सत्यमेव जयते

National Commission for Allied and Healthcare Professions

(NCAHP)

Competency Based Curriculum

For

Nuclear Medicine Technology



As per NCAHP Act, 2021

(Intellectual property of National Commission for Allied and Healthcare Professions, Ministry of Health and Family Welfare)

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Chapter 1

Introduction

Brief about the Profession:

The report "*From Paramedics to Allied Health Professionals: Landscaping the Journey and Way Forward*", published in 2012, highlighted the diversity in education and training practices for allied and healthcare courses across the country. This underscored the crucial need for the Ministry of Health and Family Welfare to develop national guidelines for education and career pathways of allied and healthcare professionals. As key stakeholders in the healthcare system, universities, colleges, healthcare providers, and educators are instrumental in implementing these guidelines. This handbook has been meticulously designed to familiarize you with these national standards, empowering you to play a vital role in shaping the future of healthcare.

Individually tailored for different professional groups in allied and healthcare, this handbook is a beacon of hope for the future of healthcare. It aims to reduce the variation in education by introducing a standardized curriculum, career pathways, nomenclature, and other details for each profession. This shift from a purely didactic approach promises to create a new generation of better-skilled professionals, thereby significantly improving the quality of patient care. Based on the recommendations of the NCAHP Act, this handbook can also guide the thousands of young adults who choose healthcare as a profession, offering them a clear and promising path to becoming skilled allied and healthcare professionals of the future.

Who is an Allied and Healthcare Professional?

The Ministry of Health and Family Welfare accepted in its entirety the definition of an allied and healthcare professional based on the report above, though the same has evolved after multiple consultations, and the recommended definition is now as follows-

"Allied and healthcare professionals (AHPS) include individuals involved with delivering health or healthcare-related services, with qualifications and competence in therapeutic, diagnostic, curative, preventive and/or rehabilitative interventions. They work in multidisciplinary health teams in varied healthcare settings, including doctors (physicians and specialists), nurses and public health officials, to promote, protect, treat and/or manage a person's physical, mental, social, emotional, environmental health and holistic wellbeing." The National Commission for Allied and Healthcare Professions Act, 2021 (The NCAHP Act 2021) was passed by Rajya Sabha on March 16, 2021, and by Lok Sabha on March 24, 2021. The Government notified it in the Gazette of India on March 28, 2021, after it received the assent of the President. The NCAHP Act is to provide for the regulation and maintenance of standards of education and services by allied and healthcare professionals, assessment of institutions, maintenance of a central register and state register and creation of a system to improve access, research and development and adoption of latest scientific advancement and for matters connected therewith or incidental thereto.

Scope and Need for Allied and Healthcare Professionals in the Indian Healthcare System

The quality of medical care has improved tremendously in the last few decades due to technological advances, thus creating fresh challenges in the healthcare field. It is now widely recognized that health service delivery is a team effort involving both clinicians and non-clinicians, and is not the sole duty of physicians and nurses. Professionals who can competently handle sophisticated machinery, advanced protocols, interpret reports, and analyze results are now in high demand globally. Diagnosis is now so dependent on technology that allied and healthcare professionals (AHPS) are vital to diagnosis and successful management. [1]

As the Indian Government aims for Universal Health Coverage, the lack of skilled human resources may be the biggest impediment to achieving its targeted goals. The benefits of having AHPs in the healthcare system are still unexplored in India. Although an enormous amount of evidence suggests that the benefits of AHPS range from improving access to healthcare services to a significant reduction in the cost of care, the Indian healthcare system still revolves around the doctor-centric approach, leading to long waiting lists and delayed treatments. .[2.][3.]

1. Privatizing healthcare has also led to an ever-increasing out-of-pocket expenditure by the population. However, many examples assert the need for skilled allied and healthcare professionals in the system, such as in the case of stroke survivors, it is the support of AHPS that significantly enhances their rehabilitation, and long-term treatment ensures return to normal life. AHPS also play a significant role in reducing chronic workforce shortages and improving patient access in a range of locations and special care for patients who struggle mentally and emotionally in the current challenging environment and require mental health support, and helps them return to wellbeing.
2. Children with communication difficulties, the elderly, cancer patients, patients with long-term conditions such as diabetes, people with vision problems and amputees; the list of people and potential patients who benefit from AHPS is indefinite.

Thus, allied health professionals can provide a broad range of diagnostic, technical, therapeutic, and direct health services to improve the health and wellbeing of the consumers they support. The breadth and scope of the allied and healthcare practice vary from one end to another, including areas of work listed below:

1. Across the age span of human development from neonate to old age;
2. With patients having complex and challenging problems resulting from systemic illnesses, such as in the case of diabetes, cardiac abnormalities/conditions, and elderly care, to name a few;
3. Towards health promotion and disease prevention, as well as assessment, management, and evaluation of interventions and protocols for treatment;

4. In a broad range of settings, from a patient's home to community, primary care centers, to tertiary care settings,
5. With an understanding of the healthcare issues associated with diverse socio-economies and cultural norms within the society
6. To provide management and rehabilitative therapies to patients/individuals where non-surgical treatments are indicated or advocated.

Learning Goals and Objectives for Allied and Healthcare Professionals

The handbook has been designed focusing on performance-based outcomes at different levels. The learning goals and objectives of the undergraduate and graduate education programs will be based on the performance expectations. They will be articulated as learning goals (why we teach this) and objectives (what the students will learn). Using the framework, students will learn to integrate their knowledge, skills, and abilities in a hands-on manner in a professional healthcare setting. These learning goals are divided into nine key areas, though the degree of required involvement may differ across various levels of qualification and professional cadres:

1. Clinical care
2. Communication
3. Membership of a multidisciplinary health team
4. Ethics and accountability at all levels (clinical, professional, personal, and social)
5. Commitment to professional excellence
6. Leadership and mentorship
7. Social accountability and responsibility
8. Scientific attitude and scholarship (only at the higher level- PhD)
9. Lifelong learning

1. Clinical Care

Using a patient/family-centerd approach and best evidence, each student will organize and implement the prescribed preventive, investigative, and management plans; and offer appropriate follow-up services. Program objectives should enable the students to:

- Apply the principles of basic science and evidence-based practice.
- Use relevant investigations as needed.
- Identify the indications for basic procedures and appropriately perform them.
- Provide care to patients efficiently and cost–effectively in a range of settings, with the interests of individual patients foremost.
- Identify the influence of biological, psychosocial, economic, and spiritual factors on patients' wellbeing and act appropriately.
- Incorporate strategies for health promotion and disease prevention with their patients.

2. Communication

The student will learn how to communicate effectively and appropriately with patients/clients, care-givers, other health professionals, and other community members. Communication is a fundamental requirement in the provision of health care services. .[4.] Program objectives should enable the students to:

- Provide sufficient information to ensure that the patient/client can participate as actively as possible and respond appropriately to the information.
- Discuss the diagnosis and options with the patient, and negotiate appropriate treatment plans in a sensitive manner that is in the patient's and society's best interests.
- Explain the proposed healthcare service – its nature, purpose, possible positive and adverse consequences, its limitations, and reasonable alternatives wherever they exist.
- Use effective communication skills to gather data and share information, including attentive listening, open-ended inquiry, empathy and clarification to ensure understanding.
- Appropriately communicate with and provide relevant information to other stakeholders, including healthcare team members.
- Use communication effectively and flexibly in a manner that is appropriate for the reader or listener.
- Explore and consider the influence that the patient's ideas, beliefs, and expectations have during interactions with them, along with varying factors such as age, ethnicity, culture, and socioeconomic background.
- Develop efficient techniques for all written and verbal communication forms, including accurate and timely record keeping.
- Assess their communication skills, develop self-awareness, and be able to improve their relationships with others.
- Possess skills to counsel for lifestyle changes and advocate for health promotion.

3. Membership of a multidisciplinary health team

The student will put a high value on effective communication within the team, including transparency about aims, decisions, uncertainty, and mistakes. Team-based health care provides health services to individuals, families, and/or their communities by at least two health providers who work collaboratively to accomplish shared goals within and across settings to achieve coordinated, high-quality care. Program objectives will aim at making the students able to: [5.]:

- Recognize, clearly articulate, understand, and support shared goals in the team that reflect patient and family priorities.
- Possess distinct roles within the team; to have clear expectations for each member's functions, responsibilities, and accountabilities, which in turn optimize the team's efficiency and make it possible for them to use division of labor advantageously, and accomplish more than the sum of its parts.
- Develop mutual trust within the team to create strong norms of reciprocity and greater opportunities for shared achievement.
- Communicate effectively so the team prioritizes and continuously refines its communication channels, creating an environment of general and specific understanding.
- Recognize measurable processes and outcomes, so that the individual and team can agree on and implement reliable and timely feedback on successes and failures in both the team's functioning and the achievement of their goals. These can then be used to track and improve performance immediately and over time.

4. Ethics and accountability

Students will understand core concepts of clinical ethics and law so that they may apply these to their practice as healthcare service providers. Program objectives should enable the students to: .[6.]

- Describe and apply the basic concepts of clinical ethics to actual cases and situations.
- Recognize the need to make health care resources available to patients fairly, equitably and without bias, discrimination, or undue influence.
- Demonstrate an understanding and application of basic legal concepts to the practice in nuclear medicine.
- Employ professional accountability for the initiation, maintenance, and termination of patient-provider relationships.
- Demonstrate respect for each patient's autonomy, privacy, and confidentiality rights.

5. Commitment to professional excellence

The student will execute professionalism to reflect in their thought and action a range of attributes and characteristics that include technological competence, appearance, image, confidence level, empathy, compassion, understanding, patience, manners, verbal and non-verbal communication, an anti-discriminatory and non-judgmental attitude, and appropriate physical contact to ensure safe, effective, and expected delivery of healthcare. Program objectives will aim at making the students able to:

- Demonstrate distinctive, meritorious, and high-quality practice that leads to excellence and depicts commitment to competence, standards, ethical principles, and values, within the legal boundaries of practice.
- Demonstrate the quality of being answerable for all actions and omissions to all, including service users, peers, employers, standard-setting/regulatory bodies or oneself.
- Demonstrate humanity in everyday practice by having respect (and dignity), compassion, empathy, honor and integrity.
- Ensure that self-interest does not influence actions or omissions, and demonstrate regard for service-users and colleagues.

6. Leadership and mentorship

The student must take on a leadership role where needed in order to ensure clinical productivity and patient satisfaction. They must be able to respond autonomously and confidently to planned and uncertain situations, and should be able to manage themselves and others effectively. They must create and maximize opportunities for improving the health-seeking experience and delivery of healthcare services. Program objectives should enable the students to:

- Act as agents of change and be leaders in quality improvement and service development, so that they contribute and enhance people's wellbeing and their healthcare experience.
- Systematically evaluate care; ensure the use of these findings to improve people's experience and care outcomes and shape clinical treatment protocols and services.
- Identify priorities and effectively manage time and resources to ensure the maintenance or enhancement of the quality of care.
- Recognize and be self-aware of the effect their values, principles and assumptions may have on their practice. They must take charge of their own personal and professional development and should learn from experience (through supervision, feedback, reflection, and evaluation).
- Using a range of professional and personal development skills, they facilitate themselves and others in developing their competence.

- Work independently and in teams. They must be able to take a leadership role to coordinate, delegate and supervise care safely, manage risk and remain accountable for the care given; actively involve and respect others' contributions to integrated person-centered care; yet work effectively across professional and agency boundaries. They must know when and how to communicate with patients and refer them to other professionals and agencies, to respect the choices of service users and others, to promote shared decision-making, to deliver positive outcomes, and to coordinate smooth and effective transitions within and between services and agencies.

7. Social accountability and responsibility

The students will recognize that allied and healthcare professionals must be advocates within the health care system, manage resources judiciously, and acknowledge their social accountability. They are mandated to serve the community, region and the nation and will direct all research and service activities towards addressing their priority health concerns. Program objectives should enable the students to:

- Demonstrate knowledge of the determinants of health at local, regional, and national levels and respond to the population's needs.
- Establish and promote innovative practice patterns by providing evidence-based care and testing new models of practice that translate research results into practice and thus more effectively meet individual and community needs.
- Develop a shared vision of an evolving and sustainable health care system for the future by working in collaboration with and reinforcing partnerships with other stakeholders, including academic health centers, governments, communities, and other relevant professional and non-professional organizations.
- Advocate for the services and resources needed for optimal patient care.

8. Scientific attitude and scholarship

The student will utilize sound scientific and/or scholarly principles during interactions with patients and peers, educational endeavors, research activities, and other aspects of their professional lives. Program objectives should enable the students to:

- Engage in ongoing self-assessment and structure their continuing professional education to address the population's needs.
- Exercise evidence-based practice by applying principles of scientific methods.
- Take responsibility for their educational experiences.
- Acquire basic skills such as presentation skills, giving feedback, patient education, and the design and dissemination of research knowledge, for their application to teaching encounters.

9. Lifelong learning

The student should be committed to continuously improving skills and knowledge while harnessing modern tools and technology. Program objectives will aim at making the students able to: [7.]:

- Perform objective self-assessments of their knowledge and skills; learn and refine existing skills; and acquire new skills.
- Apply newly gained knowledge or skills to patient care.
- Enhance their personal and professional growth and learning by constant introspection and utilizing experiences.
- Search (including through electronic means), and critically evaluate medical literature to enable its application to patient care.
- Develop a research question and become familiar with basic, clinical, and translational research and its application to patient care.
- Identify and select an appropriate, professionally rewarding, and personally fulfilling career pathway.

Introduction of New Elements in Allied and Healthcare Education - Competency-based curriculum.[8.][9.]

A significant skill gap has been observed in the professionals offering healthcare services, irrespective of the hierarchy and level of responsibility in the healthcare settings. The large variation in the quality of services is due to the diverse methodologies in healthcare education and the difference in expectations from a graduate after completion of a course and at work. What one is expected to perform at work is assumed to be learned during the course. However, the course design focuses on what one is expected to know. The competency-based curriculum thus connects the dots between the 'know what' and 'do how'.

The efficiency and effectiveness of any educational program largely depend on the curriculum design being followed. With emerging medical and scientific knowledge, educators have realized that learning is no longer limited to memorizing specific lists of facts and data; when the professional aims to practice in the healthcare setting, the acquired knowledge may be outdated. Thus, competency-based education is the answer; a curricular concept designed to provide the skills that professionals need. A competency-based program is a mix of skills and competencies based on individual or population needs (such as clinical knowledge, patient care, or communications approaches), which is then developed to teach relevant content across various courses and settings. While the traditional education system focuses on objectives, content, a teacher-centric approach and summative evaluation, competency-based education focuses on competencies, outcomes, performance and accomplishments. In such a case, teaching activities are learner-centered, and evaluation is continuous and formative in structure.

The competency-based credentials depend on demonstrating a defined set of competencies which enable a professional to achieve targeted goals. Competency frameworks comprise an articulated statement of a person's ability to complete the credential, allowing students, employers, and other stakeholders to set their expectations appropriately.

Bloom's taxonomy for action verbs ad Boolean operators for logic are generally used to provide hierarchy of action verbs for different levels of cognitive learning. This will be adopted to create clear and assessable learning outcomes in this curriculum.

Considering the needs of the present and future healthcare delivery system, the curriculum design depicted in this handbook will thus be based on skills and competencies.

Credit Hours vs Traditional System

Recently, the National Assessment and Accreditation Council (NAAC) and the University Grants Commission (UGC) have highlighted the need for the development of a Choice-Based Credit System (CBCS), at par with global standards and the adoption of an effective grading system to measure a learner's performance. .[10] All the major higher education providers across the globe are operating a system of credits. The European Credit Transfer System (ECTS), the 'National Qualifications Framework' in Australia, the Pan-Canadian Protocol on the Transferability of University Credits, the Credit Accumulation and Transfer System (CATS) in the UK, as well as the systems operating in the US, Japan, etc., are examples of these. Globally, a need now exists for using a fully convertible credit-based system that can be accepted at other universities. It has become imperative to offer flexible curricular choices and provide learners mobility due to the popularity of initiatives such as 'twinning programs', 'joint degrees' and 'study abroad' programs.

To ensure the graduates' global acceptability, the current curriculum structure is divided into smaller sections, with a focus on hours of studying that can be converted into credit hours as per the international norms followed by various other countries.

Integrated Structure of the Curriculum

Vertical Integration, in its truest sense, is the interweaving of teaching clinical skills, and knowledge into the basic science years and reinforcing and continuing to teach the applications of basic science concepts during the clinical years. (Many efforts called 'vertical integration' include only the first half of the process).

Horizontal Integration is the identification of concepts or skills, especially those that are clinically relevant, that cut across (for example, the basic sciences), and then putting these to use as an integrated focus for presentations, clinical examples, and course materials. e.g. Integration of some of the basic science courses around organ systems, e.g., human anatomy, physiology, pathology; or incorporating ethics, legal issues, finance, political issues, humanities, culture and computer skills into different aspects of a course like the Clinical Continuum.

An integrated curriculum aims to lead students to a level of scientific fluency beyond mere fact and concept acquisition by using a common language of medical science, with which they can begin to think creatively about medical problems.

This innovative new curriculum has been structured to facilitate horizontal and vertical integration between disciplines and bridge the gaps between theory and practice and between hospital-based practice and community practice. The amount of time devoted to basic and laboratory sciences (integrated with their clinical relevance) would be the maximum in the first year, progressively decreasing in the second and third years of the training, making clinical exposure and learning more dominant. However, depending on the professional group, it may differ from course to course.

Introduction of a Foundation Course in the Curriculum

The foundation course for allied and healthcare professions is an immersive program designed to impart the required knowledge, skills and confidence for seamless transition to the second year/third semester of a professional allied and healthcare course. Post admission, the foundation course is designed in the initial 12 months or first two semesters, to prepare students to study the respective allied and healthcare course effectively and understand the healthcare system's basics. This aims to orient the student to national health systems and the basics of public health, medical ethics, medical terminologies, communication skills, basic life support, computer learning, infection prevention and control, environmental issues and disaster management, as well as orientation to the community with focus on issues such as gender sensitivity, disability, human rights, civil rights etc. Though, the flexibility to the course designers has been provided in terms of modifying the required number of hours for each foundation subject and appropriate placement of the subject across various semesters.

Learning Methodologies

The curriculum will focus on self-directed learning and include a foundation course on communication, basic clinical skills, and professionalism. It will also incorporate clinical training from the first year itself. It is recommended that the primary care level have sufficient clinical exposure integrated with the learning of basic and laboratory sciences. There should also be an emphasis on introducing case scenarios for classroom discussion/case-based learning.

Healthcare education and training are the backbone of an efficient healthcare system, and India's education infrastructure is yet to gain from the ongoing international technological revolution. The report '*From Paramedics to Allied Health: Landscaping the Journey and Way Ahead*', indicates that teaching and learning of clinical skills occur at the patient's bedside or other clinical areas such as laboratories, augmented by didactic teaching in classrooms and lecture theatres.

In addition to keeping up with technological advancements, there has been a paradigm shift to outcome-based education by adopting effective assessment patterns. However, the demand for demonstration of competence in institutions where it is currently limited needs to be promoted. The report also mentions some of the allied and healthcare schools in India that have instituted clinical skill centres and high-fidelity simulation laboratories to enhance the practice and training for allied and healthcare students and professionals. The report reiterates that simulation replicates part or all of a clinical encounter through mannequins, computer-assisted resources and simulated patients. Using simulators addresses many issues, such as suboptimal use of resources and equipment, by adequately training the workforce on newer technologies, limitations for practical training in real-life scenarios, and ineffective skills assessment methods, among others. The list below mentions the various teaching and learning opportunities that harness advanced tools and technologies.

Clinical learning opportunities imparted through the use of advanced techniques.

Teaching modality and Learning opportunity examples

- Practice, teach and assess in selected clinical scenarios
- Practice soft skills
- Practice physical examination
- Receive feedback on performance
- Mannequins perform acquired techniques
- Practice basic Physics and chemistry Lab skills
- Practice basic procedural skills
- Apply basic science understanding to clinical problem solving
- Simulators practice teamwork and leadership
- Perform cardiac and pulmonary care skills
- Apply basic science understanding to clinical problem solving
- Task under trainers: Practice phlebotomy, lumbar puncture, etc.

Assessment Methods:

Traditional assessment of students consists of the yearly system of assessments. In most institutions, assessments consist of internal and external assessments, and a theory examination at the end of the year or semester. This assesses knowledge instead of assessing skills or competencies. In competency-based training, the evaluation of the students is based on the performance of the skills as per their competencies. Hence, all three attributes – knowledge, skills, and attitudes – are assessed as required for the particular competency.

Several new methods and tools are now readily accessible, the use of which requires special training. Some of these are given below:

- Objective Structured Clinical Examination (OSCE), Objective Structured Practical Examination (OSPE), Objective Structured Long Examination Record (OSLER)
- Mini Case Evaluation Exercise (CEX)
- Case-based discussion (CBD)
- Direct observation of procedures (DOPS)
- Portfolio
- Multi-source feedback
- Patient satisfaction questionnaire

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Chapter 2

Curriculum Development

2.0 Methodology of Curriculum Development

The Ministry of Health and Family Welfare has emphasized the need to strengthen and standardize educational frameworks for Allied and Healthcare Professions, particularly those involving the use of ionizing radiation. Nuclear Medicine Technology is a critical allied health discipline that supports diagnostic and therapeutic nuclear medicine services, requiring high levels of technical competence, radiation safety awareness, and patient-centered practice.

Given the direct involvement of Nuclear Medicine Technologists in radiopharmaceutical handling, imaging procedures, quality control, and radiation protection, the curriculum has been developed using a competency-based and nationally uniform approach. The framework aligns with the provisions of the National Commission for Allied and Healthcare Professions (NCAHP) Act, Atomic Energy Regulatory Board (AERB) regulations, and international best practices recommended by the International Atomic Energy Agency (IAEA).

2.1 Process of Curriculum Development

A uniform national curriculum framework for Nuclear Medicine technology education was developed to address evolving healthcare needs while adhering to the provisions of the NCAHP Act. The framework encompasses Bachelor's, Master's, and Doctoral programs, ensuring academic continuity, progressive competency acquisition, and clear professional pathways.

International curricula from globally recognized universities, SNMMI, AERB and best practices from established Nuclear Medicine education and training programs were reviewed and contextualized to suit national healthcare requirements and regulatory environments. Stakeholder inputs from academia, clinical practice, and regulatory bodies were systematically incorporated.

2.1.1 Constitution of the Nuclear Medicine Technology Task Force Committee

The NCAHP constituted a Nuclear Medicine Technology Task Force Committee comprising:

Experienced Nuclear Medicine Technologists from high-volume diagnostic and therapeutic centres and Medical Physicists & Radiation safety and regulatory experts

The Task Force followed a standardized national framework to develop competency-driven guidelines for Nuclear Medicine Technology education and training.

2.2 Curriculum Development Guidelines for Nuclear Medicine Technology

2.2.1 Scope of the Curriculum

The Nuclear Medicine Technology curriculum adopts a patient-centric and safety-oriented approach. It integrates theoretical knowledge with extensive practical training in SPECT, PET, PET/CT imaging, radiopharmaceutical handling, quality assurance, and radiation safety. The curriculum prepares graduates to function effectively in clinical nuclear medicine departments under licensed conditions.

2.2.2 Mode of Education

The program shall be conducted strictly in full-time mode. Given the mandatory requirement for supervised clinical practice in hot laboratories and imaging suites, part-time or distance-learning modes are not permitted. Full-time education ensures standardized skill development and compliance with AERB and NCAHP norms.

2.2.3 Components of the Curriculum

The curriculum framework defines eligibility criteria, program nomenclature, duration, internship requirements, and professional roles of Nuclear Medicine Technologists. It is structured around defined competencies covering theory, laboratory practice, and clinical skills.

Assessment methods include theory examinations, practical evaluations, clinical competency assessments, and internship performance reviews. Faculty qualifications, student intake capacity, and student–faculty ratios are specified to ensure quality training.

2.2.4 Alignment with Choice-Based Credit System (CBCS)

The curriculum is aligned with the National Education Policy (NEP) 2020 and Choice-Based Credit System (CBCS). Credits are assigned based on lecture hours, practical sessions, and clinical training. Continuous assessment and skill-based evaluations are integral components.

2.2.5 Entrance Mechanism and Entry Criteria

Admission to the Nuclear Medicine Technology program shall be through a transparent and merit-based process. Candidates must have completed higher secondary education with Physics & Chemistry.

2.2.6 Medium of Instruction

The medium of instruction for the program shall be English, consistent with international scientific literature and regulatory documentation.

2.2.7 Desired Competencies and Skills

Graduates shall demonstrate competencies in:

- Patient preparation and positioning
- Radiopharmaceutical handling and administration assistance
- Operation of SPECT, PET, and hybrid imaging systems
- Quality control and basic troubleshooting
- Radiation protection and waste management
- Documentation, teamwork, and patient communication

Competencies are mapped to structured assessments to ensure safe professional practice.

2.2.8 Common Preclinical and Paraclinical Subjects

The curriculum includes anatomy, physiology, biochemistry to provide biological context for nuclear medicine procedures.

2.2.9 Level and Duration of the Program

The B.Sc. Nuclear Medicine Technology program is typically four years in duration, including a mandatory one-year internship or clinical training component, in alignment with national standards.

Master's Degree (M.Sc. Nuclear Medicine Technology): Three years in duration, including a mandatory one-year internship emphasizing advanced clinical applications, instrumentation, radiopharmacy, quality assurance, and research orientation.

2.2.10 Semester versus Annual System

The program follows a semester-based structure, though institutions may adopt annual systems with appropriate credit and competency mapping.

2.2.11 Practical and Clinical Exposure

Structured and supervised clinical training is mandatory. Institutions must ensure access to licensed nuclear medicine facilities through in-house departments or MoUs. Stipends shall be provided during internship, and digital logbooks shall document competency achievement.

2.2.12 Faculty Development

Faculty members are encouraged to undergo continuous training in emerging nuclear medicine technologies, quality assurance protocols, and radiation safety practices.

2.2.13 Exit Examination

A comprehensive exit examination shall be conducted at the completion of the internship to assess theoretical knowledge, practical skills, and clinical competencies, with provision for external assessment to ensure standardization.

2.3 Task Force Meetings and Draft Curriculum – Finalization

A series of structured meetings and consultations were conducted to finalize the curriculum, incorporating academic and clinical perspectives. Throughout the process, guidance from the NCAHP was actively sought and incorporated, wherever necessary, to ensure alignment with the provisions of the Act.

2.4 Curriculum – Finalization

Based on the public feedback received, the draft curriculum was revised wherever justified and supported by appropriate rationale. Following these revisions, the curriculum was finalized and approved.

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Chapter 3

Background of the Profession

Background of the profession - Statement of Philosophy

Why this profession holds so much importance

The Profession of Nuclear Medicine Technologists, and Radiochemist forms an indispensable cornerstone of modern healthcare.

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.

Radiochemists are the innovative chemists who design and synthesize the essence of nuclear medicine – the radiopharmaceuticals. Their work in developing targeted molecular imaging agents and theranostic tools is revolutionizing disease detection and treatment. They ensure the quality and purity of these radioactive drugs, a critical aspect of patient safety and procedural reliability.

The collaborative synergy between these three professions is vital for translating the power of nuclear science into tangible benefits for patients. Together, they enable early and accurate disease diagnosis, personalized treatment strategies, and continuous medical imaging and therapy advancements. Their combined expertise spans a vast spectrum, from the initial creation of radioactive tracers to their safe administration and the interpretation of the resulting images. This multidisciplinary approach allows for a comprehensive understanding of disease at a molecular level, leading to more informed clinical decisions. The importance of these professions is underscored by their contribution to diverse medical fields, including oncology, cardiology, neurology, and endocrinology. As medical technology continues to evolve, the specialized knowledge and skills of Nuclear Medicine Technologists, and Radiochemists will remain crucial for pushing the boundaries of diagnostic and therapeutic medicine, ultimately improving patient outcomes and quality of life.

How Nuclear Medicine evolved in India:

The evolution of nuclear medicine in India, beginning in the mid-20th century and advancing to its current sophisticated status, stands as a testament to the visionary leadership of Dr. Homi Jehangir Bhabha. Often regarded as the 'Father of the Indian Nuclear Program,' Dr. Bhabha's pioneering initiatives following independence were instrumental in establishing India's atomic energy endeavors. The commissioning of India's first research reactor, APSARA, in 1956, followed by CIRUS in 1960 at the Bhabha Atomic Research Centre (BARC), marked significant milestones. These reactors played a crucial role in the indigenous production of essential medical radioisotopes such as Iodine-131 (^{131}I), Phosphorus-32 (^{32}P), and Chromium-51 (^{51}Cr), thereby laying the groundwork for various clinical applications.

The establishment of key institutions further solidified this foundation. The Radiation Medicine Center (RMC) in Mumbai, inaugurated by Dr. Bhabha in September 1963, quickly became a leading hub for nuclear medicine. Concurrently, the Institute of Nuclear Medicine and Allied Sciences (INMAS) in Delhi, dedicated to the nation, established in February 1964, also played a vital role in early development. Notably, INMAS pioneered a Delhi University-approved structured postgraduate diploma in nuclear medicine in 1963, an innovative course globally. The indigenous production of radioisotopes by BARC's Isotope Division was critical, including the development of economical Technetium-99m (^{99m}Tc) generators, which significantly fueled the field's growth.

The 1970s to the 2000s marked a significant growth and expansion phase for nuclear medicine in India. The launch of Mumbai University-recognized diploma courses for physicians and technologists in 1973 at the Radiation Medicine Center (RMC) was a key milestone in professionalizing nuclear medicine education. The commissioning of the first gamma camera at RMC in 1969 represented a major diagnostic leap, leading to a gradual increase in nuclear medicine departments nationwide. This growth trajectory instilled optimism and hope for the future of nuclear medicine in India.

The 2000s ushered in the molecular imaging revolution with transformative technologies. In 2002, India's first medical cyclotron and Positron Emission Tomography (PET) scanner was introduced in Mumbai. This was swiftly followed by commissioning the first PET-computed tomography (PET-CT) scanner in 2004. This milestone revolutionized molecular imaging by enabling earlier and more accurate disease diagnosis, particularly for cancer. The subsequent rapid adoption of PET-CT scanners and cyclotrons across the country underscored the significant expansion of molecular imaging capabilities. India has also increasingly embraced theranostics, a concept combining diagnostic imaging with targeted radionuclide therapy, offering a personalized approach to medicine and becoming a major growth area, especially for prostate cancer and neuroendocrine tumours.

As the field of nuclear medicine in India continues to integrate with advanced technologies, the role of the private sector becomes increasingly significant. While governmental institutions laid the groundwork, the rapid expansion of nuclear medicine facilities is largely attributed to the pivotal role played by the private sector. This growth has led to international recognition, with India emerging as a significant contributor to nuclear medicine. The country is now attracting international patients seeking quality services at affordable prices, particularly from South Asia.

Despite this impressive progress, challenges persist, including the need for greater awareness among other medical specialties regarding nuclear medicine's capabilities. There is also a need to rationalize resources, subsidize equipment and radioisotopes, and increase personnel training to ensure wider accessibility and affordability of nuclear medicine services nationwide. To address these challenges and accelerate future growth, the government has initiated moves to open the atomic energy sector for private participation and foster public-private partnerships for medical isotope production. These efforts aim to ensure that nuclear medicine continues its dynamic evolution, benefiting a broader segment of the Indian population.

Current Status of Nuclear Medicine Courses in India:

Nuclear Medicine Technology (NMT) education in India is currently in a dynamic and expanding phase, catering to the growing demands of a sophisticated healthcare sector. The field has evolved significantly from its early diploma offerings to comprehensive degree programs. At the undergraduate level, the **B.Sc. in Nuclear Medicine Technology** is the foundational course, typically spanning three years of academic study and a mandatory one-year internship, totaling four years. This program is designed to equip students with core knowledge in nuclear physics, radiation biology, radiopharmacy, and the operation of imaging equipment like gamma cameras, SPECT and PET-CT.

For those aspiring to advanced roles or a deeper specialization, **M.Sc. in Nuclear Medicine Techonology** programs are widely available. These two-year postgraduate courses delve into advanced principles of molecular imaging, including SPECT, PET, PET-CT, and SPECT-CT, as well as Cyclotron and complex aspects of radiopharmaceutical production and quality control, and radionuclide therapy and dosimetry. Prominent institutions across India, such as AIIMS New Delhi, PGIMER Chandigarh, TMH, Mumbai, Manipal College of Health Professions, Christian Medical College (Vellore), DRRMLIMS, Lucknow and Sanjay Gandhi Postgraduate Institute of Medical Sciences (Lucknow), offer these master's programs. Some institutes also were earlier providing M.Tech degrees in Nuclear Medicine, further broadening the scope of advanced studies.

A crucial aspect of NM education in India is the regulatory oversight provided by the **Atomic Energy Regulatory Board (AERB)**. AERB plays a pivotal role by recognizing institutions and their NM courses, ensuring a standardized quality of education and strict adherence to radiation safety norms. Graduating from an AERB-recognized institution is a prerequisite for individuals to be eligible for employment as Nuclear Medicine Technologists and Medical Physicists in India and to qualify for the Radiological Safety Officer (RSO) examination conducted by BARC are qualified to work as Radiological Safety Officer (RSO) in Nuclear Medicine Department.

The demand for qualified nuclear medicine technologists in India is on a steady rise, driven by the significant expansion of healthcare infrastructure, including new hospitals and specialized diagnostic centres. The widespread adoption of advanced imaging technologies and the growing focus on theranostics – combining diagnosis and therapy – further propel the demand of qualified Nuclear Medicine Professionals. India's rising burden of chronic diseases like cancer and cardiovascular conditions also contributes to the need for skilled NM professionals.

Career prospects for NMT graduates are diverse, encompassing roles in public and private hospitals, diagnostic imaging centres, and research institutions. Opportunities also exist within the burgeoning radiopharmaceutical industry. Typical career paths include Nuclear Medicine Technologist, PET/CT Technologist, Radiation Safety Officer, Radiopharmacist, and even roles in education and research.

The curriculum of postgraduate NM programs is continuously updated to reflect the latest advancements in the field, incorporating modules on cutting-edge molecular imaging techniques and advanced radiopharmacy. There is an increasing emphasis on emerging areas like the integration of Artificial Intelligence (AI) and radiomics for enhanced image interpretation and treatment planning. Comprehensive training in radiation safety protocols and strict adherence to regulatory compliance are also integral parts of the curriculum.

While significant progress has been made, challenges persist in ensuring consistent quality across all NM training institutions and addressing the shortage of experienced faculty. Additionally, ongoing efforts are focused on streamlining regulatory processes and enhancing awareness of nuclear medicine and other medical specialties. The government's initiatives to foster public-private partnerships in atomic energy and medical isotope production are anticipated to further accelerate the growth and accessibility of nuclear medicine technology, along with its educational programs in India. Overall, the landscape of NM education in India is on a promising growth trajectory, offering a bright future for skilled professionals in this vital healthcare sector.

Scope of Practice:

Nuclear Medicine Technologist Professionals possess, utilize, and maintain radiation protection and safety knowledge. They thoroughly understand the body's structure, how it can be affected by injury, and the causes and effects of disease when taking a Gamma Camera / PET Scan. Their work does include a wide range of different imaging modalities, like Gamma camera, SPECT, SPECT-CT, PET-CT, PET-MR, Radiochemistry Lab, Radiation Safety, Decontamination of facilities and Medical Cyclotron. Nuclear Medicine Professionals are the primary liaison between patients, Nuclear Medicine Physicians and other support team members. They remain sensitive to patient needs through good communication, assessment, monitoring, and care skills. As members of the health care team, diagnostic Nuclear Medicine Technologists in Nuclear Medicine participate in quality improvement processes and continually assess their professional performance. They engage in continuing education to include their area of practice to enhance patient care, public education, knowledge and technical competence.

Specific roles with Designations

Nuclear Medicine Technologist:

- Their scope encompasses preparing and dispensing radiopharmaceuticals, operating imaging equipment (gamma cameras, PET/CT), and ensuring patient safety and comfort during procedures.
- They review patient history, explain procedures to the patients, and monitor patients for adverse reactions.
- Technologists perform routine quality control on imaging and non-imaging equipment, acquire and process static and dynamic images, and participate in radiation safety protocols, adhering to regulations and institutional policies.
- They may also perform in vitro tests and assist in therapeutic procedures under authorized user supervision.
- Their practice demands technical expertise, patient care skills, and a strong understanding of radiation safety related to radiopharmaceuticals and patients.
- Their scope involves ensuring the safe and effective use of radiation, managing quality control of imaging equipment, and optimizing image acquisition and processing techniques.
- They calculate radiation doses pertaining to the Internal Dosimetry of the unsealed radio-nuclides/radiopharmaceuticals
- They establish safety protocols and ensure regulatory compliance.
- Nuclear Medicine Technologists are crucial in acceptance testing and commissioning new equipment, and troubleshooting technical issues.
- They play vital role in developing advanced imaging and analysis methods for newer/emerging radiopharmaceuticals.

- They often train other staff and contribute to research and development in the field.
- Their expertise bridges physics principles with clinical applications in nuclear medicine.

Radiochemist:

- Their scope centers on the design, synthesis, quality control, and distribution of radiopharmaceuticals. They develop new radioactive tracers for diagnostic imaging and therapeutic applications, often targeting specific molecular pathways.
- Radio-chemist manage radiopharmaceutical production facilities, ensuring compliance with stringent regulatory standards for purity, stability, and sterility.
- Their work requires a deep understanding of chemistry, radiochemistry principles, and safety protocols for handling radioactive materials.

Nuclear Medicine Professionals use a range of imaging and non-imaging technology:

- **Gamma Camera: Gamma camera imaging** (Scintigraphy**),** is a nuclear medicine technique that uses a specialized camera to detect gamma rays emitted from radioactive tracer materials (radiopharmaceuticals) that have been administered to a patient. This allows for the visualization and assessment of the functional status of various organs and tissues within the body.
- **PET-CT Scanner: PET-CT imaging** is an advanced medical imaging technique that combines the functional information from a positron emission tomography scan with the detailed anatomical information from a computed tomography scan into a single, comprehensive examination.
- **PET-MR Scanner: PET-MR imaging** is a cutting-edge hybrid imaging technique that simultaneously combines the functional and metabolic information provided by positron emission tomography with the high-resolution anatomical and soft tissue detail offered by magnetic resonance imaging (MRI).
- **Medical Cyclotron**: A **medical cyclotron** is a type of particle accelerator used in healthcare to produce radioactive isotopes (radioisotopes) for medical imaging and therapy. It works by accelerating charged particles, typically protons or deuterons, to high energies using magnetic and electric fields. These high-energy particles are then directed to bombard a target material, inducing nuclear reactions that transform stable isotopes within the target into radioactive ones.
- **High Dose Therapy Facility: High Dose Radionuclide Therapy** or **High Dose Radioisotope Therapy** utilizes radioactive materials administered internally to deliver high doses of radiation directly to cancer cells or specific target tissues. This approach aims to maximize the therapeutic effect while minimizing damage to surrounding healthy tissues.

- **Low Dose Radionuclide Therapy: Low Dose Radionuclide Therapy** utilizes small amounts of radioactive materials, administered internally, to achieve therapeutic effects without the high levels of radiation associated with high-dose therapies. The primary uses often revolve around modulating biological processes rather than direct cell killing in the same aggressive manner.

Recognition of Title and Qualification

The practice of Nuclear Medicine Professionals is performed by allied healthcare professionals responsible for dispensing ionizing radiation for diagnostic and therapeutic purposes.

Definition of Nuclear Medicine Professionals

The Nuclear Medicine Professionals having a Bachelor's degree and Master's in Nuclear Nuclear Medicine Technology will be called Nuclear Medicine Technologists (ISCO-3211)

Nuclear Medicine Technology professionals are vital pillars in modern healthcare, wielding the power of radioactive materials to illuminate the human body's inner workings for diagnosis and therapy. Their expertise lies in the meticulous preparation and precise administration of radiopharmaceuticals (specialized drugs tagged with radioactive isotopes) under the supervision of NM Physician. These skilled practitioners operate and handle sophisticated imaging equipment, such as gamma cameras and PET scanners, which detect the minute amounts of radiation emitted by these agents within the patient. The resulting images provide valuable functional and metabolic information, often revealing disease processes at an earlier stage than anatomical imaging alone.

Beyond image acquisition, nuclear medicine technologists are deeply involved in patient care, ensuring the comfort and safety of individuals undergoing these procedures. They meticulously explain the process, address patient concerns, and monitor them closely throughout the examination. Radiation safety is paramount in their daily practice, and they adhere to strict protocols to protect themselves, patients, and the environment from unnecessary exposure. They are also responsible for quality control of the imaging equipment, ensuring optimal performance and generating high-quality diagnostic images.

Furthermore, NM technologists play a crucial role in image processing and analysis, often using specialized software to enhance and interpret the data. They work collaboratively with nuclear medicine physicians, providing them with the essential information needed to make accurate diagnoses and guide treatment strategies. Their work spans various medical specialties, including cardiology, oncology, neurology, endocrinology, and pediatrics, contributing significantly to managing various conditions. The insights gained from nuclear medicine procedures aid in detecting cancer, assessing cardiac function, identifying neurological disorders, evaluating thyroid function, and much more.

Nuclear medicine professional's comprehensive knowledge base encompasses radiation physics, radiochemistry, human anatomy, physiology, and pharmacology, forming the bedrock of their specialized skills. Continuous education and training are essential in this rapidly evolving field, keeping them abreast of the latest advancements in technology and clinical applications. In essence, nuclear medicine technologists are indispensable healthcare team members, bridging the gap between nuclear science and patient care to provide critical diagnostic and therapeutic services. Their dedication to precision, safety, and patient well-being makes them integral to improving health outcomes and countless individuals' quality of life.

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Job Description of Nuclear Medicine Technologist (NMT)

Position	Topic	
Position	**Nuclear Medicine Technologist (NMT)**	
Brief Job description	The NMT functions as the primary clinical operator, responsible for patient support, preparation and injection of radiopharmaceuticals under the supervision of NM Physician, and the acquisition of diagnostic images using highly specialized equipment. Their accountability is tied to the accurate execution of physician and Nuclear Medicine Technologist approved protocols, including daily quality control (QC) procedures. The Nuclear Medicine Technologists holds institutional responsibility for the scientific integrity of the entire operation. This encompasses the design, commissioning, and regulatory validation of imaging systems; the calculation and optimization of radiation dose, especially in hybrid systems and Radio Pharmaceutical Therapy (RPT); and the establishment of comprehensive quality management (QM) programs. The Nuclear Medicine Technologist maintains the ultimate scientific and safety authority, including the professional mandate to halt clinical operations if equipment performance compromises patient health or diagnostic accuracy.	
1. Parameter		
1.a Primary Focus	Patient Interaction and Support, Radiopharmaceutical Management, Image Acquisition, Clinical execution, patient care, daily operational QC. Regulatory compliance, dose calculation, system design, annual QA/Acceptance Testing. Oversee radiation Protection program across the facility.	
1.b Minimum Qualification	**BSc NMT/NM or BSc + DMRIT/DFIT/DNMT**	**MSc NMT or MSc + DMRIT/DFIT/DNMT**
1.c Regulatory Role	Operational execution under Nuclear Medicine Technologist/RSO/physician direction. Qualified Expert status; responsible for radiation output, shielding design, and compliance. Develop and Implement Radiation Safety Policies and Procedures. Supervise personal dosimetry and exposure records. Conduct training and education in Radiation Protection. Authorised purchase and use of radioactive materials and radiation generating equipment. Emergency preparedness and response planning for radiological events.	

Position	Topic
1.d Accountability for Error	Operational protocol deviation, error in administration, data acquisition failure. Failure of equipment performance, flawed dosimetry calculation, insufficient shielding, non-compliance resulting in patient overexposure. Conduct radiation risk assessment and surveys. Supervise decontamination and radiation equipment compliance
1.e Teaching and Research	The Nuclear Medicine Technologist serves as a vital and frequently leading figure on the medical research team, acting as a teacher and researcher involved in teaching Nuclear Medicine Technology to students of NM. The Nuclear Medicine Technologist role in driving translational science is particularly significant, as it underscores their contribution to the practical application of research. They also play a key role in developing intellectual property and establishing the educational framework necessary for advancing quantitative and therapeutic nuclear medicine. This positioning requires expertise not only in physics applications but also in research administration, curriculum design, and grant procurement.
2. Function/ Metric	**NMT Responsibility (Operational Execution)**
2.a Daily QC	RSO Defines QC tolerances; review periodic data; design the overall QM program. Perform intrinsic uniformity, center of rotation (monthly), and daily CT performance checks.
2.b Annual QA/Acceptance	Acceptance testing; annual system evaluation; measurement of CT dose indices (CTDIvol, DLP). Assist the RSO in data acquisition (e.g., placing phantoms).
2.c Image Processing	Evaluation and implementation of advanced iterative reconstruction algorithms (e.g., OSEM, MLEM, ISRA). Routine image processing, filtering, and review using established parameters.
2.d Protocol Review	Review and approve all clinical protocols annually; optimize dose-image quality trade-off. Selects correct, established imaging protocol based on physician order and patient specifics.

Position	Topic
3. Therapeutic Nuclear Medicine	**NMT Responsibility (Clinical & Data Acquisition)**
3.a. Dose Management	Calculation of safe maximum tolerated dose based on patient-specific absorbed dose estimates. Safe handling and management of high-activity therapeutic agents (e.g., 177Lu, 131I, Sm-153 base Radiopharmaceuticals).
3.b Dosimetry Data Input	Acquire quantitative SPECT/PET data post-administration at prescribed time points. Perform complex internal dosimetry calculations, converting activity images into absorbed dose (Gray).
3.c Patient Release	Establish, document, and approve patient release criteria based on measured dose rate, ensuring compliance with regulatory bodies. Measure dose rate at 1 meter from the patient's surface.
3.d Safety Training	Define institutional RPT safety policies and perform shielding design for RPT rooms. Maintain expertise in RPT safety protocols, contamination control, and high-dose waste management.

Education of Nuclear Medicine Professionals

When developing any education program, it is necessary that program planning should be outcome-based, meeting local and national workforce requirements, personal satisfaction and career potential for the professionals with a supporting pathway in the development of the profession. One of the major changes is the shift from a focus based on traditional theoretical knowledge and skills to competency-based education and training. Optimal education/training requires the student to integrate knowledge, skills and attitude to perform a professional act adequately in a given situation.

Thus, the following curriculum focuses on a skills and competencies based approach to learning and is designed accordingly. It is prescriptive and designed to standardize the content across the nation.

Course duration

It is recommended that any program developed from this curriculum should have a minimum duration of the following to qualify as an entry-level professional in Nuclear Medicine.

- **Bachelor's degree level :** Four-year program (including 1 year of clinical training /internship)
- **Master's degree level:** Three-year program (including 1 year of clinical training/internship/Residency)

A Bachelor's degree program will have a minimum of one year devoted to clinical practice and on a continuum of rotation from theory to practice over the program. The 4-year degree program aims to develop the Nuclear Medicine technologist as a key multidisciplinary team member and enable them to execute advanced preparation/ planning/delivery, and quality assurance. The emphasis during the initial year should be on the academic content, establishing a strong scientific basis and engagement with the course principles. During the second and third years of training, emphasis should be laid on the process to refine the acquired theoretical knowledge and its application to clinical/reflective practice.

With the change in disease dynamics and a multifold increase in the cases needing diagnostic medical imaging and evaluation, a well-structured postgraduate education program must also be encouraged to enhance research capacity within the country and widen the scope of clinical practice for the profession. **Thus, a master's degree program with at least two years of education in a specialized Medical Nuclear Medicine field is recommended followed by atleast one year of residency.** The postgraduate students can contribute significantly to research and academics.

A **Ph.D.** also plays a significant role in the academic system, research, and innovation**. However, for the award of Ph.D. Degree in Nuclear Medicine or in the relevant special fields, UGC Guidelines are to be followed for Ph.D. program.**

Teaching faculty and infrastructure (minimum standard to start the programs)

- The state medical colleges or institutes of national importance (INIs) in medical science or equivalent medical institutes to be associated with the teaching institute so that they can use the available patient load and medical infrastructure as part of their training curriculum (possibly through an MOU).
- Standalone institutions must have an MOU with either a medical college or hospital, or a healthcare facility as per the guidelines (desired number of Nuclear Medicine equipment along with Radiology Equipments/beds/OPD, etc.) defined in the curriculum to ensure practical exposure for the students.
- The MOU must be done with a medical college, hospital, or healthcare facility that has a minimum of 100 investigations per week, including gamma camera, PET-CT Scan, High Dose Radionuclide therapy and Low Dose Therapy.

- MoU should also define the Nuclear Medicine Techniques/ practice clinical supervision of the students, institutional staff, or clinical preceptors for valid consideration.

For the institutes to be capable of providing high-quality training to the students and exposure to all the related modalities, they should have the following:

- Gamma Camera/SPECT/SPECT-CT
- PET-CT unit
- Dose Calibrator with QC Source
- Thyroid Uptake Probe with QC Source
- Well Counter with Check Source
- High Dose Therapy Facility around 100 patients Load per annum.
- Radiochemistry/ Radiopharmacy Lab with appropriate Instruments
- Basic Radiochemistry Instruments,
- Radiopharmacy QC lab
- Gamma Spectrometer
- Phantoms for QC
- Radiation Safety Gadgets and Instruments
- Decontamination Facility
- Onsite Medical Cyclotron (optional)

Method of teaching and learning

- Lecture
- Tutorial
- Problem-based learning
- Small group teaching and learning
- Continuous interactive learning
- Case-based
- Project based
- Research projects
- Seminars
- Clinical/ nonclinical conferences
- E-learning
- Skills laboratory
- Work Place Based assessment (WPBA)

Medium of instruction:

English shall be the medium of instruction for all the subjects of study and for examination of the course.

Job availability

The job availability for Nuclear Medicine Professionals appears stable, with positive overall employment projections and consistent openings due to retirements and career changes. Opportunities exist in hospitals, outpatient imaging centers, research institutions, and industry roles and in abroad too. **Certification is increasingly important for employment**.

The job market for Nuclear Medicine Technologists seems promising, with numerous openings listed across various institutions, including hospitals and universities. Their specialized radiation safety, equipment management, and image optimization skills are in demand. Advanced degrees and board certification are typically required.
Radiochemist, crucial for developing and producing radiopharmaceuticals, also have good job prospects, particularly in pharmaceutical companies, research institutions, and hospitals with nuclear medicine programs. Advanced degrees, especially a Ph.D., are generally necessary, along with expertise in radiopharmaceutical chemistry and regulatory compliance. Advancements in molecular imaging and targeted therapies drive the field.

Job opportunities for nuclear medicine technologists in India are gradually increasing, especially in metropolitan cities and advanced healthcare centers. With the rise in diagnostic imaging and cancer treatment facilities, demand for trained professionals is growing. Expanding private healthcare and research institutions are key drivers of future growth.

Nuclear Medicine Technology provides a service for multiple departments within the hospital, including emergency, outpatients, operating theatres and wards. Therefore, close liaison and collaboration with various other health care professionals are vital.
After completion of this curriculum, broadly a nuclear medicine technologist get opportunities to work at various health care institutes, as per their educational qualifications, under the following designations:

- Quality Control Professionals
- Quality Control Manager [Nuclear Medicine Technologist or Radiochemist]
- Medical Cyclotron Operator (with mandate training and certification)
- Radiochemist
- Radiological Safety Officer (Nuclear Medicine/ Medical Cyclotron Facility/ Radiopharmaceuticals Lab/Radionuclide therapy Facility/others)
- Nuclear Medicine Technologist
- PET-CT Technologist
- PET-MR Technologist
- PET-LINAC Technologist
- Radionuclide Therapy Technologist
- Applications Specialist
- Radiological Safety Officer
- Technical Manager

- Sales and marketing in the radiological industry
- Facility Manager
- Other Administrative posts in the medical imaging department and hospitals.
- Teaching and research faculty in medical and allied health science colleges
- Research Scientists in the medical imaging industry

Infrastructure for B.Sc. Nuclear Medicine Technology Course

A. Physical Facility

Building – Institute/University shall have its own building. Standard minimum requirement for Nuclear Medicine Technology course with intake capacity of 10 students shall be as under

Dedicated space of 8000 sq. ft. area is essential Standard for 20 seats

S. No	Description	Area (sq ft)	Number
1	Principal/HOD room	400	01
2	Office	400	01
3	Store room	500	01
4	Professor room	400	01
5	Other faculty rooms	250 each	05
Teaching area			
6	Class rooms	450	03
7	Skill labs/laboratories	450	02
8	Computer lab/seminar room	450	01
9	Library	1800	01
Amenities			
10	Girls common room	200	01
11	Boys common room	200	01
12	Girls toilet	100	01
13	Boys toilet	100	01
14	Staff room/record room	100	01
15	Room for audio/visual aid	500	01
16	Auditorium/multipurpose hall	--	01
Desirable facility			
17	Drinking water		
18	Fire Extinguisher		
19	Transportation facility		
20	Girls and boys hostel required		
21	Recreation / sports facility		

Note:

- **Principal's Office:** There should be a separate office for the Principal/ Head of Department with attached Toilet and provision for visitor's room. Independent telephone facility is a must for the Principal's / Head of Department office with intercom facility connected/linked to the hospital and hostel and a computer with internet facility
- The classrooms should be well ventilated with proper lighting system. There should be built in Black/Green/White Boards/Projector. Also, there should be a desk/dais/ a big table and a chair for the teacher and tables and chairs for students.
- Common rooms should be provided for the student and for the office staff. Sufficient space with adequate seating arrangements, cupboards, lockers, cabinets, built-in-shelves and racks should be provided in all the common rooms. Toilet and hand washing facilities should be made available in each room.
- There should be a separate computer lab for students and staff for reading purpose and it should provide internet and cabin facility.
- There should be a separate record room with steel racks, built-in shelves and racks, cupboards and filing cabinets for proper storage of records and other important papers/documents belonging to the college.
- Adequate provision for extinguishing fire should be available as per the local bye-laws.
- This room should be provided for the proper and safe storage for all the Audio-Visual Aids
- **Library facility:** There should be a separate library for the Institute. The library should be easily accessible to the teaching faculty and the students. It should have internet facility. Library should have seating arrangements for at least 80 students for reading and having good lighting and ventilation and space for stocking and displaying of books and journals. The number of journals should 10 out of which one – third shall be foreign journals and subscribed on continuous basis. There should be sufficient number of cupboards, book shelves and racks with glass doors for proper and safe storage of books, magazines, journals, newspapers and other literature. In the library there should be provision for internet

Teaching faculty:

The following teaching faculty qualified as mentioned in the below table shall be faculty in the department to have a minimum of 10 candidates (10+10+10) intake

- Professor : One
- Assoc. Professor : One
- Asst. Professor : One

Note:

- Professor cum HoD, Associate Professor, and two Assistant Professors will be counted in teaching faculty
- Students:Teachers Ratio should be - 10:1 per year (Consider total students of all four years)
- Minimum required faculty for each course will be 03 and Professor and Associate Professor positions must be filled on full time basis before starting the program, Minimum two faculties shall be as NMT as academic qualification.
- Apart from the mentioned below table faculty, Guest/ Adjunct/ Part-Time Faculty can teach the peripheral subject or topic as needed, but will not be considered as core faculty.

