सत्यमेव जयते

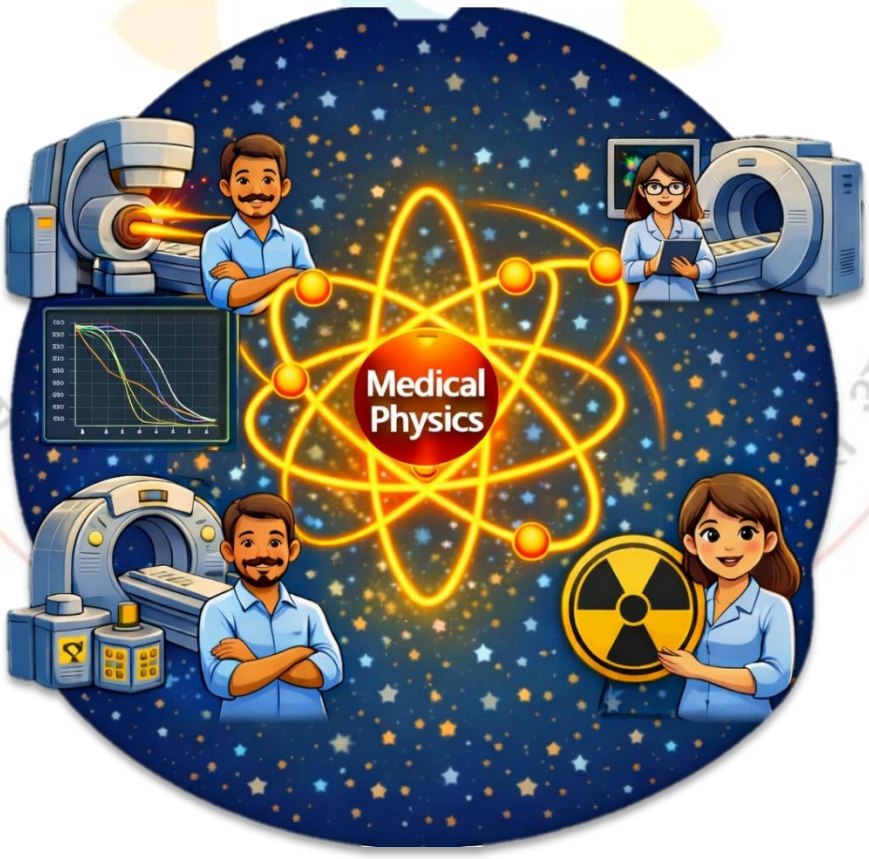
National Commission for Allied and Healthcare Professions

(NCAHP)

Competency Based Curriculum

For

MEDICAL PHYSICS



As per NCAHP Act, 2021

NATIONAL COMMISSION FOR ALLIED AND HEALTHCARE PROFESSIONS
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NCAHP
Since-2021
राष्ट्रीय सहबद्ध और स्वास्थ्य देख-रेख व्यवसाय आयोग

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List of Abbreviations

Abbreviation	Full Description
AERB	Atomic Energy Regulatory Board
AHPs	Allied and Healthcare Professionals
ALARA	As Low As Reasonably Achievable
BT	Brachytherapy
BHPA	British Hospital Physicists Association
CATS	Credit Accumulation and Transfer System
CBCS	Choice Based Credit System
CBD	Case Based Discussion
CEX	Mini Case Evaluation Exercise
CGPA	Cumulative Grade Point Average
CT	Computed Tomography
Dip RP	Diploma in Radiological Physics
Dip MP	Diploma in Medical Physics
DOPs	Direct Observation of Procedures
DRRs	Digitally Reconstructed Radiographs
DVH	Dose Volume Histogram
EBRT	External Beam Radiotherapy
ECTS	European Credit Transfer System
ESPEC	Equipment Specification and Acquisition
HBNI	Homi Bhabha National Institute
HDR	High Dose Rate
HSSC	Healthcare Sector Skill Council
IAEA	International Atomic Energy Agency
ICRU	International Commission on Radiation Units and Measurements
IEC	International Electrotechnical Commission
ILO	International Labour Organization
INFLIBNET	Information and Library Network
IRB	Institutional Review Board
IPEM	Institute of Physics and Engineering in Medicine
ISCO	International Standard Classification of Occupations

Abbreviation	Full Description
IVD	In Vivo Dosimetry
JCI	Joint Commission International
JRF	Junior Research Fellowship
LINAC	Linear Accelerator
MCQs	Multiple Choice Questions
MDCT	Multi Detector Computed Tomography
MoHFW	Ministry of Health and Family Welfare
MoU	Memorandum of Understanding
MP's	Medical Physicists
MRI	Magnetic Resonance Imaging
M.Sc.	Master of Science
NAAC	National Assessment and Accreditation Council
NABH	National Accreditation Board for Hospitals & Healthcare Providers
NCAHP	National Commission for Allied and Healthcare Professions
NET	National Eligibility Test
NIAHS TSU	National Initiative for Allied Health Sciences Technical Support Unit
NMC	National Medical Commission
NRC	National Curricula Review Committee
NSDA	National Skills Development Agency
NSQF	National Skills Qualification Framework
OBC	Other Backward Classes
OSCE	Objective Structured Clinical Examination
OSLER	Objective Structured Long Examination Record
OSPE	Objective Structured Practical Examination
PACS	Picture Archiving and Communications Systems
PDD	Percentage Depth Dose
PE	Professional Ethics
PET	Positron Emission Tomography
Ph.D.	Doctor of Philosophy
PSQA	Patient Specific Quality Assurance
PTV	Planning Target Volume

Abbreviation	Full Description
QA	Quality Assurance
QC	Quality Control
QM	Quality Management
QUANTEC	Quantitative Analysis of Normal Tissue Effects in the Clinic
RAC	Research Advisory Committee
RPS	Radiation Protection and Safety
RSO	Radiological Safety Officer
RTT	Radiotherapy Technologists
SC/ST	Scheduled Castes/Scheduled Tribes
SDL	Self Directed Learning
SPECT	Single Photon Emission Computed Tomography
TMR	Tissue Maximum Ratio
TPS	Treatment Planning System
TSD	Technical Support and Development
UGC	University Grants Commission
WHO	World Health Organization

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Chapter 1

Introduction to the Handbook

1.1 Introduction

The 2012 report, *"From Paramedics to Allied Health Professionals: Landscaping the Journey and Way Forward,"* highlighted significant variation in educational structures, training methodologies, and competency expectations across allied health programmes in India. These insights prompted the Ministry of Health and Family Welfare to develop a unified national framework for the education and career progression of allied health professionals, emphasizing structured, competency-based curricula to enhance professional standards, strengthen training quality, and improve patient safety.

