepare a short description on the connection between the RIS and the PACS and identify the type of RIS-HIS integration modality. • Explore in a short report which additional information systems and database are linked to the RIS/HIS and what important data is transferred to/from it.

Module 9- Clinical Computing and Networking	
Sub-module 9.9 – Software Validation: Computer Simulations, Phantoms and Clinical Data	
Objective	To become familiar with the underlying principles of MC simulations, the use of generic and nuclear medicine specific Monte Carlo simulation packages for generating simulated image data, and to understand the importance of its comparison with physical phantom measurements and value in improving clinical imaging studies.

Prerequisite	Sub module 9.1, 9.2, 9.4 (Operation of a clinical acquisition and processing/reviewing workstation, Computer system administration management, Computer image processing techniques)
Competencies Addressed	An understanding of the components of a Monte Carlo simulation method: computer generated phantoms, models of the imaging process, fast computational methods, and the use of physical phantoms and methods of clinical validation The ability to • perform MC simulations with one of the NM related simulation programs and properly interpret results. • assist in designing a clinical validation study with a goal to bring an appreciable improvement in image quality, quantitative accuracy and image reader's confidence.
Core Knowledge	• Understanding of the concepts related to MC simulations: random number generators, sampling, probability distributions, photon histories, modelling the object (analytical shapes and vowelized geometries) containing radionuclide, collimators, photon detection in the crystal, binning, projection formation, variance reduction techniques • Methods of a simulator validation-comparison with the physical phantom measurements. • Awareness of the range of available mathematical phantoms, their complexity, limitations advantages and disadvantages: Zubal, Cristy/Eckerman, Hoffman, VIP-Man, MCAT, NCAT and the ability to use phantoms to assess image quality for SPECT reconstruction algorithms and physical factor compensation schemes testing. • Familiarity with common physical phantoms used for software and algorithm validation: Hoffman 3D brain phantom, non-uniform Thorax phantom, dynamic phantoms. • Value of computer simulations and physical phantom measurements to improve image quality in nuclear medicine. • Knowledge of image fusion checking with phantoms and software. The application is used to fuse SPECT and CT data in SPECT/CT systems and also PET and CT data for PET/CT systems but can also be used to merge SPECT or PET data with MRI. In addition, the fusion application can be used to properly align older with current studies.

Recommended Elements of Training	• Read and be familiar with essential reference material • Use an already installed MC simulation programme or install and set up one of the freely available MC programs (e.g. Simind, SimSET) • Study one of the publications provided in the reading list and prepare a short report describing the techniques used for the simulator validation; assess the comprehensiveness of validation, and the range of parameters measured. • Test the selected program with tutorials to create simple images of Tc-99m point sources in a cylindrical water phantom; explore energy spectrums obtained with varying phantom diameters, modified energy windows and different level of complexity involved in a simulation. • ·Test the selected program to create simulated SPECT projections of available phantoms. Check simple scatter and attenuation correction with simulated sets; import projection data to into a clinical workstation to utilize the available reconstruction and image processing routines. Describe results. • Search the literature and identify a scientific paper that describes for example, a novel reconstruction algorithm or reconstruction acceleration scheme, physical factor correction scheme or simultaneous emission/transmission imaging approach; describe the computer simulations and physical phantoms measurements, parameters and indices used for validation and assessment of accuracy and general image quality metrics (e.g. profiles, contrast, mean square error (MSE), normalized MSE (NMSE), NSD etc.). • Find a publication in which ROC analysis was used to perform an analysis or features comparison of e.g. clinical SPECT images with different properties resulting from altered physical factor correction schemes, different filtering approach or reconstruction acceleration technique. Analyze it and write a short report which demonstrates an understanding of ROC methodology with a discussion on the limitations and results.

MODULE 10 – CLINICAL APPLICATIONS	
Objectives	To develop an understanding of and familiarity with commonly performed clinical procedures in nuclear medicine.
Expected Duration	10% of total time
Sub-Modules	10.1 Protocols for routine clinical procedures 10.2 Common artefacts in clinical images 10.3 Analysis of common clinical studies and sources of error 10.4 Principles and physiological basis for common clinical studies 10.5 Developing clinical protocols for the estimation of patient dosimetry 10.6 Optimization 10.7 The physiological basis of PET imaging

Module 10: Clinical Applications	
Sub-module 10.1: Protocols for Routine Clinical Procedures	
Objective	To be able to understand and justify the technical factors of the clinical procedures used in the Nuclear Medicine Department.
Prerequisite	Familiarity with the principles of operation and use of the gamma camera and SPECT systems in the trainee's Department
Competencies Addressed	Familiarity with the effect of technical factors and acquisition protocol on the final result of a clinical procedure.
Core Knowledge	• The technical factors which influence the acquisition, processing and display of the required clinical information. • Ways to optimize the acquisition parameters to maximize the clinical information. • Ways to optimize the processing parameters to maximize the clinical information. • The ability to design and implement a new clinical procedure based on published techniques.
Recommended Elements of Training	• Read, and be reasonably familiar with, the essential resource material recommended for this competency (trainee may be orally examined on aspects of this at a later stage). • Identify the technical factors which influence the acquisition, processing and display of the required clinical information. • Optimize the acquisition parameters to maximize the clinical information. • Optimize the processing parameters to maximize the clinical information.

	• Design and implement a new clinical procedure based on published techniques. • Undertake the following tasks: 1) Choose 5 different studies from the following: bone, lung, brain SPECT, gated blood pool, renal blood flow and function, infection/tumor, gastroenterology, endocrinology and post-therapy. The 5 studies must include a whole body, a dynamic and a SPECT, and at least 3 different radionuclides. For each study, describe your department's clinical protocol and compare this protocol with the corresponding protocol recommended by the Society of Nuclear Medicine. In the report include details and justification of ➢ clinical indications ➢ patient preparation ➢ choice of radiopharmaceutical ➢ (in-house) preparation and QC of radiopharmaceutical ➢ activity administered and method of administration camera type (single or dual-head, size of FoV, inter head angle) and collimators ➢ energy window(s) ➢ images to be acquired (statics, whole body, dynamic, SPECT, gated) ➢ patient positioning ➢ timing of imaging (how long after administration, phase parameters if dynamic) ➢ acquisition parameters (matrix size, duration or counts in image, etc.) ➢ for SPECT, number of images, time per image, step-and-shoot or continuous ➢ image processing required for final display (2) In association with the supervisor select a study not currently performed in the department, and, using the above resources and/or recent scientific articles, design a clinical protocol for use in your department. The new protocol should include the above list of technical factors.