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Table 1. Teaching Faculty Qualifications for B.Sc. Nuclear Medicine Technology course

Post Name	Education qualification & Experience
Professor	1.M.Sc. Nuclear Medicine/M. Sc. Nuclear Medicine Technology/MSc NMT/M.Sc. Nuclear Medicine and Molecular Imaging Technology, M.Sc Medical Physics/ M. Sc. + Postgraduate diploma in Nuclear Medicine (DMRIT/PGDFIT/PGDNMT)/M.Sc + Postgraduate diploma in Radiological Physics or its Equivalent With Ph.D. in relevant subject + 10 years of clinical/teaching/research experience. OR MD/DNB (Nuclear Medicine) + + 10 years of clinical/teaching/ research experience.
Associate Professor	1.M.Sc. Nuclear Medicine/M. Sc. Nuclear Medicine Technology/MSc NMT/M.Sc. Nuclear Medicine and Molecular Imaging Technology, M.Sc Medical Physics/ M. Sc. + Postgraduate diploma in Nuclear Medicine (DMRIT/PGDFIT/PGDNMT)/M.Sc + Postgraduate diploma in Radiological Physics or its Equivalent With Ph.D. in relevant subject + 6 years of clinical/teaching/research experience. OR MD/DNB (Nuclear Medicine) + 6 years of clinical/teaching/research experience.
Assistant Professor	1.M.Sc. Nuclear Medicine/M. Sc. Nuclear Medicine Technology/MSc NMT/M.Sc. Nuclear Medicine and Molecular Imaging Technology, M.Sc Medical Physics/ M. Sc. + Postgraduate diploma in Nuclear Medicine (DMRIT/PGDFIT/PGDNMT)/M.Sc + Postgraduate diploma in Radiological Physics or its Equivalent OR MD/DNB (Nuclear Medicine)

Basic details about clinical facility for Lab Practice or clinical practice

Clinical Institute/facility

- The Institute should have preferably NABH accredited Hospital/ NABL accredited Lab.
- The Hospital/Lab should have Pollution Control Board certificate, Clinical Establishment Act registration, Pollution control board certificate and other essential licenses/ certificates required from various departments under prevalent Act, Rules and Regulations.
- Fire NOC of both Institute and Hospital
- Hospital/Lab should have modern machine and equipment's

Required clinical facilities are as under

Name of Course	Requirements
B.Sc. in Nuclear Medicine Technology	• Applicants own hospital and clinical Training center in which around 80 Gamma/ PET-Scans, per week are conducted. Standalone institutions must have an MOU with either a medical college or hospital, or a healthcare facility as per the guidelines (desired number of Nuclear Medicine equipment along with Radiology Equipments/beds/OPD, etc.) defined in the curriculum to ensure practical exposure for the students. • Low dose radionuclide therapy ward/facility • High volume (2-5) radionuclide therapy per week) facility of High Dose Radionuclide Facility • Other Radiological Modalities Like CT, MRI are available • Facility should be three Years Old

Instruments required for Bachelor in Nuclear Medicine Technology

S. No.	Required Items	No. of Items
1	Refrigerator	01
2	Centrifuge	03
3	Hand lens	03
4	Histokinetic	02
5	Sahli's Hemoblobinometer	10
6	Hot air oven working	01
7	Stabilizers	01
8	Analytical balance	01

S. No.	Required Items	No. of Items
9	Chemical balance	02
10	Certified weight box	02
11	pH meter	02
12	Hot plates	02
13	Dessicator	01
14	Incubator (2' x 3')	02
15	Timers	02
16	Thermostatic water bath	02
17	Improved Triple ruled neubauer	
18	Counting chamber	20
19	Safety spectacles	05
20	Charts and Models	
21	Chemicals and Stains	as per standard
22	Tripod stand and burner	10
23	Autoclave	01
24	Thermometer up to 200^0 C	02
25	Candle Filter	01
26	Charts: Models showing regions / parts of human body	
27	2 sets of Histological slides and which are mentioned in the syllabus	
28	Skeleton	01
29	Sets of individual bones	01
30	Blood group antigens: anti-A, anti-B, anti-D	
31	lancets	10 boxes
32	Westergrins tubes	05
33	Wintrobe's tubes	05
34	Capillary tubes	
35	(Heparinised & Plain)	05 boxes each
36	Petridishes (diff. sizes)	50
37	Pauster pipettes	50
38	Adjustable micro pipettes	10

S. No.	Required Items	No. of Items
39	Funnels - different sizes	10
40	Beakers - different sizes	10
41	Measuring jars - different sizes	10
42	Conical flasks	20
43	Round bottom flask	20
44	Watch glass	50
45	Volumetric flask	10
46	Test Tube holder	20
47	Centrifuge Tubes	50
48	Folin Wu Tubes	10
49	Test tube racks	20
50	Serological Pipettes	20
51	Glass rods (Diff. sizes)	20
52	Rubber gloves	30 boxes
53	Surgical gloves	20 boxes
54	Rubber teats (diff. sizes)	10

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Equipment required for Bachelors in Nuclear Medicine Technology

1. SPECT/ Gamma Camera / SPECT-CT Machine – 1
2. PET-CT Machine – 1
3. Thyroid Uptake System – 1
4. Low Dose Radionuclide Facility - 1
5. One Decontamination room /Facility
6. One Radiopharmacy Lab Facility with Tc-99m Generator
7. One In-vitro lab/Nuclear Medicine Lab
8. Radiochemistry Lab
9. Radio physics/ Physics Lab
10. TLD Personnel monitoring
11. One Gamma Spectrometer with calibration sources
12. Radiation Safety Instruments like Survey Meter, Contamination Monitor,
13. Hot Plate
14. Decontamination Kits, Long Tools
15. Absorbent Sheet, Lab Accessories, Lead Bricks, L-Bench
16. Lead Lined Dust Bins
17. Radioactive Waste Storage facility
18. QC Kit and Accessories for Tc-Generator eluted 99mTc Radioisotope
19. QC Sources for Dose Calibrator, SPECT, PET/CT, Thyroid Uptake Probe, Well Counter etc.
20. Phantoms for Gamma Camera and SPECT (Fillable uniformity phantom, Co-57 Uniformity Phantom), PET (Daily QC Phantom, SUV Validation Phantom), CT (Daily CT QA Phantom), and Thyroid Probe (Daily QC Phantom, Neck Phantom)

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Infrastructure for M.Sc. Nuclear Medicine Technology Course

A. Physical Facility: Whole campus should be accessible

Building – Institute/University shall have its own building. Standard minimum requirement for Nuclear Medicine Technology course with intake capacity of 10 students shall be as under

Dedicated space of 8000 sq. ft. area is essential Standard for (20+20) seats

S. No	Description	Area (sq ft)	Number
1	Principal/HOD room	400	01
2	Office	400	01
3	Store room	500	01
4	Professor room	400	01
5	Other faculty rooms	250 each	06
Teaching area			
6	Class rooms	450	03
7	Gamma Camera room	800	01
8	PET/CT room	1200	01
9	Radio-pharmacy room	800	01
10	Therapy ward (2 bedded)	1000	01
11	Computer lab/seminar room	450	01
12	Library	1800	01
Amenities			
13	Girls common room	200	01
14	Boys common room	200	01
15	Girls toilet	100	01
16	Boys toilet	100	01
17	Staff room/record room	100	01
Desirable facility			
18	Drinking water		
19	Fire Extinguisher		
20	Transportation facility		
21	Girls and boys hostel required		
22	Recreation / sports facility		

Note:

- **Principal's Office:** There should be a separate office for the Principal/ Head of Department with attached Toilet and provision for visitor's room. Independent telephone facility is a must for the Principal's / Head of Department office with intercom facility connected/linked to the hospital and hostel and a computer with internet facility
- The classrooms should be well ventilated with proper lighting system. There should be built in Black/Green/White Boards/Projector. Also, there should be a desk/dais/ a big table and a chair for the teacher and tables and chairs for students.
- Common rooms should be provided for the student and for the office staff. Sufficient space with adequate seating arrangements, cupboards, lockers, cabinets, built-in-shelves and racks should be provided in all the common rooms. Toilet and hand washing facilities should be made available in each room.
- There should be a separate computer lab for students and staff for reading purpose and it should provide internet and cabin facility.
- There should be a separate record room with steel racks, built-in shelves and racks, cupboards and filing cabinets for proper storage of records and other important papers/documents belonging to the college.
- Adequate provision for extinguishing fire should be available as per the local bye-laws.
- This room should be provided for the proper and safe storage for all the Audio-Visual Aids
- **Library facility:** There should be a separate library for the Institute. The library should be easily accessible to the teaching faculty and the students. It should have internet facility. Library should have seating arrangements for at least 80 students for reading and having good lighting and ventilation and space for stocking and displaying of books and journals. The number of journals should 10 out of which one – third shall be foreign journals and subscribed on continuous basis. There should be sufficient number of cupboards, book shelves and racks with glass doors for proper and safe storage of books, magazines, journals, newspapers and other literature. In the library there should be provision for internet

Human Resource Requirement : Teaching Faculty per Specialty for (10+10) students :

- **Faculty/teacher to student ratio**: 1:5
- **Minimum Requirement** : Professor-1, Associate Professor-1, Assistant Professor-2
- **Teaching staff:** M.Sc. Residents – 02 (Optional)
- **Non-teaching staff :** Office Superintendent/ Assistant 1
  Computer Operator 1
  Nursing Officer 1
  Lab Assistant 1

Note:

- Professors (out of which one will be HoD), Associate Professors, and Assistant Professors will be counted in teaching faculty.
- Students: Teachers Ratio should be - 5:1 per year (Total Students of all three years).
- Apart from the teaching faculty, to manage the regular clinical/patient workload, regular Nuclear Medicine Technologists should be appointed as per requirement.
- Services of visiting faculty can be utilized, but these faculty members will not be counted in the PG teachers and they cannot register candidates under them for thesis/research project. Apart from the core subjects, Guest/ Adjunct/ Part-Time Faculty can teach the peripheral subject or topic as needed, but will not be considered as core faculty.

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Table 2. Teaching Faculty Qualifications for M.Sc. NMT course

Post Name	Education qualification & Experience
Professor	1.M.Sc. Nuclear Medicine/M. Sc. Nuclear Medicine Technology/MSc NMT/M.Sc. Nuclear Medicine and Molecular Imaging Technology, M.Sc. Medical Physics/ M. Sc. + Postgraduate diploma in Nuclear Medicine (DMRIT/PGDFIT/PGDNMT)/M.Sc. + Postgraduate diploma in Radiological Physics or equivalent With Ph.D. in relevant subject + 10 years of clinical/teaching/research experience. OR MD/DNB (Nuclear Medicine) + 10 years of clinical/teaching/research experience.
Associate Professor	1.M.Sc. Nuclear Medicine/M. Sc. Nuclear Medicine Technology/MSc NMT/M.Sc. Nuclear Medicine and Molecular Imaging Technology M.Sc. Medical Physics/ M. Sc. + Postgraduate diploma in Nuclear Medicine (DMRIT/PGDFIT/PGDNMT)/M.Sc. + Postgraduate diploma in Radiological Physics or equivalent With Ph.D. in relevant subject + 6 years of clinical/teaching/research experience. OR MD/DNB (Nuclear Medicine) + 6 years of clinical/teaching/research experience.
Assistant Professor	1.M.Sc. Nuclear Medicine/M. Sc. Nuclear Medicine Technology/MSc NMT/M.Sc. Nuclear Medicine and Molecular Imaging Technology, M.Sc. Medical Physics/ M. Sc. + Postgraduate diploma in Nuclear Medicine (DMRIT/PGDFIT/PGDNMT)/M.Sc. + Postgraduate diploma in Radiological Physics or equivalent OR MD/DNB (Nuclear Medicine)

Basic details about clinical facility for lab Practice or clinical practice

Clinical Institute/facility

- The Hospital/Lab should have Pollution Control Board certificate, Clinical Establishment Act registration, Pollution control board certificate and other essential licenses/ certificates required from various departments under prevalent Act, Rules and Regulations.
- Fire NOC of both Institute and Hospital
- The Institute may have their own NABH accredited Hospital/ NABL accredited Lab
- Hospital/Lab should have modern machine and equipment's
- Required clinical facilities are as under

Name of course	Requirements
M.Sc. in Nuclear Medicine	• Applicants own hospital and clinical Training centre in which minimum 100 Gamma/ PET-Scans, per week are conducted. Standalone institutions must have an MOU with either a medical college or hospital, or a healthcare facility as per the guidelines (desired number of Nuclear Medicine equipment along with Radiology Equipment's/beds/OPD, etc.) defined in the curriculum to ensure practical exposure for the students. • High volume (2-5 radionuclide Therapy per week) facility of High/Low Dose Radionuclide Facility • Other Radiological Modalities Like CT, MRI are available • Documented essential Medical Cyclotron training for 1 month • Facility should have In-vitro lab, Radiopharamacy, Radiochemistry and Radio physics Lab as per listed Instruments

Equipments required for MSc NMT

Minimum Equipment Required for M.Sc. Nuclear Medicine Technology

1. SPECT/ Gamma Camera / SPECT-CT machine – 1
2. PET-CT Machine – 1
3. Thyroid Uptake System – 1
4. High-Dose Radionuclide Facility – 1 (Minimum two bedded)
5. Low Dose Radionuclide Facility - 1
6. One Radio-pharmacy Lab Facility with Tc-99m Generator
7. TLD Personnel monitoring facility
8. Radioactive Waste Storage facility
9. Decontamination room /Facility
10. One gamma ray Spectrometer
11. One GM counter
12. QC Sources for Dose Calibrator, SPECT, PET-CT, Thyroid Uptake Probe, Well Counter etc.
13. Radiation Safety Instruments like Survey Meter, Contamination Monitor,
14. Radio-TLC Scanner/chromatography setup, Melting Point System, Hot Plate,
15. Decontamination Kits, Long Tools
16. Absorbent Sheet, Lab Accessories, Lead Bricks, L-Bench (03),
17. Lead Lined Dust Bin (05),
18. AERB Approved Layout of Nuclear Medicine Equipment
19. Nuclear Medicine Physics Lab
20. Radiochemistry/Radiopharmacy Lab
21. Radiation physics/ Physics Lab
22. Medical Cyclotron Facility (Optional)
23. QC Kit and Accessories for Tc-Generator eluted 99mTc Radioisotope
24. Phantoms for NEMA QC

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Table 3 Indicative Career Progression

Post Name	Eligibility and experience for Direct recruitment	Eligibility and experience for promotion
Nuclear Medicine Technologist	**Education Qualification:** B.Sc. + Postgraduate diploma in Nuclear medicine (DMRIT, PGDFIT, PGDNMT), DFIT/ DNMT Or B.Sc. Nuclear Medicine Or B.Sc. Nuclear Medicine Technology	**Experience:** Nil
Senior Nuclear Medicine Technologist	B.Sc. + Postgraduate diploma in Nuclear medicine (DMRIT, PGDFIT, PGDNMT) Or B.Sc. Nuclear Medicine Or B.Sc. Nuclear Medicine Technology or M.Sc. (Nuclear Medicine Technology)	5 Years of Experience as Nuclear Medicine Technologist or M.Sc. (Nuclear Medicine Technology) - NIL
Superintending Nuclear Medicine Technologist	B.Sc. + Postgraduate diploma in Nuclear medicine (DMRIT, PGDFIT, PGDNMT) Or B.Sc. Nuclear Medicine Or B.Sc. Nuclear Medicine Technology Or M.Sc. (Nuclear Medicine Technology)	5 Years of Experience as Senior Nuclear Medicine Technologist +
Chief Nuclear Medicine Technologist	B.Sc. + Postgraduate diploma in Nuclear medicine (DMRIT, PGDFIT, PGDNMT) Or B.Sc. Nuclear Medicine Or B.Sc. Nuclear Medicine Technology Or M.Sc. (Nuclear Medicine Technology)	5 Years of Experience as Superintending Nuclear Medicine Technologist

Post Name	Eligibility and experience for Direct recruitment	Eligibility and experience for promotion
Director Nuclear Medicine Technology Services	B.Sc. + Postgraduate diploma in Nuclear medicine (DMRIT, PGDFIT, PGDNMT) Or B.Sc. Nuclear Medicine Or B.Sc. Nuclear Medicine Technology Or M.Sc. (Nuclear Medicine Technology)	5 Years of Experience as Chief Nuclear Medicine Technologist

Table 4 Indicative Promotion criteria will be according to Institute ACR

Post Name	Eligibility and experience for Direct recruitment	Eligibility and experience for promotion
Assistant Manager	B.Sc. Nuclear Medicine Technology /B. Sc. Nuclear Medicine PG Diploma in Nuclear Medicine (DMRIT/PGDFIT/PGDNMT)	NA
Manager	M.Sc. Nuclear Medicine / M.Sc. Nuclear Medicine Technology/ M.Sc. Nuclear Medicine and Molecular Imaging Technology 5-8 years of experience as Assistant Manager	5-8 years of experience as Assistant Manager
Senior Manager	5-8 Years of Experience as a Manager	5-8 Years of Experience as Manager
Associate Director	5-8 Years of Experience as Senior Manager	5-8 Years of Experience as Senior Manager
Director	5-8 Years of Experience as Associate Director	5-8 Years of Experience as Associate Director
Vice President	5-8 Years of Experience as Director	5-8 Years of Experience as Director

Table 5. Indicative Levels of Career as Teaching Faculty for Nuclear Medicine Technology

Post Name	Education qualification	Experience
Professor	M.Sc. Nuclear Medicine/M. Sc. Nuclear Medicine Technology/MSc NMT/ M.Sc. Nuclear Medicine and Molecular Imaging Technology with Ph.D. in relevant subject **OR** M.Sc. + Postgraduate diploma in Nuclear Medicine (DMRIT, PGDFIT, PGDNMT) With Ph.D. in relevant subject	10 years teaching/research experience with Ph.D. experience included
Associate Professor	M.Sc. Nuclear Medicine/M. Sc. Nuclear Medicine Technology/MSc NMT/ M.Sc. Nuclear Medicine and Molecular Imaging Technology with Ph.D. in relevant subject **OR** M.Sc. + Postgraduate diploma in Nuclear medicine (DMRIT, PGDFIT, PGDNMT) With Ph.D. in relevant subject	6 years teaching/research experience with Ph.D. experience included
Assistant Professor	M.Sc. Nuclear Medicine/M. Sc. Nuclear Medicine Technology/MSc NMT/ M.Sc. Nuclear Medicine and Molecular Imaging Technology **OR** M.Sc. + Postgraduate diploma in Nuclear medicine (DMRIT, PGDFIT, PGDNMT)	

Pay Scale for Academic Posts: Pay Scale of Academic posts should be as per UGC Academic Grade.

Note: The promotion criteria outlined above in various tables are broad indicative guidelines. Actual promotions may vary depending on institutional policies, applicable regulations, performance evaluations, and revisions issued by the institute from time to time.

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Chapter 4

Bachelor of Science in Nuclear Medicine Technology (B.Sc. NMT)

Nature and extent of the program:

The Bachelor of Science in Nuclear Medicine Technology (B.Sc. NMT) program is an academic program designed to train students to perform diagnostic and therapeutic procedures using radioactive materials and advanced imaging systems such as SPECT and PET. The program equips them to work in the hospital, diagnostic centers, research institutes and radiopharmaceutical industries as technologists. Candidates with this degree has an opportunity for specialization in Masters of Science in Nuclear Medicine or associated degrees.

Professional Agenda

- Ensure high standard and discipline of the profession.
- Develop and maintain the technical profession in Nuclear Medicine.
- Widening the knowledge of practice, skills and research work.
- Impart academic knowledge and advances in professional practice.

Duration

Bachelor of Science in Nuclear Medicine Technology (B.Sc. NMT) is a 4 year (3 years course work + 1 year internship) full time course.

Professional Aims

By the end of the program students should be able to:

- Acquire knowledge of practice relevant to Nuclear Medicine Technology.
- Use formal research as a tool to evaluate and develop practice.
- Identify his/her professional learning and developmental needs.
- Work collaboratively with other health care professionals to achieve a quality service.
- Enable health care organization for better management of patients.
- Uphold legal ethical standards within his/ her profession.
- Acquire knowledge and required skills to pursue higher education.

Requirements for running the program:

Clinical Facility

- The Institute should preferably have its own NABH accredited Hospital/ NABL accredited Lab.
- The Hospital/Lab should have Pollution Control Board certificate, Clinical Establishment Act registration, Pollution control board certificate and other essential licenses/ certificates required from various departments under prevalent Act, Rules and Regulations. (iii) Fire NOC of both Institute and Hospital. (iv) Required clinical facilities are as under:
- Hospital/Lab should have modern machine and equipment's.
- Distance of Institute from Hospital/Lab shall be- maximum 25 Km. from city with population above 10 lakhs, and maximum 10 Km. from city with population up to 10 lakhs.

Laboratories

Each institution is expected to have at least following laboratories, to cater to the needs of undergraduate courses, size of which must be appropriate to accommodate each batch of NM student. Laboratory space may be shared with other A&HP courses as needed.

- Anatomy laboratory & Physiology laboratory
- Cell and Molecular Biology laboratory/ Biochemistry laboratory
- Physics/Radiation physics laboratory
- Chemistry/Unsealed radioisotope handling laboratory

Instruments required for Bachelor in Nuclear Medicine Technology laboratories as mentioned in chapter 2.

B.Sc. NMT Program regulation

Program Structure

- The program is a choice-based credit system.
- An academic year consists of two semesters – Odd semester (July - December) and Even semester (January – June).
- Each semester shall extend over a minimum period of 16 weeks of academic delivery excluding examination days, semester breaks, declared holidays and extracurricular events.
- Medium of instruction shall be in English

Eligibility for admission:

Selection Procedure:

- Candidate must have passed Senior Secondary (10+2) or equivalent with Physics, Chemistry & Biology.
- Admission shall be on the basis of Senior Secondary (10+2) Merit. Admission shall be made on the basis of eligibility of the Senior Secondary marks or/and entrance test to be conducted for the purpose at the State/ University/Institute level.
- Candidates who have studied abroad and have passed the equivalent qualification as determined by the Association of Indian Universities and Equivalence Committee of the NCAHP, and must fulfil the criteria as per points 1-3 above.
- For candidate has completed 17 years of age at the time of admission or will complete that age on or before 31 December of the year of his/her admission to the first year of the Undergraduate Allied and Healthcare Course.
- Medical fitness certificate is mandatory to submit and it is to be endorsed by Government medical officer.
- As per the Eligibility criteria described in Table below, candidate can take admission on disability quota for BNM program.

Guidelines regarding admission of students with "Specified Disabilities" under the Rights of Persons with Disabilities Act, 2016 with respect to admission in B.Sc. NMT Course

- Note: The "Certificate of Disability" shall be issued in accordance with the Rights of Persons with Disabilities Rules, 2017 notified in the Gazette of India by the Ministry of Social Justice and Empowerment [Department of Empowerment of Persons with Disabilities (Divyangjan)] on 15th June 2017.
- The extent of "specified disability" in a person shall be assessed in accordance with the "Guidelines for the purpose of assessing the extent of specified disability in a person included under the Rights of Persons with Disabilities Act, 2016 (49 of 2016)" notified in the Gazette of India by the Ministry of Social Justice and Empowerment [Department of Empowerment of Persons with Disabilities (Divyangjan)] on 4th January 2018.
- The minimum degree of disability should be 40% (Benchmark Disability) in order to be eligible for availing reservation for persons with specified disability.
- The term 'Persons with Disabilities' (PwD) is to be used instead of the term 'Physically Handicapped' (PH).
- Quota/ reservation policy as per the State Government norms to be followed by the State Council as applicable during allotment of seats
- Candidate who fails to attend the Medical Examination on the notified date(s) will forfeit the claim for admission and placement in the waiting list except permitted by the competent authority under special circumstances.

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Sr. No	Disability Type	Benchmark Disabilities	Specified Disability	Eligible for B.Sc. NMT Course, Not Eligible for PH Quota	Eligible for B.Sc. NMT, Eligible for PH Quota	Not Eligible for B.Sc. NMT
1.	Physical Disabilities	• Locomotor Disability including Condition (a-f)	• Leprosy* cured person • Cerebral Palsy** • Dwarfism • Muscular Dystrophy • Acid attack victim • Others*** (such as Amputation, Poliomyelitis, etc.)	Less than 40% disability	• Lower Limb: 40-50% disability • Spine: 40-50% disability • Limbs &/Spine: 40-50% disability	• More than 50% for Lower Limb • Involvement of both Upper Limbs • Involvement of dominant Upper Limb • Involvement of Non-dominant Upper Limb • More than 50% for Spine • More than 50% for Combined for Limbs and spine
		* Attention should be paid to loss of sensations in fingers and hands, amputation, as well as involvement of eyes and corresponding recommendations be looked at. ** Attention should be paid to impairment of vision, hearing, cognitive function etc. and corresponding recommendations be looked at. *** Both hands intact, with intact sensations, sufficient strength and range of motion are essential to be considered eligible for **B.Sc. NMT** course.				
		• Visual Impairment • (*)	• Blindness • Low vision	Less than 40% disability (i.e. Category '0(10%)', 'I (20%)' & 'ii (10%)	-	Equal to or More than 40% Disability Category till and above
		• Hearing Impairment	• Deaf • Hard of hearing	Less than 40% Disability	-	Equal to or more than 40% Disability
		(*) Persons with Visual impairment / visual disability of more than 40% may be made eligible to pursue BNM Course and may be given reservation, subject to the condition that the visual disability is brought to a level of less than the benchmark of 40% with advanced low vision aids such as telescopes / magnifier etc.				

<table>
<tr><th>Sr. No</th><th>Disability Type</th><th>Benchmark Disabilities</th><th>Specified Disability</th><th>Eligible for B.Sc. NMT Course, Not Eligible for PH Quota</th><th>Eligible for B.Sc. NMT, Eligible for PH Quota</th><th>Not Eligible for B.Sc. NMT</th></tr>
<tr><td></td><td></td><td colspan="5">@ Persons with hearing disability of more than 40% may be made eligible to pursue BNM
Course and may be given reservation, subject to the condition that the hearing disability is brought to a level of less than the benchmark of 40% with the aid of assistive devices.
In addition to this, the individual should have a speech discrimination score of more than 60%.</td></tr>
<tr><td></td><td></td><td>• Speech & language disability$</td><td>• Organic/ neurological causes</td><td>• Less than 40% Disability</td><td></td><td>• Equal to or more than 40% Disability</td></tr>
<tr><td></td><td></td><td colspan="5">$ Persons with Speech Intelligibility Affected (SIA) shall be eligible to pursue BNM Courses, provided Speech Intelligibility Affected (SIA) score shall not exceed 3 (three), which is 40% or below.
Persons with Aphasia shall be eligible to pursue BNM Courses, provided Aphasia
Quotient (AQ) is 40% or below.</td></tr>
<tr><td>2.</td><td>Intellectual disability</td><td></td><td>• Specific learning disability (Perceptual disability, Dyslexia, Dyscalculia, Dyspraxia & Developmental aphasia) #</td><td colspan="3"># Currently there is no Quantification scale available to assess the severity of SpLD, therefore the cut-off of 40% is arbitrary and more evidence is needed.</td></tr>
<tr><td></td><td></td><td></td><td></td><td>Less than 40% Disability</td><td>Equal to or more than 40% disability and equal to or less than 50%.
But selection will be based on the learning competency evaluated with the help of the remediation/ assisted technology/ aids/ infrastructural changes by the Expert Panel.</td><td>More than 50% or severe nature or significant cognitive/ intellectual disability.</td></tr>
</table>

Sr. No	Disability Type	Benchmark Disabilities	Specified Disability	Eligible for B.Sc. NMT Course, Not Eligible for PH Quota	Eligible for B.Sc. NMT, Eligible for PH Quota	Not Eligible for B.Sc. NMT
			• Autism spectrum disorders	Absence or Mild Disability, Asperger syndrome (disability of upto 60% as per ISAA) where the individual is fit for BNM course by an expert panel.	Currently not recommended due to lack of objective method to establish presence and extent of mental illness. However, the benefit of reservation/quota may be considered in future after developing better methods of disability assessment.	More than 60% disability or Presence of cognitive /intellectual disability and / or if the person is unfit for pursuing BNM course by an expert panel.
3.	Mental Behaviour		• Mental illness	Absence or Mild Disability: less than 40% (under IDEAS)	Currently not recommended due to lack of objective method to establish presence and extent of mental illness. However, the Benefit of reservation/quota may be considered in future after developing better methods of disability	Equal to or more than 40% disability or if the person is unfit to perform his/her duties. Standards may be drafted for the definition of "fitness to practice medicine", as are used by several institutions of countries other than India.

Sr. No	Disability Type	Benchmark Disabilities	Specified Disability	Eligible for B.Sc. NMT Course, Not Eligible for PH Quota	Eligible for B.Sc. NMT, Eligible for PH Quota	Not Eligible for B.Sc. NMT
					assessment.	
4.	Disability caused due to	• Chronic Neurologic-al Condition • Blood Disorder	• Multiple Sclerosis • Parkinsonism • Hemophilia • Thalassemia • Sickle cell disease	Less than 40% disability Less than 40% disability	40-50% disability 40-50% disability	More than 50% More than 50%
5.	Multiple disabilities including deaf blindness		• More than one of the above specified disabilities	Must consider all above while deciding in individual cases recommendations with respect to presence any of the above, namely, Visual, Hearing, Speech & Language disability, Intellectual Disability, and Mental Illness as a component of Multiple Disability. Combining Formula as notified by the related Gazette Notification issued by the Govt. of India a+ [b(90-a)/90] (where a= higher value of disability % and b=lower value of disability % as calculated for different disabilities) is recommended for computing the disability arising when more than one disabling condition is present in a given individual. This formula may be used in cases with multiple disabilities, and recommendations regarding admission and/or reservation made as per the specific disabilities present in a given individual.		

- Reservation policy for admission in undergraduate programs shall be as per the State/Centre Government norms.
- The admission criteria shall be updated by the Commission from time to time.
- Admission process shall be conducted by State/Union Territory/University.

Credit Distribution

- Each semester would consist minimum of 20 credits.
- The credit distribution hours for Lecture, Tutorial, Practical, and Clinics are as follows:
    - Lecture / Tutorial: 1 credit = 15 hours
    - Practical: 1 credit = 30 hours
    - Clinical: 1 credit = 45 hours
- A semester has courses structured as theory, practical, laboratory and clinics. Each course is of minimum 2 credits.
- Internship duration is as per the course regulation.
- Abbreviations / Symbols used in the credit distribution table:
    - L - Lectures,
    - T - Tutorials,
    - P -Practical,
    - CL - Clinics,
    - C - Total credits,
    - IAC - Internal assessment component,
    - ESE - End-Semester Exam,

Weightage for Internal Assessment Component (IAC) and End Semester Exam (ESE)

- The IAC component weightage for theory & practical is:
    - 50% from Mid-semester examination
    - 50% through Continuous assessment
- The ESE component weightage for theory & practical is:
    - 100% from end semester examination

Attendance

Minimum attendance requirements for each course is:Theory: 75 %

- Clinics / Practical: 80 %
- If attendance is less than prescribed the institute/university shall act as per its policy

Evaluation / Examination

- The final evaluation for each course shall be based on Internal Assessment Component (IAC) and the End-semester examination (ESE) as per the weightage indicated for respective courses.
- Internal Assessment Component (IAC) shall be estimated based on the performance of the student in mid semester exam or sessional exam/s, and continuous assessment (class participation, assignments, seminars or any other component as applicable to a course).

- At the end of each semester, a regular End Semester Examination (ESE) for the odd and even semesters will be conducted in November-December/ May-June cycle respectively.
- A one week of preparatory leave will be given to students before they appear for the regular end semester examination.
- A student should obtain minimum of 40% Internal Assessment Component (IA) to be eligible for End Semester Examination. Failure to secure 40%, he/she will be not appearing for the regular End Semester Examination (ESE). However, the conduct of a supplementary examination shall be subject to the university/institute guidelines.

Minimum Requirements for Pass

- A ten (10) point grading system **(credit value)** is used for awarding a letter grade in each course. .[11]

Letter Grade		A+	A	B	C	D	E	F/I/DT
Grade points		10	9	8	7	6	5	0

DT – Detained/Attendance shortage, I – Incomplete

- A pass in a ESE will be reflected as grades. Candidate shall be declared to have passed in any course, when he/she obtains not less than **"E" grade.**
- However, when a student appears for a supplementary examination, the grade shall be awarded as per the university norms. In the absence of specific norms, the maximum grade that may be awarded shall be "C" grade or below, irrespective of the student's performance.
- **Pass criteria for courses with End Semester Examination:** For theory / practical course, a candidate should secure a minimum of 40% in ESE and an overall 50% including IAC to be declared as pass.
- **Pass criteria for courses with Internal Assessment Component:** The students should obtain 50% IAC to be declared as pass in a given semester.

Calculation of GPA and CGPA

- Evaluation and Grading (**Relative Grading**) of students shall be based on GPA (Grade Point Average) & CGPA (Cumulative Grade Point Average).
- The overall performance of a student in each semester is indicated by the Grade Point Average (GPA). The overall performance of the student for the entire program is indicated by the Cumulative Grade Point Average (CGPA).
- A ten (10) point grading system **(credit value)** is used for awarding a letter grade in each course.

Letter Grade	A+	A	B	C	D	E	F/I/DT
Grade points	10	9	8	7	6	5	0

DT – Detained/Attendance shortage, I – Incomplete

Calculation of GPA & CGPA: An example is provided

Course Code	Course	Credits (a)	Grade obtained by the student	Credit Value (b)	Grade Points (a x b)
AHS 101	Course – 1	4	B	8	32
AHS 103	Course – 2	4	B	8	32
AHS 105	Course – 3	3	A+	10	30
AHS 107	Course – 4	4	C	7	28
AHS 109	Course – 5	5	A	9	45
TOTAL		**20**	**-**	**-**	**167**

1st Semester GPA = Total grade points / total credits

167/20 = **8.35**

Suppose in **2nd semester GPA** = **7** with respective course credit 25

Then 1st Year CGPA = $= \frac{(8.35 \times 20) + (7 \times 25)}{20 + 25}$

$= 7.6$

Program Exit / Probation Criteria

The candidate must complete all the course work requirements and credits by a **maximum of double the program duration** i.e., 8 years.

Semester Break

Students will have a semester break following their odd and even end- semester examinations as per the academic calendar.

Internship

- Internship will be for a duration of 1 year as per the program regulation. All students shall be paid stipend during their internship as decided by the respective State Allied and Healthcare Council.
- The intern should abide by the rules and regulations of the organization during the period of internship.
- An internship certificate with details of activities (including externship), clinical /relevant areas of postings with hours and research project will be issued to a candidate on completion of the Internship. The certificate must be authenticated by the HOD/Coordinator and HOI.
- **Degree is awarded** only on successful completion of internship.

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PROGRAM OUTCOMES (POs):

After successful completion of B.Sc. NMT program, students will be able to:

PO No.	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	**Team work**	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 framework 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

CURRICULUM OUTLINE

B.Sc. NMT 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
BNM1101	Basics of Biochemistry & Cell Biology	3	1	0	0	4	50	50	100
BNM1102	Human Anatomy and Physiology for Nuclear Medicine	4	0	0	0	4	50	50	100
BNM1103	Solid state physics and Electronics in Nuclear Medicine	3	1	0	0	4	50	50	100
BNM1104	Fundamentals of Chemistry	2	1	0	0	3	50	50	100
BNM1105	Mathematics in Nuclear medicine	2	1	0	0	3	50	50	100
BNM1106	Practicum-I	0	0	4	0	2	50	50	100
Total		**14**	**4**	**4**	**0**	**20**	**300**	**300**	**600**

***Non-credit subjects such as Environmental Science and Indian Constitution, Communication skills etc. to be included**

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B.Sc. NMT 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
BNM1201	Introduction to Nuclear Medicine, Medical ethics and Patient care	2	1	0	0	3	50	50	100
BNM1202	Applied chemistry: Organic Chemistry & Inogranic chemistry for Nuclear Medicine	3	1	0	0	4	50	50	100
BNM1203	Radiation Physics	3	1	0	0	4	50	50	100
BNM1204	Fundamentals of Electromagnetism in Nuclear Medicine	2	1	0	0	3	50	50	100
BNM1205	Practicum – II	0	1	6	0	4	50	50	100
BNM1206	Clinical Practice – I	0	0	0	6	2	50	50	100
Total		**10**	**5**	**6**	**6**	**20**	**300**	**300**	**600**

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B.Sc. NMT 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
BNM2301	Fundamentals of Immunology and Microbiology	2	1	0	0	3	50	50	100
BNM2302	Introduction to Radiopharmacy	3	1	0	0	4	50	50	100
BNM2303	Nuclear Medicine Instrumentation Physics	3	1	0	0	4	50	50	100
BNM2304	Principles of wave and optical physics in biomedical imaging	2	1	0	0	3	50	50	100
BNM2305	Practicum –III	0	0	6	0	3	50	50	100
BNM2306	Clinical Practice-II	0	1	0	6	3	50	50	100
Total		**10**	**5**	**6**	**6**	**20**	**300**	**300**	**600**

B.Sc. NMT 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
BNM2401	Radiochemistry	3	1	0	0	4	50	50	100
BNM2402	Radiobiology	2	1	0	0	3	50	50	100
BNM2403	Biostatistics	2	1	0	0	3	50	50	100
BNM2404	Health Physics & Radiation safety	3	1	0	0	4	50	50	100
BNM2405	Practicum-IV	0	1	4	0	3	50	50	100
BNM2406	Clinical practice - III	0	0	0	9	3	50	50	100
	Total	**10**	**5**	**4**	**9**	**20**	**300**	**300**	**600**

B.Sc. NMT SEMESTER V:

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
BNM3501	Radiopharmaceutical Chemistry	3	1	0	0	4	50	50	100
BNM3502	Imaging Instruments in Nuclear Medicine	2	1	0	0	3	50	50	100
BNM3503	Applications of computer in Nuclear Medicine	2	1	0	0	3	50	50	100
BNM3504	Clinical Nuclear Medicine -I	3	1	0	0	4	50	50	100
BNM3505	Practicum- V	0	1	4	0	3	50	50	100
BNM3506	Clinical Practice – IV	0	1	0	6	3	50	50	100
Total		**10**	**6**	**4**	**6**	**20**	**300**	**300**	**600**

B.Sc. NMT SEMESTER VI:

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
BNM3601	Tomography and hybrid imaging	3	1	0	0	4	50	50	100
BNM3602	Introduction to AI and recent advances in nuclear medicine	3	1	0	0	4	50	50	100
BNM3603	Clinical Nuclear Medicine-II	3	1	0	0	4	50	50	100
BNM3604	Practicum-VI	0	2	4	0	4	50	50	100
BNM3605	Clinical Practice – V	0	1	0	9	4	50	50	100
	Total	**9**	**6**	**4**	**9**	**20**	**250**	**250**	**500**

SEMESTER – VII and VIII

Internship (1 year, 48 hour/week)

SEMESTER VII				SEMESTER VIII			
Course	**Duration**	**Credit**	**Contact Hours**	**Course**	**Duration**	**Credit**	**Contact Hours**
Internship	6 months	20	900	Internship	6 months	20	900
Total	**12 months (Clinical Learning= 48 hours / week)**						

TOTAL DEGREE CREDIT DISTRIBUTION

Semester		**Credit distribution (L, T, P are hours/week)**				**Contact Hours**
	Lecture	**Tutorial**	**Practical**	**Clinical Learning**	**Credits**	
Semester – I	14	4	4	0	20	330
Semester – II	10	5	6	6	20	405
Semester – III	10	5	6	6	20	405
Semester – IV	10	5	4	9	20	420
Semester – V	10	6	4	6	20	390
Semester – VI	9	6	4	9	20	420
Semester - VII Internship	0	0	0	48	20	900
Semester - VIII Internship	0	0	0	48	20	900
Total					**160**	**4170**

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SEMESTER - I

Course Code	Course Title
BNM1101	Basics of Biochemistry & Cell Biology
BNM1102	Human Anatomy and Physiology for Nuclear Medicine
BNM1103	Solid state physics and Electronics in Nuclear Medicine
BNM1104	Fundamentals of Chemistry
BNM1105	Mathematics in Nuclear medicine
BNM1106	Practicum- I

Name of the Program	**Bachelors of Science in Nuclear Medicine Technology**
Course Title	**Basics of Biochemistry & Cell Biology**
Course Code	**BNM1101**
Academic Year	First
Semester	II
Number of Credits	4
Course Prerequisite	Basic knowledge of Biology and Chemistry at higher secondary school level
Course Synopsis	This module provides fundamental knowledge of biochemistry and cell biology relevant to nuclear medicine.

Course Outcomes (COs):
At the end of the course student shall be able to:

CO1	Explain the classification, composition and functions of macromolecules (C2)
CO2	Describe the process of digestion, absorption and metabolism of carbohydrates and lipids (C2)
CO3	Explain protein digestion and amino acid metabolism (C2)
CO4	Explain function and organization of cellular organelles (C2)
CO5	Understand basic structure and characteristics of DNA and RNA (C 2)
CO6	Understand DNA replication, transcription, and translation processes (C2)

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

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1	**x**							
CO2	**x**							
CO3	**x**							
CO4	**x**							
CO5	**x**							
CO6	**x**							

Course Content and Outcomes:

Content	Competencies	No. of Hours
Section A: Basic Biochemistry		
Unit 1: Enzymes		
	• Define and classify "enzyme" (C1) • Explain "isoenzymes" with examples (C2) • Define the term "proenzyme or zymogen" with pepsinogen and trypsinogen as examples (C1) • Describe the utility of serum enzymes as diagnostic markers(C2) • Mention the diagnostic utility of following enzymes (C1) • CK • ALP • AST • ALT • LDH	2
Unit 2: Carbohydrates		
	• Explain carbohydrates with examples for each class (C1) • Classify monosaccharides and mention the source and composition of following disaccharides (C2) • Sucrose • Lactose • Maltose • Classify polysaccharides based on composition with examples (C2) • Explain the structure of starch and glycogen with schematic representation (C2) • List the differences between starch and glycogen (C1) • Mention the occurrence and functions of heparin and chondroitin sulphate (C2) • Describe the complete digestion of dietary polysaccharides (starch and glycogen) (C2) • Describe the reactions catalyzed by the following brush border enzymes (C2) • Maltase • Sucrase-isomaltase • Lactase • Illustrate the mechanisms of absorption of monosaccharides in the small intestine (C2)	11

Content	Competencies	No. of Hours
	• Explain the significance of including sodium chloride along with glucose in the oral rehydration solution (C2) • Define aerobic and anaerobic glycolysis (C1) • Mention the site and subcellular site of glycolysis (C2) • Describe the steps of glycolysis with all the enzymes and coenzymes at each step (C2) • Mention the regulatory enzymes and list the names of hormones that regulate it in the well-fed state and starvation (C2) • Calculate the energetics of aerobic and anaerobic glycolysis (C2) • Define gluconeogenesis (C1) • Mention the sites & subcellular sites of gluconeogenesis (C2) • List the precursors for gluconeogenesis (C1) • List the key enzymes of gluconeogenesis (C1) • Describe the synthesis of glucose from pyruvate and lactate (C2) • Mention the regulatory enzymes and list the names of hormones that regulate it in the well-fed state and starvation (C1) • Explain the significance of gluconeogenesis (C2) • Recall the reaction catalyzed by pyruvate dehydrogenase complex and mention its coenzymes (C2) • Mention the site and subcellular site of citric acid cycle (C1) • Describe the reactions of citric acid cycle with all enzymes and coenzymes (C2) • Mention the regulatory enzymes of citric acid cycle (C2) • Calculate the energetics of citric acid cycle (C1) • Mention the function of glycogen in liver and muscle (C1) • Define glycogenesis & glycogenolysis (C1) • Mention the site and subcellular site of glycogen metabolism (C1) • Mention the fate of end products of glycogenolysis in liver (role of glucose 6-phosphatase) and muscle (C2)	

Content	Competencies	No. of Hours
	• Mention the regulatory enzymes and the hormones involved in regulation in well-fed state and starvation (C2) • List the glycogen storage disorders mentioning their names, defects and tissues affected (Type I, V & VI) (C1)	
Unit 3: Electron transport chain and oxidative phosphorylation		
	• Define the electron transport chain (ETC) (C1) • Name the subcellular site of ETC (C1) • Describe the complexes of ETC (with their components and order of arrangement) and mention the mobile electron carriers (C2) • Name the inhibitors for each of the complexes of ETC (C1) • Define oxidative phosphorylation (C1)	3
Unit 4: Lipids		
	• Define lipids (C1) • Explain the functions of lipids in the body (C2) • Classify lipids with examples for all the subclasses (C1) Classify fatty acids with examples-saturated, unsaturated (based on number of double bonds), essential fatty acids (C1) • Explain the process of emulsification of lipids (C2) • Describe the digestion of lipids in the stomach and intestine (C2) • Illustrate the process of absorption of lipids (C2) • Define steatorrhea and list its causes (C1) • Mention the site and subcellular site of de novo synthesis of fatty acids (C1) • List the sources of acetyl CoA for de novo synthesis of fatty acids (C1) • Explain the reaction catalyzed by acetyl CoA carboxylase (C1) • Mention the regulatory enzyme and the hormones involved in regulation in well-fed state and starvation (C1) • Show the schematic structure of triacylglycerol (C1) • Mention the site and subcellular site of TAG synthesis (C1)	7

Content	Competencies	No. of Hours
	• Describe the reactions of TAG synthesis (C2) • Mention the fate of TAG in liver and adipose tissue (C1) • Mention the site and subcellular site of lipolysis (C1) • Describe the reactions of lipolysis (C2) • Mention the regulatory enzymes and the hormones involved in regulation in well-fed state and starvation (C1) • Define beta-oxidation (C1) • List the site and subcellular site of beta-oxidation (C1) • Describe the activation of palmitic acid (C2) • Explain the transport of activated palmitic acid into (C2) • Mitochondria (carnitine shuttle) • Describe the reactions of beta oxidation • Calculate the energetics of beta oxidation of palmitic acid • Classify lipoproteins based on their electrophoretic mobility and ultracentrifugation properties (C2) • Mention the site of synthesis and the functions of Chylomicrons, VLDL, LDL and HDL (C2)	
Unit 5: Amino acid & protein		
	• Recognize the general structure of D and L amino acids (C1) • Classify amino acids based on the following with examples (C1) ➢ Presence in proteins (standard and non-standard amino acids) ➢ Metabolic fate (glucogenic and ketogenic amino acids) ➢ Nutritional requirement (essential and non-essential amino acids) • Classify proteins based on composition, functions and shape with examples (C1) • Describe the structure of mature collagen with diagram (C2) • Explain with illustrations the biosynthesis of mature collagen emphasizing the importance of prolyl hydroxylase, lysyl hydroxylase and lysyl oxidase (C2) • Outline the activation of zymogens in the GIT (C1) • List the endo and exopeptidases in the digestive juices (C1) • Explain transamination of amino acids with suitable examples (C2)	7

Content	Competencies	No. of Hours
	• Describe the generation of ammonia by oxidative deamination using L- glutamate dehydrogenase. (C2) • Study urea cycle as follows (C2) ➢ Name its site and subcellular site ➢ Describe its reactions ➢ Mention its significance • Recall the physiologically important products derived from the following amino acids (C2) ➢ Glycine ➢ Tyrosine ➢ Methionine ➢ Tryptophan	
Section B: Cell Biology		
Plasma Membrane, Nucleus and Mitochondria	• List theories of origin of life (C1) • Explain theories on molecular architecture of plasma membrane. Explain structure of plasma membrane and outline chemical composition of plasma membrane(C2) • Explain transport of molecules-active and passive (C2) • Explain role of ion channels in cellular transport (C2) • Illustrate cell-cell interaction (C2) • Demonstrate organization of Nucleus and chromosomes • Illustrate structure and function of nuclear Envelope and nuclear pore complex (C2) • Explain selective transport of proteins across nuclear pore (Import) (C2) • Explain selective transport of proteins across nuclear pore (Export) (C2) • Explain Internal organization of nucleus, chromosomes and chromatin structure (C2) • Explain structure and function of nucleolus (C2) • List functions of peroxisomes (C1) • Demonstrate peroxisomal assembly and biochemical characterization (C2) • Explain glyoxylate cycle (C2) • Explain Photorespiration (C2)	5

Content	Competencies	No. of Hours
Protein sorting and transport	• Define endoplasmic reticulum, golgi apparatus and lysosomes (C1) • Explain general organization of endoplasmic reticulum and targeting of proteins to endoplasmic reticulum (C2) • Explain Insertion of proteins into endoplasmic reticulum membrane (C2) • Explain Quality control in Endoplasmic reticulum (C2) • List functions of smooth endoplasmic reticulum (C1) • Explain role of Smooth endoplasmic reticulum in lipid synthesis (C2) • Demonstrate organization of Golgi apparatus (C2) • Explain protein sorting and export from Golgi apparatus (C2). Explain lysosome formation (C2)	5
Cell signaling	• List modes of cell-cell signaling (C1) • Explain G Protein-coupled receptor, receptor Protein-Tyrosine kinases and cytokine receptors organization (C2) • Enlist intracellular signal transduction pathways (C1) Explain cAMP pathway, cyclic GMP, Phospholipids, Ca^{2+} PI-3Kinase/Akt, mToR and MAP kinase pathways (C2)	5
DNA structure and DNA replication	• Enlist different types of DNA (A, B and Z DNA) (C1) • Understand DNA helix structures and function of Restriction endonucleases (C2) • Explain function of DNA ligases, topoisomerases and gyrase (C2) • Explain supercoiling of DNA • Explain semiconservative and semi-discontinuous nature of DNA synthesis (C2) • Explain structure, components and function of DNA polymerase (C2) • Explain process of DNA synthesis (C2)	5

Content	Competencies	No. of Hours
RNA synthesis & Processing	• List major types of RNA (C1) • Illustrate structure and function of RNA polymerase, its subunits and general transcription factors (C2) • Explain process of RNA synthesis and regulation (C2) • Explain RNA processing of ribosomal and transfer RNAs (C2) • Explain splicing and alternative splicing mechanisms (C2) • Explain RNA editing and degradation (C2)	5
Translation	• Enlist components of translation (C1) • Explain structure of tRNA (C2) • amino acid activation, fidelity of aminoacylt RNA synthetases (C2) • Explain the process of initiation of protein synthesis (C2) • Explain the process of elongation of peptide chain (C2) • Explain the process of termination of translation • Explain the role of stop codons (C2)	5

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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 Exam (Theory)
Quiz	End Semester Exam (Theory)
Assignments/Presentations	

Mapping of Assessment with COs:						
Nature of Assessment	**CO1**	**CO2**	**CO3**	**CO4**	**CO5**	**CO6**
Mid Semester	x	x	x	x	x	x
Unit Test/Quiz	x	x	x	x	x	x
Assignments/presentations	x	x	x	x	x	x
End Semester Exam	x	x	x	X		

Feedback Process:	End Semester Feedback
Main References:	1. Essentials of Biochemistry, U satyanarayana, U Chakrapani (2nd edition) 2. Handbook of Biochemistry for Allied & Nursing Students, Shivananda Nayak B (2nd edition) 3. Cell and Molecular Biology by de Robertis and de Robertis Llewellyn Pub 2001 4. Molecular Biology of the Cell by Alberts, Bray, Lewis, Raff, Roberts and Watson. Garland Science; 1997
Additional References:	1. The Cell — A Molecular Approach by Geoffrey M. Cooper, ASM Press Washington, DC, Oxford University Press 2000. 2. Genes IX, Benjamin Lewin, Jones and Bartlett; 2008 3. Molecular Cell Biology by Darnell, Lodish, Baltimore, Scientific American Books 1990.