In this context, the *Curriculum Handbook for Medical Physics* has been developed as a comprehensive academic and professional resource for institutions offering Post Master level & Master's level of Allied and Healthcare Professions (A&HP) programmes in Medical Physics.

Aligned with the recommendations of the National Commission for Allied and Healthcare Professions (NCAHP) and international best-practice guidelines, the proposed minimum standard curriculum equips Medical Physics graduates with strong scientific foundations, advanced clinical competencies, ethical grounding, and the professional skills required for safe and effective practice. This structured framework is intended to elevate the quality of Medical Physics education, promote professional mobility, and prepare graduates to meet the evolving technological and clinical demands of radiation-based healthcare. Accordingly, this handbook has been developed to familiarize universities, institutions, healthcare providers, and educators with these national standards.

1.2 Who is a Healthcare Professional?

The National Commission for Allied and Healthcare Professions Act 2021 defines healthcare professions as "healthcare professional" includes a scientist, therapist or other professional who studies, advises, researches, supervises or provides preventive, curative, rehabilitative, therapeutic or promotional health services and who has obtained any qualification of degree under this Act, the duration of which shall not be less than three thousand six hundred hours spread over a period of three years to six years divided into specific semesters;

1.3 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 the advances in technology, thus creating fresh challenges in the field of healthcare. 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. [1.] Professionals that can competently handle sophisticated machinery and advanced protocols are now in high demand. In fact, diagnosis is now so dependent on technology, that allied, and healthcare professionals (AHPs) are vital to successful treatment delivery.

Effective delivery of healthcare services depends largely on the nature of education, training and appropriate orientation towards community health of all categories of health personnel, and their capacity to function as an integrated team. For instance, in the UK, more than 84,000 AHPs, with a range of skills and expertise, play key roles within the National Health Service, working autonomously, in multi-professional teams in various settings. All of them are first- contact practitioners and work across a wide range of locations and sectors within acute, primary and community care. Australia's health system is managed not just by their doctors and nurses, but also by the 90,000 university-trained, autonomous AHPs vital to the system. [2.] [3.]

As the Indian government aims for Universal Health Coverage, the lack of skilled human resource may prove to be the biggest impediment in its path to achieve 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 significant reduction in the cost of care, though the Indian healthcare system still revolves around the doctor-centric approach. The privatization of healthcare has also led to an ever-increasing out-of- pocket expenditure by the population.

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, the breadth and scope of the allied and healthcare practice varies from one end to another, including areas of work listed below:

- Across the age span of human development from neonate to old age.
- 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.
- Towards health promotion and disease prevention, as well as assessment, management and evaluation of interventions and protocols for treatment.
- In a broad range of settings from a patient's home to community, primary care centers, to tertiary care settings; and
- With an understanding of the healthcare issues associated with diverse socio-economies and cultural norms within the society.

1.4 Learning goals and objectives

The handbook has been designed with a focus on performance-based outcomes pertaining to different levels. The learning goals and objectives of the undergraduate and graduate education program will be based on the performance expectations. They will be articulated as learning goals (why we teach this) and learning 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:

- Clinical care
- Communication
- Membership of a multidisciplinary health team
- Ethics and accountability at all levels (clinical, professional, personal and social)
- Commitment to professional excellence
- Leadership and mentorship
- Social accountability and responsibility
- Scientific attitude and scholarship (only at higher level- PhD)
- Lifelong learning

1.4.1. Clinical Care

Using a patient- and family-centered approach and best available evidence, each student in Medical Physics will organize and the scientific approach to treatment plans in collaboration with the healthcare team.

Program objectives should enable the students to:

- Apply the principles of physics, basic sciences, and evidence-based practice to the safe and effective use of radiation and medical imaging technologies in diagnosis and therapy.
- Use relevant investigations, suggestions, and prescriptions as needed, including the selection, calibration, and quality assurance of medical equipment to optimize diagnostic accuracy and therapeutic outcomes.
- Identify the indications for basic physics-based procedure such as radiation dosimetry, image quality assessment, and safety checks and perform them in a precise, ethical, and appropriate manner.
- Provide care to patients efficiently and cost-effectively by ensuring radiation protection, minimizing exposure risks, and maintaining equipment performance across a range of clinical settings, always prioritizing the safety and well-being of patients and staff.
- Identify the influence of biological, psychosocial, economic, and spiritual factors on patients' perceptions of radiation-based procedures and treatments, and communicate technical information in a way that promotes understanding, trust, and shared decision-making.
- Incorporate strategies for health promotion and disease prevention through patient and staff education on radiation safety, optimization of diagnostic procedures, and implementation of quality control measures that enhance clinical outcomes and public health.

1.4.2. Communication

The student will learn how to communicate with clients, caregivers, other health professionals and other members of the community effectively and appropriately. 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 clinician//technologist can participate as actively as possible and respond appropriately to the information.
- Clearly discuss the planning protocol with clinical team, and negotiate appropriate treatment plans in a sensitive manner that is in the patients and society's best interests
- Explain the treatment plan – 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 members of the healthcare team
- Use communication effectively and flexibly in a manner that is appropriate for the reader or listener
- Explore and consider the influence that the clinical team 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 forms of written and verbal communication including accurate and timely record keeping
- Assess their own communication skills, develop self-awareness and be able to improve their relationships with others

1.4.3. 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 is the provision of 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 being able to[5.]:

Understand the Roles of Team Members and interdependencies of radiation oncologists, radiologists, nuclear medicine physicians, technologists, dosimetrists, nurses, biomedical engineers, and hospital administrators in clinical workflows.