Module 10: Clinical Applications	
Sub-module 10.2: Common Artefacts in Clinical Images	
Objective	To be able to correctly identify common artefacts in nuclear medicine images and to recommend appropriate preventative and remedial action.
Prerequisites	Familiarity with the principles of operation and use of the gamma camera and SPECT systems in the trainee's Department.

Competencies Addressed	Familiarity with common image artefacts, their causes, and how to deal with them. The ability to identify artefacts in nuclear medicine images, identify their probable causes and undertake remedial action.
Core Knowledge	Common image artefacts, their causes, and remedial action.
Recommended Elements of Training	• Read, and be reasonably familiar with, the resource material recommended for this sub-module. • Identify artefacts in nuclear medicine images • Identify probable causes of these artefacts • Undertake remedial action to correct the problem giving rise to the artefact. • Optimize the data acquisition procedures to prevent the artefacts occurring • Undertake the following tasks: 1) **Influence of patient motion on SPECT studies**. Use a patient acquisition (projection) dataset for which there is no known motion (use the sinogram and SPECT cine to confirm this). Manually move certain images in the data set and reconstruct the data. Use any available software tools, as well as a visual comparison, to identify any artefacts in the reconstructed images. Experiment separately with movement in the x and y planes. It is suggested that either brain and/or myocardial SPECT studies be examined. Report and comment on your findings. 2) **Influence of inappropriate collimator selection on image contrast**. a) Use the supplied images of a contrast phantom (a Perspex step wedge) imaged in a solution of ^{67}Ga and acquired using both MEAP and LEHR collimators. Compare the measured contrast in the different images. b) Similarly use the supplied images of a line source filled with ^{67}Ga and acquired with the different collimators. Measure the FWHM and FWTM of the LSF and compare. c) Use the supplied images of a point source of ^{131}I acquired using LEAP, LEHR, MEAP and HEAP collimators. Comment on the differences. d) Use the supplied images of the contrast phantom of part a, which have been acquired using ^{99m}Tc instead of ^{67}Ga and using a ^{99m}Tc window with the LEAP, LEHR, MEAP and HEAP collimators. Record the measured contrast. A Petri dish containing a solution of ^{99m}Tc was imaged with the 4 collimators. Use the supplied images to calculate the relative sensitivity of the collimators for ^{99m}Tc. When might a MEAP collimator be used to image ^{99m}Tc?

	3) **Influence of inappropriate energy window settings.** a) Use the supplied images of the ^{67}Ga contrast phantom acquired using both 2 and 3 energy windows and an image collected with a ^{99m}Tc window and compare the images. b) Use the supplied flood images of a ^{57}Co sheet source. 4M count flood images were acquired with a 15% window which was initially centred on the photo peak and then positioned above and below the peak in 3 keV increments. Determine the integral and differential uniformity on each images set and visually review the images. Comment on any changes observed. 4) **Influence of collimator non-uniformity on SPECT reconstructed uniformity** a) Use a ^{57}Co sheet source or a ^{99m}Tc flood tank to acquire a 4 M count flood image with a LEHR collimator and compute the integral and differential uniformity. b) Fill a cylindrical phantom such as a Jaszczak phantom with a well-mixed solution of ^{99m}Tc (300-400 MBq) and acquire a SPECT study. Use the acquisition protocol recommended by the AAPM (ref 3). Assess the reconstructed uniformity both visually and quantitatively using the AAPM method (protocol 3 of ref 3) c) Firmly attach to the surface of the collimator a disc (approx. 2 cm diameter) of a material which will attenuate the ^{99m}Tc photons by no more than 2%, and repeat steps a and b. The "non-uniformity" should initially be placed near the centre of the FOV and then at increasing 5 cm distances away from the centre. d) Comment on any changes observed. **(5) Clinical artefacts** a) Review a series of images (both clinical and QC) and suggest possible causes for the artefacts observed. Compare your suggestions with the answers provided by the supervisor.

Module 10: Clinical Applications	
Sub-module 10.3: Analysis of common clinical studies and sources of error	
Objective	Analyze a range of common clinical studies using software provided by the gamma camera manufacturer/supplier, or through in-house programs.

Prerequisite	Familiarity with the types of studies and methods used for analyzing these studies in the trainee's department.
Competencies Addressed	Familiarity with sources of error in clinical procedures, their impact on the patient and how to validate clinical procedures.
Core Knowledge	· The ability to determine whether particular clinical analyses have been validated in the clinical arena, and limitations of the validation studies. · Familiarity with the sources of error which may arise during the analysis of nuclear medicine studies. · An understanding of the effect of the scan result on patient management and the consequences of an inaccurate scan result
Recommended Elements of Training	• Read, and be reasonably familiar with, the essential resource material recommended for this competency. • For a range of study types: o determine whether the study has been validated in the clinical arena, and limitations of the validation study. o investigate the effect of the scan result on patient management. o assess consequences of an inaccurate scan result. • Undertake the following tasks: Select an acquired study for each of the following three scan types: Myocardial SPECT, gated blood pool, and renal blood flow and function. **For each study, include the following in the report:** (1) Description of your department's clinical protocol: (a) clinical indications for study (b) precautions and contra-indications (c) patient preparation (2) Choice of method to achieve myocardial stress: (a) Physical exercise (b) Pharmacologic stress (discuss available agents) (3) Choice of radiopharmaceutical: (a) ^{201}Tl vs. ^{99m}Tc agents for Myocardial SPECT (c) in-vivo vs. modified in-vivo vs. in-vitro blood labelling for GBPS (d) DTPA vs. MAG3 for renal studies (e) uptake/clearance/radiation dosimetry of radiopharmaceutical (4) Study validation assessment: (a) has the study been validated in the clinical setting? (b) describe the gold standard used for validation (c) what was the outcome of the validation – include relevant sensitivity/specificity, correlation coefficient, ROC analysis (d) discuss limitations of the validation

	(5) Analyze the acquired study and comment on: (a) frequency filter used for Gated Cardiac SPECT (b) 8 frames vs. 16 frames vs. 32 frames for GBPS (c) automated vs. semi-automatic vs. manual ROIs for LVEF and renal function evaluation (6) Patient Management outcome: (a) comment on clinical relevance of the study (b) consequences of an inaccurate result