Name of the Program	**Bachelors of Science in Nuclear Medicine Technology**
Course Title	**Human Anatomy & Physiology for Nuclear Medicine**
Course Code	**BNM1102**
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):

At the end of the course student shall be able to:

CO1	Explain the General Anatomy of the human body (C2)
CO2	Explain the anatomy and physiology of respiratory, cardiovascular and digestive system (C2)
CO3	Explain the anatomy and physiology of renal and reproductive system (C2)
CO4	Explain the anatomy and physiology of endocrine, central nervous system and special senses (C2)

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						

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Course Content and Outcomes

Content	Competencies	No. 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

Content	Competencies	No. of Hours (Theory):
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) • List the differences between small intestine and large 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)	5
Unit 5: Renal system		

Content	Competencies	No. of Hours (Theory):
	• 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) • 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)	2

Content	Competencies	No. of Hours (Theory):
	• 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	

Content	Competencies	No. of Hours (Theory):
	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)	
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)	
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	

Content	Competencies	No. of Hours (Theory):
	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)	
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)	
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)	

Content	Competencies	No. of Hours (Theory):
	• Describe the composition and function of Gall bladder(C1) • Describe the composition and function of Succus entericus (C1) • Describe the composition and function of large intestine, Movements of small intestines(C2) • Describe Deglutition(C1)	
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)	
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 &	

Content	Competencies	No. of Hours (Theory):
	functions. (C2) • EEG – Definition and uses (C1) • What is Autonomic nervous system: Organization & functions (C2) • What is Cerebrospinal fluid: Composition and function (C2)	
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)	
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)	
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	

Content	Competencies	No. of Hours (Theory):
	(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)	

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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**
Assignments/Presentations	**x**	**x**	**x**	**X**
End Semester Exam	**x**	**x**	**x**	**X**

Feedback Process:	**End-Semester Feedback**
Main Reference:	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

Name of the Program	**Bachelors of Science in Nuclear Medicine Technology**
Course Title	**Solid state physics and electronics in Nuclear Medicine**
Course Code	**BNM1103**
Academic Year	**First Year**
Semester	**I**
Number of Credits	**4**
Course Prerequisite	Students should have knowledge of basic physics at secondary school level.
Course Synopsis	Upon successful completion of this course, students will gain a strong conceptual understanding of the physical behaviour of solid-state materials and optical systems. They will develop the ability to relate crystal structure and band theory to electronic and optical properties critical for the design and operation of detectors and imaging instruments in nuclear medicine. Emphasis will also be placed on the application of magnetism, dielectric behaviour, and laser technology in the clinical and research settings of medical imaging.

Course Outcomes (COs): At the end of the course student shall be able to:

CO1	To understand and apply the concepts of crystal lattice structure in scintillation materials used in Nuclear Medicine (C4)
CO2	To understand and apply the concepts of electric, magnetic and dielectric properties of materials in nuclear Medicine instrumentation devices (C4)
CO3	To understand and apply electronic components in Nuclear Medicine instrumentation devices (C4)
CO4	To understand the working and application of amplifiers, rectifiers, power supplies, electronic filters, coincidence, anti-coincidence circuits, pulse height analysers, timing discriminators and gating circuits in Nuclear Medicine instrumentation devices (C4)
CO5	To understand the Boolean algebra and logic gates and their application in Nuclear Medicine instrumentation devices (C4)

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

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

Course Content and Outcomes:

Content	Competencies	Number of Hours
Unit 1: Solid State Physics in Nuclear Medicine		
Crystal structure	• Classify solids into crystalline and amorphous, and explain isotropy vs. anisotropy (C2) • Define lattice points, unit cells, and crystal systems; describe lattice parameters (C2) • Identify and describe Bravais lattices in 2D and 3D and types of cubic lattices (simple, BCC, FCC) (C2) • Describe types of crystal bonding: ionic, covalent, metallic, and molecular (van der Waals) (C2) • Identify crystal defects: point defects (vacancy, interstitial, substitutional), dislocations, and surface defects (C1) • Analyze effects of defects on electrical and optical (scintillation, etc.) properties of materials (C4) • Explain the properties and applications of scintillator crystals (NaI (Tl), BGO, LSO, etc.) in Nuclear Medicine (C2) • Describe structural features, role of activators, and their influence on energy resolution in scintillator crystals (C4)	**8**
Electronic Properties of Solids	• Describe the free electron model and discuss its limitations (C2) • Explain the formation of energy bands in solids and the band theory of solids (C2) • Classify materials based on band structure: conductors, semiconductors, and insulators (C2) • Describe intrinsic semiconductors, carrier generation, energy gap, and conductivity (C2) • Explain extrinsic semiconductors, including n-type and p-type doping, donor and acceptor levels (C2) • Define Fermi energy and the Fermi-Dirac distribution; explain temperature dependence (C2) • Explain carrier mobility, diffusion, drift current, and recombination processes (C2) • Describe the p-n junction diode structure and operation (C2)	**15**

Content	Competencies	Number of Hours
	• Explain the Hall effect, derive the Hall coefficient, and discuss applications (C3) • Discuss applications of semiconductors in Nuclear Medicine: CZT and Si photodiodes in radiation detection, semiconductor-based gamma cameras (C3)	
Magnetic and Dielectric Properties of Materials	• Define origin of magnetic moment and Bohr magneton (C1) • Explain the concept of magnetic moment and its quantum origin (C2) • Classify magnetic materials: diamagnetic, paramagnetic, ferromagnetic, antiferromagnetic, ferrimagnetic (C2) • Describe magnetization curves including hysteresis loop, coercivity, retentivity, and magnetic energy loss (C2) • Analyze the features of magnetization curves related to magnetic properties (C4) • Explain magnetic susceptibility and permeability and their temperature dependence according to Curie and Curie-Weiss laws (C2) • Describe polarization mechanisms in dielectric materials: electronic, ionic, dipolar, and space charge polarization (C2) • Explain dielectric constant and loss, dielectric strength, energy storage, and breakdown phenomena (C2) • Discuss frequency dependence of dielectric properties and dielectric hysteresis (C2) • Apply knowledge of magnetic properties of materials in shielding used in PET/MR (C4) • Apply knowledge electrical properties of materials to design a dielectric for high-voltage isolation (C4) • Analyze the role of magnetic and dielectric materials in these applications (C4)	**8**

Content	Competencies	Number of Hours
Unit 2: Devices and Electronics		
Components of electrical circuits used in Nuclear Medicine devices	• Define resistors, capacitors, inductors, and transformers, and explain their basic properties and circuit behavior (C2) • State and apply Ohm's Law for current, voltage, and resistance relationships in circuits (C3) • Explain Kirchhoff's Current Law (KCL) and Kirchhoff's Voltage Law (KVL) and apply them in circuit analysis (C3) • Describe the variation of resistivity with temperature (C2) • Interpret and analyze the I-V characteristics of diodes (C4) • Describe Zener diode functions and applications (C2) • Explain the behavior and characteristics of Bipolar Junction Transistors (BJT) in Common Base (CB), Common Emitter (CE), and Common Collector (CC) modes (C2)	**8**
Amplifiers, Rectifiers and Power Supplies	• Describe types of amplifiers, gain concept, and applications (C2) • Explain the common emitter amplifier (C2) • Explain single-stage and two-stage coupled amplifiers and their operation (C2) • Describe operational amplifier characteristics and configurations: inverting, non-inverting, and comparator (C2) • Explain rectifiers: half-wave, full-wave, bridge rectifiers; define ripple factor and filters used for smoothing (C2) • Classify transducers types and explain their use in Nuclear Medicine (e.g., dose monitors, pressure sensors) (C2) • Describe LEDs and CRTs as display components and indication systems (C2) • Classify power supplies: linear, switching types; explain voltage stabilizers, regulators, SMPS, and inverters (C2)	**8**

Content	Competencies	Number of Hours
	• Describe pulse shaping methods including Gaussian shaping and CR-RC networks and their role in resolution enhancement (C2) • Apply knowledge of voltage regulation and signal processing in Nuclear Medicine imaging systems (C3)	
Electronic filters and circuits in Nuclear Medicine devices	• Define low-pass, high-pass, and band-pass filters and explain their applications in signal conditioning (C2) • Explain timing discriminators and gating circuits and their functions in signal processing (C2) • Apply event selection and noise reduction techniques in Nuclear Medicine instrumentation (C3)	**6**
Unit 3: Boolean Algebra		
Binary system and Truth tables	• Define the binary number system and explain its base-2 structure (C2) • Convert numbers from one number system to another, including binary to decimal and vice versa (C3) • Perform binary addition and subtraction operations (C3) • Define logic gates: AND, OR, NOT, NAND, NOR, XOR (C1) • Construct truth tables for individual logic gates (C2) • Combine multiple logic gates to create logical circuits (C3) • Apply De Morgan's theorem to simplify logical expressions and circuits (C4) • Explain the working of ADCs and DACs in signal conversion for digital instrumentation (C2) • List applications of digital circuits and signal processing in Nuclear Medicine (C1) •	**7**

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					
Mapping of Assessment with COs:					
Nature of Assessment	**CO1**	**CO2**	**CO3**	**CO4**	**CO5**
Mid Semester	**X**	**X**			
Unit Test/Quiz	**X**	**X**	**X**	**X**	**X**
Assignments	**X**	**X**	**X**	**X**	**X**
End Semester Exam	**X**	**X**	**X**	**X**	**X**
Feedback Process:	End-Semester Feedback				
Main Reference:	• Solid State Physics Charles Kittel, "Introduction to Solid State Physics" Wiley India UG/PG, resear • Devices & Electronics Streetman & Banerjee, "Solid State Electronic Devices" • Devices (Fundamentals) Nair & Somanathan, "Solid State Devices" Applied Electronics R.S. Sedha, "A Textbook of Applied				
Additional References	• Solid State Physics S.L. Kakani & C. Hemrajani, "Solid State Physics" Sultan Chand & Sons				

Name of the Program	**Bachelors of Science in Nuclear Medicine Technology**
Course Title	**Fundamentals of chemistry**
Course Code	**BNM1104**
Academic Year	**First Year**
Semester	**I**
Number of Credits	**3**
Course Prerequisite	Students should have the knowledge of basic chemistry at higher secondary level.
Course Synopsis	This course introduces fundamental principles of chemistry, including atomic structure, chemical bonding, thermodynamics, and chemical kinetics. It provides a foundational understanding of the periodic table, molecular shapes, and basic organic chemistry concepts such as electronic and steric effects, stereochemistry, and reaction mechanisms.

Course Outcomes (COs): At the end of the course student shall be able to:	
CO1	Understand the basic concepts of Chemistry and atomic structure (C3).
CO2	Explain the fundamental principles of basic kinetics and thermodynamics (C2).
CO3	Analyze periodic table and periodicity (C4).
CO4	Describe chemical bonding theories/laws and organic chemistry principles (C3).

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

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

Course Content and Outcomes:

Content	Competencies	Number of Hours
Unit 1: Introduction to Chemistry and Atomic Theory		
	• Define fundamental terms like atom, molecule, element, compound, and the laws of chemical combination (C1). • Explain the concepts of mole, molar mass, and percentage composition (C2). • Solve problems to calculate empirical and molecular formulae and stoichiometry (C3). • Write electronic configurations for various elements and ions using the Aufbau principle, Pauli exclusion principle, and Hund's rule (C3).	**8**
Unit 2: Chemical kinetics and thermodynamics		
	• Explain the basic laws of thermodynamics, reaction rates, and equilibrium concepts (C2). • Describe the physical properties of matter, including surface tension, viscosity, and vapor pressure (C2).	**5**
Unit 3: Periodic table and periodicity		
	• Describe the periodic classification of elements (C2). • Compare and contrast periodic trends such as atomic and ionic radii, ionization enthalpy, electron affinity, and electronegativity (C4). • Explain how effective nuclear charge influences these periodic trends (C4).	**8**
Unit 4: Chemical bonding, hybridization & molecular orbital theory		
	• Explain the basic principles of chemical bonding, including Valence Bond Theory and the types of bonds (ionic, covalent) (C2). • Draw Lewis structures for simple molecules (C3). • Determine the molecular geometry of compounds using VSEPR theory and hybridization concepts (C3). • State the laws of chemical combination (conservation of mass, definite and multiple proportions) (C1).	**10**

Content	Competencies	Number of Hours
Unit 5: Basic chemical laws and introduction to organic chemistry		
	• Explain fundamental concepts of organic chemistry, including electronic effects (resonance, inductive, hyper conjugation) and steric effects (C2). • Use electronic and steric effects to explain the acid/base properties of organic compounds (C3). • Describe the principles of optical isomerism and stereocenters (C2). • Predict the conformations of acyclic and cyclic systems, such as substituted ethane's and cyclohexenes (C3).	**11**

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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/Presentations	

Mapping of Assessment with COs:						
Nature of Assessment	**CO1**	**CO2**	**CO3**	**CO4**		
Mid Semester	**X**	**X**				
Unit Test/Quiz	**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 Reference:	1. Lee, J.D. Concise Inorganic Chemistry ELBS, 1991. 2. Douglas, B.E. and McDaniel, D.H. Concepts & Models of Inorganic Chemistry Oxford, 1970 3. Atkins, P.W. & Paula, J. Physical Chemistry, 10th Ed., Oxford University Press, 2014. 4. Day, M.C. and Selbin, J. Theoretical Inorganic Chemistry, ACS Publications, 1962. 5. Rodger, G.E. Inorganic and Solid State Chemistry, Cengage Learning India Edition, 2002 6. Cotton, F.A., Wilkinson, G. &Gaus, P.L. Basic Inorganic Chemistry, 3rd ed., Wiley. 7. Huheey, J.E., Keiter, E.A., Keiter, R.L. &Medhi, O.K. Inorganic Chemistry: Principles of Structure and Reactivity, Pearson Education India, 2006. 8. Graham Solomon, T.W., Fryhle, C.B. &Dnyder, S.A. Organic Chemistry, John Wiley & 9. Sons (2014). 10. McMurry, J.E. Fundamentals of Organic Chemistry, 7th Ed. Cengage Learning India 11. Edition, 2013.

Learning Strategies, Contact Hours and Out of Class Engagement	
	12. Sykes, P. A Guidebook to Mechanism in Organic Chemistry, Orient Longman, New Delhi 13. (1988). 14. Eliel, E.L. Stereochemistry of Carbon Compounds, Tata McGraw Hill education, 2000. 15. Finar, I.L. Organic Chemistry (Vol. I & II), E.L.B.S. 16. Morrison, R.T. & Boyd, R.N. Organic Chemistry, Pearson, 2010.

Name of the Program					**Bachelors of Science in Nuclear Medicine Technology**			
Course Title					**Mathematics in Nuclear medicine**			
Course Code					**BNM1105**			
Academic Year					**First Year**			
Semester					**I**			
Number of Credits					**3**			
Course Prerequisite					Students should have knowledge in the fundamentals of mathematics at secondary school level.			
Course Synopsis					The course is designed to strengthen the concepts of mathematics required for the application in nuclear medicine.			
Course Outcomes (COs): At the end of the course, the student shall be able to:								
CO1	To understand and apply vector analysis, matrices, trigonometric functions, and limits and derivatives (C3)							
CO2	To understand and apply Integration and differentiation (C3)							
CO3	To understand and apply mathematics in radio pharmacy and health physics, Compartment Analysis, Tracer Kinetics (C4)							
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**				**X**	**X**	

Course Content and Outcomes:

Content	Competencies	Number of Hours
Unit 1: Basic mathematical concepts		
Vector analysis	• Recall the definitions of vector addition, dot product, cross product, gradient, divergence, and curl (C1) • Describe the geometric and physical meaning of curl and divergence (C2) • Solve problems involving derivatives and integrals of vector functions (C3) • Distinguish between conservative and non-conservative vector fields (C4)	**3**
Matrices	• List the rules for matrix addition, subtraction, scalar multiplication, and matrix multiplication (C1) • Explain how matrix multiplication can represent data organization (C2) • Perform operations on matrices and apply them to image or data matrices (C3) • Examine the structure and transformation of a matrix representing image data (C4) • State the definitions of eigenvalues and eigenvectors (C1) • Describe the significance of eigenvalues and eigenvectors in linear systems (C2) • Compute eigenvalues and eigenvectors for given matrices (C3) • Compare eigenvalues of different matrices and analyze their implications (C4) • State the properties and definitions of matrices and determinants (C1) • Summarize the geometric meaning of determinants (C2) • Solve for determinants and use matrices to solve linear systems (C3) • Break down the concepts of invertibility and rank of matrices (C4) • Recall the forms and properties of complex numbers (C1)	**6**

Content	Competencies	Number of Hours
	• Explain the effect of complex multiplication on rotation and scaling (C2) • Solve equations and perform arithmetic operations with complex numbers (C3) • Compare polar and rectangular representations (C4)	
Trigonometry & Functions and Application in Nuclear Medicine	• Define trigonometry, angles, allied angles, and inverse functions (C1) • Explain the foundational concepts of trigonometry and angle types (C2) • Apply trigonometric identities and functions to solve problems (C3) • Analyze how allied angles and inverse functions modify solutions (C4) • Apply the use of trigonometry and its functions to real-world or mathematical problems (C3) • Analyze problem statements to select appropriate trigonometric approaches (C4) • Recall principles of graphical representation in nuclear medicine (C1) • Describe common types of medical and nuclear imaging graphs (C2) • Use graphical data to extract or demonstrate clinical information (C3) • Analyze features of nuclear medicine graphs for diagnostic interpretation (C4) • Define polynomial functions and identify basic properties (C1) • Describe characteristics of exponential functions (C2) • Apply polynomial and exponential models to physical or data-based scenarios (C3) • Analyze graphs and behavior of polynomial vs. exponential functions (C4) • Explain the growth and decay models using exponential and logarithmic functions (C2) • Apply exponential and logarithmic equations to solve real-world problems (C3)	**8**

Content	Competencies	Number of Hours
Limits & Derivatives	• Define limit and state its relevance in calculus (C1) • Explain derivative (C2) • Apply differentiation to standard functions (C3) • Analyze the use of derivatives to find rate of change in standard functions (C4) • State the fundamental rules of differentiation (C1) • Explain how rules of differentiation are used (C2) • Apply differentiation rules to composite functions (C3) • Analyze the structure of composite functions and their derivatives (C4) • Apply differentiation techniques to implicit functions (C3) • Analyze how to extract dy/dx from implicit relationships between variables (C4) • Apply differentiation techniques to logarithmic functions (C3) • Analyze the results of differentiating logarithmic functions (C4) • Explain successive differentiation (C2) • Apply successive differentiation to various functions (C3) • Analyze patterns and results in higher derivatives (C4) •	**8**
Unit 2: Advanced mathematical concepts		
Integration	• Define integration and explain an indefinite integral (C1) • Describe the concept and purpose of the indefinite integral (C2) • Explain the method of integration by substitution (C2) • Apply integration by substitution to solve integrals (C3) • Analyze when and how substitution simplifies integration problems (C4) • Explain the method of integration by partial fractions (C2)	**8**

Content	Competencies	Number of Hours
	• Apply partial fraction decomposition to integrate rational functions (C3) • Analyze the structure of rational functions to perform partial fraction integration (C4) • Describe the integration by parts method (C2) • Apply integration by parts to solve integrals (C3) • Analyze the parts of an integral to decide suitable functions for integration by parts (C4) • State and explain properties of definite integrals (C2)	
Differential Equations and its application in Nuclear Medicine	• Define differential equations and their significance (C1) • Explain the basic concepts behind differential equations (C2) • Solve given ordinary differential equations (C3) • Analyze solution methods for differential equations (C4) • Construct differential equations from physical or mathematical problems (C3) • Analyze and solve constructed differential equations in context (C4) • Derive the attenuation coefficient equation for materials (C3) • Analyze the physical meaning and implications of the attenuation coefficient (C4) • Derive the exponential decay equation for radioactive activity (C3) • Justify the exponential decay model for activity decaying processes (C4)	**6**
Application of mathematics in radiopharmacy and health physics	• Derive the Bateman equation and analyze its application in radioactivity calculations (C4) • Define unit conversion and explain specific concentration of activity (C2) • Solve problems related to radiation exposure rate (C3) • Analyze radiation exposure in different scenarios (C4)	**6**

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	**X**	**X**	
Quiz/Unit test	**X**	**X**	**X**
Assignments/Presentations	**X**	**X**	**X**
End Semester Exam	**X**	**X**	**X**
Feedback Process:	Mid-Semester Feedback		
	End-Semester Feedback		
Main Reference:	1. Mathematical Methods in the Physical Sciences – Mary L. Boas 2. Physics in Nuclear Medicine – Simon Cherry, James Sorenson, Michael Phelps 3. Basic Physics in Nuclear Medicine – Gopal B. Saha 4. Additional References: 5. Introduction to Mathematical Physics – Charlie Harper 6. Introduction to Probability and Statistics – Mendenhall & Beaver 7. Practical Statistics for Medical Research – Douglas G. Altman 8. Physics in Nuclear Medicine- Sorenson 9. Quality control of Nuclear Medicine instruments Tecdoc-602 10. Radiation Detection and Measurement- Knoll G.F		

Learning Strategies, Contact Hours and Out of Class Engagement	
Additional References	1. Mosby's Manual of Nuclear Medicine Procedures D.Brucee Sodes, Paul J Early 2. Nuclear Medicine-Robert E. Henkin, Mark A. Boles 3. Computers in Nuclear Medicine-Lee Kai Hi

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Course Title	Practicum – I
Course Code	BNM1106
Academic Year	First
Semester	I
Number of Credits	2
Course Prerequisite	Basic knowledge of physics and chemistry at higher secondary level
Course Synopsis	This module provides practical insights of solid-state physics and electronics, radiation physics and basic chemistry.

Course Outcomes (COs):

At the end of the course, the student shall be able to:

CO1	To perform and analyze the experiments in electronics and solid-state physics to verify the theoretic principles (C3,P3)
CO2	To identify the components and demonstrate the basic operation of gamma ray spectrometer and Geiger-muller counter (C2,P1)
CO3	To perform chemistry experiments following standard procedures, handling reagents and apparatus safely, and recording observations accurately to verify fundamental chemical principles (C2,P3)

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

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

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Content	Competencies	Number of Hours
Unit 1: Solid state physics and electronics		
Fundamentals of Solid-state physics and Electronics	• To demonstrate the working of a digital multimeter and measure resistances of given resistors and compare with color coding values (C2,P3) • To measure capacitance of given set of capacitors using digital multimeter and compare with calibrated values (C2,P3) • To test diodes using digital multimeter (C2,P2) • To measure voltage output from a given source using digital multimeter and find error in the measured values (C2,P3) • To measure voltage and frequency of a given signal using digital oscilloscope (C2,P2) • To demonstrate the operation of low pass and high pass filter using oscilloscope (C2,P2) • Determination of reverse saturation current and material constant of PN junction also determine energy band gap • Determine the energy gap of a semiconductor using experimental measurements and analyze its (C3,P3) significance	24
Unit 2: Radiation Physics		
Radiation physics Practical	• To demonstrate functioning of various parts of a gamma ray spectrometer (C2,P1) • To observe the gamma ray energy spectrum of Cs-137, Ba-133, Co-57, Co-60, etc, radioisotopes and identify various types of processes (C2,P1) • To demonstrate working of a NaI (Tl) detector and observe its output on an oscilloscope (C2,P1) • To determine the half value layer of lead, copper, aluminum etc. for Ba- 133 (C2,P2) • To determine the half value layer of lead, copper, aluminum etc. for Cs- 137 (C2, P2) • To determine the half value layer of lead, copper, aluminum etc. for Tc- 99m (C2,P2)	18

Content	Competencies	Number of Hours
Unit 3: Fundamentals of chemistry		
Chemistry practical	• To demonstrate the use of apparatus (weighing balance, pipettes, pH meter etc.) (C3, P2) • To estimate the amount of carbonate and hydroxide/bicarbonate present together in mixture (C3, P3) • To conduct the pH metric titration of (i) strong acid vs. strong base, (ii) weak acid vs. strong base (iii) weak acid-weak base (iv)Strong acid-weak base (C3, P2) • Determination of dissociation constant of a weak acid (C3, P2) • Estimation of sodium carbonate and sodium hydrogen carbonate present in a mixture (C3, P3) • Estimation of water of crystallization in Mohr's salt by titrating with KMnO4 (C3, P3) • Identification of Cations and anions by qualitative analysis (chemical confirmatory tests) (C2, P3)	18

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Learning Strategies, Contact Hours and Out of class engagement:		
Learning Strategies	**Contact Hours**	**Out of class engagement**
Practical	54	54
Small group discussion	06	6
Total	**60**	**60**

Assessment Methods:	
Formative:	**Summative:**
Unit Test	Mid Semester/Sessional Exam (Practical)
Quiz	End Semester Exam (Practical)
Viva	Viva
Practical Logbook/Record Book	Record Book

Mapping of Assessment with COs:			
Nature of Assessment	**CO1**	**CO2**	**CO3**
Mid Semester	X	X	X
Quiz /Viva/ Unit Test	X	X	X
Clinical/Practical Logbook/ Record Book	X	X	X
End Semester Exam			

Feedback Process:	**Mid-Semester Feedback**
	End-Semester Feedback
Main Reference:	1. Practical electronics handbook by Ian Sinclari 2. Practical Physics vol-3 by Dr Vinod Goel 3. Solid State Physics by Kakani SL and Hemarajini 4. Principle Medical Electronics and Biomedical Instrumentation by R.C Rajan, Guha S K 5. Physics in Nuclear Medicine by Sorenson 6. Quality control of Nuclear Medicine instruments by Tecdoc 602 7. Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson, 2009. 8. Khosla, B. D.; Garg, V. C. & Gulati, A. Senior Practical Physical Chemistry, R. Chand & Co.: New Delhi (2011). 9. Garland, C. W.; Nibler, J. W. & Shoemaker, D. P. Experiments in Physical Chemistry 8th Ed.; McGraw-Hill: New York (2003). 10. Ogel, A.I., Tatchell, A.R., Furnis, B.S., Hannaford, A.J. & Smith, P.W.G., Text book of Practical Organic Chemistry, Prentice-Hall, 5th edition, 1996.

Learning Strategies, Contact Hours and Out of class engagement:	
Additional References	1. Radiation Detection and Measurement- Knoll G. F. 2. Introductory Nuclear Physics- Krane K. S. 3. Mann, F.G. & Saunders, B.C. Practical Organic Chemistry Orient-Longman, 1960. 4. Halpern, A. M. &McBane, G. C. Experimental Physical Chemistry 3rd Ed.; W.H. Freeman & Co.: New York (2003).

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SEMESTER - II

Course code	Course Title
BNM1201	Introduction to nuclear medicine, medical ethics and patient care
BNM1202	Applied Chemistry: Organic chemistry & Inorganic chemistry for nuclear medicine
BNM1203	Radiation physics
BNM1204	Fundamentals of Electromagnetism in Nuclear Medicine
BNM1205	Practicum – II
BNM1206	Clinical Practice – I

Name of the Program	**Bachelors of Science in Nuclear Medicine Technology**
Course Title	**Introduction to Nuclear Medicine, Medical ethics and Patient care**
Course Code	**BNM1201**
Academic Year	First
Semester	II
Number of Credits	3
Course Prerequisite	Basic knowledge of medical terminology
Course Synopsis	This module provides an introduction to Nuclear Medicine, ethical practices and patient care. It will familiarize students with hospital organization and functioning, use of drugs, and equipment in nuclear medicine

Course Outcomes (COs):

At the end of the course student shall be able to:

CO1	Understand the working of Nuclear Medicine facility (C2)
CO2	Understand principles of Medical and bioethics in handling patients (C2)
CO3	Understand the Indian Legal system, medico legal records, human rights act, disaster management, Human Organ Transplantation Act, mental Health act, professional indemnity insurance policy and IPR (C2)
CO4	Understand the different hospital procedures for patient safety and principle of care of patients (C 2)
CO5	Understand application of different drugs available in the department of nuclear medicine and equipment in nuclear medicine laboratory (C 2)

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**				
CO5		**x**	**x**		**x**			

Course Content and Outcomes:

Content	Competencies	Number of Hours
Unit 1		
Fundamentals of Nuclear Medicine and Imaging	• Define and understand diagnostic and therapeutic roles and application of nuclear medicine in disease detection (C2) • Define the basic terminologies of radiopharmacy (e.g. tracer uptake, dose etc.) (C2) • Explain the administration routes of dosing in nuclear medicine (C2) • Explain the properties of common agents used in nuclear medicine like Tc-99m, I-131, F-18 FDG and its applications in clinical protocols (C2) • Explain the working of diagnostic nuclear medicine facility (C2) • Explain the working of therapeutic nuclear medicine facility (C2)	4
Unit 2		
Medical Terminology basics	• List the basic medical terminology, abbreviation and symbols and their application in documentation (C1) • List the basic anatomical terminology, abbreviation and symbols and their application in documentation (C1) • List the basic pathological and diagnostic terminology, abbreviation and symbols and their application in documentation (C1) • List the basic pharmacological terminology, abbreviation and symbols and their application in documentation (C1) • List the basic clinical procedure terminology, abbreviation and symbols and their application in documentation (C1)	4
Unit 3		
Medical ethics	• Outline historical overview of bioethics (C2) • Define goal, scope, prayer, oath, covenants, declarations • Explain guidelines and basic principles of medical ethics (C2)	3

Content	Competencies	Number of Hours
Organizational Ethics	• Explain Malpractice and negligence - Rational and irrational drug therapy(C2) • Explain the risk benefit analysis, compensation, care of terminally ill patient and euthanasia (C2) • What is an informed consent? (C1) • Explain autonomy and informed consent - Right of patients (C2) • Explain Professional Indemnity insurance policy and development of standardized protocol to avoid near miss or sentinel events (C2)	6
Hospital organization and procedure	• Explain the hospital organization (C2) • Explain organization and functioning of nuclear medicine unit/department(C2) • Explain maintenance of hospital records and stocks (C3) • Explain importance of professional attitude towards patients and other members of the staff (C3) • List do's and don'ts for patient safety during various clinical/diagnostic procedures (C1)	8
Care of the patient	• Demonstrate patient care in Diagnostic Nuclear Medicine (C2) • Demonstrate patient care in Therapeutic Nuclear Medicine (C2) • Explain patient care and safety at both organization and department level (C2)	6
Unit 4		
Medico legal aspects of medical records	• What are patient rights and privacy laws (C1) • What is Medico legal case and type- Records and document related to MLC - ownership of medical records? (C1) • Explain the confidentiality privilege communication (C2) • Explain release of medical information - Unauthorized disclosure and retention of medical records - other various aspects (C2) • Understand healthcare facility regulations (C2) • Understand Radiation safety regulations and its applications in nuclear medicine (C2) • Understand professional standards and conduct (C2)	4

Content	Competencies	Number of Hours
Unit 5		
Drugs in the department	• Understand the application of different drugs in nuclear medicine (C2) • List the emergency drugs in nuclear medicine (C1)	3
Acquaintance of equipment	• Define and explain the principles of the various radiation/non-radiation equipment/devices available in Nuclear Medicine department (C2) • Explain the setting of trays, trolleys and emergency instruments in the Nuclear Medicine patient handling area (C2) • Explain the methods of sterilization and use of CSSD (C2)	7

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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
Quiz	End Semester Exam
Assignments/Presentations	

Mapping of Assessment with COs:						
Nature of Assessment	**CO1**	**CO2**	**CO3**	**CO4**	**CO5**	
Mid Semester	x	x	x			
Quiz /Unit Test	x	x	x	X	x	
Assignments/Presentations	x	x	x	X	x	
End Semester Exam	x	x	x	X	x	

Feedback Process:	**Mid-Semester Feedback**
	End-Semester Feedback
Main Reference:	1. Hazel Biggs-Healthcare Research Ethics and Law. Regulation, Review &Responsibility. (2010). Cavendish Biomedical Law & Ethics Library 2. Care of patient in diagnostic Radiography By: Chesney & Chesney. 3. Chesney's Care of the patient in Diagnostic Radiography By: Pauline J Culmer. 4. Aid to Tray and Trolley Setting By: Marjorie Hougton 5. Medical Terminology for Health Professions – Ann Ehrlich, Carol L. Schroeder, Cengage Learning; detailed guide to medical language and communication.
Additional References	Bonnie F. Fremgen – Medical Law and Ethics, Pearson Education

Name of the Program	**Bachelors of Science in Nuclear Medicine Technology**
Course Title	**Applied Chemistry: Organic chemistry & Inorganic chemistry for nuclear medicine**
Course Code	**BNM1202**
Academic Year	**First Year**
Semester	**II**
Number of Credits	**4**
Course Prerequisite	Students should have the knowledge of basic chemistry at higher secondary level.
Course Synopsis	This course integrates key concepts of organic and inorganic chemistry relevant to nuclear medicine. It covers organic reaction mechanisms, spectroscopic analysis, natural products, aromatic and heterocyclic systems, along with bonding theories, coordination chemistry, and analytical techniques. Emphasis is placed on understanding the chemical basis of radiopharmaceutical synthesis and analysis.

Course Outcomes (COs): At the end of the course student shall be able to:

CO1	Analyse the mechanisms of various organic reactions and their synthetic applications in the development of radiopharmaceutical intermediates (C4)
CO2	Analyse spectroscopic and qualitative test results to deduce the structure and functional groups of organic molecules relevant to nuclear medicine (C4)
CO3	Understand the types, structures, synthesis, and chemical significance of natural products and organometallic compounds used in diagnostic and therapeutic chemistry (C2)
CO4	Interpret the principles of inorganic, coordination, and analytical chemistry—including bonding, periodicity, extraction, and titrimetric methods—applied to nuclear medicine (C3)

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

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

Course Content and Outcomes:

Content	Competencies	Number of Hours
Section A: Organic Chemistry for Nuclear Medicine		
Unit 1:		
Organic reaction mechanism and synthetic applications	• Compare and contrast the mechanisms of different rearrangement reactions (e.g., Pinacol-pinacolone vs. Favorskii) (C4) • Use organometallic reagents (e.g., Grignard, organolithium) to perform specific transformations in organic synthesis (C3). • Solve structural problems by using a series of chemical reactions to identify an unknown compound (C3).	**05**
Unit 2:		
Qualitative organic analysis	• Explain chemical tests to identify common functional groups in organic molecules (C2). • Interpret basic UV, IR, and 1H NMR spectra to determine the structure of a simple organic molecule (C4).	**03**
Unit 3:		
Natural products chemistry	• Describe the fundamental structures and classifications of major natural products, including alkaloids, steroids, carbohydrates, amino acids, and nucleic acids (C2) • Describe the chemical properties and synthetic applications of different classes of natural products (C2)	**06**
Unit 4:		
Aromatic and heterocyclic chemistry	• Describe the concept of aromaticity and the properties of aromatic and heterocyclic compounds (C2) • Predict the products of electrophilic and nucleophilic aromatic substitution reactions (C3)	**05**

Content	Competencies	Number of Hours
Section B: Inorganic Chemistry for Nuclear Medicine		
Unit 5:		
Classification of elements and periodicity in properties	• Explain the organization of the periodic table and the principles of periodicity and Aufbau's principle (C2). • Compare and contrast the trends of atomic, covalent, and ionic radii, ionization enthalpy, electron gain enthalpy, and electronegativity across periods and down groups (C4). • Explain the influence of effective nuclear charge on these periodic properties (C4). • Describe the electronic configurations of diatomic molecules of first and second-row elements (C2).	**06**
Unit 6:		
Extractions of metals & chemical bonding and shapes of molecules	• Describe the general methods for isolating and purifying metals in d-block elements (Technetium, Gallium, Gold, Silver, and Copper etc.) (C2). • Explain the principles and applications of the Ellingham diagram in metallurgy (C2). • Explain the principles of ionic and covalent bonding, including concepts like the Born-Haber cycle, Fajan's rules, and Valence Bond Theory (C2). • Use the Born-Lande equation and Kapustinskii expression to calculate lattice energy (C3).	**05**
Unit 7:		
Main group elements (s and p blocks)	• Explain the reactions of alkali and alkaline earth metals with oxygen, hydrogen, and water (C2). • Understand the properties of main group elements within a group, including the concept of the inert pair effect (C2). • Describe the synthesis, structure, and properties of important compounds like diborane, ammonia, and silane (C2). • Explain the synthesis and reactions of oxoacids and halides of various elements (C2)	**05**

Content	Competencies	Number of Hours
Unit 8:		
Transition metals (d block)	• Describe the general characteristics of d-block elements (C2). • Explain the structure, isomerism, and electronic spectra of coordination complexes using theoretical approaches like VB, MO, and Crystal Field Theory (C2). • Understand the structure, color, and magnetic properties of metal complexes using different theoretical models (C2). • Describe the structure and bonding in organometallic compounds like metal carbonyls and metallocenes (C2). • Explain the mechanism of homogeneous catalysis using Wilkinson's catalyst (C2).	**06**
UNIT 9:		
Analytical chemistry	• Explain the fundamental principles of qualitative and quantitative analysis (C2). • Understand the various titrations, including acid-base, oxidation-reduction, and complex metric titrations (C2). • Describe the use and types of indicators in chemical analysis (C2).	**04**

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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/presentations	

Mapping of Assessment with COs:						
Nature of Assessment	**CO1**	**CO2**	**CO3**	**CO4**	**CO5**	**CO6**
Mid Semester / Sessional Examination 1	**X**	**X**		**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 Reference:	• Graham Solomon, T.W., Fryhle, C.B. &Dnyder, S.A. Organic Chemistry, John Wiley & • Sons (2014). • McMurry, J.E. Fundamentals of Organic Chemistry, 7th Ed. Cengage Learning India • Edition, 2013. • Sykes, P. A Guidebook to Mechanism in Organic Chemistry, Orient Longman, New Delhi • (1988). • Eliel, E.L. Stereochemistry of Carbon Compounds, Tata McGraw Hill education, 2000. • Finar, I.L. Organic Chemistry (Vol. I & II), E.L.B.S. • Morrison, R.T. & Boyd, R.N. Organic Chemistry, Pearson, 2010 • Morrison, R. N. & Boyd, R. N., Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education). • Shriver, D. E. & Atkins, P. W., Inorganic Chemistry, Oxford University Press, 5th Edition.

Learning Strategies, Contact Hours and Out of Class Engagement	
	• Huheey, J. E., Keiter, E. A., & Keiter, R. L., Inorganic Chemistry – Principles of Structure and Reactivity, Pearson Education, 4th Edition, 2002. Day, M.C. and Selbin, J. Theoretical Inorganic Chemistry, ACS Publications, 1962. • Rodger, G.E. Inorganic and Solid State Chemistry, Cengage Learning India Edition, 2002 • Cotton, F.A., Wilkinson, G. & Gaus, P.L. Basic Inorganic Chemistry, 3rd ed., Wiley.
Additional References	• March, J., Advanced Organic Chemistry: Reactions, Mechanisms, and Structure, Wiley, 4th Edition, 1992. • Morrison, R. N. & Boyd, R. N., Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education). • Finar, I. L., Organic Chemistry, Volumes 1 and 2, Pearson Education. • Das, Asim K., Fundamentals of Inorganic Chemistry, Vol. II, CBS Publications, 2nd Edition, 2010. • Pradeep's, Inorganic Chemistry, Vol. I & II, Universal Book Seller, 14th Edition, 2017.

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Name of the Program	**Bachelor of Science in Nuclear Medicine Technology**
Course Title	**Radiation Physics**
Course Code	**BNM1203**
Academic Year	First Year
Semester	I
Number of Credits	**4**
Course Prerequisite	Students should have knowledge in the fundamentals of physics at higher secondary school level.
Course Synopsis	This course provides fundamental knowledge of modern physics, radioactive decay process, interaction of ionizing radiations with matter, detection of ionizing radiations,

Course Outcomes (COs): At the end of the course student shall be able to:

CO1	To understand and apply modern physics, general properties of nuclei and nuclear models in nuclear medicine related problems (C4)
CO2	To understand nuclear reactions and production of radionuclides (C4)
CO3	To understand and apply the concepts of interaction of radiation with matter to nuclear medicine related situations (C4)

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	X	
CO3	X	X				X	X	

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Course Content and Outcomes:

Content	Competencies	Number of Hours
Unit 1: Modern physics and Introduction to radiation physics		
Modern Physics	• Define inertial frames and explain Galilean invariance (C2) • State the postulates of special relativity (C1) • Describe Lorentz transformations and their significance (C2) • Apply relativistic velocity addition theorem and explain mass-energy equivalence (C3) • Analyze problems involving Lorentz transformations and relativistic velocity addition (C4) • Describe Bohr's and Rutherford's atomic models (C2) • Explain the production of X-rays (C2) • Outline the X-ray diffraction process (C2) • Explain wave-particle duality and wave properties of matter (C2) • Describe de Broglie waves and the uncertainty principle (C2) • Recall the basics of the Schrödinger equation (C1) • List particle properties of waves and different types of electromagnetic waves (C1) • Explain the working principle of the electron microscope (C2) • Analyze how electron microscope uses wave and particle concepts for imaging (C4)	**8**
General properties of nuclei	• Discuss the composition of the atomic nucleus and intrinsic properties such as mass, radius, matter density, and charge density (C2) • Explain nuclear stability, binding energy, and the fate of unstable nuclei (C2) • Describe radioactivity and the different decay modes: beta emission, beta-gamma emission, isomeric transition/internal conversion, electron capture-gamma emission, positron-gamma decay, alpha emission (C2) • List properties of alpha, beta, gamma particles, positrons, neutrons, and X-rays (C1) • Explain the beta decay spectrum (C2)	**20**

Content	Competencies	Number of Hours
	• Define radioactivity, decay constant, and list units of radioactivity (C1) • State laws of radioactivity (C1) • Derive and analyze the radioactivity decay equation (C4) • Define, derive, apply, and analyze the radioactive half-life concept (C4) • Explain specific activity and apply its concept in nuclear medicine contexts (C3) • Explain decay of mixed radionuclide samples and apply this knowledge in nuclear medicine scenarios (C3) • Explain parent-daughter decay relationships (C2) • Describe N/A plot, nuclear stability curve, and separation energy (C2) • Explain nuclear spin, parity, magnetic moments, and electric moments (C2) • Discuss nuclear excited states and transitions (C2)	
Nuclear models	• Describe the liquid drop model, its assumptions, and explain the semi-empirical mass formula (C2) • Explain the Fermi gas model including degenerate fermion gas and symmetry potential (C2) • Describe the shell model: evidence for shell structure, magic numbers, mean field, and residual interactions (C2) • Explain basic characteristics of nuclear forces and provide an overview of meson theory (C2) • Analyze how these models explain nuclear properties and phenomena (C4)	**8**
Unit 2: Nuclear Reactions and Interaction of radiation with matter		
Nuclear reactions and production of radionuclides	• Illustrate nuclear reactions, nuclear energy levels, nuclear isomers, and bombardment processes (C2) • Explain nuclear fission and fusion reactions and their differences (C2) • List various types of nuclear reactors, including breeder reactors (C1) • Illustrate design features of nuclear reactors (C1) • List different types of medical cyclotrons (C1) • illustrate design of nuclear reactors (C1)	**8**

Content	Competencies	Number of Hours
Interaction of Radiation with matter	• Define black body radiation and explain its significance (C2) • Explain interaction of charged particles with matter including collisional and radiative losses (C2) • Describe charged particle tracks and their characteristics (C2) • Define the Cerenkov effect (C1) • Explain the photoelectric effect (C1) • Apply photoelectric effect to problems, and analyze its outcomes (C4) • Explain Compton scattering (C1) • Apply it, and analyze scattering results (C4) • Explain pair production (C2) • Describe energy loss mechanisms of electrons and positrons (C2) • Explain Bremsstrahlung radiation processes (C3) • Define coherent scattering (C1) • Explain the importance of radiation attenuation in radiology and nuclear medicine (C2) • Describe transmission of high-energy radiation through matter, including Linear Energy Transfer (LET) (C2) • Explain linear and mass attenuation coefficients and interpret cross-section curves with respect to gamma energy and atomic number (C2) • Apply linear and mass attenuation coefficients in nuclear medicine contexts (C3) • Describe the positron annihilation process (C2) • Explain heavy charged particles' stopping power, range, and the Bethe-Bloch formula (C2) • Discuss neutron interactions with matter, including scattering and absorption (C2)	**16**

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
Assignment	2		2
Total	**60**		**60**
Assessment Methods:			
Formative:	**Summative:**		
Unit Test	Mid Semester Exam (Theory)		
Quiz	End Semester Exam (Theory)		
Assignments/Presentations			
Mapping of Assessment with COs:			
Nature of Assessment	**CO1**	**CO2**	**CO3**
Mid Semester Examination	X	X	
Quiz/Unit	X	X	X
Test/Assignments/Presentations	X	X	X
End semester Exam	X	X	X
Feedback Process:	Mid-Semester Feedback		
	End-Semester Feedback		
Main Reference:	1. Concepts of Modern Physics – Arthur Beiser 2. Nuclear Medicine Physics – Ramesh Chandra 3. Physics in Nuclear Medicine – Simon Cherry, 4. Physics in Nuclear Medicine- Sorenson 5. Nuclear Medicine Physics- Ramesh Chandra		
Additional References	1. Essential Nuclear medicine Physics- Rachel A. Powsner, Edward R. Powsner 2. Introductory Nuclear Physics- Krane K. S. 3. 3. Radiation Detection and Measurement- Knoll G. F.		

Name of the Program				Bachelors of Science in Nuclear Medicine Technology				
Course Title				**Fundamentals of Electromagnetism in Nuclear Medicine**				
Course Code				**BNM1204**				
Academic Year				**First Year**				
Semester				**II**				
Number of Credits				**3**				
Course Prerequisite				Students should have the knowledge of basic physics at higher secondary level				
Course Synopsis				This course is designed to impart knowledge of electricity, electric field properties, magnetism, magnetic field properties and electromagnetism.				
Course Outcomes (COs): At the end of the course student shall be able to:								
CO1	To understand fundamental principles of electricity, and electrical circuits in nuclear medicine physics (C4)							
CO2	To understand concepts of magnetic fields and potential, and understand maxwell laws, and apply it in MRI magnetism, magnetic shielding, and inductance use in electronics (C4)							
Mapping of Course Outcomes (COs) to Program Outcomes (POs):								
COs	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**
CO1	**X**	**X**				**X**	**X**	
CO2	**X**	**X**				**X**	**X**	

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Content	Competencies	Number of Hours
Unit 1:		
Fundamentals of Electricity	• State Coulomb's law and explain the concept of electric field and electric potential (C2) • Explain Gauss's law and apply electrostatic boundary conditions (C3) • Solve Laplace's equation for simple boundary conditions (C3) • Describe capacitors, linear dielectrics, and dielectric polarization (C2) • Explain volume and surface bound charges and electrostatic energy (C2) • State Biot-Savart law and Ampere's law (C1) • Explain Faraday's law of electromagnetic induction and self and mutual inductance (C2)	**7**
Capacitance, Inductance and AC circuits	• Describe alternating currents (AC), and simple DC and AC circuits with resistors, inductors, and capacitors (R, L, C) (C2) • Explain displacement current, impedance in RC, RL, RLC circuits, resonance, and quality factor Q (C2) • Analyze power in AC circuits: real, reactive, apparent power, and power factor (C4) • Describe transformers (ideal and real), efficiency, and isolation (C2) • Explain electrical safety concepts including shock hazards, grounding, insulation, and isolation in medical systems (C2) • Describe circuit protection devices such as fuses and circuit breakers (C2) • Apply electrical safety principles in Nuclear Medicine settings, including power supply safety in imaging rooms and reducing electrical artifacts (C4)	**8**

Content	Competencies	Number of Hours
Unit 2: Magnetism		
Magnetic fields and electromagnetic concepts.	• Define magnetic fields, including magnetic flux and field lines (C1) • Explain the motion of charged particles in magnetic fields via Lorentz force and cyclotron motion (C2) • Describe different magnetic properties of materials: diamagnetic, paramagnetic, ferromagnetic, antiferromagnetic, ferrimagnetic (C2) • Analyze magnetization curves including hysteresis loop, coercivity, retentivity, and energy loss (C4) • Explain electromagnetic induction using Faraday's law and Lenz's law (C3) • Derive and apply the formula for induced emf (C3) • Analyze the direction of induced emf and current using Lenz's law and understand its relation to conservation of energy (C4) • Describe self-inductance, mutual inductance, eddy currents, and their suppression (C2) • State Maxwell's equations and explain plane electromagnetic waves and related concepts such as the Poynting vector and Poynting's theorem (C2) • Explain reflection and refraction at dielectric interfaces and calculate transmission and reflection coefficients at normal incidence (C2) • Apply Lorentz force to describe motion of charged particles in combined electric and magnetic fields (C3) • Discuss applications in Nuclear Medicine including MRI magnetism, magnetic shielding, and inductance use in electronics (C3) •	**30**

Learning Strategies, Contact Hours and Out of Class Engagement		
Learning Strategies	**Contact Hours**	**Out of Class Engagement**
Lecture	30	30
Seminar	11	15
Revision	2	-
Assessment	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**
Mid Semester	**X**	
Unit Test/Quiz	**X**	**X**
Assignments	**X**	**X**
End Semester Exam	**X**	**X**

Feedback Process:	End-Semester Feedback
Main Reference:	1. Sehgal, Chopra & Sehgal, Electricity &Magnetism 2. D.C. Tayal, Electricity & Magnetism 3. S.P. Taneja, Electricity & Magnetism (Hons) 4. R. Murugeshan, Electricity & Magnetism
Additional References	1. K.K. Tewari, Electricity & Magnetism with Electronics S. Chand 2. Brij Lal & N. Subrahmanyam, Electricity & Magnetism 3. Griffiths, Introduction to Electrodynamics 4. Purcell & Morin, Electricity and Magnetism

Name of the Program	Bachelor of Science in Nuclear Medicine Technology
Course Title	**Practicum – II**
Course Code	**BNM1205**
Academic Year	First
Semester	II
Number of Credits	4
Course Prerequisite	Basic knowledge of cell biology, molecular biology, Biochemistry and organic chemistry.
Course Synopsis	This course develops practical skills in cell and molecular biology, electricity and magnetism, and organic chemistry for nuclear medicine.

Course Outcomes (COs):

At the end of the course student shall be able to:

CO1	To understand the practical aspects of cell biology and molecular biology (C2, P3)
CO2	To understand practical aspects of biochemistry (C2, P3)
CO3	To apply theoretical principles of electricity and magnetism relevant to Nuclear Medicine (C3, P3)
CO4	To apply laboratory techniques for melting/boiling point determination, functional group identification, compound preparation, reaction kinetics, spectroscopic analysis (UV, IR, NMR), and separation/estimation methods (C4, P3)

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

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

Content	Competencies	Number of Hours
Unit 1: Cell Biology and Molecular Biology		
Cell and Molecular Biology Practical	• To study different part of light microscope and their use (C2, P1) • To observe cheek cells under dark and bright field microscopy (C2, P1) • To demonstrate the microscopic organization of tissues using light microscopy (C2, P1) • To demonstrate total leukocyte counting in blood sample using hemocytometer (C2, P3) • To demonstrate total Red blood cell counting in blood sample using hemocytometer (C2, P3) • To prepare peripheral blood smear slide using wedge technique followed by May-Grunewald-Giemsa stained leukocytes under light microscope (C2, P3) • To demonstrate osmotic fragility of RBC (C2, P3) • To demonstrate liver function markers: ALT/AST and interpret (C2, P4) • To perform lipid profile analysis, renal function tests (C2, P4) • To study the process of mitosis in onion root tip cells or prepared slides and identify different stages (C2, P1) • To demonstrate the effect of hypotonic and hypertonic solutions on red blood cell (RBC) morphology (crenation and hemolysis) (C2, P2) • To demonstrate the technique of paper chromatography for the separation of amino acids or pigments (C2, P2) • To observe and interpret common morphological abnormalities of red blood cells (RBCs) and white blood cells (WBCs) using pre-stained slides (C2,P2)	35
Unit 2: Biochemistry		
Biochemistry practical	• To perform qualitative tests for carbohydrates (Benedict's, Barfoed's, Molisch) (C2, P3) • To estimate the amount of glucose using colorimetric method (C2, P3)	20

Content	Competencies	Number of Hours
	• To perform protein estimation using Lowry/Bradford method (C2, P3) • To determine the absorption spectra of a biological sample with a colorimeter/single/double beam spectrophotometer (C2, P3)	
Unit 3: Electricity and Magnetism		
Electricity and Magnetism	• To construct and demonstrate the working of RC and RLC circuits (C3, P2) • To determine self-inductance in coils (C3, P1) • To measure magnetic field in solenoids (C3, P1) • To verify the three Faraday's laws using magnets and coils. (C3, P3) • To apply Thevenin's, Norton's, and Superposition theorems in circuit analysis (C3,P3)	20
Unit 4: Applied chemistry: Organic Chemistry & Inorganic chemistry for Nuclear Medicine		
Applied chemistry: Organic Chemistry & Inogranic chemistry for Nuclear Medicine practical	• Determine melting and boiling points of organic compounds (C3, P3) • Identify functional groups through chemical tests (C2, P3) • Prepare an organic compound, such as an ester, by reacting a carboxylic acid with an alcohol under acidic conditions and isolate the product (C3, P3) • Study the reaction kinetics of organic reactions by measuring concentration changes over time and analyzing the rate and order of the reactions (C4, P2) • Estimation of phenol and aniline by bromination method (C4, P3) • To calibrate burette, pipette and volumetric flask using gravimetric method (C3, P2) • To determine metal ions by gravimetric analysis through precipitation and weighing (C3, P3) • To prepare and analyze coordination complexes by synthesizing metal–ligand compounds and studying their properties (C3, P3) • To determine the amount of iodine liberated from a compound using redox titration (C3, P3)	30

Learning Strategies, Contact Hours and Out of class engagement:		
Learning Strategies	**Contact Hours**	**Out of class engagement**
Practical	96	96
Small group discussion	9	9
Total	**105**	**105**

Assessment Methods:	
Formative:	**Summative:**
Unit Test	Mid Semester Exam (Practical)
Quiz	End Semester Exam (Theory)
Viva	Viva
Practical Logbook/ Record Book	Record Book

Mapping of Assessment with COs:				
Nature of Assessment	**CO1**	**CO2**	**CO3**	**CO4**
Mid Semester / Sessional Examination 1	X	X	X	X
Quiz /Viva/Unit Test	X	X	X	X
Clinical/Practical Logbook/ Record Book	X	X	X	X
End Semester Exam	X	X	X	X

Feedback Process:	Mid-Semester Feedback
	End-Semester Feedback
Main Reference:	1. Laboratory Manual of Cell and Molecular Biology by K.V. Chaitanya / PHI Learning 2. Molecular Biology Techniques: A Laboratory Manual by S. Ignacimuthu / Narosa Publishing House 3. IIT Roorkee Teaching Laboratories, Prof. Moumita Mait, Smt. Meena Kothyar 4. Elements of Electromagnetics: M.N.O.sadiku (Oxford University Press) 5. Textbook of Practical Organic Chemistry" (5th Edition) by A. I. Vogel et al., 6. Vogel's Textbook of Practical Organic Chemistry" by A.I. Vogel 7. Organic Chemistry" by Paula Yurkanis Bruice 8. Molecular Cell Biology by Darnell, Lodish, Baltimore, Scientific American Books 1990 9. Plummer. D.T. (2004). An introduction to practical biochemistry. New Delhi: Tata McGraw Hill Publishers Co.