- Participate in joint discussions such as treatment planning meetings, tumor boards, radiology/IMRT/VMAT planning reviews, equipment commissioning decisions, and safety committees to contribute scientific insights that support optimal patient management.
- Develop the ability to convey technical information in a clear, concise, and clinically meaningful manner to clinicians and technical staff,
- Work collaboratively to implement safety protocols, perform machine quality assurance, manage radiation incidents, and support evidence-based clinical practices that promote a culture of safety

1.4.4. 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:

- Professional Ethical Principles, Ensure that all procedures maximize patient benefit while minimizing radiation exposure and risk.
- **Confidentiality:** Protect patient information and adhere to institutional and legal privacy standards
- Ensure accuracy and precision in all measurements, dosimetry calculations, treatment planning, and quality assurance activities.
- Avoid falsification, fabrication, or deliberate misrepresentation of data, results, or clinical findings.
- Maintain transparent documentation and traceability of clinical decisions, calibrations, and equipment performance records.
- Adhere to AERB safety codes, licensing requirements, equipment QA guidelines, and statutory reporting obligations
- Ensure rigorous QA/QC, adherence to radiation protection principles (ALARA), and immediate reporting of deviations or near-miss events

1.4.5. Commitment to professional excellence

The student will execute professionalism to reflect in his/her thought and action a range of attributes and characteristics that include technical 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 being able to:

- Adhere to National and International Standards of Practice, guidelines of AERB, NCAHP, AAPM, IAEA
- Commit to rigorous quality assurance, precision in clinical measurements, accuracy in treatment planning
- Maintain high ethical standards, integrity, accountability, and professionalism in all interactions with patients, colleagues, institutions, and regulatory bodies
- Actively engage in professional societies, academic forums, and collaborative clinical initiatives

1.4.6. Leadership and mentorship

The student must take on a leadership role where needed to ensure clinical productivity and patient satisfaction. The curriculum should provide structured opportunities for students to develop leadership competencies and mentoring skills that will enable them to guide teams, support trainees, and engage in professional growth throughout their careers. Program objectives should enable the students to:

- Cultivate the ability to lead clinical, academic, and technical initiatives within radiation medicine
- Understand the responsibilities associated with leadership positions, including adherence to regulatory standards, implementation of quality assurance programmes
- Acquire the skills to mentor junior physicists, interns, technologists, and students
- Lead and mentor peers in adopting new technologies, implementing best practices, and contributing to research.

1.4.7. Social accountability and responsibility

Students will recognize their responsibility as healthcare professionals to act as advocates within the healthcare system, ensuring the safe, ethical, and judicious use of radiation. They shall serve the community, region, and nation by directing their academic, clinical, research, and service activities toward addressing priority health concerns. The program will enable students to:

- Advocate for safe, ethical, and responsible use of radiation in academic, clinical, and research settings.
- Apply the principles of justification, optimization of practice, and ALARA to minimize radiation risks to patients, workers, research participants, and the public.
- Demonstrate ethical, legal, and professional accountability in compliance with regulatory and institutional requirements.
- Participate in ethically approved, socially relevant research addressing community and national health priorities.
- Contribute to academic dissemination and community awareness related to radiation safety and public health.

1.4.8. 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 in all 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 specific needs of the population.
- Practice evidence-based 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

1.4.9. Lifelong learning

The student should be committed to continuous improvement in skills and knowledge while harnessing modern tools and technology. Program objectives will aim at making the students being 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
- Participate regularly in workshops, conferences, professional enhancement credit programmes

- Keep updated with innovations in imaging technologies, treatment planning systems, radiation measurement tools, AI-driven clinical workflows
- Pursue Research and Academic Contributions
- Uphold Professional Standards and Certifications

1.5 New elements in healthcare curriculum

1.5.1. Competency-based curriculum

A significant skill gap exists among healthcare professionals, regardless of their hierarchy or responsibility in healthcare settings. The variation in service quality is attributed to differing healthcare education methods and the gap between expectations of graduate's post-course and in the workplace. While a course emphasizes what one is expected to "know," it is assumed that practical skills are learned through the job. Competency-based education bridges the gap between "know what" and "do how." The effectiveness of any educational program relies on its curriculum design. With rapidly evolving medical knowledge, educators recognize that learning should go beyond memorizing facts, as knowledge may become outdated by the time a professional enters practice.

Competency-based education addresses this by equipping professionals with relevant skills and competencies needed for real-world practice. It focuses on learner-centered activities, continuous evaluation, and performance outcomes, contrasting with the traditional teacher- centered approach. Competency-based credentials depend on the demonstration of specific competencies, allowing stakeholders to set clear expectations. [8.][9.]

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

1.5.2. Promoting self-directed learning of the professionals.

The shift in the focus from traditional to competency-based education has made it pertinent that the learning processes may also be revisited for suitable changes. It is a known fact that learning is no more restricted to the boundaries of a classroom, or the lessons taught by a teacher. The new tools and technologies have widened the platform and introduced innovative modes of how students can learn and gain skills and knowledge. One of the innovative approaches is learner-centric and follows the concept of self- directed learning.

Self-directed learning, in its broadest meaning, describes a process in which individuals take the initiative with or without the help of others, in diagnosing their learning needs, formulating learning goals, identifying resources for learning, choosing and implementing learning strategies and evaluating learning outcomes (Knowles, 1975).[xiv] In self-directed learning, learners themselves take the initiative to use resources rather than simply reacting to transmissions from resources, which helps them learn more in a better way.[10.]

Lifelong, self-directed learning has been identified as an important ability for medical graduates (Harvey, 2003) [11.] and so is applicable to other health professionals including AHPs. It has been proven through many studies worldwide that the self-directed method is better than the teacher-centric method of learning. Teacher-directed learning makes learners more dependent and the orientation to learning becomes subject-centered. If a teacher provides the learning material, the student is usually satisfied with the available material, whereas if a student is asked to work on the same assignment, he or she invariably has to explore extensive resources on the subject. [11.] This handbook promotes self-directed learning, apart from the usual classroom teaching and opens the platform for students who wish to engage in lifelong learning.

1.5.3. 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. [12.] 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 the use of a fully convertible credit-based system that can be accepted at other universities. It has now become imperative to offer flexible curricular choices and provide learners mobility due to the popularity of initiatives such as twinning programmes, joint degrees and study abroad progrmes. [13.]

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

1.5.4. Integrated structure of the curriculum

The Medical Physics curriculum adopts an integrated structural framework that ensures seamless alignment between theoretical instruction, practical skill development, clinical training, and professional competencies

The curriculum is organized into core theoretical modules**,** laboratory-based practical components**,** and structured clinical residency training, delivered in a coordinated and sequential manner. Foundational topics in radiation physics, anatomy, physiology, instrumentation, and radiobiology are introduced early, providing the scientific base for more advanced modules in radiation therapy, diagnostic radiology, nuclear medicine, treatment planning, quality assurance, and radiation protection.