Module 10: Clinical Applications	
Sub-module 10.4: Principles and Physiological Basis for Common Clinical Studies.	
Objective	To be able to explain the principles and physiological basis for common clinical investigations, and be able to translate this knowledge to the development of new investigations.
Prerequisites	· An understanding of basic human biology, biochemistry and cell function. · An understanding of basic human anatomy and some medical terminology. The ability to identify the main organ systems of the body, and the major bones. · If the trainee has no formal education in the above areas, undertaking a suitable university course is recommended. Alternatively, most medical libraries have good introductory texts covering these areas. The IAEA Distance Assisted Training Programme has a module on "Introductory Human Biology", which includes a workbook.
Competency Addressed	To understand the physiology of the principal organ systems of the body, and how nuclear medicine can be used to elucidate information about the function of these organ systems.
Core Knowledge	· Basic human biology, biochemistry and cell function. · The impact of disease and altered physiology on quantitative parameters measured using nuclear medicine techniques. · The physiological basis for investigations performed in the area they have chosen, as well as being aware of factors affecting study quality and accuracy. · Drug use for the enhancement and blocking of uptake in certain imaging protocols. · The common reasons for patients to be referred for the clinical investigations.
Recommended Elements of Training	(1) Review all the main areas of clinical application at your institution. Aim to develop an overview of the knowledge you would be expected to have to understand the clinical investigations and to meet the above competency specifications. This is an opportune time to seek physician input into development of your training requirements. (2) From this review, prepare a syllabus for yourself on physiology and disease as it relates to nuclear medicine. Focus on both traditionally

	strong areas of nuclear medicine (e.g. cardiac scanning), but include knowledge that may reflect trends you see in the development of nuclear medicine (topical issues). (3) From the review, and with your syllabus in mind, choose one area of clinical investigation which you would like to further explore. This should be a topical area and preferably one in which your department is involved. (4) Discuss your syllabus related to your chosen area with your advisor. You need to agree on the content of the syllabus and whether the syllabus will cover the area in sufficient detail. From the resources discussed above and the resources available within your department, prepare a directed reading programme for the area you have chosen. (5) For the chosen clinical area, prepare a portfolio of 5 case studies. Try to choose case studies that reflect different aspects of physiology and dysfunction, along with any quantitative assessment that was performed. For each study, detail the indication for the procedure; the imaging procedure performed (including the basis for the chosen radiopharmaceutical and its biological behavior); methods of analysis and normal ranges for quantitative parameters; and the likely physiological basis for any abnormal function. Remember, this is a training exercise. Choose challenging cases that will help teach you varying aspects of your personal syllabus. (6) If possible, arrange to attend reporting sessions with the nuclear medicine physician/radiologist. These can be an important opportunity to gain further knowledge relating to the clinical utilization of nuclear medicine results, and to test your understanding of the clinical procedures and quantitative measures.

Module 10: Clinical Applications	
Sub-module 10.5: Developing Clinical Protocols for the Estimation of Patient Dosimetry	
Objective	To be able to develop and validate a protocol for the estimation of the radiation absorbed dose to the critical organs following administration of a new diagnostic radiopharmaceutical.
Prerequisite	Module 6.2 Familiar with the principles of activity quantitation using planar and tomographic imaging and with the MIRD system of internal dosimetry. Mention that a program is required to complete this module
Competency Addressed	The ability to estimate the patient dose associated with a new nuclear medicine investigation.

Core knowledge	· The ability to select the appropriate imaging methods and sampling times to adequately measure the cumulative activity for organs and for any excreta to determine the biodistribution and radiation dosimetry for a new radiopharmaceutical · The ability to select and use the appropriate data analysis methods · The ability to use the MIRD method to calculate the organ doses and the effective dose. · To understand the limitations of the MIRD method of internal dosimetry.
Recommended Elements of Training	· Read, and be reasonably familiar with, the essential resource material recommended for this competency (trainee may be orally examined on aspects of this at a later stage). · Undertake the following tasks: Use the data below, obtained using 99mTc-XYZ in rats, to design the acquisition protocols for a Phase 1 dosimetry study in humans for this new agent. This should include an attenuation correction method. Prepare detailed worksheets for the staff performing the studies. ^{99m}Tc-XYZ was injected intravenously into female rats and groups of animals were sacrificed at the following times: 10 mins, 30 min, 1, 2, 4, 8, 16, 24 hours. Total urinary activity was determined at the same times. The results obtained were corrected for physical decay and, when extrapolated to man, are given below as percent of administered dose

	10 min	30 min	1 hr	2 hr	4 hr	8 hr	16 hr	24 hr
Blood	40	15	7	3	2	1	0.5	0.25
Liver	6	4	3	3	2	2	1	0.5
Lung	2	1.8	1.5	1.0	0.8	0.6	0.4	0.2
Kidneys	5	4	4	3	3.5	2.5	2	1
Bone	7	18	25	30	32	31	33	35
S Bowel	0.5	0.8	1.2	1.5	0.8	0.5	0.3	0.1
L Bowel	0.4	0.3	0.4	0.6	1.5	2.5	2.3	3.5
Urinary excreta	4	20	28	32	35	40	45	48
Remainder of the body	35.1	36.1	29.9	25.9	22.4	19.9	15.5	11.5

Undertake physical phantom experiments with an anthropomorphic phantom to determine the possible errors in the activity quantitation and determine how these would impact on the absorbed dose estimates. This should include activity estimation separately from planar and from tomographic studies. The assessment of errors should include a consideration of CT/SPECT registration errors and 3D volume definition errors.

Module 10: Clinical Applications	
Sub-module 10.6: Optimization	
Objective	To understand the principles of optimization in nuclear medicine procedures
Prerequisite	None
Competency Addressed	An understanding of the procedures used for risk/benefit evaluation of diagnostic and therapeutic nuclear medicine procedures. To be able to evaluate (a) diagnostic nuclear medicine procedures and diagnostic information with respect to absorbed dose to the patient. (b) radionuclide therapy procedures with respect to possibility of cure and risk for complications
Core Knowledge	· Assessment of trade-off between absorbed dose to the patient and diagnostic information in diagnostic nuclear medicine procedures · Assessment of trade-off between probability of cure and risk for complications in radionuclide therapy · The definition and appropriate use of diagnostic reference levels (DRLs). · How DRLs affect practices in the clinical setting.
Recommended Elements of Training	· Read and be reasonably familiar with the source materials relating to DRLs in nuclear medicine. · Understand why reducing the administered dose can affect image quality. · Review examination procedures and discuss whether decreased administered dose could still result in adequate image quality or if an increase in administered dose should be recommended. · Identify some reference sources for DRLs for common nuclear medicine procedures. · Develop an understanding of how the DRL is intended to guide selection of the amount of radioactivity to administered for a given diagnostic nuclear medicine procedure, and circumstances in which it might be appropriate to exceed the recommended DRL. · Develop an understanding of when it is appropriate to employ a dose reduction technique, such as the use of alternative investigations, increasing fluid intake, reducing dose and increasing scanning time, and use of thyroid blocking agents. · Be familiar with special considerations for children and young people. · Review a radionuclide therapy procedure and discuss the probability of cure and risk for complications

Module 10: Clinical Applications	
Sub-module 10.7: The Physiological Basis of PET Imaging	
Objective	To gain an understanding of the principles and physiological basis for common clinical PET and PET/CT studies.