Learning Strategies, Contact Hours and Out of class engagement:	
Additional reference:	1. Molecular Cell Biology by Darnell, Lodish, Baltimore, Scientific American Books 1990 2. Raj K. Bansal's "Laboratory Manual of Organic Chemistry" (2025 edition), and typical organic practical manuals 3. Principles and Techniques of Biochemistry and Molecular Biology by Keith Wilson and John Walker

Name of the Program	**Bachelors of Science in Nuclear Medicine Technology**
Course Title	**Clinical Practice – I**
Course Code	**BNM1206**
Academic Year	First
Semester	II
Number of Credits	2
Course Prerequisite	A basic understanding on safe handling of radio-isotopes.
Course Synopsis	This course deals with development of overall awareness towards nuclear medicine hospital setup, radiopharmaceutical, scintigraphy and radiation safety practices.

Course Outcomes (COs):

At the end of the course student shall be able to:

CO1	To understand practical aspects of safely handling of radiopharmaceuticals for clinical applications in Nuclear Medicine (C2, A1)
CO2	To observe the different imaging and non-imaging Nuclear Medicine procedures (C2, A1)

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**		
CO2	**x**	**x**	**X**	**x**	**x**	**x**		

Course Content and Outcomes:

Content	**Competencies**	**Number of Hours**
Unit 1		
	• To understand the principles and observe the practices in hospital radio pharmacy (C2, A1)	24
	• To understand the principles and observe the practices in in-vitro Nuclear Medicine (C2, A1)	16

Content	Competencies	Number of Hours
Unit 2		
	• To understand the principles and observe the practices in SPECT Scintigraphy (C2, A1)	36
	• To understand the principles and observe the practices in radiation therapy (C2, A1)	14

Learning Strategies, Contact Hours and Student Learning Time		
Learning Strategies	**Contact Hours**	**Out of Class Engagement**
Small group discussion (SGD)	10	10
Problem Based Learning (PBL)	4	4
Case Based Learning (CBL)	24	24
Clinic	52	52
Total	**90**	**90**

Assessment Methods:	
Formative:	**Summative:**
Unit Test	Mid Semester Exam (Practical)
Quiz	Viva
Viva	Record Book
Clinical assessment (OSCE, OSPE)	
Clinical/Practical Log Book/ Record Book	

Mapping of Assessment with COs:		
Nature of Assessment	**CO1**	**CO2**
Mid Semester Examination	x	X
Quiz /Viva/Unit Test	x	X
Clinical Assessment	x	X
Clinical/Practical Log Book/ Record Book	x	X

Feedback Process:	Mid-Semester Feedback
	End-Semester Feedback
Main Reference:	1. Quality control of Nuclear Medicine instruments - Tecdoc 602 2. Nuclear Medicine – The Requisites by Harvey A. Ziessman, Janis P. O'Malley, James H. Thrall
Additional References	1. Radiopharmaceuticals in Nuclear Medicine by Kowalsky, Richard J., and Steven W. Falen 2. NUCLEAR MEDICINE FACILITIES, CODE NO. AERB/RF-MED/SC-2 (Rev. 2) or as revised from time to time by AERB Mumbai

SEMESTER - III

Course code	Course Title
BNM2301	Fundamentals of immunology and Microbiology
BNM2302	Introduction to Radio pharmacy
BNM2303	Nuclear Medicine Instrumentation Physics
BNM2304	Principles of wave and optical physics in biomedical imaging
BNM2305	Practicum – III
BNM2306	Clinical Practice – II

Name of the Program	**Bachelors of Science in Nuclear Medicine Technology**
Course Title	**Fundamentals of Immunology and Microbiology**
Course Code	**BNM2301**
Academic Year	Second
Semester	III
Number of Credits	3
Course Prerequisite	Students should have knowledge in Basics of biology
Course Synopsis	By the end of the course the students will be able to 1) understand the structure, classification and role of microorganisms relevant to healthcare 2) Explain methods for sterilization, foundational concepts of immunology 3) Apply methods to prevent contamination and interpret diagnostic tests based on immune principle.

Course Outcomes (COs): At the end of the course student shall be able to:

CO1	Explain and understand principle and types of microscopes (C2)
CO2	Understand the growth and interaction of Microorganism (C2)
CO3	Understand Immune system (C2)
CO4	Explain and understand the antigen-antibody reactions (C2)

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

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

Course Content and Outcomes:

Content	Competencies	Number of Hours
Unit 1: Introduction to Microbiology and Microscopy		
	• To understand the history of Microbiology, Koch postulates, discovery of antibiotics (C2) • Explain the morphology of bacteria, viruses and fungi with major emphasis on bacterial structure (C2) • What is gram positive and gram negative bacteria (C1) • Explain the principle of microscopy: Bright field, dark field, phase contrast, fluorescent, electron microscopy (C1)	10
Unit 2: Microorganism Growth and Interaction		
	• What are the phases of microbial growth (C1) • List the physical and chemical agents to kill microbes (C1) • Explain sterilization and pasteurization processes (C2) • What is the normal microflora in humans/ animals (C1) • What are the types of microbial pathogens and overview of diseases caused by them (C2) • Explain microbial interactions like symbiosis and antibiosis (C2) • Explain the host defense mechanism against pathogens (C2)	10
Unit 3: Introduction to Immune System		
	• Overviews of immune system – Historical perspectives • What is innate and acquired immunity (C1) • What is clonal nature of immune response (C1) • Explain cells of the immune system: Hematopoiesis and differentiation, lymphocyte trafficking, B- lymphocytes, T-lymphocytes, macrophages, dendritic cells, Natural killer cells and lymphocyte activated killer cells, eosinophils, neutrophils & mast cells (C2) • Describe Primary and secondary lymphoid organs, systemic function of immune system (C2) • Elucidate Antigen-Immunogenicity Vs. antigenicity, factors affecting immunogenicity, nature of immunogen, epitopes, heptans and antigenicity, pattern recognition receptors (C2)	10

Content	Competencies	Number of Hours
Unit 4: Antibody and Antigen-Antibody Reactions		
	• Explain Immunoglobulins: Structure of antibody, antibody effector function, antibody classes and biological activities, antigenic determinants on Immunoglobulins, Immunoglobulins superfamilies (C2) • Understand the overview of hybridoma technology: Production of Monoclonal Antibodies, applications of polyclonal and monoclonal antibodies (C2) • Explain vaccines and immunization (C2) • Explain Antigen–Antibody interactions: Strength of interaction, cross reactivity, antibody affinity, avidity (C2) • What is precipitation and agglutination reactions (C1) • Explain immunodiffusion, immunoelectrophoresis, immunoassays, Enzyme linked immunosorbent assay (ELISA), Radioimmunoassay (RIA), western blot, Immunofluorescence (C2)	15

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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 Exam
Quiz	End Semester Exam
Assignment/presentations	

Mapping of Assessment with COs:				
Nature of Assessment	**CO1**	**CO2**	**CO3**	**CO4**
Mid Semester Examination	X	x	x	-
Quiz/Unit test	X	x	x	x
Assignment/presentation	X	x	x	x
End Semester Exam	X	x	x	x

Feedback Process:	End-Semester Feedback
Main Reference:	1. Janis Kuby, Immunology, 5th Edition 2. Ivan Roitt, Essential Immunology, 9th Edn. 3. Mary S. Leffell,& Noel R. Rose, Handbook of Human Immunology, CRC press 4 Tizzard, Immunology 4. Elgert Immunology 5. Lidyard, Instant notes in Immunology, 2nd Edition. 6. A handbook of practical and clinical immunology. Talwar GP and Gupta SK (1992) CBS Publication

Name of the Program	Bachelors of Science in Nuclear Medicine Technology
Course Title	**Introduction to Radio pharmacy**
Course Code	**BNM2302**
Academic Year	Second
Semester	III
Number of Credits	4
Course Prerequisite	Students should have basic knowledge of chemistry, human physiology and radiation physics
Course Synopsis	This course will provide introductory knowledge of radiochemistry and radio-pharmacy as one of the core subjects of nuclear medicine. The knowledge will help students understand laboratory design, set up for various radiation facilities; prepare them for practical training in safe handling of radioactive material, and preparation of radiopharmaceuticals for clinical applications in Nuclear Medicine.

Course Outcomes (COs):

At the end of the course student shall be able to:

CO1	Outline and explain radio-pharmacy laboratory design and construction (C2)
CO2	Compare and contrast the properties of radio-metals for various clinical and non-clinical applications (C2)
CO3	Understand safe-handling of radioisotopes (C2)
CO4	Explain radionuclide production methods and working concepts (C 2)
CO5	Summarize radiopharmaceutical use in nuclear medicine, the process of manufacturing to end use (C2)
CO6	Understand basics of Tc- 99m radiopharmaceutical chemistry (C2)

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

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1	**x**							
CO2	**x**							
CO3	**x**	**x**						
CO4	**x**	**x**						
CO5	**x**	**x**						
CO6	**x**	**x**						

Course Content and Outcomes:

Content	Competencies	Number of Hours
Unit 1		
General Introduction	• Explain radio pharmacy as a subject, Practice, and Laboratory (C2) • Name basic radio-pharmacy Laboratory equipment, TLC Scanner, Fume Hood, Laminar Flow hood Balance, Centrifuge, Autoclave etc. and their applications in radio pharmacy laboratory (C1)	2
Unit 2		
Radionuclides in Nuclear Medicine and General Laboratory safety	• What are the Physical and chemical Characteristics of radionuclides and Application in Nuclear Medicine (C1) • Explain Safety considerations in radio- pharmacy laboratory such as Electrical safety, chemical safety, Fire safety, Radiation safety, Biological safety (C2) • Make use of standard Radiation handling procedures: Receipt - storage - disposal of radioactive materials, International symbols of radioactivity labels (C2)	8
Unit 3		
Design, Plan layout and setting up of Radio pharmacy Lab	• How to Classify Radio different type radio pharmacy Laboratories (C1) • Compare Operational Concept, design and Plan layout of Radio pharmacy Laboratory, Hospital Radio pharmacy and Centralized Radio pharmacy (C2) • Outline setting up of a typical Hospital radio pharmacy laboratory (C2). • Outline Role and responsibility of Staff in Hospital Radio pharmacy and Central Radio pharmacy (C2).	7
Unit 4		
Production techniques for Radionuclides	• What are the methods of Artificial Production of Radionuclides - Primary (Nuclear reactors & Accelerators) and Secondary Sources (RN generators) (C1) • Explain Design, construction and working principle of typical nuclear reactor and medical cyclotron and radionuclide generator (C2) • Explain Factors affecting Production Yield (C2) • What are the different types of radionuclide generators (C1)	13

Content	Competencies	Number of Hours
	• Outline Ideal characteristics of generator system (C2) • Compare radiation characteristics of generator produced radionuclides (C2) • Explain Performance parameters for radionuclide generators (C2)	
Unit 5		
Radio pharma--ceuticals: Cold kit Manufacture, labeling and Quality control	• Classify- Diagnostic and Therapeutic Radiopharmaceuticals in Nuclear medicine (C2) • Outline Ideal Characteristics of Radiopharmaceuticals(C2) • Explain principles of Radio-labelling techniques: Radio-labelling, various methods of Radio-labelling- Direct & Indirect Labelling, factors affecting labeling efficiency(C2) • Explain mechanism of localization of Radiopharmaceuticals(C2) • Explain Cold Kits production and role of contents in labeling process (C2) • Physical, pH quality checks • Radionuclides Purity (RNP), Radiochemical Purity (RCP), • Particle size and number • Sterility, Pyrogenicity • Bio-distribution studies.	15

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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**

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**	**CO5**	**CO6**
Mid Semester Examination	**x**	**x**	**x**	**x**		
Quiz / Unit Test	**x**	**x**	**x**	**x**	**X**	**x**
Assignment/presentations	**x**	**x**	**x**	**x**	**X**	**x**
End Semester Exam	**x**	**x**	**x**	**x**	**X**	**x**

Feedback Process:	Mid-Semester Feedback
	End-Semester Feedback
Main Reference:	1. Radiopharmaceuticals in Nuclear Medicine Pharmacy and Nuclear Medicine - Kowalsky, Richard J., and Steven W. Falen 2. Fundamentals of Nuclear Pharmacy, 3rd Edition Gopal B Saha
Additional References	1. Radiopharmaceuticals and Hospital Radiopharmacy Practices - N. Ramamoorthy BRIT 2. NUCLEAR MEDICINE FACILITIES, CODE NO. AERB/RF-MED/SC-2 (Rev. 2) or as revised from time to time by AERB Mumbai 3. Hand Book of Radiopharmaceuticals Mohan H Patel

Bachelor	Bachelors of Science in Nuclear Medicine Technology
Course Title	**Nuclear Medicine Instrumentation Physics**
Course Code	**BNM2303**
Academic Year	Second
Semester	III
Number of Credits	4
Course Prerequisite	Students should have basic knowledge of Radiation Physics and basic electronics
Course Synopsis	This course covers physics and working principles of instruments used in Nuclear Medicine

Course Outcomes (COs):

At the end of the course student shall be able to:

CO1	Understand various components and working principle of instruments in nuclear medicine counting (C2)
CO2	Understand basic concepts behind calibration and quality control of nuclear medicine counting instruments (C2)
CO3	Understand various components and working principle of imaging instruments in nuclear medicine counting (C2)
CO4	Understand basic concepts behind calibration and quality control of nuclear medicine imaging instruments (C2)

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**						

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Course Content and Outcomes:

Content	Competencies	Number of Hours
Unit 1		
Radiation detection and Measurement	• Units of radiation exposure (C2) • Different types of radiation detectors (C1) • Principle of radiation detection by Gas filled detectors (C2) • Principle of radiation detection by inorganic scintillator detectors (C2) • Principle of radiation detection by organic scintillator detectors (C2) • Principle of radiation detection by semiconductor detectors (C2)	4
Unit 2		
Dose Calibrators and Well Counters	• Principle of ionization chamber-based dose calibrators and their role in measuring radiopharmaceutical activity • Detailed components: pressurized chamber, electrometer, amplifier, digital display • Importance of geometry, energy dependence, and shielding in activity measurements • Calibration techniques using standard sources, reproducibility and linearity testing • Routine quality control checks: constancy, accuracy, precision, linearity, geometry dependence • Well counters: structure and function of NaI (Tl) crystal and PMT system • Use of lead shielding, pulse height analyzer settings, and background correction • Clinical applications: thyroid uptake measurement, blood volume studies, RIA/IRMA counting procedures	2
Unit 3		
Gamma Ray Spectrometer	• Explain basic principles of scintillation detectors (C2) • Explain basic principle and working of photomultiplier tube (C2) • Explain basic principle and working of photodiodes (C2) • Explain composition and some examples of Inorganic scintillators (C2)	17

Content	Competencies	Number of Hours
	• Explain working of Inorganic scintillators (C2) • Explain Ideal characteristics of inorganic scintillators (C2) • Explain types of amplifiers used in GRS (C2) • Explain working of amplifiers (C2) • Explain working of pulse height analyser and coincidence circuit (C2) • Explain working of semiconductor detectors (C2) • Explain basic principle and working of Avalanche photodiodes (C2)	
Unit 4		
Radiation Survey and Monitoring Instruments	• Classification and comparison of radiation survey instruments: GM counter, ion chamber, scintillation survey meter • Detection principles: voltage range, dead time, efficiency, and energy response • Instrument construction, electronics, and readout mechanisms • Area monitoring systems: wall-mounted and portable monitors in NM hot labs and imaging rooms • Personal monitoring devices: film badges, TLDs, OSLDs, and electronic dosimeters • Contamination monitors for hand and surface swipes; protocols for assessment and decontamination • Regulatory framework: AERB dose limits, zone classification, and monitoring record maintenance • Applications in daily NM operations: source transport, radiopharmaceutical handling, spill response	5
Unit 5		
Gamma Probes in Nuclear Medicine	• Explain working of a multichannel analyser (C2) • Explain basic design of thyroid uptake probe (C2) • Explain Iso-response curve (C2) • Explain Quality control procedures (C2) • Explain basic Components of gamma probe (C2)	11

Content	Competencies	Number of Hours
	• Explain Instrument design and working of gamma probe (C2) • Explain basic Applications of gamma probe (C2) • Explain basic Quality control of gamma probe (C2)	
Unit 6		
Liquid Scintillation and Whole Body Counters	• Explain the Importance and need of liquid scintillation counting (C2) • Explain the Principle of liquid scintillation counting (C2) • Explain the Instrument design and working of liquid scintillation counter (C2) • Explain the Quenching and Quench correction methods (C2) • Explain the Applications of liquid scintillation counting and Quality control of liquid scintillation counter (C2) • Explain the whole body counters working principle and instrumentation (C2) • Explain the Application of whole body counters, Quality control and applications (C2)	12
Unit 7		
Rectilinear scanners and Gamma camera	• List Historical importance of rectilinear scanner (C1) • Explain the Working principle and instrument design of rectilinear scanners (C2) • Explain the drawbacks of rectilinear scanners (C2) • Explain the Introduction to gamma camera (C2) • Explain the Components of gamma camera (C1) • Explain the Detector system and event localization (C2) • Explain the Collimators and Performance characteristics of parallel hole collimators (C2) • Explain the Events in gamma camera (C2) • Explain Types of gamma camera and their use (C2) • Explain the Performance characteristics of a gamma camera (C2) • Explain Artifacts in gamma imaging (C2) • Explain the Correction methods in gamma imaging (C2)	20

Content	Competencies	Number of Hours
	• Explain Gamma camera performance measurement-Spatial Resolution (C2) • Explain Gamma camera performance measurement-Energy Resolution and sensitivity (C2) • Explain Gamma camera performance measurement-Image uniformity and counting rate (C2)	

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
Quiz	End Semester Exam
Assignments/Presentations	

Mapping of Assessment with COs:				
Nature of Assessment	**CO1**	**CO2**	**CO3**	**CO4**
Mid Semester	X	x		
Quiz / Unit Test	X	x	x	x
End Semester Exam	X	x	x	x

Feedback Process:	Mid-Semester Feedback
	End-Semester Feedback
Main Reference:	1. Physics in Nuclear Medicine- Sorenson 2. Quality control of Nuclear Medicine instruments- Tecdoc-602 3. Radiation Detection and Measurement- Knoll G.F.
Additional References	1. Mosby's Manual of Nuclear Medicine Procedures- D.Brucee Sodes, Paul J Early 2. Nuclear Medicine-Robert E. Henkin, Mark A. Boles 3. Computers in Nuclear Medicine-Lee Kai Hi

Name of the Program	**Bachelor of Science in Nuclear Medicine Technology**
Course Title	**Principles of waves and optical physics in biomedical imaging**
Course Code	**BNM2304**
Academic Year	**Second Year**
Semester	**III**
Number of Credits	**3**
Course Prerequisite	Students should have the knowledge of basic physics in higher secondary level
Course Synopsis	This course is designed to impart knowledge of the application of oscillators, wave equations and optical devices in nuclear medicine.

Course Outcomes (COs): At the end of the course student shall be able to:

CO1	To understand the concepts of oscillations and apply them in the nuclear medicine instrumentation devices (C4)
CO2	To understand the concept of waves and wave dynamics in nuclear medicine (C4)
CO3	To understand and apply the concepts of optics in nuclear medicine instrumentation devices (C3)

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

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

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Content	Competencies	Number of Hours
Unit 1: Oscillations		
Oscillators and their application in Nuclear Medicine	• Define oscillations and periodic motion and give examples from mechanical (spring–mass, pendulum) and electrical (LC circuit) systems (C2) • Explain key terms related to SHM: amplitude, frequency, time period, and phase (C2) • State and solve the differential equation for a simple harmonic oscillator and write its general solution (C3) • Explain the restoring force concept using Hooke's law and relate it to SHM (C2) • Describe the mathematical form of SHM and the physical significance of angular frequency (C2) • Analyze the superposition of two or more simple harmonic oscillators (C4) • Explain Lissajous figures and interpret their shapes from combined oscillations (C4) • Define damped and forced oscillations; explain resonance, condition for resonance, and amplitude response curve (C4) • Explain the sharpness of resonance and the quality factor (Q factor) (C2) • Discuss applications oscillators in signal timing, synchronization and frequency selection in Gamma camera, PET scanners etc.	**10**
Unit 2: Waves		
Wave equations and energy dynamics of waves	• Define types of waves: mechanical (requiring medium) versus electromagnetic (can propagate in vacuum), and classify transverse versus longitudinal waves (C2) • Explain fundamental wave parameters: wavelength, frequency, wave number, amplitude, phase (C2) • State and solve the general wave equation (C3) • Describe characteristics of traveling and standing waves in one dimension (C2) • Explain energy density and energy transmission mechanisms in waves (C2) • Define group velocity and phase velocity and distinguish between them (C2)	**15**

Content	Competencies	Number of Hours
	• Describe sound waves propagating through different media (C2) • Explain the Doppler Effect and its implications (C2) • State and explain Fermat's Principle of least time in wave propagation (C2) • Application of Fermat's Principle in scintillation imaging systems (PET, gamma cameras) (C4)	
Unit 3: Optics		
Optical properties of electromagnetic waves	• Describe the general theory of image formation (C1) • Explain wave-particle duality and electromagnetic wave theory as applicable to light (C2) • Describe interference of light and explain optical path retardation (C2) • Explain Fraunhofer diffraction: single-slit, double-slit, and diffraction grating including angular width (C2) • Explain the Rayleigh criterion and resolving power of optical systems (C2) • Describe diffraction gratings and their applications (C2) • Explain polarization: linear, circular, and elliptic types (C2) • Explain total internal reflection (C2) • Application of total internal reflection in light guides for imaging cameras (C3) • Describe double refraction, optical rotation, optical activity, and birefringence (C2) • Discuss applications in Nuclear Medicine: light transport in scintillators, optical coupling in block detectors, and the use of lasers for collimation and alignment (C3)	**20**

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**			
Mid Semester	**X**	**X**				
Unit Test/Quiz	**X**	**X**	**X**			
Assignments	**X**	**X**	**X**			
End Semester Exam	**X**	**X**	**X**			

Feedback Process:	Mid-Semester Feedback
	End-Semester Feedback
Main Reference:	1. Waves and Oscillations (Brij Lal & Subrahmanyam) Vikas Publishing 2. Oscillations and Waves (Garg, Ghosh, Gupta) PHI Learning 3. Waves & Optics (A.B. Gupta)
Additional References	1. Waves & Optics (Avadhanulu & Arun Murthy) S. Chand 2. Oscillations, Waves, Acoustics (P.K. Mittal) 3. Vibrations and Waves (A.P. French) 4. Physics of Oscillations and Waves (N.K. Bajaj)

Name of the Program	Bachelors of Science in Nuclear Medicine Technology
Course Title	**Practicum – III**
Course Code	**BNM2305**
Academic Year	Second
Semester	III
Number of Credits	3
Course Prerequisite	Basic knowledge of physics, chemistry, biology, and mathematics, along with fundamental understanding of radiation physics, radiobiology, instrumentation, and safety protocols.
Course Synopsis	This practical course covers key skills in radio pharmacy, nuclear medicine instrumentation, waves and optics, and inorganic chemistry. Students will learn radiopharmaceutical preparation and quality control, radiation detection, signal processing, and physical property measurements.

Course Outcomes (COs):

At the end of the course student shall be able to:

CO1	To demonstrate working of radio-pharmacy laboratory, Quality control procedures of radionuclide generator, and preparation of radiopharmaceuticals and their quality control (C3, P3)
CO2	To demonstrate quality control procedures of gamma camera and non-imaging instruments (C3, P3)
CO3	To understand and apply waves and optical components, fiber optic sensor techniques relevant to Nuclear Medicine applications (C3,P3)
CO4	To apply laboratory skills in calibration and measurement, and demonstrate analytical proficiency through gravimetric, complexometric, and redox titrations as well as coordination chemistry-based analyses (C4, P3)

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

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

Content	Competencies	Number of Hours (T/P)
Unit 1: Radio pharmacy		
Radio pharmacy practical	• To check functioning of fume hood (C2, P3) • To demonstrate Radioactive storage and disposal (C2, P3) • To demonstrate PH measurement of given sample (C2, P3) • To prepare Buffer solutions (C2, P3) • To demonstrate separation of 99mTc with Organic Solvent extraction method (C2, P3) • To demonstrate elution and calculation of elution efficiency of 99mTc from Column generator (C2, P3) • To demonstrate Sterilization of Sodium pertechnatate (C2, P3) • To demonstrate Parent Daughter decay Growth Relationship in Technetium generator (C2, P3) • To demonstrate Molybdenum Breakthrough Assay of Sodium Pertechnetate (C2, P3) • To demonstrate Aluminium Breakthrough Assay of Sodium Pertechnetate (C2, P3) • To illustrate Radiochemical Purity of Sodium Pertechnetate by Paper Chromatography (C2, P3) • To preparation 99mTc labelled DTPA, MDP, Mebrofenin (C2, P3) • To preparation 99mTc labelled, ECD, EC, Sulphur Colloid, MIBI (C2, P3) • To perform Quality control of 99mTc labelled Radiopharmaceuticals. (C2, P3) • To learn dispensing and administration techniques for 99mTc-Radiopharmaceuticals for patients (C2, P3)	40
Unit 2: Nuclear Medicine Instrumentation		
Nuclear Medicine Instrumentation practical	• To perform quality control of dose calibrator (C3, P3) • To determine the operational characteristics of GM counter (C3, P3) • To compare the dead time of GM counter for different radioactive sources (C3, P3)	28

Content	Competencies	Number of Hours (T/P)
	• To perform energy calibration of gamma ray spectrometer (C3, P3) • To demonstrate the role of linear amplifier in pulse shaping and amplification of pulse received from photomultiplier tube and preamplifier in a Gamma ray spectrometer (C2, P3) • To demonstrate energy linearity of gamma ray spectrometer using different radioisotopes (C2, P3) • To identify unknown radionuclide using gamma ray spectrometer (C2, P3) • To determine activity of given radioisotope using gamma ray spectrometer (C2, P3) • To perform thyroid uptake study (C2, P3) • To demonstrate human ECG recording and analyze it for QRS voltage and frequency (C2, P3) • To perform ECG measurements and carry out manual electrical axis analysis (C2, P3)	
Unit 3: Waves and Optics		
Waves and Optics experiments	• To calculate dispersive power of a prism (C3, P3) • To verify Newton's formula for a lens separated by a distance experimentally (C3, P3) • To set up fiber optics for basic transmission experiments (C3, P3) • To measure propagation loss, bending loss, and numerical aperture in fiber optics (C3, P3) • To demonstrate the working of fiber optic sensors and understand their application in endoscopy and medical imaging (C3, P3)	22

Learning Strategies, Contact Hours and Out of class engagement:				
Learning Strategies	**Contact Hours**	**Out of class engagement**		
Practical	78	78		
Small group discussion	12	12		
Total	**90**	**90**		
Assessment Methods:				
Formative:	**Summative:**			
Unit Test	Mid Semester Exam (Practical)			
Quiz	End Semester Exam (Theory)			
Viva	Viva			
Practical Logbook/ Record Book	Record Book			
Mapping of Assessment with COs:				
Nature of Assessment	**CO1**	**CO2**	**CO3**	**CO4**
Mid Semester / Sessional Examination 1	X	X	X	X
Quiz /Viva/Unit Test	X	X	X	X
Clinical/Practical Logbook/ Record Book	X	X	X	X
End Semester Exam	X	X	X	X
Feedback Process:	Mid-Semester Feedback			
	End-Semester Feedback			
Main Reference:	1. Vogel's Textbook of Quantitative Chemical Analysis" by G.H. Jeffery et al. 2. Inorganic Chemistry Laboratory Manuals used in universities (e.g., CHEM 304 Inorganic Chemistry Lab Manual) that cover similar experimental procedures precisely. 3. "Practical Manual of Inorganic Chemistry" by Dr. Akhil Nagar et al., which gives practical procedures widely used in UG and PG laboratories. 4. Nuclear Medicine Technology & Techniques Third Ed Donald Bernier et.al 5. Physics in Nuclear Medicine, Sorenson			
Additional Reference:	1. Synthesis and Technique in Inorganic Chemistry: A Laboratory Manual" by Gregory S. Girolami, Thomas B. Rauchfuss, and Robert J. Angelici (University Science Books, 2. Mosby‟s Manual of Nuclear Medicine Procedures, D.Brucee Sodee,Paul J Early 3. Quality control of Nuclear Medicine instruments, Tecdoc 602 1999)			

Name of the Program	Bachelors of Science in Nuclear Medicine Technology
Course Title	**Clinical Practice – II**
Course Code	**BNM2306**
Academic Year	Second
Semester	III
Number of Credits	3
Course Prerequisite	Students should have overall awareness of clinical nuclear medicine setup.
Course Synopsis	This course generates awareness towards nuclear medicine procedures in radiopharmacy, in-vitro, scintigraphy and radionuclide therapy.

Course Outcomes (COs):
At the end of the course student shall be able to:

CO1	Observe and understand routine radiopharmacy practices in clinical nuclear medicine (C2, P1)
CO2	Observe and understand routine scintigraphy practices in clinical nuclear medicine (C2, P1)
CO3	Observe and understand routine radionuclide therapy practices in clinical nuclear medicine (C2, P1)

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

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Course Content and Outcomes:

Content	Competencies	Number of Hours
Unit 1		
Radio pharmacy Practices	• To observe the arrangement of Radio pharmacy lab for daily activities (C1, P1) • To list and identify items in the stock inventory (C1, P1) • To observe the QC of dose calibrator (C2, P1) • To observe preparation and dispensing of radiopharmaceuticals (C2, P1) • To observe the QC of radiopharmaceuticals (C2, P1) • To observe patient preparations and practices as per regulatory guidelines (C2, P1, A1)	30
Unit 2		
In-vitro Nuclear Medicine Practices	• To list and identify stock inventory (C1, P1) • To list various non-imaging and radiation monitoring equipment (C1, P1) • To observe radiation surveillance and generation of the reports (C2, P1)	24
Unit 3		
Scintigraphy Practices	• To observe the arrangement of imaging room for daily activities (C1, P1) • To observe daily QC of imaging and other accessory devices (C2, P1) • To observe patient preparations and practices as per regulatory guidelines (C2, P1, A1)	24
Unit 4		
Radionuclide Therapy Practices	• To list and identify stock inventory (C1) • To observe the QC of dose calibrator (C2, P1) • To observe & preparation and dispensing of therapeutic radiopharmaceuticals (C2, P1) • To observe the QC of radiopharmaceuticals (C2, P2) • To observe patient preparations and practices as per regulatory guidelines (C2, P1, A1)	27

Learning Strategies, Contact Hours and Out of class engagement:		
Learning Strategies	**Contact Hours**	**Out of class engagement**
Small group discussion (SGD)	5	5
Problem Based Learning (PBL)	5	15
Case Based Learning (CBL)	5	15
Clinic	90	-
Total	**105**	**35**

Formative:	**Summative:**
Unit Test	Mid Semester (Practical)
Quiz	Viva
Viva	Log Book
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 Log Book/ 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 Reference:	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. NUCLEAR MEDICINE FACILITIES, CODE NO. AERB/RF-MED/SC-2 (Rev. 2) or as revised from time to time by AERB Mumbai 3. Nuclear Medicine Technology: Procedures and Quick Reference — Pete Shackett

SEMESTER - IV

Course code	Course Title
BNM2401	Radiochemistry
BNM2402	Radiobiology
BNM2403	Biostatistics and research methodology
BNM2404	Health Physics and Radiation Safety
BNM2405	Practicum – IV
BNM2406	Clinical Practice - III

Name of the Program	**Bachelors of Science in Nuclear Medicine Technology**
Course Title	**Radiochemistry**
Course Code	**BNM2401**
Academic Year	**Third Year**
Semester	**IV**
Number of Credits	**4**
Course Prerequisite	Students should have the knowledge of Fundamentals of chemistry.
Course Synopsis	This course provides a comprehensive understanding of physical chemistry concepts essential to chemical sciences and allied fields. It covers atomic and molecular structure, states of matter, and the fundamental laws of thermodynamics. Students will learn about chemical and phase equilibria, electrochemistry, and chemical kinetics, emphasizing quantitative problem-solving and theoretical interpretation. The course also introduces adsorption phenomena and basic spectroscopic techniques, linking molecular behaviour to observable chemical properties.
Course Outcomes (COs): At the end of the course student shall be able to:	
CO1	Recall and explain the fundamental principles of atomic and molecular structure, states of matter, and thermodynamics governing chemical systems (C2).
CO2	Apply the concepts of chemical and phase equilibria, thermodynamic relationships, and electrochemical principles to analyze the behaviour of chemical reactions and systems (C3).
CO3	Solve problems related to reaction kinetics, adsorption phenomena, and gas–liquid–solid interactions by interpreting theoretical models and experimental data (C3).

CO4	Explain the principles and applications of spectroscopy in the identification and characterization of molecules and their electronic, vibrational, and magnetic properties (C2).

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

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

Course Content and Outcomes:

Content	Competencies	Number of Hours
Unit 1:		
Atomic and molecular structure	• Recall the fundamental principles of quantum mechanics, including Planck's black body radiation, the photoelectric effect, and Heisenberg's uncertainty principle (C1). • Recall the Schröd'inger wave equation for a simple system like a particle in a one-dimensional box (C1). • Recall the principles of Pauli's Exclusion Principle and Hund's Rule of maximum multiplicity (C1). • Recall the significance of wave functions and their properties (normalized, orthogonal) (C1). • Draw the shapes of s, p, and d orbitals and explain their energy spectrum based on the radial and angular wave functions of the hydrogen atom (C2).	**06**
Unit 2:		
Gaseous state	• State and mathematically express gas laws such as Boyle's law, Charles's law, Gay-Lussac's law, and Avogadro's law (C1). • State Dalton's law of partial pressures and explain its applications (C1). • State Graham's law of diffusion and its significance (C1). • Understand the concept of Gibbs free energy (ΔG) and its significance in predicting the spontaneity of chemical reactions under constant temperature and pressure (C2).	**08**

Content	Competencies	Number of Hours
	• Describe the key concepts of the kinetic molecular model of gases, including collision frequency; mean free path, and viscosity (C2). • Understand the Maxwell-Boltzmann distribution of molecular velocities and explain its implications for heat capacities (C2). • Explain the ideal gas law and the reasons for deviations from ideal behaviour (C2). • Use the van der Waals equation to model the behaviour of real gases (Carbon dioxide and oxygen) (C3). • Describe the critical state and the law of corresponding states (C2).	
Unit 3:		
Liquid state	• Describe the physical properties of liquids, such as vapor pressure, surface tension, and viscosity (C2). • Explain how temperature and the concentration of solutes affect the surface tension and viscosity of a liquid (C2). • Use these concepts (such as viscosity, surface tension, compressibility, diffusion, and the molecular structure of liquids) to describe real-world applications of liquid properties (C3).	**07**
Unit 4:		
Solid state	• Describe the concept of unit cells, crystal systems, and Miller indices (C2). • Use Bragg's Law to solve problems related to X-ray diffraction (C3). • Explain the crystal structures of common ionic and covalent solids like NaCl, CsCl, and diamond (C2). • Describe different types of crystal defects and their impact on material properties (C2).	**07**

Content	Competencies	Number of Hours
Unit 5:		
Chemical thermodynamics	• Describe the fundamental laws of thermodynamics and the concepts of reversible and irreversible processes (C2). • Explain the properties of thermodynamic functions, including enthalpy, entropy, and Gibbs free energy (C2). • Solve problems related to thermochemistry and thermodynamic functions (C3). • Understand their dependence on composition using the Gibbs-Duhem equation (C2). • Explain the concept of chemical potential and its applications (C2).	**06**
Unit 6:		
Chemical and phase equilibria	• Explain the law of mass action and the significance of equilibrium constants (Kp , Kc , etc.) (C2). • Interpret the effect of changes in temperature, pressure, or concentration on a system at equilibrium using the Le-Chatelier principle (C3). • Describe the concepts of solubility product and salt hydrolysis (C2). • Interpret acid-base titration curves and select appropriate indicators (C3). • Use Raoult's and Henry's laws to solve problems related to dilute solutions (C3). • Interpret single and two-component phase diagrams using the Gibbs phase rule (C3).	**07**
Unit 7:		
Electrochemistry	• Explain the concepts of conductivity, molar conductivity, and ionic mobility (C2) • Use Kohlrausch's law and the Debye-Hückel-Onsager equation to calculate conductivity and ionic velocities (C3). • Describe the principles of electrolysis and its industrial applications (C2).	**06**

Content	Competencies	Number of Hours
	• Calculate the electromotive force (EMF) of a cell using the Nernst equation (C3). • Explain the concept of standard electrode potential and the electrochemical series (C2). • Use EMF measurements to perform potentiometric titrations (C3).	
Unit 8:		
Chemical kinetics	• Differentiate between the order and molecularity of a reaction (C2). • Solve integrated rate equations for zero, first, and second-order reactions (C3). • Apply the steady-state approximation to determine the rate law for complex reaction mechanisms (C3). • Explain the relationship between temperature and reaction rate using the Arrhenius equation (C2). • Describe the principles of collision theory and the mechanisms of catalysed reactions, including Michaelis-Menten kinetics (C2).	**06**
Unit 9:		
Adsorption	• Define the types of adsorption (physisorption and chemisorption) (C1). • Explain the Gibbs adsorption equation and the concept of an adsorption isotherm (C2). • Adsorption isotherms with the help of appropriate examples (C2).	**04**
UNIT 10:		
Spectroscopy	• State the Beer-Lambert's law (C1). • Explain the fundamental principles of rotational, vibrational, electronic, and magnetic resonance spectroscopy (C2).	**04**

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)
Assignments/Presentations	

Mapping of Assessment with COs:						
Nature of Assessment	**CO1**	**CO2**	**CO3**	**CO4**		
Mid Semester	**X**	**X**				
Unit Test/Quiz	**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 Reference:	• Puri, B. R., Sharma, L. R., & Pathania, M. S., Principles of Physical Chemistry, Vishal Publishing Co., 48th Edition, 2023. • Kapoor, K. L., A Textbook of Physical Chemistry (Volumes 1-5), Macmillan India, 4th Edition, 2011. • Madan, R. L., Physical Chemistry, McGraw Hill Education (India), Latest Edition.
Additional References	• Tandon, O. P., & Singh, A. S., A Textbook of Physical Chemistry (Vols. 1 & 2), G.R. Bathla & Sons, 25th Edition, 2025. • Bahadur, P., Physical Chemistry, Pragati Prakashan, Latest Edition.

Name of the Program	Bachelors of Science in Nuclear Medicine Technology
Course Title	**Radiobiology**
Course Code	**BNM2402**
Academic Year	Second
Semester	IV
Number of Credits	3
Course Prerequisite	Students should have basic knowledge of radiation physics, radiation detection and measurement, cell and molecular biology
Course Synopsis	The course aims to provide a mechanistic understanding of the biological processes involved in the interaction of ionizing radiation with living systems. This will help the student to know the relative risks and benefits of radiation and understand safety and regulatory aspects involved in personal protection and patient care.

Course Outcomes (COs):
At the end of the course student shall be able to:

CO1	Explain modes and mechanisms of radiation interactions with the biological system (C 2)
CO2	Explain the various type of radiation effects and the pathophysiological nature of radiation induced damage on the biological system (C2)
CO3	Compare the role of modifying factors in altering the biological sensitivity to radiation (C3)
CO4	Summarize detrimental effects of radiation on foetal development at various levels of radiation exposure (C2)

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 and Outcomes:

Content	Competencies	Number of Hours
Unit 1		
Bio-molecular and Cellular Radiobiology	• Outline major events in radiation interaction with biological system (C2) • Explain radiation chemistry and formation of free radicals (C2) • Compare direct and indirect interaction of radiation (C2) • Explain radiation interaction with DNA and chromosomes (C2) • Explain radiation Geno toxicity assessment (C2) • Explain radiation Cell death mechanisms and interpret cell survival assays (C2) • Identify Factors affecting cell radio- sensitivity/ survival fraction/radio-resistance (C3) • Compare Stochastic and deterministic effects of radiation (C2) • Compare Acute and delayed effects of radiation (C2) • Compare Whole body and localized organ exposure (C2)	18
Unit 2		
Early radiation effects	• Apply the concept of Lethal dose (C3) • Explain acute radiation syndrome (C2) • Explain NVD syndrome (C1) • Summarize Central nervous system syndrome, radiation dose related pathological changes (C2) • Summarize Gastrointestinal syndrome, radiation Dose related pathological changes (C2) • Summarize Bone marrow syndrome, radiation dose related pathological changes (C2)	13
Unit 3		
Delayed radiation effects	• Explain and Identify Late deterministic effects (C3) • Explain and Identify Late stochastic effects (C3) • Explain Models for estimating radiation associated cancer risk (C2)	5
Unit 4		
Radio-sensitizers and radio-protectors	• Explain role of heat as radio-sensitizer (C2) • Explain role of antioxidants as radio- protectors (C2)	4

Content	Competencies	Number of Hours
Unit 5		
Radiation effects on embryo	• What are the various phases of Embryo development? (C1) • Outline dose dependent Effects of prenatal irradiation (C2) • Compare and contrast radiation effects on animal and humans (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**
Formative:	**Summative:**	
Unit test	Mid Semester	
Quiz	End semester	
Assignment/presentations		

Mapping of Assessment with COs:				
Nature of Assessment	**CO1**	**CO2**	**CO3**	**CO4**
Mid Semester Examination	x	x		
Quiz / Unit Test	x	x	x	X
Assignment/presentations	x	x	x	X
End Semester Exam	x	x	x	X

Feedback Process:	Mid-Semester Feedback
	End-Semester Feedback
Main Reference:	1. Radiation Biology and Physics- Paul F Wilson and Joel S Bedford 2. Radiobiology for the Radiologist –Eric J Hall, and Amato J Giaccia Uma Devi
Additional References	1. Biological assessment of Radiation Damage – Thomas. L, Walden. Jr and Nushin K 2. Radiation biology – Devi P .Uma, Nagarathnam A and Rao BSS

Name of the Program	Bachelors of Nuclear Medicine Technology
Course Title	**Biostatistics**
Course Code	**BNM2403**
Academic Year	Second
Semester	IV
Number of Credits	3
Course Prerequisite	Basic knowledge of mathematics and statistics
Course Synopsis	1. To provide necessary foundation on • Introductory level biostatistics • Demography, vital statistics and epidemiology • Survey sampling methods • Fertility, morbidity, and mortality indices 2. To introduce the steps involved in research process

Course Outcomes (COs): At the end of the course student shall be able to:	
CO1	**Summarize** the variable types, scales of measurement and understand the role of biostatistics in health professions (C3)
CO2	**Apply** appropriate descriptive statistics, visualizations, point, interval estimation, and Confidence Interval, parametric and non-parametric tests to variables in healthcare studies (C3)
CO3	**Outline** the sources of demographic data and vital statistics, merits and demerits of Sampling distribution, probability and non-probability sampling techniques (C2)

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						

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Course Content and Outcomes:

Content	Competencies	Number of Hours
Unit 1: Introductory Biostatistics		
Introduction to Biostatistics	• Define statistics and biostatistics (C1) • Describe the limitations and characteristics of biostatistics (C2) • Explain the role of statistics in health sciences (C2)	3
Variables	• Summarize the types of variables with examples (C2) Distinguish between qualitative & quantitative with appropriate examples (C2) • Distinguish between continuous & discrete variables with appropriate examples (C2)	
Scales of Measurement	• Describe nominal, ordinal, interval and ratio scale of measurement of variables with appropriate examples (C2) • Distinguish between the four scales of measurement (C2)	
Unit 2: Descriptive Statistics		
Summarizing Data: Tabulation Methods	• Illustrate the qualitative, quantitative and chronological classification to tabulate and summarize data (C3)	7
Summarizing Data: Graphical Methods	• Describe graphical methods to summarize data: Pie chart, Bar chart, Line Plot, Histogram, Frequency Curve and Frequency Polygon (C2)	
Measures of Central Tendency	• Explain the concepts of Mean, Median, Mode (C2) • Explain the concepts of Quartiles and Percentiles (C2)	
Measures of Dispersion	• Describe the concepts of Range, Inter-quartile range, Variance, Standard deviation and Coefficient of variation (C2) • Explain the concept of skewness and describe three types of skewness (C2) • Explain the concept of kurtosis and describe three types of kurtosis (C2)	

Content	Competencies	Number of Hours
Unit 3: Introduction to Probability and Normal Distribution		
Probability: An Introduction	• Define the relative frequency approach to probability (C1)	3
Normal Distribution	• Explain the characteristics of normal distribution (C2) • Compute the area under the normal distribution curve (C3)	
Unit 4: Sampling Methods		
Need for Sampling	• Explain the need for sampling and the advantages of sampling over complete enumeration (C2) • Explain sampling and non-sampling error (C2) • Define and distinguish probability and non-probability sampling methods (C1)	3
Random Sampling Methods	• Explain the uses and situation of each sampling technique and mention merits and demerits (C2)	
Non-random Sampling Methods	• Explain the uses and situation of each sampling technique and mention merits and demerits (C2)	
Unit 5: Introduction to Correlation and Regression Analysis		
Correlation Analysis	• Define correlation and its properties (C2) • Explain types of correlation with diagrams and appropriate examples (C2) • Illustrate using scatter plot the different types of correlation (C3) • Explain the Pearson's correlation coefficient and outline its properties (C2) • Explain the Spearman's correlation coefficient and outline its properties (C2)	4
Regression Analysis	• Distinguish between dependent and independent variables (C2) • Explain the simple linear regression model along with the assumptions involved (C2) • Identify the slope and intercept coefficient from the model (C2) • Predict the dependent variable from the model for a given set of independent variables (C3)	

Content	Competencies	Number of Hours
Unit 6: Testing of Significance		
Understanding population, sample, parameter and statistics, estimate and estimator	• Define and differentiate parameter and statistic with examples (C2) • Define the basic terms-population, sample, sampling, parameter, statistic, estimate and estimator, point estimate (C1) • Define and differentiate standard deviation and standard error (C2)	8
Sampling distribution/ stand ard error	• Determine the sampling distribution/standard error of sample mean, sample proportion, difference between two means, difference between two proportions (Large sample approximation (CLT) (C3)	
Confidence Interval	• Construct and interpret confidence interval for mean, difference between two means, proportion, difference between two proportions (large sample approximation) (C3)	
Unit 7: Testing of Hypothesis		
General procedure of testing of hypothesis	• Define/explain with example the concept of null hypothesis, alternative hypothesis, type I and type II errors. Define level of significance, power of the test and p-value, one sided and two-sided test (C2)	6
Parametric test: Single mean test, difference between two means test, and paired t test.	• Explain the differences, merits and demerits of parametric and non-parametric over parametric tests (C2)	
Non-Parametric test: Chi-square test, Mann-whiteney test, Sign test	• Give the situation for parametric and non-parametric tests (C2)	

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 Exam	
Quiz	End Semester Exam	
Assignment/presentations		

Mapping of Assessment with COs:				
Nature of Assessment	**CO1**	**CO2**	**CO3**	**CO4**
Mid Semester Examination	x	x	X	-
Quiz/unit test	x	x	X	X
Assignment/ presentation	x	x	X	X
End Semester Exam	x	x	X	X

Feedback Process:	End-Semester Feedback
Main Reference:	1. Lwanga SK, Tye CY, Ayeni O. Teaching health statistics: lesson and seminar outlines. World Health Organization, Marketing and Dissemination, 1211 Geneva 27, Switzerland; 1999. 2. Health research methodology: a guide for training in research methods. World Health Organization; 2001. 3. Bonita R, Beaglehole R, Kjellström T. Basic epidemiology. World Health Organization; 2006. 4. Campbell MJ, Swinscow TD. Statistics at square one. John Wiley & Sons; 2011.
Additional References	1. Daniel, W. W., and Cross, C. L. (2018). Biostatistics: a foundation for analysis in the health sciences. Wiley. 2. Kothari, C. R. (2004). Research methodology: Methods and techniques. New Age International. 3. Rosner, Bernard, (2010). Fundamentals of Biostatistics, 7th Edition, Duxbury Press. 4. Peter Armitage, Geoffrey Berry, J. N. S. Matthews, (2002). Statistical Methods in Medical Research, 4th Edition, Blackwell. 5. Wayne W. Daniel, (2004). Biostatistics_ A Foundation for Analysis in the Health Sciences, 8th Edition, Wiley Series in Probability and Statistics.

Name of the Program	Bachelors of Science in Nuclear Medicine Technology
Course Title	**Health Physics and Radiation Safety**
Course Code	**BNM2404**
Academic Year	Second
Semester	IV
Number of Credits	3
Course Prerequisite	Students should have knowledge in Basics of Nuclear Medicine and safety
Course Synopsis	1. This course covers the basics in Nuclear Medicine and safety needed for nuclear medicine technology. 2. The course describes the effects of ionizing radiation on living organisms. 3. To assist the students to learn the basic Nuclear Medicine in order to understand the concept of the sealed and unsealed radioisotopes and their uses in the treatment of cancer 4. The course emphasizes radiation Safety Consideration in Radionuclide therapy 5. To deal with the different imaging techniques used in nuclear medicine and physics behind detectors and to identify the fundamentals of nuclear medicine facilities and their applications in day today life.