1.5.5. Learning methodologies

With a focus on self-directed learning, the curriculum will include a foundation course that focuses on communication, basic clinical skills and professionalism; and will incorporate clinical training from the first year itself. It is recommended that the care level should have sufficient clinical exposure integrated with the learning of basic and laboratory sciences. There should also be an emphasis on the introduction of case scenarios for classroom discussion/case- based learning. Healthcare education and training is the backbone of an efficient healthcare system and India's education infrastructure is yet to gain from the ongoing international technological revolution. In addition to keeping up with the pace of technological advancement, there has been a paradigm shift to outcome-based education with the adoption of 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, laboratories and high-fidelity simulation laboratories to enhance the practice and training for allied and healthcare students and professionals. The report reiterates the fact that simulation is the replication of part or all of a clinical encounter through the use of mannequins, computer- assisted resources and simulated patients. The use of simulators addresses many issues such as suboptimal use of resources and equipment, by adequately training the manpower on newer technologies, limitations for imparting practical training in real-life scenarios, and ineffective skills assessment methods among others. The table mentioned below lists various modes of teaching and learning opportunities that harness advanced tools and technologies.

Table 1.1: Clinical learning opportunities imparted using advanced techniques

S. No.	Teaching Modality	Learning Opportunity Examples
i.	**Patients / Clinical Settings**	• Observe and participate in clinical procedures involving the application of physics in medicine (e.g., radiotherapy planning, diagnostic imaging, nuclear medicine).
		• Understand radiation dose delivery, patient positioning, and safety protocols.
		• Communicate effectively with clinicians and technologists regarding physics-based decisions.
		• Practice patient-centred approaches in radiation protection and medical exposure justification.
		• Receive feedback on professionalism, communication, and clinical judgment.

S. No.	Teaching Modality	Learning Opportunity Examples
ii.	**Mannequins / Phantoms (Skills Laboratory Practice)**	• Perform calibration and quality assurance (QA) procedures using phantoms to simulate patient conditions.
		• Practice dosimetry measurements, image quality testing, and equipment checks in a controlled environment.
		• Apply physics principles to analyze and troubleshoot simulated system errors.
		• Develop proficiency in handling radiation instruments and measurement tools safely.
iii.	**Simulators (Virtual or Computational Simulation Tools)**	• Use treatment planning systems and simulation software to plan and optimize radiotherapy treatments.
		• Simulate imaging acquisition and processing to understand system performance and artifact correction.
		• Practice problem-solving and decision-making in simulated equipment malfunction or radiation incident scenarios.
		• Apply Monte Carlo simulations or virtual labs to explore dose distribution and safety design.
iv.	**Tasks Under Supervision (Clinical / Field Training)**	• Perform supervised clinical physics tasks including equipment commissioning, QA, and radiation dose verification.
		• Conduct machine calibration, beam data acquisition, and routine checks under mentorship.
		• Participate in radiation protection surveys and compliance audits.
		• Assist in patient-specific QA, treatment planning, and dosimetric calculations.
		• Collaborate with multidisciplinary teams in real clinical settings.
		• Develop competence in documentation, safety reporting, and ethical practice.
		• Receive structured feedback to support professional growth and readiness for independent practice.

1.5.6. Assessment method

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 basically 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 the three attributes – knowledge, skills, and attitudes – are assessed as required for the competency. Several new methods and tools are now readily accessible, the use of which requires special training. Some of these are given below in

Table 1.2: Purpose of several new methods and tools for competency based training.

Tool / Method	Purpose
1. Objective Structured Practical Examination (OSPE)	To assess *practical and technical skills* in radiation dosimetry, equipment calibration, imaging, and QA procedures.
2. Objective Structured Clinical Examination (OSCE)	To evaluate *clinical application of physics principles* in patient care (e.g., treatment planning, radiation protection, imaging protocols).
3. Objective Structured Long Examination Record (OSLER)	To assess *comprehensive case management* - from physics planning to clinical implementation.
4. Mini Clinical Evaluation Exercise (Mini-CEX)	To assess *real-time performance* during clinical workflow (e.g., performing patient-specific QA, commissioning checks).
5. Case-Based Discussion (CBD)	To evaluate *clinical reasoning, safety considerations, and ethical decision-making* in complex cases.
6. Direct Observation of Procedural Skills (DOPS)	To assess *hands-on technical competence* in specialized procedures.
7. Portfolio	To maintain a *comprehensive record of learning, projects, competencies, and professional development*.
8. Multi-Source Feedback (MSF)	To assess *professional behavior, teamwork, and communication* in a multidisciplinary environment.
9. Quality and Safety Audit Exercise (QSAE)	To assess *competence in implementing QA and radiation safety standards*.
10.Technologist/Clinician Satisfaction Questionnaire	To assess *communication, clarity, and support quality* from the physicist's role.

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राष्ट्रीय सहबद्ध और स्वास्थ्य देख-रेख व्यवसाय आयोग

Chapter 2

Curriculum Development

2.0. Methodology of Curriculum Development

The Ministry of Health and Family Welfare prioritized the recommendations related to strengthening and standardizing educational frameworks for Allied and Healthcare Professions. One of the key recommendations was the need to establish uniform, competency-based, and globally aligned curricula for Medical Physics programs, considering their critical role in radiation safety, radiotherapy, nuclear medicine, and diagnostic imaging.

Medical Physics education requires rigorous standardization due to its technical, regulatory, and patient-safety implications. The curriculum must ensure that graduates possess strong foundations in physics, radiation sciences, clinical applications, and the ability to work in regulated environments in alignment with AERB and international best practices.

2.1. Process of Curriculum Development

A uniform national Medical Physics curriculum was developed to meet evolving healthcare needs while adhering to the provisions of the NCAHP Act, ensuring high-quality education, regulatory compliance, and professional competency. The curriculum incorporates international educational models, including standards followed by globally recognized universities and recommendations from international bodies such as IAEA.