Prerequisite	Understand the principles of PET/CT, including instrumentation, FDG production and image acquisition/reconstruction.
Competency Addressed	To understand the principles and physiological basis for common clinical PET and PET/CT studies. The ability to recognize the normal appearances for brain, heart and whole-body studies as well as common abnormal appearances and artefacts.
Core Knowledge	· Mechanisms of uptake of FDG into normal tissues and tumors. · Main assumptions of the SUV method and explain its relationship to the autoradiographic FDG method. · Clinical protocols for FDG brain, heart and whole-body imaging for cancer. · Role of and typical parameters for CT in PET/CT clinical studies. · Radiation safety and patient dosimetry for PET/CT studies
Recommende Elements of Training	· Document the mechanisms of uptake of FDG into normal tissues and tumors and clearance from the blood, making note of the different mechanisms in brain, heart and other major organs. Also discuss how these mechanisms are affected by serum glucose levels, anxiety and other factors. · Write down the equation for the autoradiographic FDG method and, by making simplifying assumptions, show how it can lead to the equation that describes the SUV method. List the main assumptions and discuss their validity. · Document each of the common clinical PET protocols, including the use of CT when available (and discuss its clinical usefulness). Also discuss radiation safety issues and patient dosimetry relevant to clinical PET/CT. · Discuss in detail the normal and common abnormal appearances (including artefacts) for one of the above clinical protocols, using clinical examples to illustrate the main points. · The trainee should spend at least 2 weeks in a department with clinical PET.

MODULE 11 – PREPARATION AND QUALITY CONTROL OF RADIOPHARMACEUTICALS	
Objective	To become familiar with the quality control test associated with radiopharmaceuticals preparation.
Expected Duration	5% of overall time.
Sub-Modules	(1) The production and preparation of radiopharmaceuticals (2) Quality control of the radiopharmaceuticals

Module 11 – Preparation and Quality Control of Radiopharmaceuticals	
Sub-module 11.1-The Production and Preparation of Radiopharmaceuticals	
Objective	To understand the principles of radiopharmaceutical production and preparation for clinical nuclear medicine imaging.
Prerequisites	· Sub-module 2.1 Monitoring radiation levels including personnel monitoring · Sub-module 2.2 Exposure from sealed and unsealed sources and the risk of contamination · Sub-module 2.5 Areas designated for the use of unsealed radioactive material
Competencies Addressed	· Familiarity with the facilities necessary for the production of radionuclides and radiopharmaceuticals. · Ability to apply appropriate protocols to prepare Tc-99m- labelled radiopharmaceuticals.
Core Knowledge	· Principles of radionuclide productions · The protocol for radiopharmaceutical preparations
Recommended Elements of Training	• Study the methods for radionuclide production including o Nuclear reactor and cyclotron o Production of radionuclide o Chemistry of Technetium • Observe the procedures for the preparation of radiopharmaceuticals including o Radionuclide generator o Laboratory technique o Preparation of radiopharmaceuticals • Perform radionuclide measurement o Total activity of the eluate using a radionuclide calibrator o Calculate the activity concentration

	• Study the radionuclide and radiopharmaceuticals requirements for clinical imaging o Tc-99m –MDP for bone imaging o Tc-99m –DTPA, DMSA and MAG-3for kidney imaging o Tc-99m – DISIDA for hepato-biliary imaging o Tc-99m-Sn-RBC for cardiac imaging and function studies. o Etc.

Module 11 – Preparation and Quality Control of Radiopharmaceuticals	
Sub-module 11.2 - Quality Control of the Radiopharmaceuticals	
Objective	To understand the quality control in the radiopharmaceuticals.
Prerequisites	Sub-module 11.1: The production and preparation of radiopharmaceuticals
Competencies Addressed	An understanding of quality control procedures and their importance for radiopharmaceuticals. Be able to perform basic QC tests of radiopharmaceuticals.
Core Knowledge	• Principles of quality control and the importance of the test for the quality of the examinations. • Understanding of the Quality Control tests including: o Physical characteristics o Radionuclide purity o Radiochemical purity o Chemical purity • Procedures of an aseptic practice in daily radiopharmaceuticals preparations o Biological quality control o Mechanism of radiopharmaceutical purity.
Recommended Elements of Training	• Study the principles of quality control of radiopharmaceuticals • Review the documentation and results of quality control procedures, suggest further action • Observe the QC procedures including biological quality control o Sterility o Pyrogen test • Perform the QC of the radiopharmaceuticals including o Chemical purity using chromatographic methods o Classify the impurities o ITLC-SG (Instant thin layer chromatography silica gel) preparation o Calculation the percentage activity the free pertechnetate and reduced hydrolyzed o Typical results with pass criteria

	○ Determine the molybdenum break through using the lead pot method and alumina contamination using the spot test procedure • Describe the relevance of each QC for the quality of the examination and safety of the patients

Nuclear Medicine Technologist Resident Assessment Criteria

The **assessment** has two main goals:

1. To confirm the resident has the necessary **knowledge, experience, and skills** for common clinical nuclear medicine practice activities.
2. To assure the relevant professional and national bodies that the resident is **competent and safe** to work as a clinically qualified Nuclear Medicine Technologist.

This requires evaluating the resident's abilities during training using the following **key competency indicators**:

- **Approach:** Careful, logical, and thorough work.
- **Self-Awareness:** Confidence combined with recognizing one's limitations.
- **Knowledge:** Broad understanding of topics and adequate theoretical knowledge of nuclear medicine physics.
- **Problem-Solving:** Ability to define problems and formulate strategies.
- **Practical Skills:** Efficient task execution and completion, and a clear understanding of procedures.
- **Standards & Data:** Knowledge of relevant standards, expected results, and the ability to **correctly interpret data** (including novel data).
- **Evaluation:** Appreciation of result significance, ability to critically evaluate processes and outcomes, and make value judgments.
- **Communication:** Clear, logical, and accurate communication of scientific information.
- **Responsibility:** Taking **o**wnership of work undertaken.