Course Outcomes (COs):
At the end of the course student shall be able to:

CO1	Explain the basic principles of radiation protection, the fundamental factors by which radiation hazards can be controlled, ALARA principle, HVL, TVL, the nuclear medicine laboratories, delay tank, isolation ward, dose limitations for the discharge of effluents and patients and to solve related problems (C2)
CO2	Explain direct and indirect surface contamination, ALI, DAC, Survey meters, contamination monitors, personal dosimeters dose limits prescribed by the AERB, IAEA-BSS and the ICRP for occupational and public, Radiation safety aspects for patients referred for ablation and toxic therapy, precautions, discharge criteria, dose optimization, handling bedridden patients and other radionuclide therapies (C2)
CO3	Explain A1 and A2 values for transport, safe transport of radioactive material, transport index, classification of radioactive packages (C2)

CO4	Explain concepts and principle of radioactive waste management, on radioactive waste management in Nuclear Medicine, practical examples, fixed and loose contamination, contamination limits Regulatory aspects, duties of RSO, employer, radiation worker and the licensee, emergency response accessories, emergency planning and preparedness (C2)
CO5	Explain misadministration in nuclear medicine, types, consequences, causes and preventive measures taken to avoid misadministration, emergency situation in NM, spillage of radioactive material, dealing with emergency situation, handling cadaver administered with radionuclides, decontamination procedures (C2)

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					
CO5		x	x					

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Course content and outcomes:

Content	Competencies	Number of Hours
Radiation quantities and unit	Define (C1) • Activity (Becquerel /Curie) • Energy, exposure (C/kg/ Roentgen), • LET, • Charge particles equilibrium (CPE), • Linear and mass attenuation coefficient, • Mass stopping power, • Air kerma, • Terma, • Absorbed dosea (Gray/ rad), • Radiation weighting factor (WR) • Tissue win factor • equivalent dose • effective dose • collective effective dose person SV • annual limit of intake Ali becquerel • drived air concentration DAC becquerel/m3 • personnel dose equivalent • committed dose	2
Operational limits	• Introduction to neutral backgrounds radiation, tell the concept of occupational risk, optimization of patient dose (C1) • Explain on philosophy of radiation protection system of dose limitation ALARA dose limit to radiation workers general public dose constraint for comforter of patient. (C2) • Explain and list on AERB/ICRP recommendation (C2)	3
Radiation detection and Measurement	• Explain on principle of radiation detection, various gas detector (ionization chamber proportional counter and GM counter), solid state detector (scintillator, semiconductor and Thermo luminescent Dosimeter (TLD) and liquid scintillation counting system. (C2) • Explain on nuclear counting statistics, confidence level of measurement (C2) • Explain radiation monitoring, direct reading device. (C2) • Explain on calibration and response of radiation monitoring instruments. (C2)	4

Content	Competencies	Number of Hours
Radiation hazard Evaluation and control	• List on internal and external radiation hazard and their perspective, use of kV, mAs, filtration, screens, Image intensifiers (C2) • Explain on evaluation and control of hazard due to external radiation, individual and workplace monitoring application of time, distance and shielding, specific gamma ray constant, external radiation monitoring, survey meters. (C2) • Explain on internal hazard evaluation and control, protective measures for handling of unsealed source (e.g. fume hood, glove box), environment control, protective clothing. (C2) • Explain on contamination monitoring direct and indirect, air contamination monitoring, personal contamination monitoring and decontamination procedure surface decontamination procedure. (C2)	4
Radiation Dosimetry	• Explain and derive single compartmental model and 2 compartmental model with and without back transference (C2). • Explain in vivo dosimetry using classical dosimetry mechanism (C2) • Explain ➢ Beta dosimetry ➢ Gamma dosimetry ➢ Geometrical factor explaining the Dosimetry of low energy electromagnetic radiation (C2) ➢ Explain and derive MIRD formulation (C2) ➢ Define • cumulated activity • equilibrium absorbed dose constant absorption factor • specific absorption fraction ➢ Explain the doors reciprocity theorem ➢ Define mean dose per cumulated activity (C1) ➢ List the limitation of MIRD method (C1) ➢ what is extremity dosimetry (C1)	5

Content	Competencies	Number of Hours
Quality control (QC) in nuclear medicine	• List the importance of QC in nuclear medicine. (C1) • Explain on the test parameters and procedure of QC of isotopes calibrator, planer gamma camera system, SPECT (C2) • Explain on test parameters and procedure for QC of PET, PET-CT and radio pharmaceuticals (C2)	2
Radionuclide therapy radiation safety Aspect	• List the various radio nuclei administration technique (C1) • Explain and summarise on pre and post therapy precaution, nursing care, patient monitoring and discard criteria (C2) • Explain on optimization of radiation dose to non-target tissue, radiation safety consideration in treatment of Ca-thyroid, palliative bone, metastases and other therapeutic procedures such as radiation synovectomy peptide therapy etc. (C2)	2
Disposal of Radioactive waste	• Explain on origin and types of waste, classification of wastes and methods of disposal, disposal of short-lived solid, liquid and gaseous radioactive waste. (C2) • Explain on disposal of animal carcasses and radioactive foliage disposal limits for ground burial and sanitary sewage system incineration disposal of long-lived and indispersible radioactive waste (C2)	3
Planning of nuclear medicine facilities	• Explain on classification and general features of NM laboratories (site, typical floor plans, ventilation, surface, walls, floor and ceiling, work surfaces, containment systems, fume-hood, glove box etc.) (C2) • Explain on planning of NM laboratories, such as diagnostic and high dose therapy, PET-CT and medical cyclotron installation, shielding evaluation of NM laboratories and medical cyclotron (C2) • Outline on model layouts of various NM laboratories, commissioning, decommissioning. (C2)	3

Content	Competencies	Number of Hours
Transport of Radioactive material	• Explain on rules governing transport of radioactive material, introduction, terms used (e.g. Competent Authority, A1 & A2 values, Transport Index (TI) etc.), transport scenarios (routine, normal & accident), types of packages covered under the transport regulations, general requirement of all packaging, requirements for transport of radioactive material in liquid form, expected limit, special form and other than special form (C2) • Explain on TREMCARD, procedure for packing, marking, labelling transport documents responsibilities of consignor and consignee, consignor's declaration, instruction to the carrier, transport of surface contaminated objects, off-normal situations during transport of radioactive materials, handling off-normal situation, emergency planning (C2)	3
Radiation Accidents, Case Studies and lesson Learns	• Explains on radiation accidents involving radioisotopes, orphan and vulnerable sources, handling of emergency situations, resulting from spillage of radiopharmaceuticals/liquid radioisotopes, misadministration of radiopharmaceuticals and its consequences (C2) • Explain on general method of prevention of accident, loss of radioisotope fire accident and explosion; follow up action through emergency response plan, case study and mitigation lesson learned (C2)	3

Content	Competencies	Number of Hours
Regulatory aspect of nuclear medicine facilities	• Explain on regulation with respect to nuclear medicine laboratory relevant regulatory documents such as act, rule, code, standards and Guides, responsibility of employer, licence, radiation safety officer RSO, technologists and radio isotope supplier safety and security of radioactive source during transport any storage inventory control (C2) • Explain on security provision: administrative and technical measures, graded approach in security provision, physical protection system, regulatory requirement for import/ export, procurement, use handling transfer and disposal of radioisotope inventory control, Radiation protection programme RPP e licensing procures in India (C2)	2
Emergency response plan and preparedness	• List and explain on normal and potential exposure accident situation involving radioisotopes element of emergency planning and preparedness including procedure for notification and communication administrative and technical procedure emergency response accessories responsibilities of employer licence RSO technologists and radio isotope/equipment supplier in case of emergencies (C2)	2

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Learning Strategies, Contact Hours and Out of class engagement:		
Learning Strategies	**Contact Hours**	**Out of class engagement**
Lecture	30	25
Seminar	11	11
Revision	2	2
Assessment	2	2
Total	**45**	**45**

Assessment Methods:	
Formative:	**Summative:**
Unit Test	Mid Semester/Sessional Exam
Quiz	
Assignments/Presentations	End Semester Exam

Mapping of Assessment with COs:					
Nature of Assessment	**CO1**	**CO2**	**CO3**	**CO4**	**CO5**
Mid Semester Examination	x	x			
Quiz/Unit Test	x	x	x	x	X
Assignments/presentations	x	x	x	x	X
End Semester Exam	x	x	x	x	X

Feedback Process:	Mid-Semester Feedback
	End-Semester Feedback
Main Reference:	1. Physics in Nuclear Medicine - Simon R. Cherry, James A. Sorenson, and Michael E
Additional References	2. Fundamentals of Nuclear Pharmacy, Fifth Edition- Gopal B. Saha, Ph.D. 3. Nuclear Medicine Therapy: Principles and Clinical Applications 4. By Aktolun, Cumali, Goldsmith, Stanley J. (Eds.) 5. Nuclear Medicine Physics: The Basics 8th Edition by Ramesh Chandra and Arman Rahmim, Wolters Kluwer | Lippincott Williams and Wilkins

Name of the Program	**Bachelor of Science in Nuclear Medicine Technology**
Course Title	**Practicum – IV**
Course Code	**BNM2405**
Academic Year	Second
Semester	IV
Number of Credits	3
Course Pre-requisite	Basic knowledge of radiation physics, chemistry, biology, and instrumentation relevant to nuclear medicine.
Course Synopsis	This course provides essential practical training in radiobiology, in vitro nuclear medicine techniques, radiation protection, and nuclear medicine physical chemistry.

Course Outcomes (COs):
At the end of the course student shall be able to:

CO1	To demonstrate radiation induced cellular and DNA damage (C3, P3)
CO2	To perform radioactive non imaging diagnostic procedures (C3, P3)
CO3	To understand radiation safety rules and perform radiation surveillance following safety guidelines (C3, P3)
CO4	To determine reaction kinetics and adsorption parameters, measure and analyze physical properties (viscosity, surface tension, vapor pressure, molar refraction), perform electrochemical experiments, and study binary phase diagrams (C4, P3).

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

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

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Content	Competencies	Number of Hours (T/P)
Unit 1: Radiobiology		
Radiobiology Practical	• To demonstrate the damaging effect of gamma and beta radiations on DNA (C3, P2) • To demonstrate genotoxicity of various agents using micronucleus assay (C3, P2) • To demonstrate chromosomal aberrations induced by various agents (C3, P2) • To demonstrate effect of ionizing radiations on red blood cells (C3, P2)	15
Unit 2: In vitro Nuclear Medicine techniques		
In vitro Nuclear Medicine techniques practical	• To perform sample collection, storage and centrifugation of biological samples (C3, P3) • To perform the in vitro steps of radiolabeling (e.g., using 99mTc or 51Cr) for procedures like mass or survival studies, and to evaluate the labeling efficiency (C3, P3) • To perform RIA using kits • To perform IRMA (e.g., for a large protein hormone like TSH or hCG) and understand the direct relationship between antigen concentration and bound radioactivity (C3, P3) • To measure the absorption of orally administered Vitamin B12 by Schillings test using 57Co-B12 (C3, P3)	20
Unit 3: Health Physics and Radiation protection		
Health Physics and Radiation protection practical	• To perform radiation area survey (C3, P3) • To perform radiation decontamination (C3, P3) • To demonstrate the effect of time on radiation exposure (C3, P3) • To demonstrate the effect of distance on radiation exposure (C3, P3) • To demonstrate the effect of shielding on radiation exposure (C3, P3) • To perform calibration of contamination Monitor using standard source(s) (C3, P3) • To perform calibration of radiation survey • meter using standard source(s) (C3, P3)	20

Content	Competencies	Number of Hours (T/P)
Unit 4: Radiochemistry		
Nuclear medicine Physical Chemistry I practical	• To determine the rate constant and order of a chemical reaction from concentration measurements (C3, P2). • To measure physical properties of liquids (viscosity, surface tension, vapour pressure) and analyze the data (C4, P3). • To determine the velocity constant and concentration effect for the second-order reaction KI + $K_2S_2O_8$ (C3, P2) • To determine equilibrium constants of chemical reactions (C2, P2). • To study pH versus volume curves in acid–base titrations (C2, P3) • To determine the heat of solution of KNO_3 using solubility measurements (C3, P2).	20

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Learning Strategies, Contact Hours and Out of class engagement:		
Learning Strategies	**Contact Hours**	**Out of class engagement**
Practical	66	66
Small group discussion	9	9
Total	**75**	**75**
Formative:	**Summative:**	
Quiz	Mid Semester (Practical)	
Viva	End semester (Practical)	
Practical record book	Record Book	

Mapping of Assessment with COs:				
Nature of Assessment	**CO1**	**CO2**	**CO3**	**CO4**
Mid Semester Examination	X	X	X	X
Quiz / Viva	X	X	X	X
Clinical/Practical Log Book/ Record Book	X	X	X	X
End Semester Exam	X	X	X	X

Feedback Process:	Mid-Semester Feedback
	End-Semester Feedback
Main Reference:	1. Nuclear Medicine Technology & Techniques Third Ed Donald Bernier et.al 2. Physics in Nuclear Medicine, Sorenson 3. Physical Chemistry Lab Manual" for M.Sc. Chemistry Practical which covers kinetics, physical property measurements, and electrochemical studies. 4. American Chemical Society Guidelines on Measurement of Physical Properties. 5. Physical Chemistry of Surfaces" by Arthur W. Adamson and Alice P. Gast, a resource focusing on adsorption and surface phenomena.
Additional References	1. Mosby's Manual of Nuclear Medicine Procedures, D.Bruce Sodee, Paul J Early 2. Radioimmuno assay- Principles and Practice, Pillai & Bhandarkar 3. Physical Chemistry Laboratory Manuals" by various universities, detailing viscosity, surface tension, vapor pressure, and phase diagrams measurements. 4. Atkins' Physical Chemistry" by Peter Atkins and Julio de Paula, a comprehensive general physical chemistry textbook with strong treatment of kinetics and surface chemistry.

Name of the Program	**Bachelors of Science in Nuclear Medicine Technology**
Course Title	**Clinical Practice – III**
Course Code	**BNM2406**
Academic Year	Second
Semester	IV
Number of Credits	3
Course Prerequisite	Students should have awareness of nuclear medicine procedures in radiopharmacy, in-vitro, scintigraphy and radionuclide therapy.
Course Synopsis	This course provides the basic hands-on training for the candidate to prepare & safely handle the radiopharmaceuticals for clinical applications in Nuclear Medicine department, different imaging and non-imaging Nuclear Medicine procedures and documentation.

Course Outcomes (COs):
At the end of the course student shall be able to:

CO1	Understand and perform routine radiopharmacy practices in clinical nuclear medicine (C3, P2)
CO2	Understand and perform routine scintigraphy practices in clinical nuclear medicine (C3, P2)
CO3	Understand and perform routine radionuclide therapy practices in clinical nuclear medicine (C3, P2)

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		
CO2	x	x	X	X	x	x		
CO3	x	x	X	X	x	x		

Course Content and Outcomes:

Content	Competencies	Number of Hours
Unit 1		
Radiopharmacy Practices	• To arrange Radiopharmacy lab for daily activities (C1, P2) • To identify and produce the inventory (C2, P2) • To perform QC of dose calibrator (C3, P2) • To prepare and dispense radiopharmaceuticals (C3, P2) • To perform QC of radiopharmaceutical (C3, P2) • To express procedures to patient and to practice as per regulatory guidelines (C2, P1, A2) • To write and maintain registers (C3)	30
Unit 2		
In-vitro Nuclear Medicine Practices	• To locate and identify stock inventory (C2, P2) • To maintain various non-imaging and radiation monitoring equipment (C3, P2) • To perform radiation surveillance and produce the reports (C2, P2) • To write and maintain registers (C3)	30
Unit 3		
Scintigraphy Practices	• To arrange imaging room for daily activities (C1, P2) • To perform daily QC of imaging and other accessory devices (C3, P2) • To express procedures to patient and to practice as per regulatory guidelines (C2, P1, A2) • To write and maintain registers (C3)	45
Unit 4		
Radionuclide Therapy Practices	• To locate and identify stock inventory (C2) • To practice QC of dose calibrator (C3, P3) • To observe preparation and dispensing of therapeutic radiopharmaceuticals (C2, P1) • To practice QC of radiopharmaceuticals (C3, P3) • To express procedures to patient and to practice as per regulatory guidelines (C2, P1, A2) • To maintain radiation exposure records (C3) • To write and maintain registers (C3)	30

Learning Strategies, Contact Hours and Out of class engagement:		
Learning Strategies	**Contact Hours**	**Out of class engagement**
Small group discussion (SGD)	5	15
Problem Based Learning (PBL)	5	15
Case Based Learning (CBL)	5	15
Clinic	120	-
Total	**135**	**45**

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**
Mid Semester Examination	x	x	X
Quiz / Viva	x	x	X
Clinical/Practical Log Book/ Record Book	x	x	X
Clinical assessment (OSCE, OSPE, WBPA)	x	x	X

Feedback Process:	Mid-Semester Feedback
	End-Semester Feedback
Main Reference:	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. NUCLEAR MEDICINE FACILITIES, CODE NO. AERB/RF-MED/SC-2 (Rev. 2) or as revised from time to time by AERB Mumbai. 3. Nuclear Medicine Technology: Procedures and Quick Reference — Pete Shackett

SEMESTER - V

Course code	Course Title
BNM3501	Radiopharmaceutical chemistry
BNM3502	Imaging instruments in Nuclear Medicine
BNM3503	Application of Computers in Nuclear Medicine
BNM3504	Clinical Nuclear Medicine - I
BNM3505	Practicum – V
BNM3506	Clinical Practice – IV

Name of the Program	**Bachelor of Science in Nuclear Medicine Technology**
Course Title	**Radiopharmaceutical Chemistry**
Course Code	**BNM3501**
Academic Year	Third
Semester	V
Number of Credits	4
Course Prerequisite	Students should have basic knowledge of radionuclide production methods, radionuclide generators and general radiation safety guidelines related to safe handling of radiopharmaceuticals.
Course Synopsis	This course aims to provide a comprehensive knowledge on development process for new radiopharmaceuticals, clinical application and safe handling of existing diagnostic PET, therapeutic and theranostic radio-pharmaceuticals, particularly focusing on production, radiochemistry, and regulatory aspects.

Course Outcomes (COs):
At the end of the course student shall be able to:

CO1	Explain and apply radio-iodination chemistry and methods for the synthesis of Iodine labelled radiopharmaceuticals (C2)
CO2	Explain PET radiopharmaceutical synthesis methods and ideal radiopharmaceutical's properties for clinical use (C2)
CO3	Identify clinically useful therapeutic and theranostic radiopharmaceuticals and understand their biological interactions (C2)
CO4	Understand regulatory guidelines for development, procurement, safe handling and disposal of radiopharmaceuticals and radioactive material (C2)

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 and Outcomes

Content	Competencies	Number of Hours
Unit 1		
Iodine labelled radiopharmaceuticals	• Explain radio Iodine Chemistry (C2) • Describe the production, physical and chemical characteristics, biological behaviour 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)	11
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 • Infer monographs for 99mTc-labelled Radiopharmaceuticals (C1)	
Unit 2		
Radiopharmaceuticals for Positron emission tomography (PET)	• Describe the production of PET radionuclides (C2) • Describe the preparation method and quality control procedure for PET radiopharmaceuticals (F-18, C-11, N-13,O- 16, Ga-68) (C2) • Explain the clinical application and uptake mechanism(C2)	17

Content	Competencies	Number of Hours
	• Outline the design, working and application of automated synthesis Modules(C2) • Outline the design and working of PET Radionuclide generators(C2) • Describe safe handling procedures of positron emitters (C2)	
Unit 3		
Therapeutic and theranostic Radiopharmaceuticals	• Illustrate targeted Radionuclide therapy and theranostics in nuclear medicine(C2) • Interpret the physical, chemical and biological characteristics of Therapeutic and theranostic radionuclides(C2) • Explain the therapeutic/theranostic clinical role and biological action mechanism of radio-pharmaceuticals (C2)	14
Unit 4		
Regulatory guidelines for development of Radiopharmaceuticals	• Extend on general consideration for design of newer radiopharmaceuticals(C2) • Describe the development stages and drug terminology used in radio- pharmaceutical development process(C2) • Summarize pharmacopeia for radiopharmaceuticals (C2) • Extend on Good Hospital Radio pharmacy Practices (GHRP) and Good Manufacturing Practices (GMP) for Radiopharmaceuticals(C2) • Outline the relationship between GMP & ISO-relevant to nuclear medicine laboratory(C2)	18
Unit 5: Regulatory guidelines for procurement, Safe handling and disposal of radioactive material		
	• Outline the E- Licensing procedures for handling Radioactive materials in India(C2) • Extend on regulation ethics and registration of radiopharmaceuticals(C2) ➢ Summarize the procedure and documentations for ordering, receiving, storage, decay and disposal of Radiopharmaceuticals (C2)	

Learning Strategies, Contact Hours and Out of class engagement:		
Learning Strategies	**Contact Hours**	**Out of class engagement**
Lecture	45	40
Seminar	10	10
Revision	02	5
Assessment	03	5
Total	**60**	**60**
Formative:	**Summative:**	
Unit test	Mid Semester	
Quiz	End semester	
Assignment/seminars		

Mapping of Assessment with COs:				
Nature of Assessment	**CO1**	**CO2**	**CO3**	**CO4**
Mid Semester Examination	x	x		
Quiz / Unit Test	x	x	x	x
Assignment/Seminars	x	x	x	x
End Semester Exam	x	x	x	x

Feedback Process:	Mid-Semester Feedback
	End-Semester Feedback
Main Reference:	1. Radiopharmaceuticals in Nuclear Medicine Pharmacy and 2. Nuclear Medicine, 2nd American Pharmacists Association, 2004, ISBN 1582120315 Kowalsky, Richard J., and Steven W. Falen, 3. Fundamentals of Nuclear Pharmacy, 3rd Edition Gopal B Saha
Additional References	1. Sampson‟s Text Book of Radiopharmacy 4th Ed (Dec 2010), ISBN : 9780853697893 Edited by Theobald Tony 2. Hand Book of Radiopharmaceuticals by M H Patel

Name of the Program	Bachelors of Science in Nuclear Medicine Technology
Course Title	Imaging Instruments in Nuclear Medicine
Course Code	**BNM3502**
Academic Year	Third
Semester	V
Number of Credits	3
Course Prerequisite	Students should have basic knowledge of basic science subjects, nuclear medicine instrumentation and physics.
Course Synopsis	This course will help the student to learn about nuclear medicine imaging devices like gamma camera, SPECT and PET imaging.

Course Outcomes (COs):
At the end of the course student shall be able to:

CO1	Understand various components and working principle of Gamma Camera in nuclear medicine counting (C2)
CO2	Understand various components and working principle of SPECT imaging in nuclear medicine counting (C2)
CO3	Understand various components and working principle of PET imaging in nuclear medicine counting (C2)
CO4	Understand basic concepts behind calibration and quality control of nuclear medicine imaging instruments (C2)

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

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1	x							
CO2	x	x						
CO3			x				X	
CO4	x	x						
CO5	x				x			
CO6	x						X	

Contents	Competencies	Number of Hours
Unit 1		
Gamma Camera	• Explain the Introduction to gamma camera (C2) • Explain the Components of gamma camera (C1) • Explain the Detector system and event localization (C2) • Explain the Collimators and Performance characteristics of parallel hole collimators (C2) • Explain the Events in gamma camera (C2) • Explain Types of gamma camera and their use (C2) • Explain the Performance characteristics of a gamma camera (C2)	15
Unit 3		
Single Photon Emission Tomography	• Introduction to SPECT (C2) • Design and working principle (C2) • Components of SPECT (C2) • Data acquisition (C2) • Performance characteristics (C2), quality control aspects (C2) • SPECT artifacts (C2)	15
Unit 4		
Positron Emission Tomography	• Introduction to PET (C2), • Design, working principle (C2) • Components of PET (C2) • Data acquisition (C2) • Performance characteristics (C2), quality control (C2) • Artifacts (C2)	15

Learning Strategies, Contact Hours and Out of class engagement:		
Learning Strategies	**Contact Hours**	**Out of class engagement**
Lecture	30	30
Seminar	3	3
Revision	2	4
Assessment	2	5
Total	**45**	**45**

Assessment Methods:	
Formative:	**Summative:**
Unit Test	Mid Semester Exam (Theory)
Quiz	End Semester Exam (Theory)
Assignments/Presentations	

Mapping of Assessment with COs:						
Nature of Assessment	**CO1**	**CO2**	**CO3**	**CO4**	**CO5**	**CO6**
Mid Semester Examination	x	x	x			
Quiz /Unit Test	x	x	x	X	X	x
Assignments/Presentations	x	x	x	X	X	x
End Semester Exam	x	x	x	X	X	x

Feedback Process:	Mid-Semester Feedback
	End-Semester Feedback
Main Reference:	1. Nuclear Medicine the Requisites: Thrall James
	2. Principles and Practice of Nuclear Medicine: P J Early, D.B Sodee
Additional References	1. Nuclear Medicine in clinical diagnosis and treatment: Peter J Ell 2. Principles of Nuclear Medicine: Henry N.Wagner 3. Nuclear Medicine: Robert E.Henkin

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Name of the Program	Bachelors of Science in Nuclear Medicine Technology
Course Title	Applications of computer in Nuclear Medicine
Course Code	**BNM3503**
Academic Year	Third
Semester	V
Number of Credits	3
Course Prerequisite	Introduction to Nuclear Medicine, Basic Physics and Mathematics, Basic Computer Skills
Course Synopsis	This course provides a comprehensive introduction to the fundamental role and diverse applications of computer systems, software, and information technology in Nuclear Medicine. It covers the principles of digital image acquisition, processing, reconstruction, quantification, and archival as applied to SPECT, PET, and hybrid imaging systems. The course also explores hospital information systems (HIS), radiology information systems (RIS), and Picture Archiving and Communication Systems (PACS), emphasizing data security, ethical considerations, and regulatory compliance.

Course Outcomes (COs):
At the end of the course student shall be able to:

CO1	Explain the architecture and function of computer hardware and software essential for nuclear medicine imaging and data handling (C2)
CO2	Explain the principles of digital image acquisition, including sampling, quantization, and matrix formation, as they relate to SPECT and PET data capture (C2)
CO3	Analyze and apply common image processing techniques (e.g., filtering, smoothing, and windowing) to optimize image quality and enhance diagnostic information in clinical nuclear medicine images (C3)
CO4	Evaluate the critical need for data integrity, security, and regulatory compliance (e.g., DICOM, HIPAA/GDPR) concerning the handling and archival of patient data within PACS and RIS environments (C4)

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

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1	x							
CO2	x	x						
CO3			x				x	
CO4	x	x						
CO5	x				x			
CO6	x						x	

Contents	Competencies	Number of Hours
Unit 1		
Introduction to Computer Systems in NM	• Explain the function of key hardware components (CPU, memory, storage) and operating systems in image acquisition (C2) • What is Computer architecture (hardware, CPU, memory, storage) (C1) • Explain Operating systems (Windows/Linux basics) (C2) • What are Data types and its representation (binary, digital data) (C1) • What is the role of computers in nuclear medicine workflow (C1)	5
Unit 2		
Digital Image Fundamentals	• What are Pixels (C1) • What are matrices (C1) • Explain spatial resolution (C2) • Define: bit depth, grayscale (C1) • Explain sampling and Quantization (C2) • what is Image file format (DICOM standards) (C2)	5
Image Acquisition and Data Processing	• explain Analog-to-Digital Conversion (ADC) (C2) • what are Pulse Height Analyzer (PHA) integration (C1) • explain Frame-mode vs. List-mode acquisition (C2) • what is Uniformity (C1)	5
Unit 3		
Image Processing Techniques	• Explain Image Display: Look-Up Tables (LUTs) (C1) • Explain Window/Level (C1) • what is Image Filtering: spatial vs. frequency domain (C2) • Explain smoothing (e.g., Butterworth, Hanning) (C1) • Explain noise reduction (C1) • What is edge detection (C1)	5

Contents	Competencies	Number of Hours
Unit 4		
Image Reconstruction (SPECT and PET)	• Explain Backprojection and Filtered Backprojection – FBP(C2) • What is Iterative Reconstruction (e.g., OSEM) (C2) • What is Attenuation and Scatter Correction (C1) • What is Coincidence detection (C2) • Explain Sinogram (C1) • Explain FBP vs. Iterative methods in PET (C1) • What is Time-of-Flight (TOF) Corrections in PET (C2)	10
Unit 5		
Quantitative Analysis and Kinetic Modeling	• Explain Region of Interest (ROI) analysis • What is Time-Activity Curves (TACs) and Standardized Uptake Value (SUV) calculation and its limitations (C2) • Explain Basic kinetic models (e.g., two-compartment model) (C2)	10
Unit 6		
Network and Information Systems	• What is PACS: Architecture, components, workflow integration (C1) • Explain HIS/RIS integration with Nuclear Medicine systems. Networking basics (LAN, WAN, Teleradiology) (C2)	5

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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 Exam (Theory)
Quiz	End Semester Exam (Theory)
Assignments/Presentations	

Mapping of Assessment with COs:						
Nature of Assessment	**CO1**	**CO2**	**CO3**	**CO4**	**CO5**	**CO6**
Mid Semester Examination	x	x	x			
Quiz /Unit Test	x	x	x	X	X	x
Assignments/Presentations	x	x	x	X	X	x
End Semester Exam	x	x	x	X	X	x

Feedback Process:	Mid-Semester Feedback
	End-Semester Feedback
Main Reference:	1. Cherry, S. R., Sorenson, J. A., & Phelps, M. E. (2012). Physics in Nuclear Medicine (4th ed. or later). Elsevier. (Relevant chapters on instrumentation, computers, and imaging principles).
	2. Vendor-specific software manuals for Nuclear Medicine workstations (e.g., GE Xeleris, Siemens syngo).
Additional References	1. Selected articles and peer-reviewed journal publications as assigned by the instructor. 2. Dedicated nuclear medicine simulation software for image processing and reconstruction practice.

Name of the Program	Bachelors of Science in Nuclear Medicine Technology
Course Title	**Clinical Nuclear Medicine - I**
Course Code	**BNM3504**
Academic Year	Third
Semester	V
Number of Credits	4
Course Prerequisite	Students should have basic knowledge of human anatomy, physiology, nuclear medicine imaging equipment, radio-pharmacy, radiation handling procedures and radiation dosimetry
Course Synopsis	The course aims to provide understanding of disease pathophysiology, clinical features of diseases, Clinical indication and appropriate use of radiopharmaceuticals for various disease diagnosis, patient preparation, image acquisition, processing, analysis and interpretation.

Course Outcomes (COs):
At the end of the course student shall be able to:

CO1	Understand the pathological basis of various diseases (C2)
CO2	Relate and identify the type of nuclear medicine scan indicated, use of appropriate radiopharmaceuticals and patient care procedures (C2)
CO3	Understand the acquisition and processing of scanning procedures using gamma camera, SPECT/CT and PET/CT (C2)
CO4	Analyze and interpret scintigraphy scan (C2)

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 and Outcomes:

Content	Competencies	Number of Hours
Endocrine System	• Recall important anatomical and physiological features of the system (C1) • Describe pathophysiology of thyroid and parathyroid gland disorders (C2) • Elaborate on Thyroid imaging (C2) ➢ Dynamic and static thyroid scan ➢ Radiopharmaceuticals ➢ Imaging protocol/s, ➢ processing and scan interpretation • Elaborate on Thyroid uptake (C2) ➢ Radiopharmaceutical ➢ Procedure and calculation, ➢ Interpretation of uptake value • Elaborate on Parathyroid imaging (C2) ➢ Dual phase, dual isotope technique ➢ Radiopharmaceuticals ➢ Imaging protocol/s, ➢ processing and scan interpretation	14
Unit 2		
Skeletal System	• Recall important anatomical and physiological features of the system (C1) • Describe the skeletal tissue damage and systemic response bone remodeling process (C2) • Describe the general features of Infection and inflammation and acute and chronic inflammation (C2) • Describe the pathophysiology of bone metastatic tumors (C2) • Describe the pathophysiology of metabolic bone diseases (C2) • Describe the pathophysiology of bone metastatic tumors (C2) • Describe the pathophysiology of osteomyelitis (C2) • Elaborate on radiopharmaceuticals Imaging protocol/s, processing, scan interpretation and quantitative analysis for (C2) ➢ Whole body bone scan ➢ 3 phase bone scan ➢ Infection imaging	17

Content	Competencies	Number of Hours
Unit 3		
Gastrointestinal System	• Recall important anatomical and physiological features of the system (C1) • Describe pathophysiology of oesophageal (C2) • Describe pathophysiology of gastric disorders (C2) • Elaborate on radiopharmaceuticals Imaging protocol/s, processing, scan interpretation and quantitative analysis for (C2) • Oesophageal transit, • Gastro- oesophageal reflux, • Gastric emptying and motility • Describe the pathophysiology of intestinal disorders (C2) • Elaborate on radiopharmaceuticals Imaging protocol/s, processing and scan interpretation for (C2) ➢ Meckel's diverticulum, ➢ Gastrointestinal bleed • Describe the pathophysiology of liver and spleen disorders (C2) • Elaborate on radiopharmaceuticals Imaging protocol/s, processing, scan interpretation and quantitative analysis for liver and spleen (C2) ➢ Structural ➢ functional imaging	17
Unit 4		
Respiratory System	• Recall important anatomical and physiological features of the system (C2) • Describe the pathophysiology obstructive pulmonary disease (C2) • Describe the pathophysiology of Pulmonary embolism and Ventilation perfusion mismatch (C2) • Describe the pathophysiology of right to left cardiac shunt (C2) • Elaborate on radiopharmaceuticals Imaging protocol/s, processing, scan interpretation and quantitative analysis (C2) ➢ lung ventilation ➢ lung perfusion imaging, ➢ right to left cardiac shunt imaging	12

Content	Competencies	Number of Hours

Learning Strategies, Contact Hours and Out of class engagement:		
Learning Strategies	**Contact Hours**	**Out of class engagement**
Lecture	45	40
Seminar	11	11
Revision	02	02
Assessment	02	02
Total	**60**	**60**

Assessment method:	
Formative:	**Summative:**
Unit test	Mid Semester
Quiz	End semester
Assignment/presentations	

Mapping of Assessment with COs:				
Nature of Assessment	**CO1**	**CO2**	**CO3**	**CO4**
Mid Semester Examination	X	x	x	
Quiz /Unit Test	X	x	x	X
Assignment/presentations	X	x	x	X
End Semester Exam	X	x	x	x

Feedback Process:	Mid-Semester Feedback
	End-Semester Feedback
Main Reference:	1. Robbins & Cotran Pathologic Basis of Disease, 9e, Elsevier – 2013 2. Nuclear Medicine – The Requisites Harvey A. Ziessman Janis P. O'Malley James H. Thrall
	1. Nuclear medicine technology and techniques Donald Bernier 2. Mosby's Manual of Nuclear Medicine procedures D. Bruce Sodee

Name of the Program	Bachelor of Science in Nuclear Medicine Technology
Course Title	**Practicum – V**
Course Code	**BNM3505**
Academic Year	Third
Semester	V
Number of Credits	3
Course Prerequisite	Basic knowledge of radiation physics, radioactivity, chemistry, and principles of radiopharmaceuticals, including radiation safety and handling of radioactive materials.
Course Synopsis	This course provides practical training in radiopharmaceutical preparation, quality control, and clinical nuclear medicine imaging and therapy procedures.

Course Outcomes (COs):
At the end of the course student shall be able to:

CO1	To demonstrate safe handling of therapeutic radioisotopes and administration to the patients (C3, P3)
CO2	To demonstrate quality control and biodistribution for radiopharmaceuticals (C3, P3)
CO3	To organize regulatory documentation and inventory for radiopharmaceuticals (C3, P2)
CO4	To demonstrate practical knowledge of clinical nuclear medicine procedures (C3, P3)
CO5	To analyze chemical equilibria, reaction kinetics, catalysis, and molecular properties using pH-metric, spectroscopic, colligative, and magnetic susceptibility methods (C4, P2).

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

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

Content	Competencies	Number of Hours
Unit 1: Radiopharmaceuticals in Nuclear Medicine		
Radiopharmaceuticals in Nuclear Medicine practical	• To perform elution & interpret elution efficiency of PET Radiotracers from Radionuclide generator (C3, P3) • To demonstrate & interpret quality checks of PET Radiopharmaceuticals (C3, P3) • To demonstrate process for ordering of Radiopharmaceuticals and cold kits (C3, P3) • To demonstrate record keeping of daily elution in Radio pharmacy laboratory (C3, P3) • To demonstrate record keeping of Inventory & stock of cold kits Radioactive materials (C3, P3) • Handling of Radioactive Spillage and contamination (C3, P3) • To demonstrate radiopharmaceutical biodistribution (C3, P3)	25
Unit 2: Clinical Nuclear Medicine – I		
Clinical Nuclear Medicine - I	• To perform PET Fusion Imaging (18 F- FDG Scan) in Hematological malignancies (C3, P4) • To perform PET Fusion Imaging (18 F- FDG Scan) for Prostate Cancer/Bladder Cancer/Renal cell carcinoma (C3, P4) • To perform PET Fusion Imaging (18 F- FDG Scan) for Thyroid Cancer (C3, P4) • To perform PET Fusion Imaging (18 F- FDG Scan) for Neuro endocrine Pancreatic Cancer — metabolic characterization (C3, P4) • To perform PET Fusion Imaging (18 F- FDG Scan) for Hepatocellular Carcinoma/ Spleen Cancer / Liver Cancer (C3, P4) • To perform PET Fusion Imaging (18 F- FDG Scan) of Brain F-18 scan Alzheimer's disease/ Epilepsy/ Dementia (C3, P4) • To perform PET Fusion Imaging (18 F- FDG Scan) for cardiac PET Scan (C3, P4)	40

Content	Competencies	Number of Hours
	• To perform PET Fusion Imaging (18 F- FDG Scan) for Sarcoidosis -Cardiac sarcoidosis and pulmonary sarcoidosis (C3, P4) • To perform PET Fusion Imaging (18 F- FDG Scan) for lung cancer diseases (C3, P4) • To Perform PET Fusion Imaging (18 F- FDG scan) for treatment planning & assessment of early therapy response (C3, P4) • To perform PET Fusion Imaging (18 F- FDG Scan) for fever of Unknown origin (C3, P4) • To perform PET Fusion Imaging (18 F- FDG Scan) for oncological malignant imaging (C3, P4) • To perform PET Fusion Imaging (18 F- FDG Scan) for benign Non-oncological imaging (C3, P4) • To perform PET Fusion Imaging (18 F- FDG Scan) for Breast Cancer (C3, P4)	
Unit 3: Therapeutic Nuclear Medicine		
Therapeutic Nuclear Medicine	• To demonstrate dispensing and oral administration of I-131 (C3, P4) • To demonstrate dispensing and intravenous administration of I-131 MIBG/ Sm-153 (C3, P4)	10

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राष्ट्रीय सम्बद्ध और स्वास्थ्य देख-रेख वृत्ति आयोग

Learning Strategies, Contact Hours and Out of class engagement:		
Learning Strategies	**Contact Hours**	**Out of class engagement**
Practical	66	66
Small group discussion	9	9
Total	**75**	**75**
Formative:	**Summative:**	
Unit test	Mid Semester (Practical)	
Quiz	Viva	
Viva	Record book	
Practical Log Book/Record Book	End Semester (Practical)	

Mapping of Assessment with COs:				
Nature of Assessment	**CO1**	**CO2**	**CO3**	**CO4**
Mid Semester Examination	X	X	X	x
Quiz / Viva/ Unit Test	X	X	X	x
Clinical/Practical Log Book/ Record Book	X	X	X	x
End Semester Exam	X	X	X	x

Feedback Process:	Mid-Semester Feedback
	End-Semester Feedback
Main Reference:	1. Nuclear Medicine Technology &Techniques: Donald Bernier et.al 2. Physics in Nuclear Medicine: Sorenson 3. Physics in Nuclear Medicine: Sorenson
Additional References	1. Mosby's Manual of Nuclear Medicine Procedures: D.Brucee Sodee, Paul J early 2. Quality control of Nuclear Medicine instruments: Tecdoc 602 3. Nuclear Medicine – The Requisites: Ziessman et. Al 4. Mosby's Manual of Nuclear Medicine Procedures: D.Brucee Sodee, Paul J early 5. Quality control of Nuclear Medicine instruments: Tecdoc 602 6. Nuclear Medicine – The Requisites: Ziessman et. al

Name of the Program	Bachelor of Science in Nuclear Medicine Technology
Course Title	**Clinical Practice – IV**
Course Code	**BNM3506**
Academic Year	Third
Semester	V
Number of Credits	3
Course Prerequisite	Students should have awareness of nuclear medicine procedures in radiopharmacy, scintigraphy, in-vitro and radionuclide therapy.
Course Synopsis	This course provides hands-on training for the candidate to prepare & safely handle the radiopharmaceuticals for clinical and therapeutic applications in Nuclear Medicine department and to maintain documentations and stock inventory.

Course Outcomes (COs):
At the end of the course student shall be able to:

CO1	Perform routine radiopharmacy practices in clinical nuclear medicine (C3, P2, A2)
CO2	Perform routine scintigraphy practices in clinical nuclear medicine (C3, P2, A2)
CO3	Perform routine radionuclide therapy practices in clinical nuclear medicine (C3, P2, A2)

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		
CO2	x	x	X	x	X	x		
CO3	x	x	X	x	X	x		

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Course content and Outcomes:

Content	Competencies	Number of Hours
Unit 1		
Radiopharmacy Practices	• To arrange Radiopharmacy lab for daily activities (C1, P3) • To identify and produce the inventory (C2, P3) • To practice QC of dose calibrator (C3, P3) • To prepare and dispense radiopharmaceuticals (C3, P3) • To practice QC of radiopharmaceutical (C3, P3) • To express procedures to patient and to practice as per regulatory guidelines (C2, P3) • To write and maintain registers (C3, P3)	34
Unit 2		
In-vitro Nuclear Medicine Practices	• To locate and identify stock inventory (C2, P3) • To operate various non-imaging and radiation monitoring equipment (C3, P3) • To produce, analyze and comment on QA reports of all devices in Nuclear Medicine (C3, P3) • To produce radiation surveillance reports (C3, P3) • To write and maintain registers (C3, P3)	21
Unit 3		
Scintigraphy Practices	• To arrange imaging room for daily activities (C1, P2) • To practice daily QC of imaging and other accessory devices (C3, P3) • To express procedures to patient and to practice as per regulatory guidelines (C2, P3) • To practice scans and processing techniques (C3, P3) • To write and maintain registers (C3)	28
Unit 4		
Radiation Therapy Practices	• To locate and identify stock inventory (C2, P3) • To practice QC of dose calibrator (C3,P3) • To prepare and dispense radiopharmaceuticals (C3, P3) • To practice QC of radiopharmaceutical (C3, P3) • To express procedures to patient and to practice as per regulatory guidelines (C2, P3) • To produce radiation exposure records (C3) • To write and maintain registers (C3, P3)	22

Learning Strategies, Contact Hours and Out of class engagement:		
Learning Strategies	**Contact Hours**	**Out of class engagement**
Small group discussion (SGD)	5	15
Problem Based Learning (PBL)	5	15
Case Based Learning (CBL)	5	15
Clinic	90	
Total	**105**	**45**

Formative:	**Summative:**
Unit test	Mid Semester (Practical)
Quiz	Viva
Viva	Log Book
Clinical assessment (OSCE, OSPE, WBPA)	End Semester Exam
Clinical Log Book/practical / Record Book	

Mapping of Assessment with COs:			
Nature of Assessment	**CO1**	**CO2**	**CO3**
Mid Semester Examination	X	x	X
Quiz / Viva	X	x	X
Clinical/Practical Log Book/ Record Book	X	x	X
Clinical assessment (OSCE, OSPE, WBPA)	X	x	X

Feedback Process:	Mid-Semester Feedback
	End-Semester Feedback
Main Reference:	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	3. Radiopharmaceuticals and Hospital Radiopharmacy Practices - N. Ramamoorthy BRIT
	4. Radiation safety in Nuclear Medicine - AERB Mumbai
	5. Nuclear Medicine Technology: Procedures and Quick Reference - Pete Shackett

SEMESTER - VI

Course code	Course Title
BNM3601	Tomography and Hybrid Imaging
BNM3602	Recent Advances and AI in Nuclear Medicine
BNM3603	Clinical Nuclear Medicine - II
BNM3604	Practicum – VI
BNM3605	Clinical Practice – V

Name of the Program	**Bachelors of Science in Nuclear Medicine Technology**
Course Title	**Tomography and Hybrid Imaging**
Course Code	**BNM3601**
Academic Year	Third
Semester	VI
Number of Credits	4
Course Prerequisite	Student should have a basic understanding of Nuclear Medicine Instrumentation, Basic mathematics and Radiopharmaceuticals
Course Synopsis	The course aims to provide understanding on application mathematics and statistics in nuclear medicine. The course also aims to introduce students to imaging modalities like x-ray CT, MRI, SPECT, PET and hybrid imaging.

Course Outcomes (COs):
At the end of the course student shall be able to:

CO1	The application of basic mathematics in various aspects of Nuclear Medicine (C3)
CO2	The application of counting statistics in various aspects of Nuclear Medicine (C3)
CO3	Understand working and instrumentation details of X-ray computed tomography and Magnetic resonance imaging (C2)
CO4	Understand working and instrumentation details of Single photon emission tomography (C2)
CO5	Understand working and instrumentation details of Positron emission tomography (C2)
CO6	Understand working and instrumentation details of Hybrid imaging systems in Nuclear medicine (C2)

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**						
CO5	**x**	**x**						
CO6	**x**	**x**						

Course Content and Outcomes:

Content	Competencies	Number of Hours
Unit 1		
Mathematics in Instrumentation	• Explain the use of mathematics in Instrumentation in Nuclear Medicine (C2) • Apply Vectors in instrumentation in Nuclear Medicine (C3) • Apply Matrices in instrumentation in Nuclear Medicine (C3) • Apply Determinants in instrumentation in Nuclear Medicine (C3) • Explain the Interpolation and apply its use in instrumentations (C3) • Transformation and apply its use in instrumentations (C3) • Explain uptake Calculation(C2) • What is Calibration factors and calculations (C1)	10
Mathematics in image reconstruction	• What is Fourier Transformation (C1) • Explain Fourier Transformation use in Image Reconstruction. (C3) • What is Laplace Transformation Z transformation (C1) • Explain and apply the Interpolation in image reconstruction (C3) • Explain Attenuation correction using radon transformation in Nuclear Medicine (C2) Explain and Solve Iterative reconstructions C3)	10
Counting Errors:	• Explain types of errors (C2) • Explain the measuring errors (C2) • Explain Type I error and Type II error (C2)	5
Propagational errors:	• Define and demonstrate propagation errors and used as sums and differences (C3) • Explain propagation error used as products and ratios (C2) and demonstrate complicated combination (C3) • Application of propagation error in effects of average, counting rates (C3) • Demonstrate the errors in effects of background, MDA (C3) and compare counting system in Nuclear Medicine (C4)	10

Content	Competencies	Number of Hours
	• Analyse the optimization of Time, Counting error in Image (C4) • Uncertainty calculation in all the nuclear medicine experiments (C3) • Apply statistical tests in counting statistics (C3)	
Unit 2		
Computed Tomography and Magnetic Resonance Imaging	• Introduction to computed tomography (C2) • Generations of X-ray CT (C2) • Design and working principle of CT (C2) • Components of CT (C2), Reconstruction techniques (C2), Performance characteristics and quality control aspects (C2) • Introduction to MRI (C2) • Design and working principle of MRI (C2) • Components of MRI (C2), • Reconstruction techniques (C2), • Performance characteristics and quality control aspects (C2)	10
Unit 3		
Hybrid Imaging Devices	• Principle of modality co-registration SPECT- CT, PET-CT, PET-MR (C2) • Co-registration of images (C2)	15

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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 Exam
Quiz	
Assignments/Presentations	End Semester Exam

Mapping of Assessment with COs:
Note: Map how each of the COs are assessed (e.g. indicate with a cross)

Nature of Assessment	**CO1**	**CO2**	**CO3**	**CO4**	**CO5**	**CO6**
Mid Semester Examination	x	x	x			
Quiz / Viva/Unit test	x	x	x	x	X	x
Assignments/Presentations	x	x	x	x		
End Semester Exam	x	x	x	x	X	x

Feedback Process:	Mid-Semester Feedback
	End-Semester Feedback
Main Reference:	1. Physics in Nuclear Medicine by Sorenson 2. Text Book of Mathematics by Grawel B.S.
Additional References	1. Nuclear Medicine by Robert E. Henkin, Mark A. Boles 2. Mosby's Manual of Nuclear Medicine Procedures by D.Brucee Sodee, Paul J Early 3. Medical Imaging Physics by William R.Hendee, Russell Ritenour 4. Nuclear Medicine Physics by Ramesh Chandra

Name of the Program	Bachelors of Nuclear Medicine Technology
Course Title	**Introduction to AI and recent advances in Nuclear Medicine**
Course Code	**BNM3602**
Academic Year	Third
Semester	VI
Number of Credits	4
Course Prerequisite	Basic knowledge of physics, chemistry, biology and imaging science.
Course Synopsis	By the end of the course student will be able to understand the concepts of artificial intelligence and machine learning. They will be able to apply AI techniques in medical image acquisition, reconstruction, image analysis, radiopharmaceuticals, patient management and dosimetry.

Course Outcomes (COs): At the end of the course student shall be able to:	
CO1	Explain the basic principles of AI, ML, and deep learning in the context of medical technology (C2)
CO2	Relate AI applications to nuclear medicine imaging workflows (SPECT, PET, hybrid imaging) (C2)
CO3	Demonstrate ability to use AI-based software for image segmentation, noise reduction, and lesion detection (C2)
CO4	Discuss the role of AI in theranostics, personalized medicine, and radiopharmacy (C2)

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 and Outcomes:

Contents	Competencies	Number of Hours
Unit 1: Introduction to Artificial Intelligence		
	• To illustrate history and evolution of AI in medicine (C1) • To understand the core concepts of AI, Machine learning and deep learning (C2) • To understand different types of machine learning: supervised, unsupervised, reinforcement learning (C2) • To provide overview of neural networks and CNN (C2)	4
Unit 2: AI in Medical Imaging		
	• To understand role of AI in Image pre-processing and noise reduction (AI filters in PET/SPECT) (C2) • To understand role of AI in image reconstruction using AI (deep learning–based PET/SPECT reconstruction) (C2) • To understand role of AI in Lesion detection and segmentation using CNNs (C2) • To understand role of AI in Quantification improvements with AI (C2)	14
Unit 3: AI in Nuclear Medicine Workflow		
	• To understand the role of AI in patient scheduling, workflow optimization, and radiation safety (C2) • To understand the role of AI in dosimetry and treatment planning in radionuclide therapy (C2) • To understand the role of AI in predictive analytics in theranostics (e.g., Lu-177, I-131 therapies) (C2) • To understand the role of AI in Automation in quality control of imaging equipment (C2)	14
Unit 4: AI in Radiopharmacy and Research		
	• To understand the role of AI in radiopharmaceutical discovery and development (C2) • To understand the role of AI in predictive modelling for tracer kinetics (C2) • To understand the role of AI in data mining in clinical trials and big data in nuclear medicine (C2) • To understand the role of AI in applications in personalized medicine and drug response prediction (C2)	14

Contents	Competencies	Number of Hours
Unit 5: Ethical, Legal, and Professional Aspects		
	• To understand the role of AI in data privacy, patient consent, and GDPR/HIPAA perspectives (C2) • To understand the role of AI in bias in AI algorithms and its clinical impact (C2) • To understand the role of AI in regulatory approvals (FDA, CE) for AI software in nuclear medicine (C2)	14

Learning Strategies, Contact Hours and Out of class engagement hours:				
Learning Strategies	**Contact Hours**	**Out of class engagement hours**		
Lecture	45	45		
Seminar	11	11		
Revision	2	2		
Assessment	2	2		
Total	**60**	**60**		
Assessment Methods:				
Formative:		**Summative:**		
Unit test		Mid Semester Exam		
Quiz		End Semester Exam		
Assignments/Presentations				
Mapping of Assessment with COs:				
Nature of Assessment		**CO1**	**CO2**	**CO3**
Midsem Examination		x	X	x
Quiz/unit test		x	X	x
Assignments/Presentations		x	X	x
Feedback Process:	Mid-Semester Feedback			
	End-Semester Feedback			
Main Reference:	• Artificial Intelligence in Medical Imaging – Lei Xing & James Orton. • Nuclear Medicine Physics – International Atomic Energy Agency (IAEA) modules (with AI add-ons). • Digital Image Processing – Gonzalez and Woods, 3rd 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.			

Learning Strategies, Contact Hours and Out of class engagement hours:	
Additional References	• Machine Learning in Medicine – Ton J. Cleophas, Aeilko H. Zwinderman, Springer; supports machine learning applications. • Radiomics and Radiogenomics – Ruijiang Li, Lei Xing, Sandy Napel, CRC Press; covers radiomics for nuclear medicine. • Artificial Intelligence in Healthcare – Adam Bohr, Kaveh Memarzadeh, Springer; addresses ethics and validation.

Name of the Program	**Bachelors of Nuclear Medicine Technology**
Course Title	**Clinical Nuclear Medicine – II**
Course Code	**BNM3603**
Academic Year	**Third**
Semester	**VI**
Number of Credits	**4**
Course Prerequisite	Students should have basic knowledge of human anatomy, physiology, nuclear medicine imaging equipment, radio-pharmacy, radiation handling procedures and radiation dosimetry
Course Synopsis	The course aims to provide understanding of disease pathophysiology, clinical features of diseases, Clinical indication and appropriate use of radiopharmaceuticals for various disease diagnosis, patient preparation, image acquisition, processing, analysis and interpretation.

Course Outcomes (COs):
At the end of the course student shall be able to:

CO1	Understand the pathological basis of various diseases
CO2	Relate and identify the type of nuclear medicine scan indicated, use of appropriate radiopharmaceuticals and patient care procedures
CO3	Understand the acquisition and processing of scanning procedures using gamma camera, SPECT/CT and PET/CT
CO4	Analyse and interpret scintigraphy scans

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

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

Course Content and Outcomes:

Content	Competencies	Number of Hours
Unit 1		
Cardiovascular System	• Recall important anatomical and physiological features of the system (C1) • Describe pathophysiology of cardiovascular disorders (C2) • Elaborate on Myocardial perfusion scintigraphy (C3) ➢ Interpretation • Elaborate on multi-gated acquisition, radionuclide ventriculography (C3) ➢ Radiopharmaceuticals ➢ Procedure for calculation of ejection fraction and first pass extraction ➢ Image processing ➢ Interpretation and quantitative analysis	15
Unit 2		
Genitourinary System:	• Recall important anatomical and physiological features of the system (C1) • Describe the pathophysiology of hydronephrosis, tubular obstruction, renovascular hypertension, vesico-uretral reflux (C2) • Elaborate on renal dynamic imaging Renogram, diuretic renogram, Captopril renogram study (C3) ➢ Radiopharmaceutical ➢ Procedure ➢ Time activity curve characteristics ➢ Image processing ➢ Interpretation and quantitative analysis • Elaborate on renal cortical imaging study (C3) ➢ Radiopharmaceuticals ➢ Procedure ➢ Interpretation • Describe vesicoureteral reflux (VUR) study (C3) ➢ Radiopharmaceuticals ➢ Protocol for direct and indirect VUR scan ➢ Image processing ➢ Interpretation and quantitative analysis	15

Content	Competencies	Number of Hours
Unit 3		
Central Nervous System	• Recall important anatomical and physiological features of the system (C1) • Describe pathophysiology of dementia, epilepsy brain death, hydrocephalus (C2) • Elaborate on brain perfusion imaging describing radiopharmaceuticals Imaging protocol/s, processing, scan interpretation (C3) for ➢ Various forms of dementia ➢ Epilepsy ➢ Brain death ➢ Blood brain barrier integrity ➢ Brain tumors ➢ Brain metabolism • Elaborate on radionuclide cysternography describing radiopharmaceuticals Imaging protocol/s, processing, scan interpretation and quantitative analysis (C3) for ➢ Hydrocephalus ➢ Cerebrospinal fluid (CSF) leak ➢ CSF shunt patency	15
Unit 4		
Miscellaneous Studies	• Recall important anatomical and physiological features of the immune system, basic immuno-biology, lymphatic system (C2) • Describe the pathophysiology of infection and inflammation in general (C2) • Elaborate on radiopharmaceuticals Imaging protocol/s, processing, scan interpretation and quantitative analysis (C3) for ➢ Non skeletal infection imaging ➢ Lympho-scintigraphy ➢ Dacroscintigraphy ➢ Sialoscintigraphy ➢ Testicular Scintigraphy ➢ Immunoscintigraphy	7

Content	Competencies	Number of Hours
Unit 5: Radionuclide therapy		
General principles of Radionuclide therapy	• What are the physical and chemical characteristics of therapeutic radionuclides? (C1) • Relate interaction of therapeutic radionuclide with matter/ body/ disease (C2) • Recall radiation safety in radionuclide therapy (C1) • Explain routes of radionuclide therapy (C2) • Extend the effects of radionuclide therapy (C2)	8

Learning Strategies, Contact Hours and Out of class engagement				
Learning Strategies	**Contact Hours**	**Out of class engagement**		
Lecture	45	40		
Seminar	13	15		
Assessment	2	5		
Total	**60**	**60**		
Formative	**Summative**			
Unit test	Mid Semester			
Assignment/seminars	End semester			
Mapping of Assessment with COs:				
Nature of Assessment	**CO1**	**CO2**	**CO3**	**CO4**
Mid Semester Examination				
Quiz / Viva/ Unit Test				
End Semester Exam				
Feedback Process:	Mid-Semester Feedback			
	End-Semester Feedback			
Main Reference:	1. Robbins & Cotran Pathologic Basis of Disease, 9e, Elsevier — 2013 2. Nuclear Medicine – The Requisites Harvey A. Ziessman Janis P. O'Malley James H. Thrall			
Additional References	1. Nuclear medicine technology and techniques Donald Bernier 2. Mosby's Manual of Nuclear Medicine procedures D. Bruce Sodee			

Name of the Program	Bachelors of Nuclear Medicine Technology
Course Title	**Practicum – VI**
Course Code	**BNM3604**
Academic Year	Third
Semester	VI
Number of Credits	4
Course Prerequisite	Basic knowledge of radiation physics, radioactivity, chemistry, and principles of radiopharmaceuticals, including radiation safety and handling of radioactive materials.
Course Synopsis	This course will impart training in the practical aspects of Radiopharmacy, quality control of tomography and hybrid imaging units and clinical techniques in nuclear medicine department.