2.1.1. Constitution of the Medical Physics Task Force Committee

To ensure broad representation and address the multidisciplinary demands of the Medical Physics profession, the National Commission for Allied and Healthcare Professions (NCAHP) constituted a Medical Physics Task Force Committee with expertise from:

- Experienced Clinical Medical Physicists working in multidisciplinary department like Radiotherapy, Nuclear Medicine, Diagnostic Radiology and Proton Therapy
- Medical Physics academicians/representations from leading government and universities which is running courses from more than 20 years
- Researchers specialized in radiation physics & medical physics
- The Task Force used a standardized national framework to develop and recommend updated guidelines for Medical Physics education and training in India.

2.2. Curriculum Development Guidelines for Allied and Healthcare Professions

2.2.1. Scope of the Curriculum

The curriculum concept for Medical Physics has been designed with a forward-looking, patient-centric approach, ensuring that the educational experience prioritizes patient safety, care, and clinical relevance. It incorporates the latest advancements in medical imaging, radiation therapy, nuclear medicine, and diagnostic technologies, equipping students with cutting-edge knowledge and practical skills. Additionally, the curriculum is structured to align with global standards and best practices, facilitating international recognition and mobility, while fostering competencies that allow graduates to seamlessly adapt to evolving healthcare and research environments worldwide.

2.2.2. Mode of Education

In accordance with national guidelines, Medical Physics programs must be delivered strictly in full-time mode to ensure adequate academic rigor, clinical exposure, and hands-on training. The discipline requires continuous laboratory engagement, equipment handling, and supervised clinical practice in radiotherapy, diagnostic imaging, and nuclear medicine facilities, making part-time or distance-learning models inappropriate and unsafe. Full-time delivery ensures standardized skill acquisition, enhances student preparedness for real-world radiation environments, and promotes consistent compliance with regulatory expectations under the NCAHP Act and AERB norms.

2.2.3. Components of the Curriculum

The curriculum for Medical Physics encompasses a comprehensive framework that defines the profession, entry criteria, and qualifications along with the corresponding nomenclature, program duration, and residency requirements. It is structured around clearly defined competencies that guide the development of course content, ensuring that graduates acquire the knowledge, practical skills, and professional behaviours essential for clinical and research roles. The program includes a robust evaluation and assessment framework at each stage to measure learning outcomes. Faculty requirements, including hierarchy, designations, and minimum qualifications, are specified to maintain educational quality, while batch sizes and student-to-faculty ratios are optimized for effective training. Additionally, the curriculum incorporates recommended reference books, journals, and essential and desirable equipment to provide students with access to up-to-date resources and hands-on experience in modern medical physics technologies.

2.2.4. Alignment with Choice-based Credit System (CBCS)

In the context of Medical Physics, the curriculum structured following the **NEP 2020 and Choice Based Credit System (CBCS)** framework, which emphasizes flexibility, interdisciplinary learning, and continuous assessment. Each course is assigned a specific number of credits based on lecture, practical, and clinical training hours, allowing students to accumulate credits progressively toward program completion. Core, elective, and skill-enhancement courses are included to ensure both depth in Medical Physics and exposure to related scientific and technological domains. Assessment is continuous and multi-faceted, including theory, practical, project work, and clinical competencies, in alignment with NEP-CBCS principles.

2.2.5. Entrance Mechanism and Entry Criteria

Admission to Medical Physics programs should follow a structured and transparent entrance mechanism. Universities may consider national or state level examinations, or their own entrance assessments, ensuring that candidates possess strong foundations in physics at the undergraduate level. Given the advanced nature of Medical Physics education, bridging or remedial courses not been provided. The entry criteria are designed to ensure that incoming students have the academic readiness to succeed in rigorous scientific and clinical training.

2.2.6. Medium of Instruction

The medium of instruction for all Medical Physics programs is English, as the field relies extensively on international scientific literature, global safety protocols, and advanced technological documentation.

2.2.7. Desired Competencies and Skills

Competencies form the backbone of the Medical Physics curriculum and span knowledge, technical skills, performance criteria, and professional behaviours. The curriculum mandates measurable competencies across radiotherapy planning and QA, imaging physics, nuclear medicine instrumentation, radiation safety, regulatory compliance, medical device handling, and patient centered communication. Soft skills, including documentation, risk communication, and interdisciplinary collaboration, are emphasized. Competencies are mapped to assessments to ensure that graduates demonstrate safe and effective professional practice.

2.2.8. Common Preclinical and Paraclinical Subjects

All Medical Physics programs incorporate foundational subjects that help students understand human anatomy, physiology, pathology fundamentals, and radiobiology, ensuring they appreciate the biological effects of radiation on human tissues. Preclinical and paraclinical subjects provide essential context for the safe and effective application of physics in medicine.

Although the depth and credit weightage may differ from other health science programs, these subjects ensure Medical Physicists can collaborate effectively with clinicians and understand the clinical implications of radiation procedures.

2.2.9. Levels and Duration of the Program

Medical Physics education is structured across multiple levels to meet certification, regulatory, and professional practice requirements. The minimum duration for the Master's program (M.Sc. Medical Physics) is two years, followed by a mandatory one clinical residency required for clinical deployment. These durations align with international norms and ensure adequate exposure to radiotherapy planning, imaging QA, equipment commissioning, and safety systems. Doctoral programs (Ph.D. in Medical Physics) typically extend over three to five years and emphasize research, innovation, and academic leadership in the field.

2.2.10. Semester vs. Annual System

While curricula are designed in a semester-based structure for uniform credit distribution and progressive competency acquisition, universities may adopt either semester or annual assessment systems depending on their regulations. Where annual systems are used, compatibility tables ensure alignment with competency progression defined in the semester model. This flexibility accommodates institutional variations while maintaining national consistency in Medical Physics training standards.

2.2.11. Practical Exposure

Clinical exposure is central to Medical Physics training. All programs require structured, supervised residency postings in radiotherapy, diagnostic imaging, and nuclear medicine departments. Students gain hands-on experience in equipment calibration, QA procedures, treatment planning, imaging analysis, and radiation safety audits. Institutions must ensure access to well-equipped clinical facilities, either on campus or through MoUs with authorized hospitals. Stipends must be provided to interns, and transportation offered when off-campus facilities are used. A digital logbook tracks all competencies, procedures, and performance evaluations, ensuring transparency and accountability in clinical training.