AN EXAMPLE OF THE ASSESSMENT MATRIX OF A SUB-MODULE

Sub module 5.1: Acquisition and Life Cycle of Nuclear Medicine Equipment

Knowledge Base	**Level of Competency Achieved**	
	2	**1**
To understand the procedures for acceptance testing and equipment maintenance as well as verification of equipment performance after maintenance.	Demonstrates a **basic understanding** of the generic elements of the life cycle of nuclear medicine equipment **including** planning, purchase, acceptance and commissioning, maintenance and verification of equipment performance after maintenance.	Demonstrates a **good understanding** of the elements of the life cycle of nuclear medicine equipment.
Date Achieved	3 March 2010	6 June 2010
Supervisor's Initials	*A*	*AK*

Practical Skills	**Level of Competency Achieved**		
	3	**2**	**1**
The capability to make budgetary requests, prepare specifications and acquire suitable equipment through a tendering process	Is capable of **contributing** to the **development** of budgetary requests, preparing specificatios and acquiring equipment through a tendering process. **Requires assistance** with the concepts involved.	Is capable of **providing the "Nuclear Medicine Technology related"** input to budgetary requests, preparation of specifications and acquisition of equipment through a tendering process.	Is capable of **independently providing the "Nuclear Medicine Technology related"** input to budgetary requests, preparation of specifications and acquisition of equipment through a tendering process.

Practical Skills	**Level of Competency Achieved**		
	3	**2**	**1**

		Requires only minimal assistance to ensure all necessary elements are included. **Any omissions are minor.**	
Date Achieved	6 June 2010		19 Dec 2010
Supervisor's Initials	*AK*		*AK*

Date	**Supervisor's comments**
3 March 2010	Needs to learn more detail of the principals involved.
6 June 2010	Has made good progress in acquiring this competency.
19 Dec 2010	This Resident is capable of providing this departments input to a tender process.

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LOGBOOK CERTIFICATE

This is to certify that **Mr./Ms**. _____, Registration No. _____, admitted to the **M.Sc. Nuclear Medicine programme** in the academic year _____, has satisfactorily completed / not completed all the requirements prescribed in this logbook for the First Year / Second Year of the M.Sc. Nuclear Medicine programme during the period from _____ to _____ at _____ (Department of Nuclear *Medicine/Hospital)*.

Faculty InCharge (Department of Nuclear Medicine)

Name _____

Date _____

Signature of the Principal/Dean HoD

(University/College)

Name

Date

FINAL ASSESSMENT SUMMARY OF NUCLEAR MEDICINE TECHNOLOGIST

NAME: .....

ENROLLMENT NUMBER: .....

NAME OF SUPERVISOR: .....

MODULE 1: CLINICAL AWARENESS

Level of Competency Achieved (Date)					
	Knowledge		**Practical skills**		
	2	**1**	**3**	**2**	**1**
1.1 Essential anatomy and physiology for the Nuclear Medicine Technologist	a) b)				
1.2 Basic principles of radiation biology and epidemiology					
1.3 Clinical activities and factors that affect patient care Nuclear medicine Radiology Radiation oncology Other areas				`	

MODULE 2: RADIATION PROTECTION

Level of Competency Achieved (Date)					
	Knowledge		**Practical skills**		
	2	**1**	**3**	**2**	**1**
(2.1) Monitoring radiation levels including personnel monitoring.	(a) (b)				

(2.2) Exposure from sealed and unsealed sources and the risk of contamination.			a) b)		
(2.3) ALARA and radiation safety precautions in nuclear medicine diagnostic and therapeutic procedures.					
(2.4) Risk assessment and advice to staff, patients and others regarding radiation risk.	(a) (b) (c)				
(2.5) Areas designated for the use of unsealed radioactive material.	(a) (b)				
(2.6) Radiation shielding considerations in the design of new facilities.	(a) (b)				
(2.7) Regulatory controls and other guidance on the safe use of ionizing radiation in nuclear medicine.					

MODULE 3: RESEARCH, DEVELOPMENT AND TEACHING

Level of Competency Achieved (Date)					
	Knowledge		**Practical skills**		
	2	**1**	**3**	**2**	**1**
3.1 Research & development.					
3.2 Teaching.					

MODULE 4: PROFESSIONAL DEVELOPMENT

Level of Competency Achieved (Date)					
	Knowledge		**Practical skills**		
	2	**1**	**3**	**2**	**1**

4.1 Professional awareness.					
4.2 Communication.					
4.3 Quality management.					
4.4 Clinical audit.					

MODULE 5: EQUIPMENT PROCUREMENT, ACCEPTANCE TESTING AND COMMISSIONING

Level of Competency Achieved (Date)					
	Knowledge		**Practical skills**		
	2	**1**	**3**	**2**	**1**
5.1 Equipment acquisition and life cycle of nuclear medicine equipment.					
5.2 Dose calibrator acceptance testing.					
5.3 Scintillation probe and well counter acceptance testing.					
5.4 Gamma camera, SPECT/ CT acceptance and commissioning.					
5.5 PET/CT acceptance and commissioning.			(a) (b)		

MODULE 6: RADIOACTIVITY MEASUREMENTS AND INTERNAL DOSIMETRY

Level of Competency Achieved (Date)					
	Knowledge		**Practical skills**		
	2	**1**	**3**	**2**	**1**
6.1 Use of traceable standards for radioactivity measurements.					

6.2 Formalism and application of internal dosimetry.					
6.3 Radiation dose from diagnostic nuclear medicine radiopharmaceuticals.					
6.4 Quantitative nuclear medicine imaging.					
6.5 Patient-specific dosimetry.					

MODULE 7: QUALITY CONTROL OF NUCLEAR MEDICINE EQUIPMENT

Level of Competency Achieved (Date)					
	Knowledge		**Practical skills**		
	2	**1**	**3**	**2**	**1**
7.1 Design and supervision of a routine QC program.					
7.2 QC of a dose calibrator.					
7.3 QC of a scintillation probe and well counter.					
7.4 QC of gamma camera and SPECT.			(a) (b)		
7.5 QC of PET/CT systems.					
7.6 QC of display and hardcopy devices.	(a) (b)				
7.7 QC of DXA systems.					

MODULE 8: RADIONUCLIDE THERAPY USING UNSEALED SOURCES

Level of Competency Achieved (Date)					
	Knowledge		**Practical skills**		
	2	**1**	**3**	**2**	**1**

8.1 Principles of radionuclide therapy.					
8.2 Facility design for radionuclide therapy.					
8.3 Treatment procedures.					
8.4Selectionof radiopharmaceuticals for nuclear medicine therapy.	(a) (b)				
8.5Dosimetry for radionuclide therapeutic procedures.					
8.6 Radiation safety precautions for therapy using unsealed radionuclide sources.	(a) (b)		(a) (b)		

MODULE 9 – CLINICAL COMPUTING AND NETWORKING

Level of Competency Achieved (Date)					
	Knowledge		**Practical skills**		
	2	**1**	**3**	**2**	**1**
9.1 Operation of a clinical acquisition and processing/reviewing workstation.					
9.2 Computer system administration management.					
9.3 First line computer system troubleshooting.			(a) (b)		
9.4 Computer image processing techniques.					
9.5 Image analysis in a high-level programming language (optional).					
9.6 Image reconstruction, registration and fusion, and tracer kinetic modelling.			(a) (b)		

9.7 Standard image file formats used in nuclear medicine.					
9.8 Computer networking, PACS, RIS and HIS.			(a) (b) (c)		
9.9 Software validation: computer simulations, phantoms and clinical data.			(a) (b)		

MODULE 10: CLINICAL APPLICATIONS

Level of Competency Achieved (Date)					
	Knowledge		**Practical skills**		
	2	**1**	**3**	**2**	**1**
10.1 Protocols for routine clinical procedures.					
10.2 Common artefacts in clinical images.					
10.3 Analysis of common clinical studies and sources of error.					
10.4 Principles and physiological basis for common clinical studies.					
10.5 Developing clinical protocols for the estimation of patient dosimetry.					
10.6 Optimization.			(a) (b)		
10.7 The physiological basis of PET imaging.					