Course Outcomes (COs):
At the end of the course student shall be able to:

CO1	To demonstrate safe handling of therapeutic radioisotopes and administration to the patients (C3, P3)
CO2	To demonstrate quality control and biodistribution for radiopharmaceuticals (C3, P3)
CO3	To organize regulatory documentation and inventory for radiopharmaceuticals (C3, P3)
CO4	To demonstrate practical knowledge of clinical nuclear medicine procedures (C3, P4)

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

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

Course Content and Outcomes

Content	Competencies	Number of Hours
Unit 1: Tomography and hybrid imaging		
Tomography and hybrid imaging	• To perform pixel size test (C3, P4) • To perform SPECT QC (C3, P4) • To perform Daily tube, warm up of SPEC/CT and PET/CT, air calibration. (C3, P4) • To perform PET Daily QC (C3, P4)	12
Unit 2: Clinical Nuclear Medicine –II		
Clinical Nuclear Medicine –II	• To perform Radionuclide ventriculography (C3, P3) • To perform Myocardial perfusion imaging (C3, P3) • To perform Myocardial viability imaging (C3, P3) • To perform Cortical imaging (C3, P3) • To perform Renal dynamic scan/ Transplant evaluation (C3, P3) • To perform DRCG/VCUG (C3, P3) • To perform Radionuclide cisternography (C3, P3) • To perform Ventriculo-peritoneal shunt evaluation (C3, P3) • To perform Brain perfusion imaging (C3, P3) • To perform Infection imaging (C3, P3) • To perform Lymphoscintigraphy (C3, P3) • To perform Dacroscintigraphy (C3, P3) • To perform Sentinal lymphnode imaging (C3, P3) • To perform Sialoscintigraphy (C3, P3)	58
Unit 3: Counting statistics		
Counting statistics	• Explain, apply and analyse the effect of background in NM (C3, P3) • Explain, apply and analyse the Counting Rate uncertainity in NM (C3, P3) • Explain, apply and analyse the Comparison of various Counting systems (C3, P3) • Explain, apply and analyse the Minimum detectable activity of the counting instruments (C3, P3) • Demonstrate the pipetting Efficiency using weighing balance (C3, P3) • Explain, apply and analyse the pipetting Efficiency using radioactivity (C3, P3)	20

Learning Strategies, Contact Hours and Out of class engagement:		
Learning Strategies	**Contact Hours**	**Out of class engagement**
Practical	80	80
Small group discussion	10	10
Total	**90**	**90**

Formative:	**Summative:**
Unit test	Mid Semester (Practical)
Quiz	Viva
Viva	Record book
Practical Log Book/Record Book	End Semester (Practical)

Mapping of Assessment with COs:				
Nature of Assessment	**CO1**	**CO2**	**CO3**	**CO4**
Mid Semester Examination	X	x	X	x
Quiz / Viva/ Unit Test	X	x	X	x
Clinical/Practical Log Book/ Record Book	X	x	X	x
End Semester Exam	X	x	X	x

Feedback Process:	**Mid-Semester Feedback**
	End-Semester Feedback
Main Reference:	1. Nuclear Medicine Technology &Techniques Donald Bernier et.al 2. Physics in Nuclear Medicine Sorenson
	3. Mosby's Manual of Nuclear Medicine Procedures D.Bruce Sodee, Paul J early
Additional References	4. Quality control of Nuclear Medicine instruments Tecdoc 602
	5. Nuclear Medicine - The Requisites-Harvey A. Ziessman Janis P. O'Malley, James H. Thrall

Name of the Program	Bachelors of Nuclear Medicine Technology
Course Title	**Clinical Practice – V**
Course Code	**BNM3605**
Academic Year	Third
Semester	VI
Number of Credits	4
Course Prerequisite	Students should have awareness of nuclear medicine procedures in radiopharmacy, scintigraphy, in-vitro and radionuclide therapy.
Course Synopsis	This course provides the essential, interlinking skills to manage different clinical nuclear medicine procedures effectively.

Course Outcomes (COs):
At the end of the course student shall be able to:

CO1	Independently execute the entire nuclear medicine diagnostic procedure, demonstrating competency in all stages (C4, P4, A4)
CO2	Independently execute the entire nuclear medicine therapeutic procedure, demonstrating competency in all stages (C4, P4, A4)
CO3	Apply knowledge of patient care, safety protocols and quality assurance (C4, P4, A4)

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

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

Course Content and Outcomes:

Content	Competencies	Number of Hours
Unit 1		
Radiopharmacy Practices	• To execute the arrangement of Radiopharmacy lab for daily activities (C1, P4) • To execute identification and production of the inventory (C3, P4) • To execute QC of dose calibrator (C4, P4) • To prepare, dispense and administer radiopharmaceuticals (C4, P4, A2) • To execute QC of radiopharmaceutical (C4, P4) • To perform nuclear medicine clinical procedures as per regulatory guidelines (C4, P4) • To write and maintain registers (C4, P4)	45
Unit 2		
In-vitro Nuclear Medicine Practices	• To execute operation of various non-imaging and radiation monitoring equipment (C4, P4) • To produce, analyze and comment on QA reports of all devices in Nuclear Medicine (C4, P4) • To analyze and execute radiation surveillance reports (C4, P4) • To write and maintain registers (C4, P4)	30
Unit 3		
Scintigraphy Practices	• To execute arrangement of imaging room for daily activities (C1, P4) • To execute daily QC of imaging and other accessory devices (C4, P4) • To perform and analyze procedures to patient and to practice as per regulatory guidelines (C4, P4) • To perform scans and processing techniques (C4, P4, A2) • To write and maintain registers (C4, P4)	45
Unit 4		
Radiation Therapy Practices	• To execute QC of dose calibrator, fumehood (C4, P4) • To prepare, dispense and administer radiopharmaceuticals (C4, P4) • To execute QC of radiopharmaceutical (C4, P4) • To express procedures to patient and to practice as per regulatory guidelines (C4, P4) • To maintain radiation exposure records (C4, P4)	30

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	135	
Total	**150**	**45**

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 Log Book/ 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 Reference:	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. NUCLEAR MEDICINE FACILITIES, CODE NO. AERB/RF-MED/SC-2 (Rev. 2) or as revised from time to time by AERB Mumbai. 3. Nuclear Medicine Technology: Procedures and Quick Reference — Pete Shackett

SEMESTER - VII & VIII

Internship

Name of the Program	Bachelors of Nuclear Medicine Technology
Course Title	**Internship**
Academic Year	**Fourth**
Semester	VII & VIII
Duration	6+6=12 months (1 year)
Course Prerequisite	Students should have knowledge of core nuclear medicine subjects and general hospital practices.
Course Synopsis	This course will give training and confidence for the trainees to prepare as well as to safely handle radiopharmaceuticals, perform various Nuclear Medicine diagnostics and therapeutic procedures, perform various quality control procedures, record keeping and stock inventory.

Course Outcomes (COs):
At the end of the course student shall be able to:

CO1	Safely handle radioisotopes, practice radiation safety and regulatory norms (C4, P4, A4)
CO2	Perform various quality control checks of equipment, radiopharmaceutical etc. and address trouble shooting (C4, P5, A5)
CO3	Perform various clinical Nuclear Medicine procedures (C4, P5, A5)
CO4	Maintain record keeping and stock inventory. Learn the importance of effective communication, team work, ethical values and professionalism (C3, P4, A5)
CO5	Display entrepreneurship, leadership and mentorship skills to practice independently as well as in collaboration with the interdisciplinary health care team (C4, P5, A5)

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 and Outcomes:

Content	Competencies
Area 1: Radiopharmacy Practices	
	• 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)
Area 2: In-vitro Nuclear Medicine Practices	
	• To locate and identify stock 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)
Area 3: 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)
Area 4: Radionuclide Therapy Practices	
	• To locate and identify stock inventory (C3) • To evaluate QC of dose calibrator (C3, P4) • 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) • To produce radiation exposure records (C3) • Documentation and record keeping (C3)

Content	Competencies
Area 5: 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)

Learning Strategies: Small group discussion (SGD), Problem Based Learning (PBL), Case Based Learning (CBL), Clinics, Seminars

Formative Assessment: Clinical Log Book

Internship completion certificate will be issued from Dean's office, only after obtaining satisfactory completion certificate from the head of the department at the end of internship.

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Program Outcomes (POs) and Course Outcomes (COs) Mapping

Semester	Course Code	Course Title	Credits	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
I	**BNM1101**	Human Anatomy and Physiology for Nuclear Medicine	4	CO1 CO2 CO3 CO4	CO1 CO2 CO3 CO4						
	BNM1102	Mathematics in Nuclear medicine	3	CO1 CO2 CO3	CO1 CO2 CO3				CO2 CO3	CO3	
	BNM1103	Radiation Physics	4	CO1 CO2 CO3	CO1 CO2 CO3				CO2 CO3	CO2 CO3	
	BNM1104	Fundamentals of Chemistry	3	CO1 CO2 CO3 CO4							
	BNM1105	Solid state physics and Electronics in Nuclear Medicine	4	CO1 CO2 CO3 CO4 CO5	CO1 CO2 CO3 CO4 CO5				CO1 CO2 CO3 CO4 CO5	CO1 CO2 CO3 CO4 CO5	
	BNM1106	Practicum-I	2	CO1 CO2 CO3							
II	**BNM1201**	Biochemistry	3	CO1 CO2 CO3 CO4							
	BNM1202	Organic Chemistry for Nuclear Medicine	3	CO1 CO2 CO3							
	BNM1203	Fundamentals of Electromagnetism in Nuclear Medicine	3	CO1 CO2	CO1 CO2				CO1 CO2	CO1 CO2	
	BNM1204	Cell and molecular Biology	3	CO1 CO2 CO3 CO4							
	BNM1205	Introduction to Nuclear Medicine, Medical ethics and Patient care	3		CO1 CO3 CO4 CO5	CO5	CO1 CO2 CO3 CO4	CO2 CO5			
	BNM1206	Practicum - II	4	CO1 CO2 CO3 CO4							
	BNM1207	Clinical Practice	1		CO1	CO1 CO2	CO2				

Semester	Course Code	Course Title	Credits	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
III	**BNM2301**	Introduction to Radiopharmacy	4	CO1 CO2 CO3 CO4 CO5 CO6	CO3 CO4 CO5 CO6						
	BNM2302	Nuclear Medicine Instrumentation Physics	4	CO1 CO2 CO3 CO4	CO1 CO2 CO3 CO4						
	BNM2303	Physics of oscillations, waves, and optics in biomedical imaging	3	CO1 CO2 CO3	CO1 CO2 CO3				CO1 CO2 CO3	CO1 CO2 CO3	
	BNM2304	Inorganic Chemistry	4	CO1 CO2 CO3 CO4							
	BNM2305	Practicum -III	3	CO1 CO2 CO3 CO4	CO1 CO2 CO3 CO4	CO2			CO1 CO2	CO1 CO2	
	BNM2306	Clinical Practice	2	CO1 CO2 CO3	CO1 CO2 CO3	CO1 CO2 CO3	CO1 CO2 CO3	CO1 CO2 CO3	CO1 CO2 CO3		
IV	**BNM2401**	Nuclear Medicine Physical Chemistry- I	3	CO1 CO2 CO3 CO4							
	BNM2402	Radiobiology	3	CO1 CO2 CO3 CO4	CO4					CO1 CO2 CO3	
	BNM2403	Fundamentals of Immunology and Microbiology	3	CO1 CO2 CO3 CO4							
	BNM2404	Health Physics	3	CO1 CO2 CO3	CO1 CO2 CO3 CO4 CO5	CO4 CO5					
	BNM2405	Practicum-IV	3	CO1 CO2 CO3 CO4							
	BNM2406	Clinical practice	5	CO1 CO2 CO3	CO1 CO2 CO3	CO1 CO2 CO3	CO1 CO2 CO3	CO1 CO2 CO3	CO1 CO2 CO3		

Semester	Course Code	Course Title	Credits	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
V	**BNM3501**	Radiopharmaceutical Chemistry	4	CO1 CO3	CO2 CO4		CO4			CO1 CO2 CO3	
	BNM3502	Therapeutic Nuclear Medicine	3	CO1 CO2 CO4 CO5 CO6	CO2 CO4	CO3		CO5		CO3 CO6	
	BNM3503	Nuclear medicine in physical chemistry-II	3	CO1 CO2 CO3 CO4							
	BNM3504	Clinical NuclearMedicine -I	4	CO1 CO2	CO2 CO3 CO4	CO3			CO1 CO4		
	BNM3505	Practicum- V	3	CO1 CO2 CO3 CO4							
	BNM3506	Clinical Practice	3	CO1 CO2 CO3	CO1 CO2 CO3	CO1 CO2 CO3	CO1 CO2 CO3	CO1 CO2 CO3	CO1 CO2 CO3		
VI	**BNM3601**	Tomographyand hybrid imaging	3	CO1 CO2 CO3 CO4 CO5 CO6	CO1 CO2 CO3 CO4 CO5 CO6						
	BNM3602	Biostatistics and Research methodology	3	CO1 CO2 CO3 CO4	CO2 CO3				CO4	CO1	
	BNM3603	Recent Advances & AI in Nuclear Medicine	**2**	CO1 CO2 CO3							
	BNM3604	Clinical NuclearMedicine-II	4	CO1 CO2 CO3 CO4							
	BNM3605	Practicum-VI	4	CO1 CO2 CO3 CO4	CO4	CO4	CO4	CO4	CO4	CO4	
	BNM3606	Clinical Practice	4	CO1 CO2 CO3	CO1 CO2 CO3	CO1 CO2 CO3	CO1 CO2 CO3	CO1 CO2 CO3			

Semester	Course Code	Course Title	Credits	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
VII & VIII	**NA**	**Internship**	**20+ 20**	CO1 CO2 CO3 CO4 CO5	CO1 CO2 CO3 CO4 CO5	CO1 CO2 CO3 CO4 CO5	CO1 CO2 CO3 CO4 CO5	CO1 CO2 CO3 CO4 CO5	CO1 CO2 CO3 CO4 CO5	CO1 CO2 CO3 CO4 CO5	CO1 CO2 CO3 CO4 CO5

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Chapter 5

Master of Science in Nuclear Medicine Technology (M.Sc. NMT)

Introduction:

1. **Learning Objectives:**

Masters in Nuclear Medicine Technology is specifically aimed at those candidates pursuing a professional/academic career in Nuclear Medicine. It is designed to 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. It is designed as a higher degree course suitable for graduates having experience in the nuclear medicine. The objective of the program is to train students to be qualified, patient focused, compassionate, critical thinkers for the community who are engaged in lifelong learning.

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.

2. **Expectation from the Future Postgraduates in Providing Research/Academics/Patient Care**

1. Perform and analyze quality assurance and NEMA quality control tests of equipment, and machine installation report.
2. Designing imaging protocol for radionuclide therapy dosimetry and perform dosimetry analysis.
3. Perform a range of nuclear medicine diagnostic and therapeutic procedures on patients to produce high quality images.
4. Verifying informed consent, assuming responsibility for patient needs during procedures.
5. Applying principles of ALARA to minimize exposure to patient, self, and others.
6. Identifying, preparing, and dispensing of radiopharmaceuticals as prescribed.
7. Evaluating images for technical quality, ensuring proper identification is recorded.
8. Performing diagnostic scintigraphic procedures.
9. Assist nuclear medicine physicians in complex examinations like PET guided biopsy.
10. Record imaging identification and patient documentation quickly and accurately and observes protocols.
11. Research and development of new techniques and imaging procedures as assigned.
12. 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.

13. Follow established safety practices including biohazards, exposure control plan.
14. Demonstrate respect and regard for the dignity of all patients, families, visitors and fellow employees to ensure a professional, responsible and courteous environment.
15. Identifying and managing emergency situations.
16. Perform ongoing quality assurance activities.
17. 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.
18. Understands and observes health and safety regulations/precautions and instruction for self and others protection. He/she should wear a dosimeter during duty hours.
19. Attends all in service education program required as per hospital policy.
20. Providing education and monitoring students and other health care providers.
21. Orientation and teaching students and new employees.
22. Learns new technologies and technologies as required by the professional bodies.
23. Impart appropriate training to the students and other staff.
24. Should have management and research skills.
25. To exhibit keen interest, initiative & drive in the overall development of the Department and 'Leadership Qualities' for others to follow.
26. He / She is expected to be confident and to perform all the duties diligently with utmost sincerity and honesty.
27. Any other duty/task/work assigned by any higher authority like Director, Dean, Medical
28. Superintendent, Head of the Department from time to time; either in "Public Interest" or in the interest of upkeep / development of the Department / Institutions.

Eligibility for Admission:

Selection Procedure :

- Bachelor of Science in Nuclear Medicine Technology or equivalent, Bachelor of Science in Physics, Bachelor of Science in Chemistry, or any Bachelor of Science 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. In the future, this second pathway shall be restricted exclusively to candidates holding a Bachelor of Science in Nuclear Medicine Technology or an equivalent qualification like B.Sc (NM), primarily for academic enrichment and research-oriented progression. At that stage, such candidates may be considered for waiver of the mandatory internship requirement at the Master's level, subject to regulatory approval.

- 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. The board will include the Head of the Department of Nuclear Medicine (Chairman of the Board) and other members as per the policy of institute/ university, whose recommendations shall be final for the selection of the students.
- During subsequent counselling (s) the seat will be allotted as per the merit of the candidate depending on the availability of seats on that particular day.
- Selection of the candidate on the basis of entrance examination conducted by the national commission (NCAHP) norms if needed in future.
- Medical fitness certificate is mandatory to submit and it is to be endorsed by Government medical officer.
- Reservation policy for admission in post graduate programs shall be as per the State/Centre Government norms.

Duration of the Course

- Duration of the course: 3 years [4 semesters or 2 Years of course work plus 1 Year mandatory Residency under clinically qualified Nuclear Medicine Technologist].
- All students shall be paid as stipend during their internship as decided by the respective State Allied and Healthcare Council.

Medium of instruction:

English shall be the medium of instruction for all the subjects of study and for examination of the course.

Maximum Period for Completion of the Course:

- 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.

Seat Capacity

Accordance with NCAHP regulations, Institution/University having medical college with hospital setup shall be permitted an annual intake capacity of 10 admissions. The phase-wise requirements to be fulfilled by the applicant colleges for obtaining letter of intent and Letter of Permission for establishment of new college or increase in annual intake in Master of Science in Nuclear Medicine Technology admissions annually from 10 to 15 intake. Maximum of intake in the Master degree program is 15 candidates. No institute shall be granted permission for intake of more than 15 candidates.

Intake of Students

The Nuclear Medicine teacher/guide to student's ratio shall be 1:5 for admission in M.Sc. Nuclear Medicine Technology first year and cannot be increased in any case. The guide should be of the same specialty stream. The intake of students to the course shall be at the starting of academic year only.

For student benefit, services of **visiting faculty** can be utilized, but these faculty members will not be counted in the Postgraduate teachers.

Guide/Mentor

- To be recognized as a guide, one must be an Assistant Professor/ Associate Professor/Professor as per faculty mentioned in Table 1.
- Guide should be of the same elective/ specialty stream/relevant subject as of student.
- Students cannot be left without a guide for more than 3 months in total during their post-graduation study (i.e. in the event of resignation of guide, the college should appoint a guide within 3 months)

Attendance and Monitoring Progress of Studies:

- 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.

Methods of Training

- The training of the M.Sc. Nuclear Medicine Technology student shall be conducted on a full-time basis, with progressively increasing responsibilities in the management and treatment of patients assigned to their care. Acquisition of practical competencies being the keystone of post graduate education, the training should be skills oriented. Learning in post graduate program should be essentially self-directed and primarily emanating from clinical and academic work. The formal sessions are merely meant to supplement this core effort.
- Participation of all the students in all facets of educational process is essential and each candidate should take part in seminars, group discussions, clinical rounds, case presentations, clinics, journal review meetings and continuous professional education (CPE).
- Training should also include involvement in clinical research studies and every postgraduate candidate should be actively engaged in the training programs.

Formal Teaching Sessions [minimum]

The departments may select a mix of the following sessions:

- Journal club / once a week Seminar;
- Lecture twice a week;
- Case discussions twice a week;
- Interdepartmental case or seminar once a week

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. The assessment may be structured using checklists that assess various aspects of competencies.

Log Book

- 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.

Periodic Tests

- The department may conduct 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).

Summative Assessment

- **Theory Examination:** Clinical / Practical and viva voce Examination: All examiners with a minimum of 3 years of teaching experience after post-graduation as per faculty mentioned in Table 1.
- At least 50 % of total examiners in the last and final semester (IV semester) shall be externals (from other universities/Institutes).
- **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.
- **Practical Examination** shall be conducted at the end of each semester will be evaluated by a panel of two internal examiners. Practical examination conducted at the end of fourth semester will be evaluated by a panel of two internal and two external examiners, out of which at least one should be from other institutions.
- Marks to be awarded separately be each examiner and an average shall be taken as the final marks awarded to the student in both practical as well as dissertation.

Examiners: 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 **(as per chapter 2 qualifications Table 1)**.

Essential Requirements for M.Sc. Nuclear Medicine Technology Conducting Institution

All existing Nuclear Medicine Departments/ institutes may start to impart Masters of Science in Nuclear Medicine course provided that following conditions are fulfilled.

- Any tertiary care government /Private/ Self Financing Educational Trust/Charitable Trust/ Society/ Company registered under the relevant Act; applicant will be eligible to apply, preferably NABH.
- Standalone institutions must have a memorandum of understanding (MOU) with either a medical college or hospital, or a healthcare facility as per the guidelines (desired number of Nuclear Medicine equipment along with Radiology Equipment/beds/OPD, etc.) defined in the curriculum to ensure practical exposure for the students.

- The MOU must be done with a medical college, hospital, or healthcare facility that has a minimum of 100 investigations per week, including gamma camera based, PET-CT scan, high dose radionuclide therapy and low dose therapy.
- MOU to also define the nuclear medicine techniques/ practice clinical supervision of the students, institutional staff, or clinical preceptors can be considered.

Administrative Office Land and space requirement

There shall be no separate land required for starting M.Sc. Nuclear Medicine Technology course subject to fulfilment of eligibility criteria to start the Master program. However, the essential requirements in terms of physical infrastructure, manpower as given below must be furnished.

Physical Infrastructure: Whole campus should be accessible for candidates.

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Infrastructure for M.Sc. Nuclear Medicine Technology Course			
Physical Facility Building – Institute/University shall have its own building. Standard minimum requirement for Nuclear Medicine Technology course with intake capacity of 10 students shall be as under Dedicated space of 8000 sq. ft. area is essential Standard for 20 seats			
S. No	**Description**	**Area (sq ft)**	**Number**
1	Principal/HOD room	400	01
2	Office	400	01
3	Store room	500	01
4	Professor room	400	01
5	Other faculty rooms	250 each	06
Teaching area			
6	Class rooms	450	02
7	Skill labs/laboratories	450	01
8	Gamma Camera room	800	01
9	PET/CT room	1200	01
10	Radiopharmacy room	800	01
11	Therapy ward (2 bedded)	1000	01
12	Computer lab/seminar room	450	01
13	Library	1800	01
Amenities			
14	Girls common room	200	01
15	Boys common room	200	01
16	Girls toilet	100	01
17	Boys toilet	100	01
18	Staff room/record room	100	01
Desirable facility			
19	Drinking water		
20	Fire Extinguisher		
21	Transportation facility		
22	Girls and boys hostel required		
23	Recreation / sports facility		

Note:

- **Principal's Office:** There should be a separate office for the Principal/ Head of Department with attached Toilet and provision for visitor's room. Independent telephone facility is a must for the Principal's / Head of Department office with intercom facility connected/linked to the hospital and hostel and a computer with internet facility.
- The classrooms should be well ventilated with proper lighting system. There should be built in Black/Green/White Boards/Projector. Also, there should be a desk/dais/ a big table and a chair for the teacher and tables and chairs for students.
- Common rooms should be provided for the student and for the office staff. Sufficient space with adequate seating arrangements, cupboards, lockers, cabinets, built-in-shelves and racks should be provided in all the common rooms. Toilet and hand washing facilities should be made available in each room.
- There should be a separate computer lab for students and staff for reading purpose and it should provide internet and cabin facility.
- There should be a separate record room with steel racks, built-in shelves and racks, cupboards and filing cabinets for proper storage of records and other important papers/documents belonging to the college.
- Adequate provision for extinguishing fire should be available as per the local bye-laws.
- A room should be provided for the proper and safe storage for all the Audio Visual Aids
- **Library Facility:** There should be a separate library for the Institute. The library should be easily accessible to the teaching faculty and the students. It should have internet facility. Library should have seating arrangements for at least 80 students for reading and having good lighting and ventilation and space for stocking and displaying of books and journals. The number of journals should 10 out of which one – third shall be foreign journals and subscribed on continuous basis. There should be sufficient number of cupboards, book shelves and racks with glass doors for proper and safe storage of books, magazines, journals, newspapers and other literature.

Human Resource Requirement : Teaching Faculty per Specialty for (10+10) students :

- Faculty/teacher to student ratio: 1:5
- Minimum Requirement :
  - Professor-1,
  - Associate Professor-1,
  - Assistant Professor-2
- Teaching staff:
  - M.Sc. Residents – 02(Preferable)
- Non-teaching staff:
  - Office Superintendent/ Assistant 1
  - Computer Operator 1
  - Nursing Officer 1
  - Lab Assistant 1

Note:

- Professor cum HoD, Associate Professor, and Assistant Professor will be counted in teaching faculty. Minimum two faculties shall be as NMT as academic qualification.
- Apart from the teaching faculty, to manage the regular clinical/patient workload, regular Nuclear Medicine Technologists should be appointed as per requirement.
- Services of visiting faculty can be utilized, but these faculty members will not be counted in the PG teachers and they cannot register candidates. **Apart from the core subjects, Guest/ Adjunct/ Part-Time Faculty can teach the peripheral subject or topic as needed, but will not be considered as core faculty (as per chapter 2 Table 1)**

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Teaching Faculty Qualifications for M.Sc. NMT Course

Post name	Education qualification & Experience
Professor	1.M.Sc. Nuclear Medicine/M. Sc. Nuclear Medicine Technology/MSc NMT/M.Sc. Nuclear Medicine and Molecular Imaging Technology, M.Sc. Medical Physics/ M. Sc. + Postgraduate diploma in Nuclear Medicine (DMRIT/PGDFIT/PGDNMT)/M.Sc.+ Postgraduate diploma in Radiological Physics or equivalent With Ph.D. in relevant subject + 10 years of clinical/teaching/research experience. OR MD/DNB (Nuclear Medicine) + 10 years of clinical/teaching/research experience.
Associate Professor	1.M.Sc. Nuclear Medicine/M. Sc. Nuclear Medicine Technology/MSc NMT/M.Sc. Nuclear Medicine and Molecular Imaging Technology M.Sc. Medical Physics/ M. Sc. + Postgraduate diploma in Nuclear Medicine (DMRIT/PGDFIT/PGDNMT)/M.Sc. + Postgraduate diploma in Radiological Physics or equivalent With Ph.D. in relevant subject + 6 years of clinical/teaching/research experience. OR MD/DNB (Nuclear Medicine) + 6 years of clinical/teaching/research experience.
Assistant Professor	1.M.Sc. Nuclear Medicine/M. Sc. Nuclear Medicine Technology/MSc NMT/M.Sc. Nuclear Medicine and Molecular Imaging Technology, M.Sc. Medical Physics/ M. Sc. + Postgraduate diploma in Nuclear Medicine (DMRIT/PGDFIT/PGDNMT)/M.Sc. + Postgraduate diploma in Radiological Physics or equivalent OR MD/DNB (Nuclear Medicine)

Minimum Equipment Required for M.Sc. Nuclear Medicine Technology

1. SPECT/ Gamma Camera / SPECT-CT machine – 1
2. PET-CT Machine – 1
3. Thyroid Uptake System – 1
4. High-Dose Radionuclide Facility – 1 (Minimum two bedded)
5. Low Dose Radionuclide Facility - 1
6. One Radio-pharmacy Lab Facility with Tc-99m Generator
7. TLD Personnel monitoring facility
8. Radioactive Waste Storage facility
9. Decontamination room /Facility
10. One gamma ray Spectrometer
11. One GM counter
12. QC Sources for Dose Calibrator, SPECT, PET-CT, Thyroid Uptake Probe, Well Counter etc.
13. Radiation Safety Instruments like Survey Meter, Contamination Monitor,
14. Radio-TLC Scanner/chromatography setup, Melting Point System, Hot Plate,
15. Decontamination Kits, Long Tools
16. Absorbent Sheet, Lab Accessories, Lead Bricks, L-Bench (03),
17. Lead Lined Dust Bin (05),
18. AERB Approved Layout of Nuclear Medicine Equipment
19. Nuclear Medicine Physics Lab
20. Radiochemistry/Radiopharmacy Lab
21. Radiation physics/ Physics Lab
22. Medical Cyclotron Facility (Optional)
23. QC Kit and Accessories for Tc-Generator eluted 99mTc Radioisotope
24. Phantoms for NEMA QC

Criteria for pass:

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.

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1. LEARNING OBJECTIVES

The learning objectives of M.Sc. Nuclear Medicine Technology program are:

Education Objectives
• 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.
• 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
• 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.
• Students will be able to use inter personal and collaborative skills to identify, assess and formulate problems and execute the solution.
• Students will be able to imbibe the culture of research, innovation, entrepreneurship and incubation.
• 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.

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2. PROGRAM OUTCOMES (POs):

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

PO No.	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

CURRICULUM OUTLINE

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**

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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**

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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**

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.

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

Name of the Program	**Master of Science in Nuclear Medicine Technology**
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):
At the end of the course student shall be able to:

CO1	Explain the General Anatomy of the human body (C2)
CO2	Explain the anatomy and physiology of respiratory, cardiovascular and digestive system (C2)
CO3	Explain the anatomy and physiology of renal and reproductive system (C2)
CO4	Explain the anatomy and physiology of endocrine, central nervous system and special senses (C2)

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 and Outcomes

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		

Content	Competencies	Number of Hours (Theory):
	• 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) • List the differences between small intestine and	5

Content	Competencies	Number of Hours (Theory):
	large 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		

Content	Competencies	Number of Hours (Theory):
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) • 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)	2
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

Content	Competencies	Number of Hours
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)	4

Content	Competencies	Number of Hours
	• Cardiac output: Definitions, normal values, physiological variations (C1) • Arterial blood pressure: Definitions, normal values, physiological variations, factors maintaining blood pressure. (C2)	
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

Content	Competencies	Number of Hours
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)	3

Content	Competencies	Number of Hours
	• 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)	
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

Content	Competencies	Number of Hours
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)	2

Content	Competencies	Number of Hours
	• 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)	

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**	
Assignments/Presentations	**x**	**x**	**x**	**X**	
End Semester Exam	**x**	**x**	**x**	**X**	
Feedback Process:	**End-Semester Feedback**				
Main Reference:	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				

Name of the Program	**Master of Science in Nuclear Medicine Technology**
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 operation, 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 (COs): At the end of the course, the student shall be able to:

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).
CO2	Explain the operational principles, workflow optimization strategies, and safety design features of automated radiopharmaceutical preparation facilities in accordance with AERB/IAEA regulatory guidelines (C2).

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

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

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Course Content and Outcomes:

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

Content	Competencies	Number of Hours
	• **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

Content	Competencies	Number of Hours
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

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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	-
Assignments/Presentations	X	X	-
End Semester Exam	X	X	-
Feedback Process:	Mid-Semester Feedback		
	End-Semester Feedback		
Main Reference:	Textbooks: 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		

Name of the Program	**Master of Science in Nuclear Medicine Technology**
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 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 (COs): At the end of the course student shall be able to:

CO1	Explain radiation safety and survey principles (C2)
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)
CO3	Design and evaluate the layout and safety systems of a medical cyclotron facility in accordance with AERB/IAEA regulatory and radiological protection standards (C2)

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 and Outcomes:

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 1: 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 2: 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.	20

Content	Competencies	Number of Hours
	• 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.	
Unit 3: 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 (C2) • 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 4: 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
Assignment	2	2
Total	60	60
Assessment Methods:		
Formative:	**Summative:**	
Unit Test	Mid Semester Exam (Theory)	
Quiz	End Semester Exam (Theory)	
Assignments/Presentations		

Mapping of Assessment with COs:			
Nature of Assessment	**CO1**	**CO2**	**CO3**
Mid Semester Examination	X	X	X
Quiz/Unit	X	X	X
Test/Assignments/Presentations	X	X	X
End semester Exam	X	X	X

Feedback Process:	Mid-Semester Feedback
	End-Semester Feedback
Main Reference:	Textbooks: 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

Name of the Program	**Master of Science in Nuclear Medicine**
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 systematic reviews.

Course Outcomes (COs): At the end of the course student shall be able to:

CO1	To understand the principles of Bioethics (C2)
CO2	To understand the principles of Research publication ethics (C2)
CO3	To understand the different aspects of pedagogy (C4)

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**						

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Course Content and Outcomes:

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)	15

Content	Competencies	Number of Hours
	• 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)	
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		
Unit Test/Quiz	X	X	X		
Assignments	X	X	X		
End Semester Exam	X	X	X		

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

Learning Strategies, Contact Hours and Out of Class Engagement	
Additional References	• Principles of Medical Education. Editor(s): Tejinder Singh, Piyush Gupta, Daljit Singh. Jaypee Brothers. 2012. New Delhi. • Patricia A Marshall. Ethical challenges in study design and informed consent for health research in resource poor settings. World Health Organization. 2007.

Name of the Program	**Master of Science in Nuclear Medicine**
Course Title	**Practical-I**
Course Code	**MNM1105**
Academic Year	First
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 (COs):
At the end of the course student shall be able to:

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)
CO2	Set up non imaging devices to acquire and apply basic quenching correction or self-absorption correction factors to quantify activity in 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)
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)

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

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Course Content and Outcomes:

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)	15

Content	Competencies	Number of Hours
	• 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)	
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)	15

Content	Competencies	Number of Hours
	• 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 calibration requirements (C6, P5)	
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

Content	Competencies	Number of Hours
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

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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**

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/RecordBook	x	x	x	x	x	x
Clinical assessment (OSCE, OSPE, WBPA)	x	x	x	x	x	x

Feedback Process:	Mid-SemesterFeedback
	End-Semester Feedback
Main Reference:	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

Name of the Program	**Master of Science in Nuclear Medicine**
Course Title	**Clinical Practice-I**
Course Code	**MNM1106**
Academic Year	First
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 (COs):
At the end of the course student shall be able to:

CO1	Safely handle radioisotopes, practice radiation safety and regulatory norms (C4, P4, A4)
CO2	Perform various quality control checks of equipment, radiopharmaceutical etc. and address trouble shooting (C4, P5, A5)
CO3	Perform various clinical Nuclear Medicine procedures (C4, P5, A5)
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)
CO5	Apply the importance of effective communication, teamwork, ethical values and professionalism (C3, P3, A5)

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 and Outcomes:

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**

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 Reference:	• Radiopharmaceuticals in Nuclear Medicine Pharmacy and Nuclear Medicine - Kowalsky, Richard J., and Steven W. Falen • Nuclear Medicine-The Requisites: Harvey A. Ziessman, Janis P.O'Malley, James H.Thrall
Additional References	• Radiopharmaceuticals and Hospital Radiopharmacy Practices - N. Ramamoorthy BRIT • Radiation safety in Nuclear Medicine -AERB Mumbai • 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

Name of the Program	**Master of Science in Nuclear Medicine Technology**
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 (COs): At the end of the course, the student shall be able to:

CO1	Apply the concepts of probability distribution, hypothesis testing and other statistical tools to real world problems **(C4)**
CO2	Explain the steps involved in a research process, epidemiology and observational study designs (C2)
CO3	Apply statistical methods to conduct systematic reviews and meta-analysis (C4)

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 and Outcomes:

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 (C4) • Create effective data visualizations using tools such as G gplot2 and forest plots to present and communicate research findings (C4)	5

Content	Competencies	Number of Hours
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)	5

Content	Competencies	Number of Hours
	• 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)	
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) • 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)	**5**

Content	Competencies	Number of Hours
	• 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	**X**	**X**	-
Quiz/Unit test	X	X	X
Assignments/Presentations	X	X	X
End Semester Exam	X	X	X

Feedback Process:	Mid-Semester Feedback
	End-Semester Feedback
Main Reference:	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.

Learning Strategies, Contact Hours and Out of Class Engagement	
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 Davey Smith, 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.

Name of the Program	**Master of Science in Nuclear Medicine Technology**
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 (COs): At the end of the course, the student shall be able to:

CO1	To understand working and recent advances in gamma camera, SPECT and PET camera (C2)
CO2	To understand working and recent advances in CT and MRI (C2)
CO3	To understand and compare hybrid imaging systems (C4)

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 and Outcomes:

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)	5

Content	Competencies	Number of Hours
	• 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)	
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)	6

Content	Competencies	Number of Hours
	• Discuss CT architecture and integration with PET (C2) • Discuss registration and fusion algorithms for PET/CT (C2) • Discuss work flow optimization and radiation dose management (C2)	
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	

Mapping of Assessment with COs:			
Nature of Assessment	**CO1**	**CO2**	**CO3**
Mid Semester			
Quiz/Unit test			
Assignments/Presentations			
End Semester Exam			

Learning Strategies, Contact Hours and Out of Class Engagement	
Feedback Process:	Mid-Semester Feedback
	End-Semester Feedback
Main Reference:	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

Name of the Program		**Master of Science in Nuclear Medicine**
Course Title		**SPECT & PET Radiopharmaceuticals**
Course Code		**MNM1103**
Academic Year		**First Year**
Semester		**II**
Number of Credits		**3**
Course Prerequisite	Basic knowledge of chemistry and radiopharmacy for Nuclear medicine 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 (COs): At the end of the course student shall be able to:	
CO1	Understand and explain about various gamma emitting radio pharmacy and Radiopharmaceuticals used in nuclear medicine (C2)
CO2	To understand synthesis of PET radiopharmaceuticals (C2)
CO3	To understand Drug Development and Trials for nuclear medicine (C2)

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 and Outcomes:

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)	**20**

Content	Competencies	Number of Hours
	• 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 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/Presentations	

Mapping of Assessment with COs:						
Nature of Assessment	**CO1**	**CO2**	**CO3**	**CO4**		
Mid Semester	**X**					
Unit Test/Quiz	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 Reference:	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.

Learning Strategies, Contact Hours and Out of Class Engagement	
Additional reference:	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.

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Name of the Program	Master of Science in Nuclear Medicine Technology
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 (COs): At the end of the course, the student shall be able to:

CO1	To apply Computational Algorithms in Nuclear Medicine (C3)
CO2	To use Programming and Software Tools relevant to nuclear medicine (C3)
CO3	To use computer algorithms for evaluating tracer kinetics in Nuclear Medicine (C3)

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 and Outcomes:

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 algorithms.	**3**

Content	Competencies	Number of Hours
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). • To understand Debugging: Profiling, error handling applications in ensuring robust dosimetry programs (C2).	4
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

Content	Competencies	Number of Hours
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	X			
Quiz/Unit test	X	X	X	
Assignments/Presentations	X	X	X	
End Semester Exam	X	X	X	
Feedback Process:	Mid-Semester Feedback			
	End-Semester Feedback			

Learning Strategies, Contact Hours and Out of Class Engagement	
Main Reference:	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.

Name of the Program	**Master of Science in Nuclear Medicine**
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 (COs): At the end of the course student shall be able to:	
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)
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)
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)
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)
CO5	Formulate and assess the performance of an in house cold kit, and develop a formalized protocol for the safe dispensing and administration of a high-activity therapeutic radiopharmaceutical (Lu-177) including patient specific considerations (C6, P5)

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 and Outcomes:

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 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)	45

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

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 Reference:	• Radiopharmaceuticals in Nuclear Medicine Pharmacy and Nuclear Medicine - Kowalsky, Richard J., and Steven W. Falen • Nuclear Medicine-The Requisites: Harvey A. Ziessman, Janis P.O'Malley, James H.Thrall
Additional References	• Radiopharmaceuticals and Hospital Radiopharmacy Practices - N. Ramamoorthy BRIT • Radiation safety in Nuclear Medicine –AERB Mumbai • Nuclear Medicine Technology: Procedures and Quick Reference–Pete Shackett

Name of the Program	Master of Science in Nuclear Medicine
Course Title	**Clinical Practice-II**
Course Code	**MNM1106**
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 (COs):
At the end of the course student shall be able to:

CO1	Safely handle radioisotopes, practice radiation safety and regulatory norms (C4, P4, A4)
CO2	Perform various quality control check sof equipment, radiopharmaceutical etc. and address trouble shooting for therapeutic nuclear medicine procedures (C4, P5, A5)
CO3	Perform various clinical therapeutic nuclear medicine procedure (C4, P5, A5)
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)
CO5	Apply knowledge of patient care, safety protocols and quality assurance (C4, P4, A4) (C3, P3, A5)

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 and Outcomes :

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	135	-
Total	**150**	**45**

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 Reference:	• Radiopharmaceuticals in Nuclear Medicine Pharmacy and Nuclear Medicine - Kowalsky, Richard J., and Steven W. Falen • Nuclear Medicine-The Requisites: Harvey A. Ziessman, JanisP.O'Malley, JamesH.Thrall
Additional References	• Radiopharmaceuticals and Hospital Radiopharmacy Practices - N. Ramamoorthy BRIT • Radiation safety in Nuclear Medicine –AERB Mumbai • Nuclear Medicine Technology: Procedures and Quick Reference–Pete Shackett

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

Name of the Program	**Master of Science in Nuclear Medicine**
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 (COs):
At the end of the course student shall be able to:

CO1	To apply advanced computational technique in Nuclear medicine (C3)
CO2	To apply Machine Learning Fundamentals for Nuclear Medicine (C3)
CO3	To apply AI in Diagnostics and Theranostic Nuclear Medicine (C3)
CO4	To understand and apply Ethical consideration in AI (C3)

Mapping of Course Out comes (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				

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Course Content and Outcomes:

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) 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).	10

Content	Competencies	Number of Hours
Unit2: 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).	7

Content	Competencies	Number of Hours
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

Content	Competencies	Number of Hours
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 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).	10

Content	Competencies	Number of Hours
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).	10

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**

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/ Unit Test	**X**	**X**	**X**	**X**		
Assignment/presentations	**X**	**X**	**X**	**X**		
End Semester Exam	**X**	**X**	**X**	**X**		

Feedback Process:	Mid-Semester Feedback
	End-Semester Feedback

Main Reference:	Textbooks 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.

Name of the Program	**Master of Science in Nuclear Medicine**
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 (COs):
At the end of the course student shall be able to:

CO1	To create Protocols for routine clinical SPECT and PET Procedures (C6)
CO2	To analyse clinical studies and sources of error (C5)
CO3	To develop and optimize clinical protocols for the estimation of patient dosimetry

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 and Outcomes:

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

Content	Competencies	Number of Hours
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

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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:**
UnitTest	Mid Semester/Sessional Exam
Quiz	End Semester Exam
Assignments/Presentations	

Mapping of Assessment with COs:				
Nature of Assessment	**CO1**	**CO2**	**CO3**	
Mid Semester	X			
Quiz/ Unit Test	X	X	X	
End Semester Exam	X	X	X	

Feedback Process:	Mid-Semester Feedback
	End-Semester Feedback
Main Reference:	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
Additional reference:	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 UNITS AND MEASUREMENTS, Absorbed-dose specification in Nuclear Medicine, ICRU Rep. 67, Bethesda, MD (2002).

Name of the Program	Master of Science in Nuclear Medicine
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 (COs):

At the end of the course student shall be able to:

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)
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)
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)

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 and Outcomes:

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.	20

Content	Competencies	Number of Hours
	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.	
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

Content	Competencies	Number of Hours
	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**

Formative:	**Summative:**
Unit Test	Mid Semester
Quiz	End Semester Exam
Assignment & presentations	

Mapping of Assessment with COs:

Nature of Assessment	**CO1**	**CO2**	**CO3**			
Mid Semester Examination	x	x	X			
Quiz/Viva	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 Reference:	1. Quantitative Analysis in Nuclear Medicine Imaging – Habib Zaidi, Springer; covers advanced image analysis techniques. 2. 2.Image Reconstruction in Radiology – J.A. Seibert, CRC Press; provides comprehensive reconstruction methods. 3. 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

Name of the Program	**Master of Science in Nuclear Medicine**
Course Title	**Research Project-I**
Course Code	**MNM2304**
Academic Year	Second Year
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 (COs): At the end of the course student shall be able to:	
CO1	Understand the process and get trained in designing, drafting, executing are search study(C1, P1, A1)
CO2	Understand regulatory aspects involved in research (C3,P3,A2)
CO3	Conduct research experiments relevant to their study (C3,P3,A2)

Mapping of Course Outcomes (COs)toProgramOutcomes(POs):

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

Course Content and Outcomes:

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

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Learning Strategies, Contact Hours and Out of class engagement hours:			
learning Strategies	**Contact Hours**		**Out of class engagement hours**
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 Examination1	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 Reference:	Research journals, Scientific literatures		

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Name of the Program	**Master of Science in Nuclear Medicine**
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 (Cos):

At the end of the course student shall be able to:

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)
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)
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)

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 and Outcomes:

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

Content	Competencies	Number of Hours
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

Content	Competencies	Number of Hours
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). 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)	15
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

Content	Competencies	Number of Hours
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

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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**

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 Log Book/ 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 Reference:	• Radio pharmaceuticals in Nuclear Medicine Pharmacy and Nuclear Medicine – Kowalsky, Richard J., and Steven W. Falen • Nuclear Medicine-The Requisites: Harvey A. Ziessman, Janis P.O'Malley, James H. Thrall
Additional References	• Radio pharmaceuticals and Hospital Radio pharmacy Practices – N. Ramamoorthy BRIT • Radiation safety in Nuclear Medicine –AERB Mumbai • 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

Name of the Program	**Master of Science in Nuclear Medicine Technology**
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 (COs): At the end of the course, the student shall be able to:

CO1	To recall Fundamentals of Radiation Dosimetry (C1)
CO2	To apply Internal Dosimetry and MIRD in nuclear medicine (C3)
CO3	To understand and apply Treatment Planning in Nuclear Medicine Therapy (C3)

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 and Outcomes:

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

Content	Competencies	Number of Hours
	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)
Assignment/Presentation	

Mapping of Assessment with COs:			
Nature of Assessment	**CO1**	**CO2**	**CO3**
Mid Semester	X	**X**	
Quiz/Unit test	X	X	X
Assignments/Presentations	X	X	X
End Semester Exam	X	X	X

Feedback Process:	Mid-Semester Feedback
	End-Semester Feedback
Main Reference:	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

Name of the Program	Master of Science in Nuclear Medicine Technology
Course Title	**Therapeutic Radiopharmaceuticals**
Course Code	**MNM2402**
Academic Year	**Second Year**
Semester	**IV**
Number of Credits	3
Course Prerequisite	Basic understanding of radiopharmacy and radiochemistry at B.Sc. NM level
Course Synopsis	

Course Outcomes (COs): At the end of the course, the student shall be able to:

CO1	To recall radiopharmaceuticals used in therapy (C1)
CO2	To critically review PRRT and Targeted Radionuclide Therapy (C5)
CO3	To critically review Target Alpha Therapy (C5)

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						

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Course Content and 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 Radiosynovectomy: Radiopharmaceutical used, mode of administration, dose and regulatory requirements (C5)	15

Content	Competencies	Number of Hours
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)
Assignment/Presentation	

Mapping of Assessment with COs:			
Nature of Assessment	**CO1**	**CO2**	**CO3**
Mid Semester			
Quiz/Unit test			
Assignments/Presentations			
End Semester Exam			

Feedback Process:	Mid-Semester Feedback
	End-Semester Feedback

Learning Strategies, Contact Hours and Out of Class Engagement	
Main Reference:	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

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Name of the Program	Master of Science in Nuclear Medicine
Course Title	**Quality Assurance and Quality Control in Nuclear Medicine**
Course Code	**MNM2403**
Academic Year	Second
Semester	III
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):
At the end of the course student shall be able to:

CO1	Explain the fundamental principles of Quality assurance and quality control of the various equipment (C2)
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)
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)

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 and Outcomes:

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

Content	Competencies	Number of Hours
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 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)	20

Content	Competencies	Number of Hours
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. • 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 reliability.	20

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**

Formative:	**Summative:**
Unit Test	Mid Semester
Quiz	End Semester Exam
Assignment & presentations	

Mapping of Assessment with COs:						
Nature of Assessment	**CO1**	**CO2**	**CO3**			
Mid Semester Examination	x	x	x			
Quiz/Viva	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 Reference:	• Quality Control in Nuclear Medicine – James A. Ponto, Society of Nuclear Medicine • Nuclear Medicine Physics: The Basics – Ramesh Chandra, Wolters Kluwer
Additional References	• Nuclear Medicine and PET/CT: Technology and Techniques – Paul E. Christian, Kristen M. Waterstram-Rich, Mosby

Name of the Program	Master of Science in Nuclear Medicine
Course Title	**Research Project -II**
Course Code	**MNM2404**
Academic Year	Second Year
Semester	IV
Number of Credits	10
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 (COs):
At the end of the course student shall be able to:

CO1	Execute research experiments independently or as part of a team (C3, P3, A5)
CO2	Explain, analyse, present, and defend the research findings (C4, P5, A4)
CO3	Compile and communicate scientific articles (C6, P3, A4)

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 and Outcomes:

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 hours:		
Learning Strategies	**Contact Hours**	**Out of class engagement hours**
Seminar	0	0
Practical	300	300
Revision	0	0
Assessment	0	0
Total	**300**	**300**

Assessment Methods:	
Formative:	**Summative:**
Unit Test/Quiz	Mid Semester/Sessional Exam (Theory)
Assignments/Presentations	End Semester Exam (Theory)

Mapping of Assessment with COs:			
Nature of Assessment	**CO1**	**CO2**	**CO3**
Mid Semester/SessionalExamination1	x	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 Reference:	1.Research journals, Scientific literatures
Additional References	

Name of the Program	Master of Science in Nuclear Medicine
Course Title	**Clinical Practice-IV**
Course Code	**MNM2405**
Academic Year	Second
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 (COs):
At the end of the course student shall be able to:

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)
CO2	Systematically analyze and mitigate complex artifacts in hybrid imaging () and accurately calculate and interpret advanced quantitative metrics (etc.) (C4, P5, A3)
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)
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)
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)

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 and Outcomes :

Content	Competencies	Number of Hours
Unit 1: Advanced Radiopharmacy and Clinical Correlation: Troubleshooting and Error Analysis		
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

Content	Competencies	Number of Hours
Unit 3: Molecular and Theranostic Applications: Clinical Decision-Making and Management		
Neuroendocrine and Prostate Theranostics	• In-depth interpretation of pre-therapy scans (^{68}Ga-DOTATATE, ^{68}Ga-PSMA) for eligibility and dosimetry. Post-therapy analysis of treatment response and complication management (e.g., ^{177}Lu 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
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**

Formative:	**Summative:**
Unit Test	Mid Semester (Practical)
Quiz	Viva
Viva	Log Book
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 Reference:	• Radiopharmaceuticals in Nuclear Medicine Pharmacy and Nuclear Medicine - Kowalsky, Richard J., and Steven W. Falen • Nuclear Medicine-The Requisites: Harvey A. Ziessman, JanisP.O'Malley, JamesH.Thrall
Additional References	• Radiopharmaceuticals and Hospital Radiopharmacy Practices - N. Ramamoorthy BRIT • Radiationsafety in Nuclear Medicine –AERB Mumbai • Nuclear Medicine Technology: Procedures and Quick Reference–Pete Shackett

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Chapter 6

Residency/Internship Clinical Training

Residency/Clinical Training of Nuclear Medicine Technologist

I. 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

II. 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

- **Direct Supervision:** Initially, the trainee works under the immediate guidance of the supervisor for all tasks until a pre-defined competency milestone is achieved.
- **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.
- **Mentorship:** The supervisor also functions as a mentor, guiding the trainee's professional development, participation in research, and teaching activities.