2.2.12. Faculty Development

Faculty development is integral, requiring continuous training in emerging technologies such as image-guided therapy, AI-driven imaging, adaptive radiotherapy, and advanced dosimetry systems. Collaboration with industry and equipment vendors is encouraged to ensure that faculty and students remain updated with the latest advancements in medical radiation sciences.

2.2.13. Exit Examination

An exit examination/evaluation shall be conducted at the end of the Medical Physics Residency program to comprehensively assess the knowledge, skills, and clinical competencies required for professional practice, and this evaluation will be carried out by the designated residency supervisor, which may be considered as a form of third-party evaluation. A provision is included for 50% external assessment to ensure objectivity, transparency, and credibility in the overall evaluation process. In the future, this exit examination may evolve into a licensure-style assessment conducted through an NCAHP-nominated third-party examiner, selected from among experienced clinical Medical Physicists with more than 20 years of professional practice, thereby further strengthening the standardization and rigor of professional certification.

2.3. Task Force Meetings/Process

Based on the above guidelines, a series of structured online meetings, each lasting one to two hours, along with continuous email communication, discussions, and collaborative chat exchanges, were conducted to finalize the curriculum framework and overall program structure. These interactions facilitated systematic deliberations among experts to integrate clinical, academic, and regulatory requirements essential for Medical Physics education. Throughout the process, guidance from the NCAHP was actively sought and incorporated to ensure alignment with national standards, regulatory expectations, and the evolving needs of the healthcare system. The AMPI formed team had earlier proposed an outline of the draft curriculum, which was shared with the Council members a couple of months prior to the formation of the task force. This document has been referred to and utilized wherever necessary during the development of the current curriculum framework.

2.4. Draft Curriculum – Finalisation

A physical meeting was organized by the NCAHP at its Office in Delhi, among all the task force members on 19th November 2025 to finalise and approve the draft curriculum, enabling focused deliberations and collective decision-making on the remaining components of the Medical Physics program structure.

2.5. Curriculum – Finalisation

Based on the public feedback received from over 1,600 respondents, the draft curriculum was revised through deliberations with all members, wherever such revisions were justified and supported by appropriate rationale. Following these revisions, the curriculum was finalized and submitted to the Commission.

NATIONAL COMMISSION FOR ALLIED AND HEALTHCARE PROFESSIONS
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Chapter 3

Medical Physics in Health Care

3.1. Historical Development of Medical Physics

The profession of Medical Physics has its origins in the early 20th century, closely linked to the discovery and application of ionizing radiation in medicine. The foundation was laid soon after Wilhelm Conrad Roentgen's discovery of X-rays in 1895, followed by Henri Becquerel's discovery of natural radioactivity in 1896 and Marie and Pierre Curie's pioneering work on radium. These landmark discoveries revolutionized medical diagnostics and therapy, marking the beginning of radiological sciences and the eventual emergence of Medical Physics as a distinct discipline. [14.]

In the early decades of the 20th century, physicists and engineers began collaborating with physicians to optimize the use of radiation for both imaging and treatment. Their primary responsibilities included radiation dose measurement, calibration of equipment, and radiation protection. This practical need gave rise to the first generation of medical physicists, often working in hospitals or research institutions.

The profession gained formal recognition during and after World War II, particularly with advancements in nuclear physics, radiobiology, and computing technologies. The introduction of artificial radioisotopes, cobalt-60 teletherapy units, and linear accelerators further emphasized the need for trained physicists in hospitals. By the 1950s and 1960s, Medical Physics had evolved into a well-established academic and clinical profession, with formal education and training programs emerging in Europe and North America.

3.2. Early Developments and Pioneering Contributions

The use of physics in medicine began almost immediately after Roentgen's discovery of X-rays in 1895. Within weeks, physicians and physicists across Europe and America began experimenting with X-rays for diagnostic imaging and cancer treatment.

- In 1896, only a few months after Roentgen's discovery, Leopold Freund, a physicist and physician in Vienna, performed the first documented therapeutic use of X-rays to treat a skin lesion (a hairy mole in a young girl).[15.]
- Around the same time, Antoine Béclère in France and John Hall-Edwards in England were among the first to apply X-rays clinically for diagnostic purposes. [16.][17.]
- In 1898, the discovery of radium by Marie and Pierre Curie opened the path to brachytherapy and radioisotope applications in medicine.

These developments led to the emergence of a new role the hospital physicist, who assisted doctors in understanding and safely applying radiation. [xxi]

The field continued to expand with technological innovations such as CT, MRI, PET, and ultrasound imaging, as well as computerized treatment planning systems and radiation dosimetry. These developments diversified the role of medical physicists into specialized branches such as Radiation Therapy Physics, Diagnostic Radiology Physics, Nuclear Medicine Physics, and Radiation Protection.

Today, Medical Physics is a globally recognized healthcare profession that integrates physics, biology, and engineering principles for the diagnosis and treatment of diseases, particularly cancer. Medical physicists are integral members of multidisciplinary clinical teams, contributing to precision medicine, radiation safety, quality assurance, and research in emerging modalities such as proton therapy, artificial intelligence in imaging, and adaptive radiotherapy.

- Sidney Russ became the first physicist to be formally appointed by a British hospital (Middlesex Hospital in London) in 1913. This marked a pivotal moment in recognizing that physicists needed a formal role in clinical work. [14.]
- The first organized course in Radiological Physics is generally credited to the University of Chicago (USA), where Dr. Edith Hinkley Quimby and Dr. Robert K. Parker pioneered systematic training in radiation measurement and protection during the 1920s–1930s. [18.]
- In the United Kingdom, the British Hospital Physicists Association (BHPA) was established in 1943, which later evolved into today's Institute of Physics and Engineering in Medicine (IPEM). Around this time, structured hospital-based physicist training programs began, particularly in London and Cambridge.
- In Europe, the early 1950s saw the establishment of formal postgraduate programs in Medical and Radiological Physics in countries such as Sweden, Germany, and France.