MODULE 11: PREPARATION AND QUALITY CONTROL OF RADIOPHARMACEUTICALS

Level of Competency Achieved (Date)					
	Knowledge		Practical skills		
	2	1	3	2	1
11.1 Production and preparation of radiopharmaceuticals					
11.2 Quality control of the radiopharmaceuticals					

MODEL PAPER

M.NMT Semester-I
Paper Code: MNM1101

Master of Science in Nuclear Medicine Technology
Semester-I
Human Anatomy & Physiology for Nuclear Medicine
Time: 2 Hours | Maximum Marks: 50

Q1. Long Answer Questions (Attempt any 2 out of 3) **2 × 10 = 20**

a) Describe the structure of a long bone with a neat labelled diagram. [CO1; L:2]
b) Classify the joints and explain a typical synovial joint with a neat labelled diagram. [CO1; L:2]
c) Describe the cardiac cycle with a neat labelled diagram. [CO1; L:2]

Q2. Short Answer Questions (Attempt any 6 out of 8) **6 × 5 = 30**

a) Define erythropoiesis. [CO2; L1]
b) Explain briefly lung volumes and capacities. [CO2; L2]
c) Write a short note on glomerular filtration rate (GFR). [CO3; L2]
d) Explain briefly testosterone. [CO3; L2]
e) Differentiate between conductive and sensorineural deafness. [CO4; L3]
f) Write a short note on the lymph node. [CO2; L2]
g) Define rods and cones. [CO4; L1]
h) Write a short note on cochlea. [CO4; L2]

MODEL PAPER

M.NMT Semester-I
Paper Code: MNM1102

Master of Science in Nuclear Medicine Technology
Semester-I
Nuclear Medicine Physics and Instrumentation
Time: 2 Hours | Maximum Marks: 50

Q1. Long Answer Questions (Attempt any 2 out of 3) **2 × 10 = 20**

a) Explain the working principle of a dose calibrator and describe the quality control tests performed on it. [CO1; L: 4]

b) Describe the working principle, applications, advantages and limitations of liquid scintillation counters. [CO1; L: 4]

c) Explain the principles of automated radiopharmaceutical preparation and safety systems in a nuclear medicine facility. [CO1; L: 2]

Q2. Short notes (Attempt any 6 out of 8) **6 × 5 = 30**

a) Explain the working principle of an intraoperative gamma probe. [CO1; L2]
b) Differentiate between NaI(Tl) and CZT detectors. [CO2; L4]
c) Write a short note on the Geiger-Müller (GM) counter. [CO1; L2]
d) Explain the role of radiation survey meters in nuclear medicine. [CO1; L2]
e) Write a short note on quenching in liquid scintillation counting. [CO1; L3]
f) Explain the purpose of primary and secondary shielding in a hot laboratory. [CO2; L2]
g) Write a short note on negative pressure ventilation in a nuclear medicine facility. [CO2; L1]
h) Explain the importance of safety interlocks and emergency shutdown systems. [CO1; L2]

MODEL PAPER

M.NMT Semester-I
Paper Code: MNM1103

Master of Science in Nuclear Medicine Technology
Semester-I
Radiological Physics, Safety and Regulatory Planning of Facility
Time: 2 Hours | Maximum Marks: 50

Q1. Long Answer Questions (Attempt any 2 out of 3) **2 × 10 = 20**

a) Discuss the principles of pedagogy and explain the methods of teaching and assessment in medical education. [CO1; L2]
b) Discuss the design and safety systems of a nuclear medicine clinical facility according to AERB/IAEA guidelines. [CO2; L3]
c) Describe the design and workflow of a medical cyclotron facility with suitable diagrams. [CO1; L2]

Q2. Short notes (Attempt any 6 out of 8) **6 × 5 = 30**

a) Write a short note on ALARA principle. [CO1; L2]
b) Explain personnel monitoring using TLD and OSL dosimeters. [CO1; L2]
c) Write a short note on wipe testing procedures. [CO1; L2]
d) Explain shielding requirements for PET/CT and SPECT/CT facilities. [CO2; L2]
e) Write a short note on negative pressure ventilation and fume hoods. [CO2; L2]
f) Explain the roles and responsibilities of a Radiation Safety Officer (RSO). [CO3; L2]
g) Write a short note on radioactive waste segregation and decay storage. [CO3; L2]
h) Explain emergency response procedures for radioactive spills. [CO3; L2]

MODEL PAPER

M.NMT Semester-I
Paper Code: MNM1104

Master of Science in Nuclear Medicine Technology
Semester-I
Research Publication Ethics & Pedagogy
Time: 2 Hours | Maximum Marks: 50

Q1. Long Answer Questions (Attempt any 2 out of 3) **2 × 10 = 20**

a) 1.Discuss the cardinal principles of bioethics and their application in biomedical research. [CO1; L2]
b) 2.Explain the principles of research publication ethics, including plagiarism, authorship, and conflict of interest [CO2; L2]
c) 3. Discuss the principles of pedagogy and explain the methods of teaching and assessment in medical education. [CO3; L4]

Q2. Short notes (Attempt any 6 out of 8) **6 × 5 = 30**

a) Write a short note on informed consent. [CO1; L2]
b) Explain the roles of the Institutional Ethics Committee (IEC). [CO1; L2]
c) Write a short note on wipe testing procedures. [CO1; L2]
d) Explain the ICMJE criteria for authorship. [CO1; L2]
e) Write a short note on plagiarism. [CO2; L2]
f) Write a short note on Bloom's taxonomy of learning. [CO3; L2]
g) Explain microteaching. [CO3; L2]
h) Write a short note on blueprinting in assessment. [CO3; L2]