III. 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.

Module 1 Clinical Awareness	
Sub-module 1.3: Clinical Activities and Factors that Affect Patient Care	
	• 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

Module 2: Radiation Protection	
Sub-module 2.1: Monitoring Radiation Levels Including Personnel 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: ○ Inventory of the types and amounts of radio-isotope and radio- pharmaceutical entering the lab and any relevant properties (e.g. iodine is volatile) ○ Inventory of available radiation measuring instruments. Note the applications and limitations of each instrument. ○ Inventory of sealed sources, handling, storage and location ○ Use of personal monitors: type, location, frequency of changing ○ 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 misadministrations, 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: ○ receipt, storage and disposal of radioactive material ○ preparation and dispensing of radiopharmaceuticals ○ patient injection or administration procedures ○ patient movements before and after injection ○ patient scanning procedures

Module 2: Radiation Protection	
Sub-module 2.2: Exposure from unsealed Sources and the Risk of Contamination	
	• Conduct a radiation survey of the various areas in the Department (hot lab, patient waiting areas, scanning rooms etc.), noting in particular: ○ the availability and use of shields ○ whether the layout allows adequate distance from sources ○ 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 principle 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?

Module 2: Radiation Protection	
Sub-module 2.3: ALARA and Radiation Safety Precautions in Nuclear Medicine	
	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 1.1 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

Module 2: Radiation Protection	
Sub-module 2.4: Risk Assessment and Advice to Staff, Patients and Others Regarding Radiation Risk	
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. o for a concerned parent, whose 9-year-old child has been referred for a renal scan (dose to the child). o for a pregnant mother, whose 5-year-old child has been referred for a bone scan (dose to the mother/fetus) o for a pregnant registrar who is concerned about working in the stress room o for an ultra-sonographer who is concerned about scanning a nuclear medicine patient o 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 ○ Preparation, dispensing and administration of radiopharmaceuticals ○ A radioactive waste store ○ 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 ○ Surface finishes ○ Airborne contamination ○ Segregation of radionuclide and paper work ○ Security of access and stores ○ Local shielding ○ Any other features you think would be required

Module 2: Radiation Protection	
Sub-module 2.5: Areas Designated for the Use of Unsealed Radioactive Material	
	• 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 ○ Radiation dose units and metrics applicable to shielding design ○ Primary Radiation; attenuated and un-attenuated ○ Secondary Radiation; scatter and leakage ○ Transmission of primary and secondary radiation through patients, imaging components and barriers • Regulatory Requirements and Guidelines ○ Local legislation and guidance applying to the design of Nuclear Medicine facilities ○ Designation of controlled and supervised areas ○ Dose limits for workers and members of the public ○ Dose constraints and shielding design goals

Module 2: Radiation Protection	
Sub-module 2.6: Radiation Shielding Considerations in Design of New Facilities	
	• 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

Module 2: Radiation Protection	
Sub-module 2.6: Radiation Shielding Considerations in Design of New Facilities	
	• 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 ○ Personnel dose ○ Radiation licenses and registrations ○ Radiation incidents ○ 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

Module 2: Radiation Protection	
Sub-module 2.7 Regulatory Controls and Other Guidance on the Safe Use of Ionizing Radiation in Nuclear Medicine	
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: ○ Responsibilities of employers and employees including information on radiation safety ○ Licensing and supervision for anyone working in nuclear medicine including physicians, registrars, technologists/ trainees, service engineers, scientists and postgraduate students. ○ Include any requirements relating to the use of hybrid CT imaging systems Limits on radiation dose resulting from working with radiation, working near radiation, or as a member of the general public ○ Radiation monitoring of persons working in nuclear medicine ○ Area monitoring ○ 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

Module 2: Radiation Protection	
Sub-module 2.7 Regulatory Controls and Other Guidance on the Safe Use of Ionizing Radiation in Nuclear Medicine	
	• 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

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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

Module 3 - Research, Development, and Teaching	
Sub-module 3.2 - Teaching	
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: (1) Teaching to Nuclear Medicine Technologist, junior Nuclear Medicine Technologist, or other technically orientated staff (2) Teaching to nuclear medicine staff and residents (3) Teaching radiation safety to nurses or other paramedical staff (e.g., departmental secretaries) (4) Teaching technologists to carry out quality control of a specific nuclear medicine equipment

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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.

Module 4 – Professional Development and Management	
Sub-module 4.1: Professional Awareness	
	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.

Module 4 – Professional Development and Management	
Sub-module 4.1: Professional Awareness	
	(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 ○ Oral presentation competencies, ○ Mentoring competencies, and/or ○ Conducting professional meetings. • Actively participate in physics department meetings (chair a meeting if possible). • Actively participate in Department technical meetings. • Scientific presentation at meeting of Nuclear Medicine Technologist, multi- disciplinary professionals or an audience containing members of the general public.

Module 4 – Professional Development and Management	
Sub-module 4.2: Communication	
	• 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

Module 4 – Professional Development and Management	
Sub-module 4.2: Communication	
	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.

Module 4 – Professional Development and Management	
Sub-module 4.3: Quality Management	
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 "life cycle" of a 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.

Module 4 – Professional Development and Management	
Sub-module 4.4: Clinical Audit	
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.

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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

Module 5 - Equipment Procurement, Acceptance Testing and Commissioning	
Sub-module 5.1: –Acquisition and Life Cycle of Nuclear Medicine Equipment	
	• Principles of Equipment Planning ○ Creation of the business plan ○ Clinical consideration ○ Technical considerations including power supply and earthing/grounding ○ 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

Module 5 - Equipment Procurement, Acceptance Testing and Commissioning	
Sub-module 5.1: –Acquisition and Life Cycle of Nuclear Medicine Equipment	
	• 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.

Module 5 - Equipment Procurement, Acceptance Testing and Commissioning	
Sub-module 5.1: –Acquisition and Life Cycle of Nuclear Medicine Equipment	
	• 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 ○ Background activity ○ Source geometry ○ Source position ○ Sample activity ○ 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

Module 5 - Equipment Procurement, Acceptance Testing and Commissioning	
Sub-module 5.2 - Dose Calibrator Acceptance Testing	
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 ○ scintillation probe system ○ 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

Module 5 - Equipment Procurement, Acceptance Testing and Commissioning	
Sub-module 5.3 – Scintillation probe and Well Counter Acceptance Testing	
	• 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
Recommended 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)

Module 5 - Equipment Procurement, Acceptance Test and Commissioning	
Sub-module 5.4 - Gamma Camera/SPECT and CT Acceptance Testing and Commissioning	
	○ 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 processes involved 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

Module 5 - Equipment Procurement, Acceptance Testing and Commissioning	
Sub-module 5.5 – PET and CT Acceptance Testing and Commissioning	
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: ○ Gamma camera based coincidence system ○ GSO, LySO PET systems (e.g. Philips Gemini) ○ BGO based systems (e.g. GE Discovery Series) ○ LSO (e.g. Siemens Biograph,) ○ 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 ○ Count rate performance ○ Spatial Resolution ○ Corrections applied and quantitative accuracy ○ 3D vs. 2D acquisitions in terms of sensitivity, injected activity and effect of activity outside field of view. ○ Relative merits of CT vs. non-CT based attenuation correction ○ Appropriate NEMA standard to evaluate performance for whole body studies (NEMA 2001) ○ Activity injected into patient and uptake period ○ 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. ○ 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

Module 5 - Equipment Procurement, Acceptance Testing and Commissioning	
Sub-module 5.5 – PET and CT Acceptance Testing and Commissioning	
	• Design and describe an experiment to verify that the PET scanner provides accurate activity concentration values and all corrections and calibrations are appropriately applied.

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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.

Module 6 - Radioactivity Measurements and Internal Dosimetry	
Sub-module 6.1: Use of Traceable Standards for Radioactivity Measurements	
	• 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).

Module 6 - Radioactivity Measurements and Internal Dosimetry	
Sub-module 6.2: Formalism and Application of Internal Dosimetry	
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 patients.

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

Module 6 - Radioactivity Measurements and Internal Dosimetry	
Sub-module 6.3: Radiation dose from Diagnostic Nuclear Medicine Radiopharmaceuticals	
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).

Module 6 - Radioactivity Measurements and Internal Dosimetry	
Sub-module 6.4: Quantitative Nuclear Medicine Imaging	
	(4) Design and carry out a phantom experiment which demonstrates the effect of partial volume on activity quantification (can be demonstrated either for planar or 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

Module 6 - Radioactivity Measurements and Internal Dosimetry	
Sub-module 6.5 – Patient-Specific Dosimetry	
	• 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

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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 ○ Roles and responsibilities of staff involved in the QC programme ○ Which staff groups are required to perform different types of tests ○ Supervision requirements ○ Training needs and delivery ○ Reporting and record keeping • Quality Control tests ○ Types of tests ○ Complexity of differing tests ○ Applicability of tests ○ Appropriate frequencies for performance of different tests ○ Use of control charts including operating levels, upper and lower control limits

Module 7 – Quality Control of Nuclear Medicine Equipment	
Sub-module 7.1 – Design and Supervision of a Routine QC Program	
Recommended Elements of Training	• Participation in the training of staff to perform QC tests • Establishment of ○ operating levels ○ control limits ○ control charts ○ record keeping • Implement QC program to include ○ Dose calibrator ○ Scintillation probe and well counter ○ Gamma camera ○ SPECT camera ○ PET scanner ○ CT scanner ○ BMD ○ Appropriate quality control charts
	• Carry out periodic review of quality control program with other staff ○ Perform Nuclear Medicine Technologist level quality control tests ○ Develop quality control program ○ 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 ○ Physical inspection ○ High voltage visual inspection check ○ Zero check and adjustment ○ Background check

	○ Constancy ○ Geometry dependence ○ Precision and accuracy ○ Linearity of activity response • Limits of acceptability • Setting action levels • Recommended frequency of checks • Importance of record keeping • Creating a control chart • Discuss issues with measuring pure beta emitters (e.g. ^{90}Y, ^{89}Sr) and beta emitters with a non-negligible gamma-ray emissions (e.g.^{153}Sm) in standard calibrators.

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: ○ 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 • Limits of acceptability • Setting action levels • Recommended frequency of checks • Importance of record keeping • Creating a control chart

Module 7 – Quality Control of Nuclear Medicine Equipment	
Sub-module 7.3 – QC of a Scintillation Probe and Well Counter	
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

Module 7 – Quality Control of Nuclear Medicine Equipment	
Sub-module 7.4 – QC of a Gamma Camera and SPECT	
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.

Module 7 – Quality Control of Nuclear Medicine Equipment	
Sub-module 7.4 – QC of a Gamma Camera and SPECT	
	• Perform and write up the following SPECT QC tests: ○ Centre of Rotation measurement as specified by the manufacturer ○ SPECT spatial resolution as a function of the radius of rotation (ROR) ○ Perform 2 SPECT acquisitions of a line source at the minimum ROR and at 20cm ROR. ○ Collect planar views at each ROR. ○ Reconstruct the SPECT acquisitions and calculate SPECT spatial resolution as a function of ROR. ○ Compare the SPECT resolution with the static resolution for each ROR • SPECT Uniformity ○ Perform a SPECT acquisition of a uniform phantom filled with 99mTc ○ 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.

Module 7 – Quality Control of Nuclear Medicine Equipment	
Sub-module 7.4 – QC of a Gamma Camera and SPECT	
	• 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 recommended reading material. • Summarize in writing the procedures in place at the trainee's department for routine PET/CT quality control.

Module 7 – Quality Control of Nuclear Medicine Equipment	
Sub-module 7.5 – QC of PET/CT Systems	
	• 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: ○ the purpose of the procedure. ○ the steps involved in performing procedure, including mention of any phantoms and how they are positioned ○ what parameters are evaluated and how ○ the frequency with which it is performed ○ where results are stored and how they can be accessed for review ○ what results were obtained during the period. ○ how results are interpreted. ○ what values are specified as acceptable by the manufacturer. ○ 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

Module 7 – Quality Control of Nuclear Medicine Equipment	
Sub-module 7.6 – QC of Display and Hardcopy Devices	
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 ○ 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. ○ 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. ○ If paper hardcopy and/or films using a laser imager are normally produced, comment on ○ Loss of grey scale levels and range on hard copy compared to displayed image ○ Differences in color (if color printer) between hard copy and screen display ○ 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 ○ . 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. ○ Write a brief report on your findings.

Module 7 – Quality Control of Nuclear Medicine Equipment	
Sub-module 7.6 – QC of Display and Hardcopy Devices	
	• 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. ○ 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

Module 7 – Quality Control of Nuclear Medicine Equipment	
Sub-module 7.7 – QC of DXA Systems	
	• 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.

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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 ○ Radiopharmaceuticals uptake and retention ○ Quantity of radiopharmaceuticals ○ Retention of radiopharmaceuticals ○ Consideration of Physical half-life ○ Tissue factors affecting radiopharmaceuticals uptake ○ Radionuclides for therapy • Alpha emitter • Beta emitter ○ Auger and Coster-Kronig electron emission processes • Regulatory Requirements and Guidelines ○ 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

Module 8 - Radionuclide Therapy Using Unsealed Sources	
Sub-module 8.1: Understanding the principles of 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 ○ The expected effective half life ○ Basic radiation protection Principle: Time, Distance, Shielding • Regulatory Requirements and Guidelines ○ Local legislation and guidelines to be applied to the design of radionuclide therapeutic facilities • Physical Design ○ Location e.g. the facility should be away from the public area and use of external wall can reduce the radiation shielding requirements ○ The expected length of hospital stay of the patient and the expected radiation dose rate from the patient ○ The design of excretory pathways ○ The target design dose in accessible areas (e.g. the need for a dedicated shower/toilet for each room and a waste storage) ○ Dose constraints and shielding design goals, e.g. a constraint of 0.2 is often used for medical radiation workers ○ Attenuation of possible shielding materials for the radionuclide being used

Module 8 - Radionuclide Therapy Using Unsealed Sources	
Sub-module 8.2: Facility Design for Radionuclide Therapy	
	• Waste management ○ 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 ○ 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 ○ Mechanisms of different types of radiopharmaceutical uptake used in therapy ○ Bio-distribution of radiopharmaceutical

Module 8 - Radionuclide Therapy Using Unsealed Sources	
Sub-module 8.3: Treatment Procedure	
	○ Different types of radionuclide treatment and characteristics of specific radiopharmaceuticals for radionuclide therapy ○ Physical characteristics of radionuclide ○ Understand the concepts of absorbed dose, equivalent dose, cumulative absorbed dose and effective dose ○ Radiation protection principles (justification, optimization and limitation) • Procedures to be followed prior to treatment ○ Advise the patient and their attendance about preparations to follow before the treatment, during the treatment at home or in hospital and when discharged ○ 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 ○ Ensure correct radiopharmaceutical and activity is ordered for the specific patient ○ Arrange for appropriate equipment, survey instruments, personal protection and dosimeters to be provided for the purpose of treatment ○ 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 ○ Pre-treatment management ○ Protocols and procedures ○ Form of radionuclide to be administered to patient for therapy ○ Patient dose preparation and administration ○ Dose planning for treatment ○ Dose calculation of the appropriate radionuclide to be administered to the patient for therapy ○ Radionuclide therapy of distant metastases ○ Postoperative management of radionuclide therapy ○ Prepare a check-list of the whole procedure

Module 8 - Radionuclide Therapy Using Unsealed Sources	
Sub-module 8.3: Treatment Procedure	
	• Discharge ○ Safety of family members following discharge ○ Determination of the time frame when the patient can return to work or move in public environment ○ Discharge to a non-home environment • Long term advice ○ On future pregnancy. ○ Carcinogenesis e.g. the patient's follow-up and post treatment care issues. ○ 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

Module 8 - Radionuclide Therapy Using Unsealed Sources	
Sub-module 8.4: Selection of Radiopharmaceuticals for Nuclear Medicine Therapy	
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 ○ Selection of radionuclides ○ Selection of organs and tissues for dose calculation • Other considerations ○ Maximum safe administered dose ○ 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.

Module 8 - Radionuclide Therapy Using Unsealed Sources	
Sub-module 8.5: Dosimetry for Radionuclide Therapeutic Procedure	
	• 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 ○ Fundamentals of safety principles • Regulatory requirements and guidelines ○ Local legislation and guidelines applied for the radionuclide therapy

Module 8 - Radionuclide Therapy Using Unsealed Sources	
Sub-module 8.6: Radiation Safety Precautions for Therapy Using Unsealed Radionuclide Sources	
	• Radiation safety for radionuclide therapy ○ Advise the patient about preparations to follow before the treatment, during the treatment at home or in hospital and when discharged ○ Radiation monitoring and radiation safety precautions ○ Instruct ward staff on monitoring the patient, managing contaminated linen, food waste and other items and responding to medical emergencies ○ Explain to ward staff the precautions to be observed for their own personal safety and the safety of other health care employees and visitors ○ Instruct catering staff, cleaners and maintenance engineers who service therapy bedrooms and bathrooms ○ Dispense the radiopharmaceutical to within ±10% of the prescribed activity and monitor its safe administration to the patient by the physician or technologist ○ Determine when the patient may be discharged from hospital with respect to the radioactivity remaining in the body ○ Radiation protection for workers and members of the public ○ Dose limits for workers and members of the public ○ Radiation monitoring and documentation associated in the procedure ○ Ability to manage disused sources and waste ○ 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.

Module 8 - Radionuclide Therapy Using Unsealed Sources	
Sub-module 8.6: Radiation Safety Precautions for Therapy Using Unsealed Radionuclide Sources	
	• 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.

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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.

Module 9 - Clinical computing and networking	
Sub-module 9.1 - Operation of a Clinical Acquisition and Processing/Reviewing Workstation	
	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.

Module 9 - Clinical computing and networking	
Sub-module 9.1 - Operation of a Clinical Acquisition and Processing/Reviewing Workstation	
	• 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.

Module 9 - Clinical Computing and Networking	
Sub-module 9.2 – Computer System Administration Management	
	• 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 ○ Rapidly recognize and troubleshoot common computer hardware, software and networking related problems. ○ 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.

Module 9 - Clinical Computing and Networking	
Sub-module 9.3: First-line Computer System Troubleshooting	
	• 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: ○ Hard disk errors; ○ Slowly running or frozen computer; ○ Inability to start an application; ○ Unusual behavior of the software; ○ 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.

Module 9 - Clinical Computing and Networking	
Sub-module 9.4 - Computer Image Processing Techniques	
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)

Module 9 - Clinical Computing and Networking	
Sub-module 9.4 - Computer Image Processing Techniques	
	• 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.

Module 9 - Clinical Computing and Networking	
Sub-module 9.4 - Computer Image Processing Techniques	
	• 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.

Module 9 - Clinical Computing and Networking	
Sub-module 9.5 – Image Analysis in a High-Level Programming Language (optional)	
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.

Module 9 - Clinical Computing and Networking	
Sub-module 9.5 – Image Analysis in a High-Level Programming Language (optional)	
	• 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.

Module 9 - Clinical Computing and Networking	
Sub-module 9.6 – Image Reconstruction, Registration and Fusion and Tracer Kinetic Modelling	
	• 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.

Module 9 - Clinical Computing and Networking	
Sub-module 9.6 – Image Reconstruction, Registration and Fusion and Tracer Kinetic Modelling	
	• 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. *(The depth of the resident's knowledge to be acquired with this sub-module will be determined by the local conditions and organizational scheme. Some training institutions may have a number of different professionals dealing with networking, database and system administration, while in others these tasks will be shared or done almost exclusively by a Nuclear Medicine Technologist.*
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

Module 9 - Clinical Computing and Networking	
Sub-module 9.8 – Computer Networking, PACS, RIS and HIS	
	• 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

Module 9 - Clinical Computing and Networking	
Sub-module 9.8 – Computer Networking, PACS, RIS and HIS	
	○ 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 databases 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.

Module 9- Clinical Computing and Networking	
Sub-module 9.9 – Software Validation: Computer Simulations, Phantoms and Clinical Data	
	• 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.).

Module 9- Clinical Computing and Networking	
Sub-module 9.9 – Software Validation: Computer Simulations, Phantoms and Clinical Data	
	• 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.

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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.

Module 10: Clinical Applications	
Sub-module 10.1: Protocols for Routine Clinical Procedures	
	• 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.

Module 10: Clinical Applications	
Sub-module 10.2: Common Artefacts in Clinical Images	
	(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** 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

Module 10: Clinical Applications	
Sub-module 10.3: Analysis of common clinical studies and sources of error	
Recommended Elements of Training	• Read, and be reasonably familiar with, the essential resource material recommended for this competency. • For a range of study types: ○ determine whether the study has been validated in the clinical arena, and limitations of the validation study. ○ investigate the effect of the scan result on patient management. ○ 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

Module 10: Clinical Applications	
Sub-module 10.3: Analysis of common clinical studies and sources of error	
	(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 ROI's 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.

Module 10: Clinical Applications	
Sub-module 10.4: Principles and Physiological Basis for Common Clinical Studies.	
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

Module 10: Clinical Applications									
Sub-module 10.5: Developing Clinical Protocols for the Estimation of Patient Dosimetry									
		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

Module 10: Clinical Applications	
Sub-module 10.6: Optimization	
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
Recommended 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 ○ Nuclear reactor and cyclotron ○ Production of radionuclide ○ Chemistry of Technetium • Observe the procedures for the preparation of radiopharmaceuticals including ○ Radionuclide generator ○ Laboratory technique ○ Preparation of radiopharmaceuticals • Perform radionuclide measurement ○ Total activity of the eluate using a radionuclide calibrator ○ Calculate the activity concentration

Module 11 – Preparation and Quality Control of Radiopharmaceuticals	
Sub-module 11.1-The Production and Preparation of Radiopharmaceuticals	
	• Study the radionuclide and radiopharmaceuticals requirements for clinical imaging ○ Tc-99m –MDP for bone imaging ○ Tc-99m –DTPA, DMSA and MAG-3for kidney imaging ○ Tc-99m – DISIDA for hepato-biliary imaging ○ Tc-99m-Sn-RBC for cardiac imaging and function studies. ○ 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: ○ Physical characteristics ○ Radionuclide purity ○ Radiochemical purity ○ Chemical purity • Procedures of an aseptic practice in daily radiopharmaceuticals preparations ○ Biological quality control ○ 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 – ○ Sterility ○ Pyrogen test

Module 11 – Preparation and Quality Control of Radiopharmaceuticals	
Sub-module 11.2 - Quality Control of the Radiopharmaceuticals	
	• Perform the QC of the radiopharmaceuticals including ○ Chemical purity using chromatographic methods ○ Classify the impurities ○ ITLC-SG (Instant thin layer chromatography-silica gel) preparation ○ Calculation the percentage activity the free pertechnetate and reduced hydrolyzed ○ 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.

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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 **ownership** of work undertaken.

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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 specifications 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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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 and 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.						

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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)		

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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.						

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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.						

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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.						
8.4 Selection of radiopharmaceuticals for nuclear medicine therapy.	(a) (b)					
8.5 Dosimetry for radionuclide therapeutic procedures.						
8.6 Radiation safety precautions for therapy using unsealed radionuclide sources.	(a) (b)			(a) (b)		

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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						

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Chapter 7

Ph.D in Nuclear Medicine Technology

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Minimum Standards and Procedures for Award of Ph.D. Degree in Nuclear Medicine Technolgoy or in the related special fields, to be followed as per UGC Guidelines

1. Short Title, Application, and Commencement

These Regulations may be called Minimum Standards and Procedure for Award of Ph.D. Regulations, 2025.

2. Definitions

In these Regulations, unless the context otherwise requires

- "Adjunct Faculty" means a part-time or contingent instructor, but not full-time faculty member hired to teach by a Higher Educational Institution
- "Cumulative Grade Point Average (CGPA)" means a measure of the overall cumulative performance of a student over all semesters. The CGPA is the ratio of total credit points secured by a student in various courses in all semesters and the sum of the total credits of all courses in all semesters. It is expressed up to two decimal places;
- "Credit" means the number of hours of instruction required per week over the duration of a semester. A three-credit course in a semester means three one-hour lectures per week, with each one-hour lecture counted as one credit;
- "College" means an institution engaged in higher education and/or research, either established by a University as its constituent unit or is affiliated with it;
- "Course" means one of the specified units which go to comprise a program of study;
- "Course Work" means courses of study prescribed by the Department/ Centre/Institution to be undertaken by a student registered for the Ph.D. Degree;
- "Degree" means a degree awarded by a Higher Educational Institution in accordance with NCAHP act;
- "External examiner" means an academician/researcher with published research work who is not part of the Higher Educational Institution where the Ph.D. scholar has registered for the Ph.D. program;
- "Foreign Educational Institution" means–(i) an institution duly established or incorporated in its home country and offering educational programs at the undergraduate, postgraduate and higher levels in its home country and (ii) which offers program(s) of study leading to the award of a degree through conventional face-to-face mode, but excluding distance, online mode;
- "Grade Point" means a numerical weight allotted to each letter grade on a 10-point scale;
- "Guide/Research Supervisor" means an academician/researcher recognized by Higher Educational Institution to supervise the Ph.D. scholar for his/her research;
- "Higher Educational Institution" (HEI) means a university or institution;

- "Interdisciplinary Research" means research conducted by a Ph.D. scholar in two or more academic disciplines;
- "Plagiarism" means the practice of taking someone else's work or idea and passing them as one's own;
- "Program" means a higher education program pursued for a degree specified by the NCAHP;
- "Research Proposal" means a brief write-up giving an outline of the proposed research work which the Ph.D. scholar shall submit along with the application for registration for Ph.D. program;
- Stipend/Remuneration to be paid to the candidate as per UGC Guidelines.

3. Program Overview

The Ph.D. in Nuclear Medicine Technology is a highly advanced research program created to cultivate innovative scientific leaders capable of pioneering at the intersection of molecular imaging, radiopharmaceutical sciences, and precision medicine etc. The program provides a broad interdisciplinary education and training in several core areas such as imaging science, radiopharamacy, image analysis, instrumentation, radiomics, radiation protection, dose measurement, and pharmaceutical development etc. Individuals completing this program will be well-equipped for professional roles in academia, industry, healthcare, and regulatory fields, and will play a part in developing and improving diagnostic and therapeutic approaches in nuclear medicine.

4. Eligibility Criteria for Admission to the Ph.D. Program

The following are eligible to seek admission to the Ph.D. program:

- Candidates who have completed: M.Sc. degree in Nuclear Medicine Technology or M.Sc. degree plus PG Diploma in Nuclear Medicine or its equivalent or M.Sc. degree in science and advance life sciences (Biology, Chemistry, Radiation biology, Medical Physics, Bio technology) with at least 55% marks in aggregate or its equivalent grade in a point scale wherever grading system is followed.
- Qualifications declared equivalent to the master's degree by the corresponding statutory regulatory body of NCAHP, with at least 55% marks in aggregate or its equivalent grade in a point scale wherever grading system is followed.
- A relaxation of 5% marks or its equivalent grade may be allowed for those belonging to SC/ST/OBC (non-creamy layer)/Differently-Abled, Economically Weaker Section (EWS) and other categories of candidates as per the decision of the Commission from time to time.
- Medical fitness certificate is mandatory to submit and it is to be endorsed by Government medical officer.
- Reservation policy for admission in diploma/under graduate/post graduate/PhD programs shall be as per the State/Centre Government norms.

5. Duration of the Program

- Ph.D. Program shall be for a minimum duration of three years, including course work, and a maximum duration of six years from the date of enrolment to the Ph.D. program.
- A maximum of an additional two years can be given through a process of re-registration as per the Statute/Ordinance of the Higher Educational Institution concerned; provided, however, that the total period for completion of a Ph.D. program should not exceed eight years from the date of admission in the Ph.D. program. Provided further that, female Ph.D. scholars and persons with disabilities (having more than 40% disability) may be allowed an additional relaxation of two years; however, the total period for completion of a Ph.D. program in such cases should not exceed ten years from the date of admission in the Ph.D. program.
- Female Ph.D. Scholars may be provided Maternity Leave/Child Care Leave for up to 240 days in the entire duration of the Ph.D. program.

6. Procedure for Admission

- The admission shall be based on the criteria notified by the institution, keeping in view the guidelines/norms in this regard issued by the NCAHP and other statutory/regulatory bodies concerned, and taking into account the reservation policy of the Central/State Government from time to time.
- Admission to the Ph.D. program shall be made using the following methods:
- HEIs may admit students through an Entrance Test conducted at the level of the individual HEI. The Entrance Test syllabus shall consist of 50% of research methodology, and 50% shall be subject- specific.
- HEIs may decide the number of eligible students to be called for an interview based on the number of Ph.D. seats available.
- Universities and Colleges which are eligible to conduct Ph.D. programs, shall:
- Notify a prospectus well in advance on the institution's website specifying the number of seats for admission, subject/discipline-wise distribution of available seats, criteria for admission, the procedure for admission, and all other relevant information for the candidates;
- Adhere to the National/State-level reservation policy, as applicable.
- The Higher Educational Institution shall maintain a list of Ph.D. supervisors (specifying the name of the supervisor, his or her designation, and the department/school/centre), along with the details of Ph.D. scholars (specifying the name of the registered Ph.D. scholar, the topic of his/her research and the date of admission) admitted under them on the website of the institution and update this list every academic year.

7. Allocation of Research Supervisor

Eligibility criteria to be a Research Supervisor, Co-Supervisor, number of Ph.D. scholars permissible per supervisor, etc.

- Permanent faculty members working as Professor/Associate/Assistant Professor of the Higher Educational Institution with a Ph.D., can act as Supervisors as classified in Chapter 2. And with Ph.D with advance life sciences (Biology, Chemistry, Radiation biology, Bio technology) can act as supervisor or guide.
- These recognized research supervisors cannot supervise research scholars in other institutions, where they can only act as co-supervisors.
- Ph.D. awarded by a university under the supervision of a faculty member who is not an employee of the university or its affiliated postgraduate colleges/institutes would be in violation of these regulations.
- For Ph.D. scholars working in Central government/ State government research institutions whose degrees are given by Higher Educational Institutions, the scientists in such research institutions who are equivalent to Professor/Associate Professor/Assistant Professor can be recognized as supervisors if they fulfill the above requirements. Provided that in areas/disciplines where there is no, or only a limited number of peer-reviewed or refereed journals, the Higher Educational Institution may relax the above condition for recognition of a person as Research Supervisor with reasons recorded in writing.
- Co-Supervisors from within the same department or other departments of the same institution or other institutions may be permitted with the approval of the competent authority.
- Adjunct Faculty members shall not act as research supervisors and can only act as co-supervisors.
- In case of interdisciplinary/multidisciplinary research work, if required, a co-Supervisor from outside the Department/School/Centre/College/University may be appointed.
- An eligible Professor/Associate Professor/Assistant Professor can guide up to six / four / two Ph.D. scholars, respectively, at any given time or as per the UGC criteria.
- Faculty members with less than three years of service before superannuation shall not be allowed to take new research scholars under their supervision. However, such faculty members can continue to supervise Ph.D. scholars who are already registered until superannuation and as a co-supervisor after superannuation, but not after attaining the age of 70 years.

8. Admission of International Students in Ph.D. program

The HEIs may decide their own selection procedure for Ph.D. admission of international students keeping in view the guidelines/norms in this regard issued by statutory/regulatory bodies concerned from time to time.

9. Course Work

Credit requirements, number, duration, syllabus, minimum standards for completion, etc. are mentioned below:

- The Credit requirement for the Ph.D. coursework is a minimum of 12 credits, including a "Research and Publication Ethics" course as notified by UGC vide D.O. No. F.1- 1/2018(Journal/CARE) in 2019 and a research methodology course. The Research Advisory Committee can also recommend UGC recognized online courses as part of the credit requirements for the Ph.D. program. However, a draft of the minimum Course work is attached in Appendix A.
- All Ph.D. scholars, irrespective of discipline, shall be required to train in teaching /education /pedagogy/writing related to their chosen Ph.D. subject during their doctoral period. Ph.D. scholars may also be assigned 4-6 hours per week of teaching/research assistantship for conducting tutorial or laboratory work and research/clinical evaluations.
- A Ph.D. scholar must obtain a minimum of 55% marks or its equivalent grade in the UGC 10-point scale in the course work to be eligible to continue in the program and submit his or her thesis.

10. Research Advisory Committee and its Functions

- There shall be a Research Advisory Committee or an equivalent body as defined in the Statutes/Ordinances of the Higher Educational Institution concerned for each Ph.D. scholar. The Research Supervisor of the Ph.D. scholar concerned shall be the Convener of this committee, and this committee shall have the following responsibilities:
- To review the research proposal and finalize the topic of research.
- To guide the Ph.D. scholar in developing the study design and methodology of research and identify the course(s) that he/she may have to do.
- To periodically review and assist in the progress of the research work of the Ph.D. scholar.
- Each semester/annually, a Ph.D. scholar shall appear before the Research Advisory Committee to make a presentation and submit a brief report on the progress of his/her work for evaluation and further guidance. The Research Advisory Committee shall submit its recommendations along with a copy of Ph.D. scholar's progress report to the Higher Educational Institution concerned. A copy of such recommendations shall also be provided to the Ph.D. scholar.
- In case the progress of the Ph.D. scholar is unsatisfactory, the Research Advisory Committee shall record the reasons for the same and suggest corrective measures. If the Ph.D. scholar fails to implement these corrective measures, the Research Advisory Committee may recommend, with specific reasons, the cancellation of the registration of the Ph.D. scholar from the Ph.D. program.

11. Evaluation and Assessment Methods, Minimum Standards/Credits for Award of the Degree

- Upon satisfactory completion of course work and obtaining the marks/grade prescribed in-clause iii of Regulation 9 above, the Ph.D. scholar shall be required to undertake research work and produce a draft dissertation/thesis.
- Before submitting the dissertation/thesis, the Ph.D. scholar shall make a presentation before the Research Advisory Committee of the Higher Educational Institution concerned, which shall also be open to all faculty members and other research scholars/students.
- The Higher Educational Institution concerned shall have a mechanism using well-developed software applications to detect Plagiarism in research work and the research integrity shall be an integral part of all the research activities leading to the award of a Ph.D. degree.
- A Ph.D. scholar shall submit the thesis for evaluation, along with (a) an undertaking from the Ph.D. scholar that there is negligible plagiarism and (b) a certificate from the Research Supervisor attesting to the originality of the thesis and that the thesis has not been submitted for the award of any other degree/diploma to any other Higher Educational Institution.
- The Ph.D. thesis submitted by a Ph.D. scholar shall be evaluated by his/her Research Supervisor and at least two external examiners who are experts in the field and not in employment of the Higher Educational Institution concerned. Such examiner(s) should be academics with a good record of scholarly publications in the field. The viva-voce board shall consist of the Research Supervisor and at least one of the two external examiners and may be conducted online. The viva-voce shall be open to the members of the Research Advisory Committee/faculty members/research scholars, and students. Higher Educational Institutions may formulate appropriate rules/ordinances to effect the provisions of this Regulations.
- The viva-voce of the Ph.D. scholar to defend the thesis shall be conducted if both the external examiners recommend acceptance of the thesis after incorporating any corrections suggested by them. If one of the external examiners recommends rejection, the Higher Educational Institution concerned shall send the thesis to an alternate external examiner from the approved panel of examiners, and the viva-voce examination shall be held only if the alternate examiner recommends acceptance of the thesis.
- The Higher Educational Institution concerned shall complete the entire process of evaluating a Ph. D. thesis, including the declaration of the viva-voce result, within a period of six (6) months from the date of submission of the thesis.

12. Academic, Research, Administrative, and Infrastructure Requirements to be Fulfilled by Colleges for Getting Recognition for Offering Ph.D. Programs

- Postgraduate Colleges offering 4-year Undergraduate Programs and/or Postgraduate Programs, may offer Ph.D. programs, provided they satisfy the availability of eligible Research Supervisors, required infrastructure, and supporting administrative and research facilities as per these Regulations.
- Colleges and research institutions established by the central government or a State government whose degrees are awarded by Higher Educational Institutions shall offer Ph.D. programs provided they have:
- At least two faculty members in a college or two Ph.D.-qualified scientists in the research institution.
- Adequate infrastructure, administrative support, research facilities and library resources as specified by the HEI.

13. Ph.D. Through Part-time Mode

- Ph.D. programs through part-time mode will be permitted, provided all the conditions stipulated in these Regulations are fulfilled
- The Higher Educational Institution concerned shall obtain a "No Objection Certificate" through the candidate for a part-time Ph.D. program from the appropriate authority in the organization where the candidate is employed, clearly stating that:
- The candidate is permitted to pursue studies on a part-time basis.
- His/her official duties permit him/her to devote sufficient time for research.
- If required, he/she will be relieved from the duty to complete the course work.
- Not with-standing anything contained in these Regulations or any other law, for the time being in force, no Higher Educational Institution or research institution of the Central government or a State Government shall conduct Ph.D. programs through distance and/online mode.

14. Issuing a Provisional Certificate

Prior to the actual award of the Ph.D. degree, the degree-awarding Higher Educational Institution shall issue a provisional certificate to the effect that the Ph.D. is being awarded in accordance with the provisions of these Regulations.

15. Depository with INFLIBNET

Following the successful completion of the evaluation process and before the announcement of the award of the Ph.D. degree(s), the Higher Educational Institution concerned shall submit an electronic copy of the Ph.D. thesis to INFLIBNET, for hosting the same so as to make it accessible to all the Higher Educational Institutions and research institutions. [12]

***NOTE: Above contents are prepared as per UGC Guidelines**

APPENDIX A

The syllabus given below is a model syllabus for pre-Ph.D. coursework; however, universities may have different syllabi depending on their curriculum and current guidelines.

1. Research and Publication Ethics

Ethics, and Scientific Conduct Ethics with respect to science, social science and research. Ethical Principles in Human Research (ICMR Guidelines, Helsinki Declaration), Informed Consent, and IRB Approval, Intellectual and research honesty and research integrity, Falsification, Fabrication and Plagiarism (FFP), duplicate and overlapping publications, salami slicing. Selective reporting and misrepresentation of data, Publications Ethics and Misconduct Definition, introduction, and importance of publication ethics, Best practices in research / standards-setting initiatives and guidelines: COPE, WAME, etc. Conflicts of interest Research and Publications misconduct: definition, concept, problems that lead to unethical behavior and vice versa, publication types Violation of publications ethics, authorship, and contributorship, Identification of publication misconduct, complaints and appeals. Use of plagiarism software like Turnitin, Urkund and other open-source software tools Predatory publishers and journals. Open Access Publishing Open access publications and initiatives SHERPA/RoMEO online resource to check publisher copyright & self-archiving policies Software tool to identify predatory publications developed by SPPU Journal finder / journal suggestion tools viz. JANE, Elsevier Journal Finder, Springer Journal Suggester, etc. Databases and Research Metrics Indexing databases, Citation databases: Web of Science, Scopus, etc. Impact Factor of journal as per Journal Citation Report, SNIP, SJR, IIP, Cite Score. Metrics: h-index, g index, i10 index, etc

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2. Research Methodology and Biostatistics

Research Methodology and Study Design: Introduction to research in nuclear medicine; Types of Research: Basic, Clinical, Translational, and Epidemiological; Identification and formulation of research problem, FINER criteria for research questions; Review of Literature: Databases, PRISMA, Critical Appraisal Hypothesis generation and operational definitions; Type of studies: observational (cross-sectional, case-control, cohort), interventional (randomized controlled trials), experimental vs. non-experimental, diagnostic accuracy; Bias, Confounding, and Effect Modification; Sampling and Data Collection; Sampling Methods: Random, Stratified, Cluster Sample Size Estimation and Power Analysis; Tools for Data Collection: Questionnaires, Interviews, Clinical Data Validity and Reliability, Data Management and Entry (with software tools); Biostatistics and its Application in Nuclear Medicine, Types of data and data distribution, Measures of central tendency and dispersion, Probability distributions: Normal, Binomial, Poisson; Hypothesis testing: t-tests, chi-square, ANOVA Confidence intervals and p-values; Correlation and regression analysis, Non-parametric tests, ROC curves and diagnostic test evaluation (sensitivity, specificity, AUC); Survival analysis: Kaplan-Meier, cox proportional hazards; Basics of meta-analysis; Statistical software: SPSS/ R / Python (Hands-on sessions); Statistical interpretation in nuclear medicine.

Ph.D. Subject Specific Courses

The remaining courses can be suggested by research advisory committee based on the critical review of the Ph.D. research topic of the candidate.

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Reference Books

- Medical Terminology: A Short Course – Davi-Ellen Chabner, Elsevier; covers word structure, anatomical, and procedural terminology.
- Health Care Ethics: Critical Issues for the 21st Century – Eileen E. Morrison, Beth Furlong, Jones & Bartlett Learning; provides comprehensive coverage of ethical principles and dilemmas.
- Legal Aspects of Health Care Administration – George D. Pozgar, Jones & Bartlett Learning; introduces patient rights, privacy laws, and regulatory compliance.
- Medical Terminology for Health Professions – Ann Ehrlich, Carol L. Schroeder, Cengage Learning; detailed guide to medical language and communication.
- Ethics in Health Services Management – Kurt Darr, Health Professions Press; covers ethical decision-making and professional conduct.
- Radiation Protection in Hospitals – Richard F. Mould, CRC Press; provides context for radiation safety regulations in nuclear medicine.
- Nuclear Medicine Technology & Techniques – Donald R. Bernier, Paul E. Christian, James K. Langan, Mosby; includes nuclear medicine-specific applications.
- Practical Statistics for Medical Research – Douglas G. Altman, Chapman & Hall; supports understanding of clinical data in ethical and legal contexts.
- Biostatistics: A Foundation for Analysis in the Health Sciences – Wayne W. Daniel, Chad L. Cross, Wiley; covers advanced statistical methods for medical research.
- Designing Clinical Research – Stephen B. Hulley, Steven R. Cummings, Warren S. Browner, Wolters Kluwer; provides comprehensive research methodology.
- Medical Statistics: A Textbook for the Health Sciences – Michael J. Campbell, David Machin, Stephen J. Walters, Wiley; detailed guide to biostatistics.
- Systematic Reviews in Health Care: Meta-Analysis in Context – Matthias Egger, George Davey Smith, Douglas G. Altman, BMJ Books; covers meta-analysis techniques.
- R for Data Science – Hadley Wickham, Garrett Grolemund, O'Reilly; supports statistical programming for research.

APPENDIX-B

MODULE WISE ASSESSMENT NUCLEAR MEDICINE TECHNOLOGIST IN RESIDENCY/CTP

MODULE 1: CLINICAL AWARENESS

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

Sub-module 1.1: Essential Anatomy and Physiology for the Nuclear Medicine Technologist

Knowledge Base (a)	**Level of Competency Achieved**	
	2	**1**
An understanding of anatomy and physiology as seen on nuclear medicine images and in dynamic studies.	Demonstrates **a basic understanding** of anatomy and physiology as seen on static and dynamic nuclear medicine images.	Demonstrates **a good understanding** of anatomy and physiology as seen on static and dynamic nuclear medicine images.
Date Achieved		
Supervisor Initials		
Knowledge Base (b)	**Level of Competency Achieved**	
	2	**1**
Basic knowledge of anatomy and physiology as seen on other types of medical images.	Demonstrates **a basic understanding** of anatomy and physiology as seen on **two** of the following types of medical images: - **radiographs, CT, MRI, US**	Demonstrates **a basic understanding** of anatomy and physiology as seen on the following types of medical images: - **radiographs, CT, MRI, US**
Date Achieved		
Supervisor Initials		

Practical Skills	Level of Competency Achieved		
	3	2	1
The ability to discuss with nuclear medicine specialist the important features of diagnostic images	Has only a **limited ability** to discuss the important features of diagnostic NM images with medical specialists.	**A good knowledge of** the important features of diagnostic NM images. However n**ot yet capable of independent input** to a discussion with medical specialists.	Is capable of **independently discussing** the important features of diagnostic NM images with medical specialists.
Date Achieved			
Supervisor's Initials			

Date	Supervisor comments

Sub-module 1.2: Basic Principles of Radiation Biology and Epidemiology

Knowledge Base	Level of Competency Achieved	
	2	1
An understanding of the basic principles of radiation biology and epidemiology	Demonstrates a **basic understanding** of **most** aspects of radiation biology and epidemiology of **relevance to nuclear medicine imaging.**	Demonstrates a **good understanding** of **all** of radiation biology and epidemiology of **relevance to nuclear medicine imaging.**
Date Achieved		
Supervisor Initials		

Date	Supervisor comments

Sub-module 1.3: Clinical Activities and Factors that Affect Patient Care.

Knowledge Base	**Level of Competency Achieved**	
	2	**1**
An understanding of the factors that affect patient care	Demonstrates a **basic understanding** of clinical activities and their relation to patient care.	Demonstrates a **good understanding** of clinical activities and their relation to patient care.
Date Achieved		
Supervisor Initials		
Practical Skills	**Level of Competency Achieved**	
	2	**1**
An ability to discuss clinical activities and their relation to patient care in the following areas.	**Demonstrates a limited ability** to contribute to a discussion of the important features of clinical activities and their relation to patient care.	**Is capable of independent and well-informed input** to a discussion of the important features of clinical activities and their relation to patient care.
Date Achieved - Nuclear Medicine		
Supervisor Initials		
Date Achieved – Radiology		
Supervisor Initials		
Date Achieved – Radiation Oncology		
Supervisor Initials		

Date Achieved – Other Areas		
Supervisor Initials		

Date	Supervisor comments

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MODULE 2: RADIATION PROTECTION

2.1 Monitoring radiation levels including personnel monitoring
2.2 Exposure from sealed and unsealed sources and the risk of contamination
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
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

Sub-module 2.1: Monitoring Radiation Levels Including Personnel Monitoring

Knowledge Base (a)	**Level of Competency Achieved**	
	2	**1**
An understanding of the principles of operation of equipment used for monitoring radiation levels in nuclear medicine.	Demonstrates a **basic understanding** of the **principles of operation** and **limitations** of a **variety of the equipment** used for monitoring radiation levels**.**	Demonstrates a **good understanding** of the principles of operation and limitations of **equipment** used for monitoring radiation levels
Date Achieved		
Supervisor's Initials		
Knowledge Base (b)	**Level of Competency Achieved**	
	2	**1**
An understanding of the purpose, principles and operation of a personnel dosimetry program.	Demonstrates a **basic understanding** of **principles of operation** and **limitations of a variety of personnel dosimeters**	Demonstrates a **good understanding** of the principles of operation, and limitations of **most personnel dosimeters of relevance to nuclear medicine.**
Date Achieved		
Supervisor's Initials		

Practical Skills	Level of Competency Achieved		
	3	2	1
Ability to measure radiation levels and to perform quantitative measurement of contamination.	Is capable of measuring radiation levels **and** performing quantitative measurement of contamination. **Requires supervision.**	Is capable of measuring radiation levels and performing quantitative measurement of contamination. **Requires only limited assistance.**	Is capable of measuring radiation levels and **independently** performing quantitative measurement of contamination.
Date Achieved			
Supervisor's Initials			

Date	Supervisor's comments

Sub-module 2.2: Exposure from Sealed and Unsealed Sources and the Risk of Contamination

Knowledge Base	Level of Competency Achieved	
	2	1
An understanding of methods to reduce exposure.	Possesses a **basic** understanding of the methods used to reduce exposure.	Possesses a **good** understanding of the methods used to reduce exposure.
Date Achieved		
Supervisor's Initials		

Practical Skills (a)	Level of Competency Achieved		
	3	2	1
The ability to safely handle unsealed radioactive sources.	**Requires close supervision** when handling unsealed radioactive sources to ensure safe practice**.**	Requires **only limited supervision** when handling unsealed radioactive sources to ensure safe practice**.**	Is capable of safely handling unsealed radioactive sources.
Date Achieved			
Supervisor's Initials			
Practical Skills (b)	**Level of Competency Achieved**		
	3	**2**	**1**
Ability to handle accidents and spills.	Is capable of **assisting with the response** related to accidents and spills. **Requires close supervision.**	Requires only limited assistance in responding to accidents and spills. **Requires only loose supervision.**	Is capable of **independently responding** to accidents and spills.
Date Achieved			
Supervisor's Initials			

Date	Supervisor's comments

Sub-module 2.3: ALARA and Radiation Safety Precautions in Nuclear Medicine Diagnostic and Therapeutic Procedures.

Knowledge Base	**Level of Competency Achieved**	
	2	**1**
An understanding of the application of the ALARA principle	Demonstrates a **basic understanding** of the need to keep **doses as low as reasonably achievable** and to **ensure regulatory compliance.**	Demonstrates a **good understanding** of the need to keep doses as low as reasonably achievable and to ensure regulatory compliance.
Date Achieved		
Supervisor's Initials		

Practical Skills	**Level of Competency Achieved**		
	3	**2**	**1**
Ability to apply radiation protection regulations in clinical nuclear medicine practice.	Is capable of applying radiation protection regulations **under supervision. Needs assistance** to identify and implement remedial measures	Is capable of applying radiation protection regulations **with only limited supervision.** Able to identify and implement **most** remedial measures	Is capable of **independently** applying radiation protection regulations and is able to **independently** identify and implement remedial measures.
Date Achieved			
Supervisor's Initials			

Date	**Supervisor's comments**

Sub-module 2.4: Risk Assessment and Advice to Staff, Patients and Others Regarding Radiation Risk

Knowledge Base (a)	**Level of Competency Achieved**	
	2	**1**
An understanding of the methods for estimating effective dose to the patient from diagnostic nuclear medicine scans.	Possesses a **basic** understanding of methods for estimating effective dose to the patient from diagnostic nuclear medicine scans.	Possesses a **good** understanding of methods for estimating effective dose to the patient from diagnostic nuclear medicine scans.
Date Achieved		
Supervisor's Initials		
Knowledge Base (b)	**Level of Competency Achieved**	
	2	**1**
Knowledge of the risks associated with radiation exposure.	Demonstrates a **basic** understanding of regulatory requirements and the principles of hazard assessment and control mechanisms. **Requires assistance** with understanding of the **more difficult aspects**.	Demonstrates a **good understanding** of all aspects of hazard assessment and control mechanisms and is able to instruct others.
Date Achieved		
Supervisor's Initials		
Knowledge Base (c)	**Level of Competency Achieved**	
	2	**1**
An understanding of the procedures for risk assessment.	Possesses a **basic** understanding of the procedures for risk assessment. **Requires guidance** to ensure that **all risks are identified.**	Possesses a **good** understanding of the procedures for risk assessment.