3.3. Definition of the Profession and Professionals

- **Medical Physics** Medical physics is a branch of applied physics, pursued by medical physicists, who use physics principles, methods and techniques in practice, in the clinical environment and in research, for the prevention, diagnosis and treatment of human diseases with the specific goal of improving human health and well-being. Medical physics encompasses a wide range of applications in multiple areas and has recently been classified internationally as a profession [19]
- **Medical Physicists** are engaged in patient treatment planning, dose calculation, dosimetry, quality assurance & medical radiation physics for safe and effective medical use of ionizing & non ionising radiation.
- This profession has been recognised by The International Labour Organization's *International Standard Classification of Occupations (ISCO-08)* classifies Medical Physicists under the code "2111 – Physicists and Astronomers**"**,, In India, the National Commission for Allied and Healthcare Professions (NCAHP) also aligns Medical Physicists under the same ISCO code 2111
- **Dosimetrist:** The medical Dosimetrist (may also be called as Physics Assistant) is a member of the radiation therapy team who has knowledge of the overall characteristics of radiation therapy treatment machines and procedures normally used in external beam therapy and brachytherapy and has the education and expertise necessary to generate radiation dose distributions and dose calculations in collaboration with the medical physicist and radiation oncologist.

Dosimetrists are educated to perform duties under the supervision of CQMPs and radiation oncologists. It is necessary that appropriate supervision is available for all the actions and decisions taken by the medical dosimetrist. In addition, many tasks performed by medical dosimetrists include participation by additional members of the radiation therapy team, such as radiation therapy technologists and nurses [19]. They carrying out necessary procedures to initiate treatment planning process in, manual/computer generated dose calculations and participation in the review of patient chart, maintaining accurate documentation of all facets of the treatment plan, clinical dose measurement and machine calibration, support in brachytherapy source loadings, quality assurance procedures and radiation protection surveys. At different institutions, the relative levels of responsibility vary among the different members of the team to accomplish a given task. [19]

- In some countries, particularly in North America, a separate group of professionals, known as medical dosimetrists, has emerged. In most countries, the roles and responsibilities of medical dosimetrists are performed by CQMPs. [19]. Similarly, in India, the responsibilities that are typically performed by dosimetrists are carried out by Medical Physicists. Accordingly, The Medical Physics education framework, syllabus, and curriculum are systematically incorporated to encompass all components essential for the professional training of Medical Physicists and Dosimetrists, thereby ensuring robust theoretical proficiency and clinical competency. Accordingly, the Medical Physics programs and corresponding annual student intake are permitted in alignment with the national requirement for qualified healthcare professionals, thereby ensuring national requirement of qualified healthcare professionals, thereby meeting the clinical needs of the country without having separate course for dosimetrist.

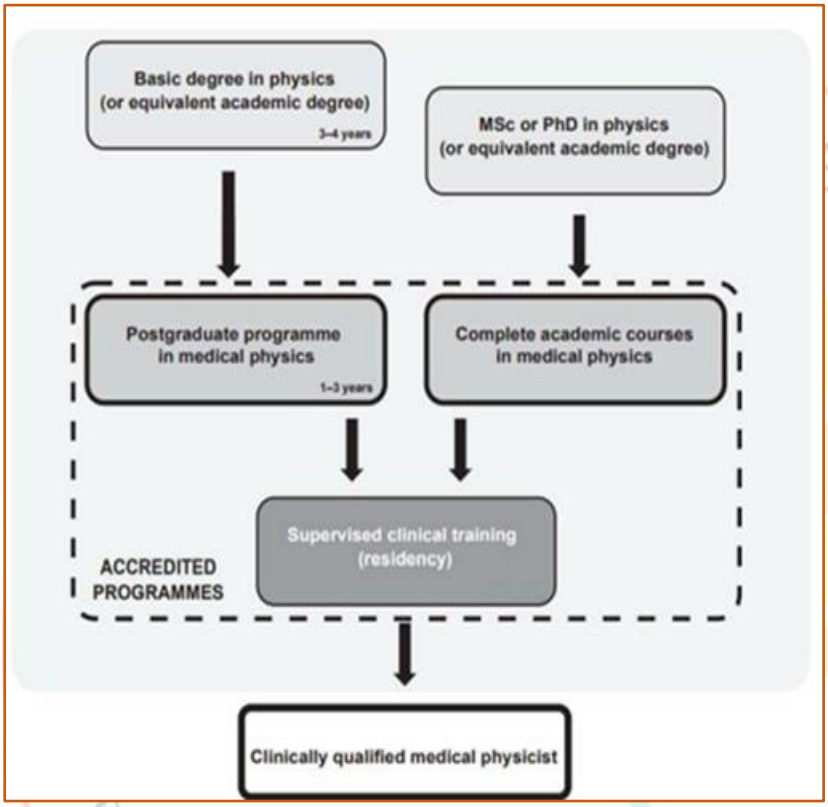
3.4. Medical Physics in India

Dr. Ramaiah Naidu was the pioneer medical physicist of India. For his doctoral thesis he worked with Madam Curie of Radium Institute, Paris under a Curie-Carnegie Research Fellowship. He joined the Tata Memorial Hospital in 1936. He established the radium plant facility in 1941.

The Radiological Physics and Advisory Division of BARC launched a training programme in Radiological and Hospital Physics in 1962 with support from WHO to develop qualified professionals for the safe use of ionizing radiation. This initiative later became an academic programme recognized by the University of Mumbai in 1972, awarding the Diploma in Radiological Physics (DipRP), which gained national and international acceptance. Over time, the faculty was drawn from BARC and other national institutions, and from 2007 onward the course has been conducted under HBNI.

As radiation use expanded, another pathway of Master's programme in Medical Physics was introduced in 1982 in Anna university in collaboration with Cancer Institute (WIA) Adyar Chennai, Tamil Nadu.

Since 2000, more institutions have begun offering either one of the models of Medical Physics programmes, and currently 27 universities run these courses in India under recognition from AERB. AERB mandates that radiation facilities employ qualified personnel, including Medical Physicists and RSOs trained through recognized programmes. To ensure adequate clinical competence, AERB made internship/clinical training a mandatory requirement for medical physicists from July 2013 onwards.



In fig :
The recommendations on minimum requirements for the academic education and clinical training of clinically qualified medical physicists. Successful completion of accredited programmes as shown within the dashed line in the figure, equips a medical physicist with the necessary knowledge, skills and competence to provide a safe and effective medical physics clinical service. [20.]

Presently, there are around 3700 qualified Medical Physicists providing their services to various healthcare centres, research institution, health care associated companies and regulatory authorities in the country. Various medical physics education and training programmes were started in the country to fulfil the demand of medical physicists in the country. India, being a Member State of IAEA since its establishment in 1957, IAEA provides a detailed pathway to be followed by one to become a clinically qualified medical physicist and So far India followed a similar pathway with minimal variation of residency/internship of one year majorly on radiotherapy instead of 2-3 years.