MODEL PAPER

M.NMT Semester-II
Paper Code: MNM1201

Master of Science in Nuclear Medicine Technology
Semester-II
Advanced Biostatistics and Research Methodology
Time: 2 Hours | Maximum Marks: 50

Q1. Long Answer Questions (Attempt any 2 out of 3) **2 × 10 = 20**

a) Explain the principles of hypothesis testing and discuss the applications of parametric and non-parametric statistical tests in medical research. [CO1; L4]
b) Discuss the research process and explain the different observational study designs with suitable examples. [CO2; L2]
c) Explain the steps involved in conducting a systematic review and meta-analysis. [CO3; L4]

Q2. Short notes (Attempt any 6 out of 8) **6 × 5 = 30**

a) Write a short note on Bayes' theorem. [CO1; L4]
b) Differentiate between ANOVA and ANCOVA. [CO1; L4]
c) Write a short note on ROC curve. [CO1; L4]
d) Explain prevalence and incidence. [CO1; L2]
e) Differentiate between prospective and retrospective cohort studies. [CO2; L2]
f) Write a short note on CONSORT guidelines. [CO3; L2]
g) Write a short note on PRISMA guidelines. [CO3; L4]
h) Explain the importance of FAIR data principles in research. [CO3; L2]

MODEL PAPER

M.NMT Semester-II
Paper Code: MNM1202

Master of Science in Nuclear Medicine Technology
Semester-II
Advanced Nuclear Medicine Instrumentation
Time: 2 Hours | Maximum Marks: 50

Q1. Long Answer Questions (Attempt any 2 out of 3) **2 × 10 = 20**

a) Explain the working principle of a PET camera and discuss the recent advances in PET imaging. [CO1; L2]
b) Discuss the working principle of MRI and explain the recent advances in MRI technology. [CO2; L2]
c) Compare PET/CT and PET/MRI hybrid imaging systems with suitable diagrams. [CO3; L4]

Q2. Short notes (Attempt any 6 out of 8) **6 × 5 = 30**

a) Write a short note on Time-of-Flight (TOF) PET. [CO1: L2]
b) Explain total-body PET imaging. [CO1; L2]
c) Write a short note on recent advances in CT detector technology. [CO2; L4]
d) Explain radiation dose optimization in CT. [CO2 L4]
e) Write a short note on RF coil systems in MRI. [CO2: L2]
f) Explain the advantages of CZT detectors in SPECT/CT. [CO3; L2]
g) Differentiate between PET and PET/CT. [CO3; L4]
h) Write a short note on image fusion algorithms in hybrid imaging. [CO3; L2]

MODEL PAPER

M.NMT Semester-II
Paper Code: MNM1203

Master of Science in Nuclear Medicine Technology
Semester-II
SPECT & PET Radiopharmaceuticals
Time: 2 Hours | Maximum Marks: 50

Q1. Long Answer Questions (Attempt any 2 out of 3) **2 × 10 = 20**

a) Explain the chemistry of 99mTc-labelled radiopharmaceuticals and discuss their preparation and clinical applications. [CO1; L2]
b) Describe the production, synthesis, and clinical applications of PET radiopharmaceuticals. [CO2; L2]
c) Discuss the process of drug development and clinical trials for nuclear medicine radiopharmaceuticals. [CO3; L4]

Q2. Short notes (Attempt any 6 out of 8) **6 × 5 = 30**

a) Write a short note on Technetium-99m chemistry. [CO1: L2]
b) Explain sodium pertechnetate labelling. [CO1; L2]
c) Write a short note on radioiodine-labelled radiopharmaceuticals. [CO2; L2]
d) Differentiate between the radioiodination methods. [CO2; L2]
e) Write a short note on F-18 FDG. [CO2: L2]
f) Explain automated synthesis modules used in PET radio pharmacy. [CO2; L2]
g) Write a short note on packaging and transportation of PET radiopharmaceuticals. [CO3; L4]
h) Explain the phases of clinical trials for radiopharmaceuticals. [CO3; L2]

MODEL PAPER

M.NMT Semester-II
Paper Code: MNM1204

Master of Science in Nuclear Medicine Technology
Semester-II
Computers in Nuclear Medicine
Time: 2 Hours | Maximum Marks: 50

Q1. Long Answer Questions (Attempt any 2 out of 3) **2 × 10 = 20**

a) Explain the computational algorithms used in nuclear medicine image processing with suitable examples. [CO1; L3]
b) Discuss the programming languages and software tools used in nuclear medicine image processing and analysis. [CO2; L3]
c) Discuss the process of drug development and clinical trials for nuclear medicine radiopharmaceuticals. [CO3; L4]

Q2. Short notes (Attempt any 6 out of 8) **6 × 5 = 30**

a) Write a short note on Monte Carlo simulation. [CO1: L3]
b) Explain image registration algorithms. [CO1; L3]
c) Write a short note on Python applications in nuclear medicine. [CO2; L2]
d) Explain the role of DICOM in nuclear medicine imaging. [CO2; L3]
e) Write a short note on 3D Slicer. [CO2: L3]
f) Explain compartmental analysis in tracer kinetic modeling. [CO3; L3]
g) Write a short note on OLINDA/EXM software. [CO3; L4]
h) Explain workflow automation in nuclear medicine. [CO3; L3]

MODEL PAPER

M.NMT Semester-III
Paper Code: MNM2301

Master of Science in Nuclear Medicine Technology
Semester-III
Artificial Intelligence in Nuclear medicine
Time: 2 Hours | Maximum Marks: 50

Q1. Long Answer Questions (Attempt any 2 out of 3) **2 × 10 = 20**

a) Explain the advanced computational techniques used in nuclear medicine with suitable applications. [CO1; L3]
b) Discuss machine learning techniques and their applications in nuclear medicine. [CO2; L3]
c) Explain the applications of artificial intelligence in diagnostics and theragnostic nuclear medicine. [CO3,; L3]

Q2. Short notes (Attempt any 6 out of 8) **6 × 5 = 30**

a) Write a short note on DICOM processing. [CO1: L3]
b) Explain image segmentation using active contour techniques. [CO1; L3]
c) Write a short note on convolutional neural networks (CNNs). [CO2; L2]
d) Explain transfer learning in medical imaging. [CO2; L3]
e) Write a short note on radiomics in nuclear medicine. [CO2: L3]
f) Explain the role of natural language processing (NLP) in PET reporting. [CO3; L3]
g) Write a short note on ethical considerations in artificial intelligence. [CO3; L4]
h) Explain AI model validation in nuclear medicine. [CO4; L3]

MODEL PAPER

M.NMT Semester-III
Paper Code: MNM2302

Master of Science in Nuclear Medicine Technology
Semester-III
Clinical Nuclear Medicine Imaging
Time: 2 Hours | Maximum Marks: 50