Date Achieved			
Supervisor's Initials			
Practical Skills	**Level of Competency Achieved**		
	3	**2**	**1**
Ability to communicate risk or lack of risk in the context of dose, justification and relevant non-radiation risks	Possesses only a **limited ability** to advise others on correct practical aspects to reduce dose and to limit non- radiation risks.	Is capable of advising others on practical aspects to reduce dose and to limit non-radiation risks. Requires **supervision** to ensure that **no incorrect advice** is provided.	Is capable of **independently advising** others on practical aspects to reduce dose and to limit non-radiation risks. **The advice provided is at all times correct and appropriate.**
Date Achieved			
Supervisor's Initials			

Date	**Supervisor's comments**

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Sub-module 2.5: Areas Designated for the Use of Unsealed Radioactive Material

Knowledge Base (a)	**Level of Competency Achieved**	
	2	**1**
Familiarity with the designation of areas of the workplace associated with protection from unsealed radioactive materials.	Has a **basic** familiarity with the designation of areas of the workplace associated with protection from unsealed radioactive materials.	Has a **good** familiarity with the designation of areas of the workplace associated with protection from unsealed radioactive materials.
Date Achieved		
Supervisor's Initials		

Knowledge Base (b)	**Level of Competency Achieved**	
	2	**1**
Familiarity with the different radionuclide decay processes.	Possesses a **limited** understanding of radionuclide decay processes.	Possesses a **very good** understanding of radionuclide decay processes.
Date Achieved		
Supervisor's Initials		

Practical Skills	**Level of Competency Achieved**		
	3	**2**	**1**
Ability to manage a radioactive waste store for the sources used in a nuclear medicine department.	Is able to **assist** with management of a radioactive waste store. **Requires supervision** to **ensure safe practice**.	Is able to manage a radioactive waste store. **Requires only limited supervision** to **ensure safe practice**.	Is able to **independently** manage a radioactive waste store applying **best practice**.
Date Achieved			
Supervisor's Initials			

Date	Supervisor's comments

Sub-module 2.6: Radiation Shielding Considerations in the Design of New Facilities

Knowledge Base (a)	Level of Competency Achieved	
	2	1
An understanding of the principles and requirements of shielding design for radionuclide energies used for diagnostic Nuclear Medicine purposes.	Demonstrates a **basic understanding** of shielding design for radionuclide energies used in diagnostic Nuclear Medicine.	Demonstrates a **good understanding** of shielding design for radionuclide energies used in diagnostic Nuclear Medicine.
Date Achieved		
Supervisor's Initials		
Knowledge Base (b)	**Level of Competency Achieved**	
	2	**1**
Familiarity with shielding requirements for PET, SPECT installations in combination with other imaging (e.g. CT) modalities	Demonstrates a **basic understanding** of shielding requirements for PET, SPECT installations in combination with other imaging (e.g. CT) modalities	Demonstrates a **good understanding** of shielding requirements for PET, SPECT installations in combination with other imaging (e.g. CT) modalities
Date Achieved		
Supervisor's Initials		

Practical Skills	Level of Competency Achieved		
	3	2	1
The ability to design satisfactory radiation shielding for all types of nuclear medicine equipment.	Is capable of **contributing** to the design of radiation shielding for **simple** nuclear medicine equipment. **Requires significant assistance** to ensure the accuracy of the design.	Is capable of designing radiation shielding for **most** nuclear medicine equipment. **Requires only limited assistance** to ensure the accuracy of the design.	Is capable of **independently designing radiation** shielding **for all** nuclear medicine equipment **to an acceptable level.**
Date Achieved			
Supervisor's Initials			

Date	Supervisor's comments

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Since-2021

Sub-module 2.7: Regulatory Controls and Other Guidance on the Safe Use of Ionizing Radiation in Nuclear Medicine

Knowledge Base	**Level of Competency Achieved**	
	2	**1**
An understanding of the local regulatory requirements for Nuclear Medicine.	Demonstrates a **basic understanding** of **local regulatory requirements** for Nuclear Medicine and the **principles of hazard assessment and control mechanisms. Requires assistance** with understanding of the **more difficult aspects.**	Demonstrates a **good understanding** of **local regulatory requirements** for Nuclear Medicine and all aspects of hazard assessment and control mechanisms.
Date Achieved		
Supervisor's Initials		

Practical Skills	**Level of Competency Achieved**		
	3	**2**	**1**
The ability to advise on local, regional and national radiation protection and safety legislation.	Possesses only a **limited ability** to advise others on local, regional and national radiation protection and safety legislation.	Is capable of advising others on local, regional and national radiation protection and safety legislation. Requires **supervision** to ensure that **no incorrect advice** is provided.	Is capable of **independently advising** others on local, regional and national protection and safety legislation. **The advice provided is at all times correct and appropriate.**
Date Achieved			
Supervisor's Initials			

Date	**Supervisor's comments**

MODULE 3: RESEARCH, DEVELOPMENT AND TEACHING

3.1 Research and Development
3.2 Teaching

Sub-module 3.1: Research and Development

Knowledge Base	**Level of Competency Achieved**	
	2	**1**
An understanding of processes of scientific research including the role of ethics review, statistical analysis, and the publication process	Demonstrates a **basic understanding** of the various aspects of scientific research.	Demonstrates a **good appreciation** of the various aspects of scientific research.
Date Achieved		
Supervisor's Initials		

Practical Skills	**Level of Competency Achieved**		
	3	**2**	**1**
The ability to carry out research and development in nuclear medicine physics in cooperation with nuclear medicine physicians, medical physicists, and other professionals.	Is capable of **contributing** to a R&D project. **Requires significant guidance**.	Able to contribute to a R&D project **without direct supervision**.	Demonstrates a good level of ability for **independent research.**
Date Achieved			
Supervisor's Initials			

Date	**Supervisor's comments**

Sub-module 3.2: Teaching

Knowledge Base	**Level of Competency Achieved**	
	2	**1**
An understanding of the general principles of effective teaching	Demonstrates a **basic understanding** of strategies for teaching and assessment as well as development of instructional material.	Demonstrates a **good understanding** of strategies for teaching and assessment as well as development of instructional material. Pays particular attention to the **needs and background of the audience.**
Date Achieved		
Supervisor's Initials		

Practical Skills	**Level of Competency Achieved**		
	3	**2**	**1**
Ability to teach principles and methods of nuclear medicine practice.	Demonstrates a **limited ability to prepare and deliver short (1-2 hour) courses. Requires guidance.**	Demonstrates a **good ability to prepare and deliver** appropriate short courses **without significant guidance.**	Demonstrates the ability to **decide on content, prepare and deliver a comprehensive course** on principles and methods of nuclear medicine physics.
Date Achieved			
Supervisor's Initials			

Date	**Supervisor's comments**

MODULE 4: PROFESSIONAL DEVELOPMENT

4.1 Professional awareness
4.2 Communication
4.3 Quality management
4.4 Clinical audit

Sub-module 4.1: Professional Awareness

Knowledge Base	**Level of Competency Achieved**	
	2	**1**
Demonstrated understanding of professional issues.	Demonstrates only a **limited awareness** of relevant professional issues.	Demonstrates a **good awareness** of **most** relevant professional issues.
Date Achieved		
Supervisor's Initials		

Practical Skills	**Level of Competency Achieved**		
	3	**2**	**1**
Contribution to professional body activities.	**Occasionally participates** in professional body activities.	**Frequently participates** in professional body activities.	**Contributes** to professional body activities.
Date Achieved			
Supervisor's Initials			

Date	**Supervisor's comments**

Sub-module 4.2: Communication

Knowledge Base	**Level of Competency Achieved**	
	2	**1**
Demonstrate a high level of oral and written communication and interpretation skills.	Generally, demonstrates **clear and concise** expression orally and in written forms.	**Consistently demonstrates clear and concise expression** orally and in written forms. **Capable of presenting a scientific seminar** and **preparing a scientific manuscript**.
Date Achieved		
Supervisor's Initials		

Practical Skills	**Level of Competency Achieved**		
	3	**2**	**1**
The ability to communicate with clinicians and apply physical principles to clinical problems	Able to communicate with clinicians at a **basic level.**	Possesses a **good ability** to communicate with clinicians **and to apply (explain)** physical principles applied to clinical problems**.** **Occasionally requires assistance with these explanations.**	Is capable of **independently communicating** with clinicians in **relation to the physical principles of clinical problems.**
Date Achieved			
Supervisor's Initials			

Date	**Supervisor's comments**

Sub-module 4.3: Quality management

Knowledge Base	**Level of Competency Achieved**	
	2	**1**
Understanding of the structure of a quality system	Demonstrates a **basic understanding** of the **key elements** and **the role** of a quality management system in nuclear medicine.	Demonstrates a **good understanding** of the key elements and role of a quality management system in nuclear medicine.
Date Achieved		
Supervisor's Initials		

Practical Skills	**Level of Competency Achieved**		
	3	**2**	**1**
Ability to implement and maintain the physics aspects of the quality system			
Date Achieved			
Supervisor's Initials			

Date	**Supervisor's comments**

Sub-module 4.4: Clinical audit

Knowledge Base	**Level of Competency Achieved**	
	2	**1**
Understand the nature, purpose of clinical audit in the Nuclear Medicine setting	Demonstrates a **limited understanding** of the nature, purpose of clinical audit including any **local legislative requirements**.	Demonstrates a **good understanding** of the nature, purpose of clinical audit including any local legislative requirements.
Date Achieved		
Supervisor's Initials		

Practical Skills	**Level of Competency Achieved**		
	3	**2**	**1**
The ability to effectively contribute as a member of a multidisciplinary team to a nuclear medicine department	Is capable of **contributing** to a clinical audit. **Requires significant guidance**.	Able to contribute to a clinical audit **without direct supervision**.	Able to **independently conduct** the physics aspects of a clinical audit to an acceptable level.
Date Achieved			
Supervisor's Initials			

Date	**Supervisor's comments**

MODULE 5: EQUIPMENT PROCUREMENT, ACCEPTANCE TESTING AND COMMISSIONING

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

Sub-module 5.1: Equipment 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		
Supervisor's Initials		

Practical Skills	Level of Competency Achieved		
	3	2	1
The capability to make budgetary requests, prepare the specifications and acquire suitable equipment through a tendering process	Is capable of **contributing** to the **development** of budgetary requests, preparing specifications and acquiring equipment through a tendering process. **Requires assistance** with the concepts involved.	Is capable of **providing the "physics" input** to budgetary requests, preparation of specifications and acquisition of equipment through a tendering process. **Requires only minimal assistance** to ensure all necessary elements are included. **Any omissions are minor.**	Is capable of **independently providing the "physics" input** to budgetary requests, preparation of specifications and acquisition of equipment through a tendering process.
Date Achieved			
Supervisor's Initials			

Date	Supervisor's comments

Sub-module 5.2: Dose Calibrator Acceptance Testing.

Knowledge Base	**Level of Competency Achieved**	
	2	**1**
An understanding of the procedure for initial acceptance of a dose calibrator	Demonstrates a **limited understanding** of the **principles of operation** of a dose calibrator and the **recommended accepting tests**.	Demonstrates an **in-depth understanding** of the principles of operation of a dose calibrator and the recommended accepting tests.
Date Achieved		
Supervisor's Initials		

Practical Skills	**Level of Competency Achieved**		
	3	**2**	**1**
Ability to perform dose calibrator acceptance testing	Is capable of **contributing to acceptance testing** of a dose calibrator including physical inspection, precision and accuracy, linearity of activity response and background test. **Requires assistance** to ensure that there are no errors in the process.	Is **capable of performing acceptance testing** of a dose calibrator. Requires only **minimal assistance** Makes **occasional minor errors**.	Is capable of **independently performing acceptance testing** of a dose calibrator to **an acceptable clinical standard.**
Date Achieved			
Supervisor's Initials			

Date	Supervisor's comments

Sub-module 5.3: Scintillation Probe and Well Counter Acceptance Testing.

Knowledge Base	Level of Competency Achieved	
	2	1
An understanding of the procedure for initial acceptance testing of a scintillation probe or well counter	Demonstrates a **limited understanding** of the **principles of operation** of a scintillation probe or well counter and **the recommended acceptance tests**	Demonstrates an **in-depth understanding** of the principles of operation of a scintillation probe or well counter and the procedures for accepting testing.
Date Achieved		
Supervisor's Initials		

Practical Skills	Level of Competency Achieved		
	3	2	1
Ability to perform acceptance testing of a scintillation probe or well counter.	Is **capable of contributing to acceptance testing** of scintillation probe or well counter including physical inspection, energy calibration and resolution, sensitivity, precision and accuracy, linearity of activity response and background test.	Is **capable of performing acceptance testing** of a scintillation probe or well counter. Requires only **minimal assistance** Makes **occasional minor errors**.	Is capable of **independently performing acceptance testing** of a scintillation probe or well counter to **an acceptable clinical standard.**

	Requires assistance to ensure that there are no errors in the process.		
Date Achieved			
Supervisor's Initials			

Date	**Supervisor's comments**

Sub-module 5.4: Gamma Camera, SPECT and CT Acceptance and Commissioning.

Knowledge Base	**Level of Competency Achieved**	
	2	**1**
An understanding of the procedure for acceptance test of gamma camera/SPECT and CT systems	Demonstrates a **limited understanding** of the standards for **acceptance testing** of **gamma camera/SPECT and CT systems** as well as **interpretation of results**.	Demonstrates a **good understanding** of the standards for **acceptance testing** of gamma camera/SPECT systems as well as **interpretation of results**.
Date Achieved		
Supervisor's Initials		

Practical Skills	Level of Competency Achieved		
	3	2	1
Ability to perform acceptance testing of gamma camera / SPECT systems.	Is **capable of contributing to acceptance testing** of gamma camera/SPECT systems. **Requires assistance** to ensure that there are no errors in the process.	Is **capable of performing acceptance testing** of gamma camera/SPECT systems. Requires only **minimal assistance** Makes **occasional minor errors**.	Is capable of **independently performing acceptance testing** of gamma camera/SPECT systems to **an acceptable clinical standard.**
Date Achieved			
Supervisor's Initials			

Date	Supervisor's comments

Sub-module 5.5: PET/CT Acceptance and Commissioning.

Knowledge Base	Level of Competency Achieved	
	2	1
An understanding of NEMA procedures for PET acceptance testing	Demonstrates a **limited understanding** of NEMA procedures for PET acceptance testing and **interpretation of the results.**	Demonstrates a **good understanding** of NEMA procedures for PET acceptance testing and **interpretation of the results.**
Date Achieved		
Supervisor's Initials		

Practical Skills (a)	Level of Competency Achieved		
	3	2	1
Ability to perform PET acceptance testing and commissioning	Is **capable of contributing to acceptance testing** of PET systems. **Requires assistance** to ensure that there are no errors in the process.	Is **capable of performing acceptance testing** of PET systems. Requires only **minimal assistance** Makes **occasional minor errors**.	Is capable of **independently performing acceptance testing** of PET systems to **an acceptable clinical standard.**
Date Achieved			
Supervisor's Initials			
Practical Skills (b)	**Level of Competency Achieved**		
	3	**2**	**1**
Ability to perform SUV calibration and check SUV calibration accuracy.	Is **capable of contributing to** SUV calibration and accuracy checks. **Requires assistance** to ensure that there are no errors in the process.	Is **capable of performing** SUV calibration and accuracy checks. Requires only **minimal assistance** Makes **occasional minor errors**.	Is capable of **independently performing S**UV calibration and accuracy checks to **an acceptable clinical standard.**
Date Achieved			
Supervisor's Initials			

Date	Supervisor's comments

MODULE 6: RADIOACTIVITY MEASUREMENTS AD INTERNAL DOSIMETRY

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

Sub-module 6.1: Use of Traceable Standards for Radioactivity Measurements

Knowledge Base	**Level of Competency Achieved**	
	2	**1**
An understanding of the traceability chain for radionuclide activity measurements in the nuclear medicine setting.	Demonstrates a **limited understanding** of the traceability chain for radionuclide activity measurements.	Demonstrates a good **understanding** of the traceability chain for radionuclide activity measurements.
Date Achieved		
Supervisor's Initials		

Practical Skills	**Level of Competency Achieved**		
	3	**2**	**1**
The ability to apply quality assurance principles and estimate the uncertainties involved in radioactivity measurements in the clinical setting.	Is **capable of applying** quality assurance principles and estimating the uncertainties involved in radioactivity measurements. **Work requires close scrutiny** to ensure that there are no errors in the process.	Is **capable of applying** quality assurance principles and estimating the uncertainties involved in radioactivity measurements. Requires only **minimal assistance** Makes **occasional minor errors**.	Is capable of **independently applying** quality assurance principles and estimating the uncertainties involved in radioactivity measurements **without errors.**
Date Achieved			
Supervisor's Initials			

Date	Supervisor's comments

Sub-module 6.2: Formalism and Application of Internal Dosimetry

Knowledge Base	Level of Competency Achieved	
	2	1
An understanding of the formalism established for internal dose calculations, including its limitations.	Demonstrates a **limited understanding** of the formalism established for internal dose calculations, including its limitations.	Demonstrates a good **understanding** of the formalism established for internal dose calculations, including its limitations.
Date Achieved		
Supervisor's Initials		

Practical Skills	Level of Competency Achieved		
	3	2	1
Ability to calculate absorbed dose to organs according to the MIRD formalism as well as to derive the effective dose.	Is capable of calculating absorbed dose to organs according to the MIRD formalism as well as deriving the effective dose. **Results require careful checking.**	Is capable of calculating absorbed dose to organs according to the MIRD formalism as well as deriving the effective dose. **Requires only minor assistance.**	Is capable of **independently** calculating the absorbed dose to organs according to the MIRD formalism as well as deriving the effective dose. **Results are error free.**
Date Achieved			
Supervisor's Initials			

Date	Supervisor's comments

Sub-module 6.3: Radiation Dose from Diagnostic Nuclear Medicine Radiopharmaceuticals.

Knowledge Base	Level of Competency Achieved	
	2	1
An understanding of the underlying methods for the derived tables available for internal dose estimations, including the uncertainties expected for different patients.	Demonstrates a **limited understanding** of the underlying methods for the derived tables available for internal dose estimations, including the uncertainties expected for different patients.	Demonstrates a good **understanding** of the underlying methods for the derived tables available for internal dose estimations, including the uncertainties expected for different patients.
Date Achieved		
Supervisor's Initials		

Practical Skills	Level of Competency Achieved		
	3	2	1
The ability to use established tables for estimating absorbed dose and effective dose to the patient.	Is capable of using established tables to estimate absorbed dose and effective dose to the patient. **Calculations require careful checking.**	Is capable of using established tables to estimate absorbed dose and effective dose to the patient. **Requires only minor assistance.**	Is capable of using established tables to estimate absorbed dose and effective dose to the patient **without assistance. Results are error free.**
Date Achieved			
Supervisor's Initials			

Date	Supervisor's comments

Sub-module 6.4: Quantitative Nuclear Medicine Imaging.

Knowledge Base	Level of Competency Achieved	
	2	1
An understanding of the main factors affecting quantitative measurements in nuclear medicine.	Possesses a **basic** understanding of the main factors affecting quantitative measurements in nuclear medicine.	Possesses a **good** understanding of the main factors affecting quantitative measurements from **planar, SPECT and PET images**.
Date Achieved		
Supervisor's Initials		

Practical Skills	Level of Competency Achieved		
	3	2	1
Ability to acquire quantitative measures from planar, SPECT and PET studies.	Is capable of acquiring quantitative measures from planar, SPECT and PET studies. **Requires close supervision.**	Is capable of acquiring quantitative measures from planar, SPECT and PET studies. R**equires only limited assistance.**	Is capable of **independently** acquiring quantitative measures from planar, SPECT and PET studies **to an acceptable clinical standard**.
Date Achieved			
Supervisor's Initials			

Date	Supervisor's comments

Sub-module 6.5: Patient-specific Dosimetry

Knowledge Base	**Level of Competency Achieved**	
	2	**1**
An understanding of the tools and requirements needed for performing patient-specific internal dosimetry.	Possesses a **basic** understanding of the need, tools and requirements for performing patient specific dosimetry.	Possesses a **good** understanding of the need, tools and requirements for performing patient specific dosimetry.
Date Achieved		
Supervisor's Initials		

Practical Skills	**Level of Competency Achieved**		
	3	**2**	**1**
The ability to calculate patient-specific dosimetry from repeat images and uptake measurements.	Is capable of calculating patient-specific dosimetry from repeat images and uptake measurements**.** **Results require careful checking.**	Is capable of calculating patient-specific dosimetry from repeat images and uptake measurements. **Requires only minor assistance.**	Is capable of **independently** calculating, **without error,** patient-specific dosimetry from repeat images and uptake measurements.
Date Achieved			
Supervisor's Initials			

Date	**Supervisor's comments**

MODULE 7: QUALITY CONTROL OF NUCLEAR MEDICINE EQUIPMENT

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 a gamma camera and SPECT
7.5 QC of PET/Ct systems
7.6 QC of display and hardcopy devices
7.7 QC of DXA systems

Sub-module 7.1: Design and Supervision of a Routine QC Program

Knowledge Base	**Level of Competency Achieved**	
	2	**1**
An understanding of the methods for the clinical implementation and supervision of a quality control programme.	Demonstrates a **basic understanding** of the generic aspects of a clinical QC programme.	Demonstrates a **good understanding** of the methods of a clinical QC programme.
Date Achieved		
Supervisor's Initials		

Practical Skills	**Level of Competency Achieved**		
	3	**2**	**1**
The ability to manage a QC programme including the appropriate use of instrumentation, test selection and test frequency.	Is **capable of managing a QC programme** including **selection and use of appropriate equipment, test selection and test frequency. Requires assistance** to ensure that there are no errors in the process.	Is capable of managing a QC programme. **Requires only minimal supervision.** Makes **occasional minor errors**.	Is capable of **independently managing a QC programme** to an acceptable clinical standard.
Date Achieved			

Supervisor's Initials			

Date	Supervisor's comments

Sub-module 7.2: QC of a Dose Calibrator

Knowledge Base	Level of Competency Achieved	
	2	1
An understanding of the effect of geometry, energy and type of emissions on radioactivity measurements.	Possesses a **basic** understanding of the **QC requirements of a dose calibrator** including the effects of geometry, energy and type of emissions on radioactivity measurements	Possesses a **good** understanding of the **QC requirements of a dose calibrator** including the effects of geometry, energy and type of emissions on radioactivity measurements
Date Achieved		
Supervisor's Initials		

Practical Skills	Level of Competency Achieved		
	3	2	1
The ability to perform basic dose calibrator QC including constancy, background, linearity and accuracy checks and set appropriate action levels.	Is capable of **assisting** with the QC program for a dose calibrator.	Is capable of **performing** most of the QC program for a dose calibrator. **Requires limited supervision.**	Is capable of **independently performing** the QC program for a dose calibrator **to an acceptable clinical standard.**
Date Achieved			
Supervisor's Initials			

Date	Supervisor's comments

Sub-module 7.3: QC of a Scintillation Probe and Well Counter

Knowledge Base	**Level of Competency Achieved**	
	2	**1**
An understanding of the principles of operation of a scintillation probe and well counter and relevant QC procedures.	Possesses a **basic** understanding of the principles of operation of a scintillation probe and well counter and relevant QC procedures.	Possesses a **good** understanding of the principles of operation of a scintillation probe and well counter and relevant QC procedures.
Date Achieved		
Supervisor's Initials		

Practical Skills	**Level of Competency Achieved**		
	3	**2**	**1**
The ability to perform basic QC procedures for non-imaging scintillation systems	Is capable of **assisting** with the QC program for non-imaging scintillation systems.	Is capable of **performing** most of the QC program for non-imaging scintillation systems. **Requires limited supervision.**	Is capable of **independently performing** the QC program for non-imaging scintillation systems **to an acceptable clinical standard.**
Date Achieved			
Supervisor's Initials			

Date	**Supervisor's comments**

Sub-module 7.4: QC of a Gamma Camera and SPECT

Knowledge Base	Level of Competency Achieved	
	2	1
An understanding of QC procedures for planar and SPECT devices.	Possesses a **basic** understanding of relevant QC procedures for planar and SPECT devices.	Possesses a **good** understanding of relevant QC procedures for planar and SPECT devices.
Date Achieved		
Supervisor's Initials		

Practical Skills (a)	Level of Competency Achieved		
	3	2	1
The ability to perform and evaluate typical planar QC procedures including: spatial resolution and uniformity (integral and differential),	Is capable of **assisting** with the QC program for a planar imaging camera.	Is capable of **performing** most of the QC program for a planar imaging camera. **Requires limited supervision.**	Is capable of **independently performing** the QC program for a planar imaging camera **to an acceptable clinical standard.**
Date Achieved			
Supervisor's Initials			

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Practical Skills (b)	Level of Competency Achieved		
	3	2	1
The ability to perform and evaluate typical SPECT QC procedures including: spatial resolution, uniformity (integral and differential), COR, spatial resolution SPECT uniformity and tomographic image quality.	Is capable of **assisting** with the QC program for a SPECT camera.	Is capable of **performing** most of the QC program for a SPECT camera. **Requires limited supervision.**	Is capable of **independently performing** the QC program for a SPECT camera **to an acceptable clinical standard.**
Date Achieved			
Supervisor's Initials			

Date	Supervisor's comments

Sub-module 7.5: QC of PET/CT systems

Knowledge Base	Level of Competency Achieved	
	2	1
Familiarity with routine PET/CT QC procedures.	Possesses a **basic** understanding of relevant QC procedures for PET/CT systems.	Possesses a **good** understanding of relevant QC procedures for PET/CT systems.
Date Achieved		
Supervisor's Initials		

Practical Skills	Level of Competency Achieved		
	3	2	1
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.	Is capable of **assisting** with the QC program for PET/CT systems.	Is capable of **performing** most of the QC program for PET/CT systems. **Requires limited supervision.**	Is capable of **independently performing** the QC program for PET/CT systems **to an acceptable clinical standard.**
Date Achieved			
Supervisor's Initials			

Date	Supervisor's comments

Sub-module 7.6: QC of Display and Hardcopy Devices

Knowledge Base (a)	Level of Competency Achieved	
	2	1
An understanding of quality control procedures for display and hard copy devices.	Possesses a **basic** understanding of relevant QC procedures for display and hard copy devices.	Possesses a **good** understanding of relevant QC procedures for display and hard copy devices.
Date Achieved		
Supervisor's Initials		

Knowledge Base (b)	Level of Competency Achieved	
	2	1
Knowledge of film and other hard copy properties and calibration.	Possesses a **basic** understanding of the properties and calibration of film and other hard copy records.	Possesses a **good** understanding of the properties and calibration of film and other hard copy records.
Date Achieved		
Supervisor's Initials		

Practical Skills	Level of Competency Achieved		
	3	2	1
Ability to perform QC for display and hard copy devices.	Is capable of **assisting** with the QC program for display and hard copy devices.	Is capable of **performing** most of the QC program for display and hard copy devices. **Requires limited supervision.**	Is capable of **independently performing** the QC program for display and hard copy devices **to an acceptable clinical standard.**
Date Achieved			
Supervisor's Initials			

Date	Supervisor's comments

Sub-module 7.7: QC of DXA Systems

Knowledge Base	**Level of Competency Achieved**	
	2	**1**
An understanding of the theory and operation of DXA equipment and the importance of QC and calibration in the accurate use of normal ranges.	Possesses a **basic understanding** of the theory and operation of DXA equipment and the importance of QC and calibration in the accurate use of normal ranges.	Possesses a **good understanding** of the theory and operation of DXA equipment and the importance of QC and calibration in the accurate use of normal ranges.
Date Achieved		
Supervisor's Initials		

Practical Skills	**Level of Competency Achieved**		
	3	**2**	**1**
The ability to perform QC of DXA equipment.	Is capable of **assisting** with the QC program of DXA equipment.	Is capable of **performing** most of the QC program of DXA equipment. **Requires limited supervision.**	Is capable of **independently performing** the QC program of DXA equipment **to an acceptable clinical standard.**
Date Achieved			
Supervisor's Initials			

Date	**Supervisor's comments**

MODULE 8: RADIONUCLIDE THERAPY USING UNSEALED SOURCES

8.1 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 procedures
8.6 Radiation safety precautions for therapy using unsealed radionuclide sources
8.7 Advice to staff, patients and others regarding radiation risk

Sub-module 8.1: Principles of Radionuclide Therapy

Knowledge Base	**Level of Competency Achieved**	
	2	**1**
An understanding of the principles of radionuclide therapy	Possesses a **basic** understanding of the principles of radionuclide therapy.	Possesses a **good** understanding of the principles of radionuclide therapy.
Date Achieved		
Supervisor's Initials		

Date	**Supervisor's comments**

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Sub-module 8.2: Facility Design for Radionuclide Therapy

Knowledge Base	**Level of Competency Achieved**	
	2	**1**
An understanding of the principles of shielding design for the different radionuclide energies used for therapeutic purposes	Demonstrates a **basic understanding** of shielding design for radionuclide energies used in therapeutic Nuclear Medicine.	Demonstrates a **good understanding** of shielding design for radionuclide energies used in therapeutic Nuclear Medicine.
Date Achieved		
Supervisor's Initials		

Practical Skills	**Level of Competency Achieved**		
	3	**2**	**1**
The ability to design satisfactory radiation shielding for the different radionuclide energies used for therapeutic purposes	Is capable of **contributing** to the design of radiation shielding for the different radionuclide energies used for therapeutic purposes. **Requires significant assistance** to ensure the accuracy of the design.	Is capable of designing radiation shielding for the different radionuclide energies used for therapeutic purposes. **Requires only limited assistance** to ensure the accuracy of the design.	Is capable of **independently designing radiation** shielding for the different radionuclide energies used for therapeutic purposes **to an acceptable level.**
Date Achieved			
Supervisor's Initials			

Date	Supervisor's comments

Sub-module 8.3: Treatment Procedures

Knowledge Base	Level of Competency Achieved	
	2	1
An understanding of the purpose, principles and operational procedures of radionuclide therapy	Possesses a **basic** understanding of the purpose, principles and operational procedures of radionuclide therapy	Possesses a **good** understanding of the purpose, principles and operational procedures of radionuclide therapy
Date Achieved		
Supervisor's Initials		

Practical Skills	Level of Competency Achieved		
	3	2	1
Ability to manage patients appropriately from a radiation safety perspective both pre and post administration of the radionuclide.	Is capable of **assisting** in the appropriate management of patients from a radiation safety perspective both pre and post administration of the radionuclide.	Requires **only limited supervision** in providing appropriate **safe** management of patients from a radiation perspective both pre and post administration of the radionuclide.	Is capable of **independently** providing appropriate **safe** management of patients from a radiation perspective both pre and post administration of the radionuclide.
Date Achieved			
Supervisor's Initials			

Date	Supervisor's comments

Sub-module 8.4: Selection of Radiopharmaceuticals for Nuclear Medicine Therapy.

Knowledge Base (a)	Level of Competency Achieved	
	2	1
An understanding of the common indications and radiopharmaceuticals used for therapy in nuclear medicine	Possesses a **basic** understanding of the common indications and radiopharmaceuticals used for therapy in nuclear medicine	Possesses a **good** understanding of the common indications and radiopharmaceuticals used for therapy in nuclear medicine
Date Achieved		
Supervisor's Initials		
Knowledge Base (b)	**Level of Competency Achieved**	
	2	**1**
Familiarity with the wide range of diseases in which radionuclide therapy is being used and the selection of the appropriate radiopharmaceutical for the specific patient	Possesses a **basic** understanding of the range of diseases for which radionuclide therapy is used and the selection of the appropriate radiopharmaceutical for the specific patient.	Possesses a **good** understanding of the range of diseases for which radionuclide therapy is used and the selection of the appropriate radiopharmaceutical for the specific patient.
Date Achieved		
Supervisor's Initials		

Date	Supervisor's comments

Sub-module 8.5: Dosimetry for Radionuclide Therapeutic Procedures

Knowledge Base	Level of Competency Achieved	
	2	1
An understanding of the principles of internal dosimetry.	Possesses a **basic** understanding of the principles of internal dosimetry	Possesses a **good** understanding of the principles of internal dosimetry
Date Achieved		
Supervisor's Initials		

Practical Skills	Level of Competency Achieved		
	3	2	1
An ability to calculate the activity of the administered dose for therapy in nuclear medicine	Is capable of calculating the activity of the administered dose for therapy in nuclear medicine. Results need careful checking.	Requires **only limited assistance** in calculating the activity of the administered dose for therapy in nuclear medicine.	Is capable of **independently** calculating the activity of the administered dose for therapy in nuclear medicine.
Date Achieved			
Supervisor's Initials			

Date	Supervisor's comments

Sub-module 8.6: Radiation Safety Precautions for Therapy using Unsealed Radionuclide Sources

Knowledge Base (a)	**Level of Competency Achieved**	
	2	**1**
Familiarity with all legislations, guidelines and international best practices to ensure radiation safety, before, during and after administration of radionuclide therapy	Demonstrates a **basic understanding** of legislations, guidelines and international best practices and the **principles of hazard assessment and control mechanisms** to ensure radiation safety, before, during and after administration of radionuclide therapy**. Requires assistance** with understanding of the **more difficult aspects.**	Demonstrates a **good understanding** of all legislations, guidelines and international best practices and the **principles of** hazard assessment and control mechanisms to ensure radiation safety, before, during and after administration of radionuclide therapy.
Date Achieved		
Supervisor's Initials		
Knowledge Base (b)	**Level of Competency Achieved**	
	2	**1**
Familiarity with 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	Demonstrates a **basic understanding** of 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**. Requires assistance** with understanding of the **more difficult aspects.**	Demonstrates a **good understanding** of 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**.**
Date Achieved		
Supervisor's Initials		

Practical Skills (a)	**Level of Competency Achieved**		
	3	**2**	**1**
Ability to apply radiation protection regulations to personnel, patients and members of the public associated with radionuclide therapy	Possesses only a **limited ability** to apply radiation protection regulations to personnel, patients and members of the public associated with radionuclide therapy. **Requires close supervision.**	Requires **only limited assistance** in applying radiation protection regulations to personnel, patients and members of the public associated with radionuclide therapy	Is capable of **independently** applying radiation protection regulations to personnel, patients and members of the public associated with radionuclide therapy
Date Achieved			
Supervisor's Initials			
Practical Skills (b)	**Level of Competency Achieved**		
	3	**2**	**1**
Ability to communicate with the patient, staff and public about the risks associated with handling of high activity unsealed sources	Possesses only a **limited ability** to advise others on the risks associated with handling of high activity unsealed sources and **correct practical aspects to reduce dose.**	Is capable of advising others on the risks associated with handling of high activity unsealed sources and correct practical aspects to reduce dose. Requires **supervision** to ensure that **no incorrect advice** is provided.	Is capable of **independently advising** others on the risks associated with handling of high activity unsealed sources and practical aspects to reduce dose. **The advice provided is at all times correct and appropriate.**
Date Achieved			
Supervisor's Initials			

Date	Supervisor's comments

MODULE 9: CLINICAL COMPUTING AND NETWORKING

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 PACS, RIS and HIS
9.9 Software validation: computer simulations, phantoms and clinical data
9.10 Computer networking

Sub-module 9.1: Operation of a Clinical Acquisition and Processing/Reviewing Workstation

Knowledge Base	**Level of Competency Achieved**	
	2	**1**
An understanding of the basic characteristics of workstation operating systems and clinical software for image acquisition and processing.	Demonstrates a **limited understanding** of the basic characteristics of workstation operating systems and clinical software for image acquisition and processing.	Demonstrates a **good understanding** of the basic characteristics of workstation operating systems and clinical software for image acquisition and processing.
Date Achieved		
Supervisor's Initials		

Practical Skills	Level of Competency Achieved		
	3	2	1
The ability to effectively use a workstation operating system and nuclear medicine clinical software	Is **capable** of using a workstation operating system and clinical software for **most simple tasks** associated with image acquisition, display, manipulation and analysis as well as transfer and archiving of data. **Requires assistance** with more complex tasks.	Is **capable of** using a workstation operating system and clinical software for more **complex tasks** associated with image acquisition, display, manipulation and analysis as well as transfer and archiving of data. Requires only **minimal assistance**.	Is capable of **independently** using a workstation operating system and clinical software for **all tasks** associated with image acquisition, display, manipulation and analysis as well as transfer and archiving of data.
Date Achieved			
Supervisor's Initials			

Date	Supervisor's comments

Sub-module 9.2: Computer System Administration Management

Knowledge Base	**Level of Competency Achieved**	
	2	**1**
An understanding of computer system administration responsibilities and the essential commands, tools and utilities important for ensuring a consistent operation of clinical computer systems.	Demonstrates a **limited understanding** of computer system administration responsibilities and the essential commands, tools and utilities important for ensuring a consistent operation of clinical computer systems.	Demonstrates a **good understanding** of computer system administration responsibilities and the essential commands, tools and utilities important for ensuring a consistent operation of clinical computer systems.
Date Achieved		
Supervisor's Initials		

Practical Skills	**Level of Competency Achieved**		
	3	**2**	**1**
The ability to perform necessary system administration tasks.	Is **capable** of performing **many basic** system administration tasks including planning, installing, supporting and maintaining computer hardware, operating systems, clinical software and networking. **Requires assistance** with more complex tasks.	Is **capable** of performing **all basic** system administration tasks including planning, installing, supporting and maintaining computer hardware, operating systems, clinical software and networking. Requires only **minimal assistance** with more complex tasks.	Is capable of **independently** performing **all** system administration tasks including planning, installing, supporting and maintaining computer hardware, operating systems, clinical software and networking.

Date Achieved			
Supervisor's Initials			

Date	**Supervisor's comments**

Sub-module 9.3: First Line Computer System Troubleshooting

Knowledge Base	**Level of Competency Achieved**	
	2	**1**
An understanding of the possible causes of a computer system malfunction.	Demonstrates a **limited understanding** of the possible causes of a computer system malfunction.	Demonstrates a **good understanding** of the possible causes of a computer system malfunction.
Date Achieved		
Supervisor's Initials		

Practical Skills (a)	**Level of Competency Achieved**		
	3	**2**	**1**
The ability to rapidly recognize and troubleshoot common computer hardware, software and network related problems.	Is **capable** of recognizing and troubleshooting **many** common computer hardware, software and network related problems. **Requires assistance** with **more complex problems.**	Is **capable** of recognizing and troubleshooting **most** common computer hardware, software and network related problems. Requires only **minimal assistance** with more complex problems.	Is capable of **independently** recognizing and troubleshooting **all** common computer hardware, software and network related problems.
Date Achieved			

Supervisor's Initials			
Practical Skills (b)	**Level of Competency Achieved**		
	3	**2**	**1**
The ability to design, schedule and implement computer system preventive maintenance.	Is **capable** of performing **basic** aspects of the design, schedule and implementation of preventive maintenance of a computer system. **Requires assistance** with **more complex aspects.**	Is **capable** of performing **all** aspects of the design, schedule and implementation of preventive maintenance of a computer system. Requires only **minimal assistance** with more complex aspects.	Is capable of **independently** performing **all** aspects of the design, schedule and implementation of preventive maintenance of a computer system.
Date Achieved			
Supervisor's Initials			

Date	**Supervisor's comments**

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Sub-module 9.4: Computer Image Processing Techniques

Knowledge Base	**Level of Competency Achieved**	
	2	**1**
An understanding of the underlying algorithms and programming language mandatory for developing simple image analysis/processing programs in an interactive programming environment.	Demonstrates a **limited understanding** of the algorithms and programming language mandatory for developing simple image analysis/processing programs in an interactive programming environment.	Demonstrates a **good understanding** of the algorithms and programming language mandatory for developing simple image analysis/processing programs in an interactive programming environment.
Date Achieved		
Supervisor's Initials		

Practical Skills	**Level of Competency Achieved**		
	3	**2**	**1**
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 macro utility, for selected clinical tasks.	**Requires considerable assistance** 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 macro utility, for selected clinical tasks.	Requires only **minimal assistance** 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 macro utility, for selected clinical tasks.	Is capable of **independently** developing, testing and documenting efficient image processing routines/applications in a high-level programming environment and utilizing macro routines in the vendor's macro utility, for selected clinical tasks.
Date Achieved			
Supervisor's Initials			

Date	Supervisor's comments

Sub-module 9.5: Image Analysis in a High-Level Programming Language (optional)

Knowledge Base	Level of Competency Achieved	
	2	1
An understanding of the programming flowcharts and pseudo code, and the transition from this conceptual approach to development of actual programs in a high level language.	Possesses a **good understanding** of programming flowcharts and pseudo code, and a **basic understanding** of the transition from this conceptual approach to development of actual programs in a high-level language.	Possesses a **good understanding** of programming flowcharts and pseudo code, **and** of the transition from this conceptual approach to development of actual programs in a high-level language.
Date Achieved		
Supervisor's Initials		

Practical Skills	Level of Competency Achieved		
	3	2	1
The ability to write simple, readable and efficient programs in a high level (procedural) language, to test new software and properly document the code.	Is capable of writing **basic** efficient programs in a high level (procedural) language including testing and documentation of new software. **Requires assistance** with **more complex programs.**	Is capable of writing **complex** efficient programs in a high level (procedural) language including testing and documentation of new software. Requires only **minimal assistance**.	Is capable of **independently** writing **complex** efficient programs in a high level (procedural) language including testing and documentation of new software.

Date Achieved			
Supervisor's Initials			

Date	**Supervisor's comments**

Sub-module 9.6: Image Reconstruction, Registration and Fusion, and Tracer Kinetic Modelling

Knowledge Base	**Level of Competency Achieved**	
	2	**1**
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.	Possesses a **basic** 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.	Possesses a **good** 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.
Date Achieved		
Supervisor's Initials		

Practical Skills (a)	**Level of Competency Achieved**		
	3	**2**	**1**
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.	Is **capable** of performing **basic** image reconstruction and registration in clinical studies, and of proposing, designing and optimizing/evaluating new reconstruction approaches and compensation schemes for different image degrading factors. **Requires assistance** with **more complex aspects.**	Is **capable** of performing **all** image reconstruction and registration in clinical studies, and of proposing, designing and optimizing/evaluating new reconstruction approaches and compensation schemes for different image degrading factors. Requires only **minimal assistance** with more complex aspects.	Is capable of **independently** performing **all** aspects of image reconstruction and registration in clinical studies, and of proposing, designing and optimizing/evaluating new reconstruction approaches and compensation schemes for different image degrading factors.
Date Achieved			
Supervisor's Initials			
Practical Skills (b)	**Level of Competency Achieved**		
	3	**2**	**1**
The ability to apply models for the analysis of tracer kinetics	Is capable of applying **simple** models for analysis of tracer kinetics. **Requires significant assistance** with **more complex models.**	Is capable of applying **simple and complex** models for analysis of tracer kinetics. **Requires only limited assistance**.	Is capable of **independently** applying **simple and complex** models for analysis of tracer kinetics.
Date Achieved			
Supervisor's Initials			

Date	Supervisor's comments

Sub-module 9.7: Standard Image File Formats used in Nuclear Medicine

Knowledge Base	Level of Competency Achieved	
	2	1
An understanding of the structure and properties of image file formats commonly utilized in nuclear medicine.	Demonstrates a **limited understanding** of the structure and properties of image file formats commonly utilized in nuclear medicine.	Demonstrates a **good understanding** of the structure and properties of image file formats commonly utilized in nuclear medicine.
Date Achieved		
Supervisor's Initials		

Practical Skills	Level of Competency Achieved		
	3	2	1
The ability to read, display and manipulate medical image data provided in commonly used formats (Interfile 3.3, DICOM 3.0).	Is capable of reading, displaying and manipulating medical image data provided in commonly used formats. **Requires considerable assistance with more complex aspects.**	Is capable of reading, displaying and manipulating medical image data provided in commonly used formats. **Requires only limited assistance with more complex aspects**.	Is capable of **independently** reading, displaying and manipulating medical image data provided in commonly used formats **including the more complex aspects**.
Date Achieved			
Supervisor's Initials			

Date	Supervisor's comments

Sub-module 9.8: Computer networking, PACS, RIS and HIS

Knowledge Base	Level of Competency Achieved	
	2	1
An understanding of PACS technology and acceptance testing procedures as well as the essentials of RIS and HIS.	Demonstrates a **basic understanding** of PACS technology and acceptance testing procedures as well as the essentials of RIS and HIS.	Demonstrates a **good understanding** of PACS technology and acceptance testing procedures as well as the essentials of RIS and HIS. Also possesses a **good** understanding of the requirements to ensure that the system will meet the user's technical, functional and safety requirements.
Date Achieved		
Supervisor's Initials		

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Practical Skills (a)	**Level of Competency Achieved**		
	3	**2**	**1**
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.	Possesses a **limited 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. Requires **significant assistance**.	Possesses a **good 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. Requires **only limited assistance**.	Is capable of **independent input** to the maintenance of computer hardware and software that comprise a computer network, including the use, configuration and monitoring of active network equipment.
Date Achieved			
Supervisor's Initials			
Practical Skills (b)	**Level of Competency Achieved**		
	3	**2**	**1**
The ability to contribute to competent decisions related to selection of PACS that best meets the NM department needs based on its key characteristics and features.	Is capable of **contributing** to decisions related to selection of a PACS system based on its key characteristics and features **Requires significant assistance** with **some** of the concepts involved.	Is capable of **contributing** to decisions related to selection of a PACS system based on its key characteristics and features **Requires only limited assistance** with **some** of the concepts involved.	Is capable of **independently providing** the **"Nuclear Medicine Technology related" input** to decisions related to selection of a PACS system based on its key characteristics and features.
Date Achieved			
Supervisor's Initials			

Practical Skills (c)	Level of Competency Achieved		
	3	2	1
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.	Is capable of performing **most simple tasks associated with** data retrieval and storage using a workstation, server and PACS linked to the local RIS or HIS and those linked to an external PACS system. **Requires assistance** with more complex tasks.	Is capable of performing **all necessary tasks associated with** data retrieval and storage using a workstation, server and PACS linked to the local RIS or HIS and those linked to an external PACS system. Requires only **minimal assistance**.	Is capable of **independently** performing **all necessary tasks associated with** data retrieval and storage using a workstation, server and PACS linked to the local RIS or HIS and those linked to an external PACS system.
Date Achieved			
Supervisor's Initials			

Date	Supervisor's comments

Sub-module 9.9: Software Validation: Computer Simulations, Phantoms and Clinical Data

Knowledge Base	**Level of Competency Achieved**	
	2	**1**
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.	Possesses a **basic** understanding of Monte Carlo simulation methods computer generated phantoms, models of the imaging process, fast computational methods, and the use of physical phantoms and methods of clinical validation**.**	Possesses a **good** understanding of Monte Carlo simulation methods computer generated phantoms, models of the imaging process, fast computational methods, and the use of physical phantoms and methods of clinical validation**.**
Date Achieved		
Supervisor's Initials		

Practical Skills (a)	**Level of Competency Achieved**		
	3	**2**	**1**
The **ability** to perform MC simulations with one of the NM related simulation programs and properly interpret results.	Possesses a **limited ability** to perform MC simulations with one of the NM related simulation programs. Requires **significant assistance** to ensure the efficacy of the results.	Possesses a **good ability** to perform MC simulations with one of the NM related simulation programs **and properly interpret results**. Requires **only limited assistance** to ensure the efficacy of the results.	Is capable of **independently** performing MC simulations with one of the NM related simulation programs and properly interpreting the results.
Date Achieved			

Supervisor's Initials			
Practical Skills (b)	**Level of Competency Achieved**		
	3	**2**	**1**
The **ability** to 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.	Possesses a **limited ability** to assist in the design of a clinical validation study. Requires **significant assistance**.	Possesses a **good ability** to assist in the design of a clinical validation study. Requires **only limited assistance**.	Is capable of **independently** assisting in the design of a clinical validation study.
Date Achieved			
Supervisor's Initials			

Date	**Supervisor's comments**

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MODULE 10: CLINICAL APPLICATIONS

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

Sub-module 10.1: Protocols for Routine Clinical Procedures

Knowledge Base	**Level of Competency Achieved**	
	2	**1**
Familiarity with the effect of technical factors and acquisition protocol on the final result of a clinical procedure.	Possesses a **basic** understanding of the effect of technical factors and acquisition protocol on the final result of a clinical procedure.	Possesses a **good** understanding of the effect of technical factors and acquisition protocol on the final result of a clinical procedure.
Date Achieved		
Supervisor's Initials		

Date	**Supervisor's comments**

Sub-module 10.2: Common Artefacts in Clinical Images

Knowledge Base	**Level of Competency Achieved**	
	2	**1**
Familiarity with common image artefacts, their causes, and how to deal with them.	Possesses a **basic** understanding of common image artefacts and their causes. **Yet to understand how to deal with them.**	Possesses a **good** understanding of common image artefacts, their causes **and** how to deal with them**.**
Date Achieved		
Supervisor's Initials		

Practical Skills	**Level of Competency Achieved**		
	3	**2**	**1**
The ability to identify artefacts in nuclear medicine images, identify their probable causes and undertake remedial action.	Is capable of identifying **many of the artefacts** in nuclear medicine images and their probable causes. **Requires assistance** with proposing remedial action to be taken.	Is capable of identifying **most** of the artefacts in nuclear medicine images, their probable causes and applying remedial action with **only limited assistance**.	Is capable of **independently** identifying artefacts in nuclear medicine images, their probable causes and applying remedial action.
Date Achieved			
Supervisor's Initials			

Date	**Supervisor's comments**

Sub-module 10.3: Analysis of Common Clinical Studies and Sources of Error

Knowledge Base	Level of Competency Achieved	
	2	**1**
Familiarity with sources of error in clinical procedures, their impact on the patient and how to validate clinical procedures.	Possesses a **basic** understanding of sources of error in clinical procedures, their impact on the patient and how to validate clinical procedures.	Possesses a **good** understanding of sources of error in clinical procedures, their impact on the patient and how to validate clinical procedures.
Date Achieved		
Supervisor's Initials		

Date	Supervisor's comments

Sub-module 10.4: Principles and Physiological Basis for Common Clinical Studies

Knowledge Base	Level of Competency Achieved	
	2	**1**
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.	Possesses a **basic** understanding of the **normal and abnormal** 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.	Possesses a **good** understanding of the **normal and abnormal** 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.
Date Achieved		

Supervisor's Initials		

Date	**Supervisor's comments**

Sub-module 10.5: Developing Clinical Protocols for the Estimation of Patient Dosimetry

Practical Skills	**Level of Competency Achieved**		
	3	**2**	**1**
The ability to estimate the patient dose associated with a new nuclear medicine investigation.	Is capable of calculating patient dose associated with a new nuclear medicine investigation. **Results require careful checking.**	Is capable of calculating patient dose associated with a new nuclear medicine investigation. **Requires only minor assistance to ensure error free results.**	Is capable of **independently** calculating, **without error,** patient dose associated with a new nuclear medicine investigation.
Date Achieved			
Supervisor's Initials			

Date	**Supervisor's comments**

Sub-module 10.6: Optimization

Knowledge Base	**Level of Competency Achieved**	
	2	**1**
An understanding of the procedures used for risk/benefit evaluation of diagnostic and therapeutic nuclear medicine procedures.	Possesses a **basic** understanding of the procedures used for risk/benefit evaluation of diagnostic and therapeutic nuclear medicine procedures.	Possesses a **good** understanding of the procedures used for risk/benefit evaluation of diagnostic and therapeutic nuclear medicine procedures.
Date Achieved		
Supervisor's Initials		

Practical Skills (a)	**Level of Competency Achieved**		
	3	**2**	**1**
To be able to evaluate diagnostic nuclear medicine procedures and diagnostic information with respect to absorbed dose to the patient.	Requires **significant assistance** with the evaluation of diagnostic nuclear medicine procedures and diagnostic information with respect to absorbed dose to the patient.	Requires **only limited assistance** with the evaluation of diagnostic nuclear medicine procedures and diagnostic information with respect to absorbed dose to the patient.	Is capable of **independently evaluating** diagnostic nuclear medicine procedures and diagnostic information with respect to absorbed dose to the patient.
Date Achieved			
Supervisor's Initials			

Practical Skills (b)	Level of Competency Achieved		
	3	2	1
To be able to evaluate radionuclide therapy procedures with respect to possibility of cure and risk for complications.	Requires **significant assistance** with the evaluation of radionuclide therapy procedures with respect to possibility of cure and risk for complications.	Requires **only limited assistance** with the evaluation radionuclide therapy procedures with respect to possibility of cure and risk for complications.	Is capable of **independently evaluating** radionuclide therapy procedures with respect to possibility of cure and risk for complications.
Date Achieved			
Supervisor's Initials			

Date	Supervisor's comments

Sub-module 10.7: The Physiological Basis of PET Imaging

Knowledge Base	Level of Competency Achieved	
	2	1
To understand the principles and physiological basis for common clinical PET and PET/CT studies.	Demonstrates a **basic** understanding of the principles and physiological basis for common clinical PET and PET/CT.	Demonstrates a **good** understanding of the principles and physiological basis for common clinical PET and PET/CT.
Date Achieved		
Supervisor's Initials		

Practical Skills	Level of Competency Achieved		
	3	2	1
The ability to recognize the normal appearances for brain, heart and whole-body studies as well as common abnormal appearances and artefacts.	**Requires assistance** to recognize normal appearances for brain, heart and whole-body studies. Has **difficulty in differentiating** normal appearances from abnormal appearances and artefacts.	Is capable of recognizing normal appearances for brain, heart and whole-body studies and in **differentiating most** abnormal appearances and artefacts from normal appearances.	Is capable of recognizing normal appearances for brain, heart and whole-body studies and **differentiating** abnormal appearances and artefacts from normal appearances.
Date Achieved			
Supervisor's Initials			

Date	Supervisor's comments

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MODULE 11: PREPARATION AND QUALITY CONTROL OF RADIOPHARMACEUTICALS

11.1 : Production and preparation of radiopharmaceuticals
11.2 : Quality control of radiopharmaceuticals

Sub-module 11.1: Production and Preparation of Radiopharmaceuticals

Knowledge Base	**Level of Competency Achieved**	
	2	**1**
Familiarity with the facilities necessary for the production of radionuclides and radiopharmaceuticals.	Possesses a **basic** understanding of the facilities necessary for the production of radionuclides and radiopharmaceuticals.	Possesses a **good** understanding of the facilities necessary for the production of radionuclides and radiopharmaceuticals.
Date Achieved		
Supervisor's Initials		

Practical Skills	**Level of Competency Achieved**		
	3	**2**	**1**
Ability to apply appropriate protocols to prepare Tc-99m- labelled radiopharmaceuticals.	Is capable of preparing Tc-99m- labelled radiopharmaceuticals which **involve simple protocols**. Requires **close supervision.**	Is capable of preparing Tc-99m-labelled radiopharmaceuticals which **involve complex protocols**. **Requires supervision.**	Is capable of **independently** preparing Tc-99m-labelled radiopharmaceuticals.
Date Achieved			
Supervisor's Initials			

Date	**Supervisor's comments**

Sub-module 11.2: Quality Control of Radiopharmaceuticals

Knowledge Base	**Level of Competency Achieved**	
	2	**1**
An understanding of quality control procedures and their importance for radiopharmaceutical.	Possesses a **basic** understanding of QC procedures for radiopharmaceuticals.	Possesses a **good** understanding of QC procedures for radiopharmaceuticals.
Date Achieved		
Supervisor's Initials		

Practical Skills	**Level of Competency Achieved**		
	3	**2**	**1**
Be able to perform basic QC tests of radiopharmaceutical.	Is capable of performing basic QC tests of **some** radiopharmaceuticals **under close supervision**.	Is capable of performing basic QC tests of radio-pharmaceuticals. Requires only **limited supervision**.	Is capable of **independently** performing basic QC tests of radio-pharmaceuticals.
Date Achieved			
Supervisor's Initials			

Date	**Supervisor's comments**

References

- Narayan, K Kar, S Gupta, N. From 'Paramedics' to 'Allied Health Professionals': Landscaping the Journey and Way Forward. Public Health Foundation of India: New Delhi, India, 2012.
- Allied Health Professions Federation. AHPs involvement in health and social care 2011. Available from: http://www.ahpf.org.uk/files/ahpf_gov_briefing_v7_09-05-11.pdf.
- Narayan. K. How many doctors it takes to fix India's healthcare glitches? Deccan Herald [Internet]. 2014. Available from: http://www.deccanherald.com/content/381371/ how-many- doctors-takes-fix.html.
- Standards of practice for ACT Allied Health Professionals 2005. Available from: http://health.act.gov.au/c/health?a=dlpubpoldoc&document=863.
- Pamela Mitchell et al. Core principles and values of effective team based healthcare2012. Available from: https://www.nationalahec.org/pdfs/VSRT-Team-Based-Care-Principles- values.pdf.
- Social Accountability- A vision for Canadian medical schools Available from: https://www.afmc.ca/fmec/pdf/sa_vision_canadian_medical_schools_en.pdf.
- Medical Council of India. Vision 2015. Published March 2011. Available from: http://www.mciindia.org/tools/announcement/MCI_booklet.pdf.
- Sherwin J. Competency-Based Medical Education Takes Shape2011. Available from: https://www.aamc.org/newsroom/reporter/april11/184286/competency-based_medical_education.html.
- Brookfield, S. D. Self-Directed Learning in YMCA George Williams College ICE301 Lifelong Learning Unit 1 Approaching lifelong learning. London: YMCA George Williams College; 1994.
- Credit-Based-Grading-System for Assessment of Students. Available from: http://www.presiuniv.ac.in/web/exam_assessment.php.
- 9555132_Guidelines.pdf
- 0909572_Minimum-Standards-and-Procedure-for-Award-of-PhD-Degree.pdf