Q1. Long Answer Questions (Attempt any 2 out of 3) **2 × 10 = 20**

a) Describe the protocol for routine cardiac SPECT imaging. [CO1; L3]
b) Explain the clinical applications and protocol of PET/CT imaging in oncology and cardiology. [CO1; L2]
c) Discuss the common sources of error in SPECT and PET imaging and their prevention. [CO2; L2]

Q2. Short notes (Attempt any 6 out of 8) **6 × 5 = 30**

a) Write a short note on brain perfusion SPECT. [CO1: L2]
b) Explain gated PET/CT studies. [CO1; L3]
c) Write a short note on Standardized Uptake Value (SUV). [CO2; L2]
d) Explain attenuation correction artifacts in PET/CT. [CO2 L2]
e) Write a short note on motion artifacts in nuclear medicine imaging. [CO2: L2]
f) Explain the importance of quality control and SOPs in nuclear medicine imaging. [CO2; L2]
g) Write a short note on patient-specific dosimetry. [CO3; L2]
h) Explain the factors affecting optimization of clinical dosimetry protocols. [CO3; L2]

MODEL PAPER

M.NMT Semester-III
Paper Code: MNM2303

Master of Science in Nuclear Medicine Technology
Semester-III
Image Analysis
Time: 2 Hours | Maximum Marks: 50

Q1. Long Answer Questions (Attempt any 2 out of 3) 2 × 10 = 20

a) Describe the principles of image reconstruction in SPECT and PET imaging. [CO1; L3]
b) Explain iterative reconstruction algorithms used in nuclear medicine imaging. [CO2; L3]
c) Discuss quantitative image analysis and image registration techniques in nuclear medicine. [CO3; L4]

Q2. Short notes (Attempt any 6 out of 8) 6 × 5 = 30

1. Write a short note on Radon transform and Forward Projection. [CO1: L2]
2. Explain Filtered Back Projection (FBP) and its limitations. [CO1; L2]
3. Define Point Spread Function (PSF). [CO1; L2]
4. Write a short note on attenuation correction and scatter correction in PET imaging. [CO2; L2]
5. Explain the Ordered Subset Expectation Maximization (OSEM) algorithm. [CO2: L2]
6. Explain Total Variation (TV) regularization in image reconstruction. [CO3; L3]
7. Write a short note on attenuation correction and scatter correction in PET imaging. [CO2; L3]
8. Explain image registration and fusion techniques in PET/CT and PET/MRI. [CO3; L4]

MODEL PAPER

M.NMT Semester-IV
Paper Code: MNM2401

Master of Science in Nuclear Medicine Technology
Semester-IV
Radiation Dosimetry in Nuclear Medicine and Therapy Planning
Time: 2 Hours | Maximum Marks: 50

Q1. Long Answer Questions (Attempt any 2 out of 3) **2 × 10 = 20**

a) Describe the fundamentals of radiation dosimetry used in nuclear medicine. [CO1; L1]
b) Explain the MIRD formalism for internal radiation dosimetry. [CO2; L3]
c) Discuss treatment planning in radionuclide therapy with suitable examples. [CO3; L3]

Q2. Short notes (Attempt any 6 out of 8) **6 × 5 = 30**

a) Write a short note on absorbed dose, kerma and LET. [CO1; L1]
b) Explain equivalent dose and effective dose. [CO1; L1]
c) Write a short note on the MIRD equation and S-values. [CO2; L3]
d) Explain physical, biological and effective half-life. [CO2; L2]
e) Write a short note on OLINDA/EXM in internal dosimetry. [CO2; L3]
f) Explain patient-specific treatment planning in radionuclide therapy. [CO3; L3]
g) Write a short note on voxel-based dosimetry. [CO3; L4]
h) Explain the applications of BED and EQD2 in radionuclide therapy. [CO3; L2]

MODEL PAPER

M.NMT Semester-IV
Paper Code: MNM2402

Master of Science in Nuclear Medicine Technology
Semester-IV
Therapeutic Radiopharmaceuticals
Time: 2 Hours | Maximum Marks: 50

Q1. Long Answer Questions (Attempt any 2 out of 3) **2 × 10 = 20**

a) Describe the principles of radionuclide therapy and the characteristics of therapeutic radionuclides. [CO1; L2]
b) Discuss the therapy protocol of Lu-177 DOTATATE and Lu-177 PSMA-617. [CO1; L 3]
c) Explain targeted alpha therapy and its clinical applications in nuclear medicine.[CO3; L4]

Q2. Short notes (Attempt any 6 out of 8) **6 × 5 = 30**

a) Write a short note on the production and characteristics of Lu-177. [CO1; L2]
b) Explain I-131 sodium iodide therapy for thyroid disorders. [CO1; L2]
c) Write a short note on peptide receptor radionuclide therapy (PRRT). [CO2; L5]
d) Discuss bone pain palliation using therapeutic radiopharmaceuticals. [CO2; L5]
e) Explain selective internal radionuclide therapy (SIRT/TARE). [CO2; L5]
f) Write a short note on radio synovectomy. [CO3; L3]
g) Discuss the comparison between alpha emitters and beta emitters in radionuclide therapy. [CO3; L4]
h) Explain the handling, storage, and waste management of alpha-emitting radiopharmaceuticals. [CO3; L2]

MODEL PAPER

M.NMT Semester-IV
Paper Code: MNM2403

Master of Science in Nuclear Medicine Technology
Semester-IV
Quality assurance and Quality control in Nuclear Medicine
Time: 2 Hours | Maximum Marks: 50

Q1. Long Answer Questions (Attempt any 2 out of 3) **2 × 10 = 20**

a) Describe the acceptance testing of Planar Gamma Camera/SPECT according to NEMA and AERB requirements. [CO1; L3]
b) Discuss the routine quality control procedures for PET/PET-CT imaging systems. [CO2; L4]
c) Explain the implementation of a Quality Assurance (QA) program and its role in ensuring regulatory compliance in nuclear medicine. [CO3; L6]

Q2. Short notes (Attempt any 6 out of 8) **6 × 5 = 30**

a) Write a short note on intrinsic uniformity testing of a gamma camera. [CO1: L2]
b) Explain gated PET/CT studies. [CO1; L4]
c) Write a short note on center-of-rotation (COR) test.) [CO2; L4]
d) Discuss co-registration accuracy in hybrid imaging systems. [CO2; L4]
e) Explain daily quality control procedures for SPECT. [CO3: L6]
f) Write a short note on AERB requirements for QA documentation [CO3; L6]
g) Explain troubleshooting of non-uniformity in gamma camera images. [CO3; L2]
h) Discuss the importance of SOPs and record keeping in a QA program. [CO3; L6]

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