Since the national regulatory authority has not yet mandated the requirement for Medical Physicists in Nuclear Medicine and Diagnostic Radiology, while maintaining a mandatory provision for their involvement in Radiotherapy, the Indian Medical Physics programme was structured with a one-year clinical internship majorly focused on radiotherapy practice.

In the future, if regulatory bodies introduce mandatory requirements for Medical Physicists in Nuclear Medicine, Diagnostic Radiology, or other radiation based modalities, the proposed educational curriculum/framework is well positioned to adapt. If required, the duration of residency training may be extended through future revisions of the curriculum, or the distribution of training weightage across different modalities can be adjusted based on individual career path and department preference.

3.5. Philosophy of the Profession

The philosophy of the medical physics profession is grounded in the ethical and scientific application of physics principles for the service of humanity. It emphasizes that the use of radiation and technology in medicine must always be guided by precision, safety, and compassion.

The core values of the profession include:

1. **Scientific Integrity:** Commitment to accuracy, reproducibility, and evidence-based practice in all procedures.
2. **Patient Safety:** Ensuring optimal radiation dose with minimal radiological risk to patients, staff, and the public.
3. **Ethical Responsibility:** Upholding professional conduct, confidentiality, and regulatory compliance.
4. **Collaboration:** Working as part of multidisciplinary healthcare teams.
5. **Lifelong Learning:** Continuously updating knowledge and skills to keep pace with evolving technologies.

This philosophy positions the Medical Physicist as both a scientist and a healthcare professional, ensuring that technology serves humanity with responsibility and care.

3.6. General Description and work profile of Medical Physicists

Major Areas and Roles & Responsibilities of Medical Physicists

3.6.1. Radiotherapy Medical Physics

Medical physicists in radiotherapy ensure the safe and accurate delivery of therapeutic radiation. Their responsibilities include commissioning and calibrating linear accelerators and other treatment units, validating beam data, conducting routine quality assurance of equipment, and performing independent checks of treatment plans. They optimize dose distributions, verify treatment accuracy, participate in incident analysis, and maintain comprehensive radiation protection practices. They also advise on facility design, shielding, equipment procurement, and regulatory compliance, while contributing to clinical decision-making and staff training.

3.6.2. Diagnostic Radiology Medical Physics

In diagnostic radiology, medical physicists optimize imaging procedures to achieve high-quality images at the lowest reasonable radiation dose. They conduct acceptance testing of X-ray, CT, mammography, fluoroscopy, and interventional radiology equipment, followed by periodic performance evaluations. Their duties include patient dose assessment, dose-reference audits, equipment quality control, establishment of Diagnostic Reference Levels (DRLs), radiation safety for patients and staff, and protocol optimization. They support facility design and shielding calculations, ensure regulatory compliance, and provide education on radiation protection and imaging optimization to clinicians, technologists, and trainees.

3.6.3 Nuclear Medicine Medical Physics

Medical physicists in nuclear medicine oversee the safe and effective use of unsealed radioactive sources for imaging and therapy. Their responsibilities include specifying and commissioning nuclear medicine imaging systems such as gamma cameras, SPECT, and PET scanners, and establishing routine quality control procedures. They perform internal dosimetry for both diagnostic and therapeutic procedures, ensure safe radiopharmaceutical handling, develop radiation protection programmes, and supervise waste management. They support clinical workflow optimization, contribute to equipment selection and facility design, and ensure compliance with safety and regulatory requirements while providing training to nuclear medicine personnel.

3.6.4 Radiation Safety – Clinical

3.6.4.1 Ionizing Radiation Safety

Medical physicists play a critical role in ensuring radiation safety and quality in clinical environments where diagnostic imaging, nuclear medicine, or radiation therapy is performed. They are responsible for maintaining safe and effective use of ionizing radiation by monitoring, optimizing, and controlling exposure to patients, volunteers and staff. A core part of their role involves patient dose management, where medical physicists ensure that radiation doses are kept as low as reasonably achievable (ALARA) while still achieving the necessary diagnostic or therapeutic outcomes. They analyse dose levels, optimize imaging protocols, and evaluate treatment plans to balance safety with clinical effectiveness. Medical physicist plays crucial role in ensuring implementation of provisions for the safe transport of radioactive material being used in radiotherapy and nuclear medicine practices.

In addition, medical physicists conduct machine performance checks to verify the accuracy, calibration, and proper functioning of equipment used in radiotherapy, nuclear medicine and diagnostic radiology such as linear accelerators, CT scanners, and fluoroscopy units. Regular testing and preventive maintenance help detect mechanical or software issues early, minimizing the risk of radiation overexposure or equipment failure.

3.6.4.2 Non-Ionizing Radiation Safety

Non-ionizing radiation (NIR) sources other than MRI such as medical lasers, ultrasound systems, ultraviolet (UV) lamps, electrosurgical units, diathermy machines, therapeutic microwave devices, and LED-based phototherapy units pose several hazards in clinical environments, including eye injury, skin burns, tissue heating, cavitation, operating-room fires, and interference with pacemakers or other implanted devices. These risks make the role of the Medical Physicist essential in ensuring safe clinical practice, as they are responsible for developing safety protocols, performing equipment acceptance and quality assurance, establishing exposure limits, training clinical staff, monitoring compliance with NIR safety standards, and advising on protective measures such as shielding, PPE, and proper device operation. Through systematic oversight and evidence-based guidance, Medical Physicists play a critical role in minimizing accidental exposure, preventing device-related adverse events, and ensuring that all NIR technologies are used safely and effectively in patient care.

Comprehensive quality assurance (QA) programs are also established and supervised by medical physicists to ensure consistent performance, compliance with national and international safety standards, and reliability of all radiation-producing devices. Through these responsibilities, medical physicists safeguard patient safety, support clinical staff, and maintain the integrity and precision of medical imaging and therapeutic procedures in healthcare institutions.

3.6.5. Radiation Safety – Regulatory Aspect

Medical physicists possess specialized expertise in the principles of radiation protection, shielding design, which are fundamental to the safe establishment and operation of facilities utilizing ionizing radiation. The national Regulatory Authority, i.e. Atomic Energy Regulatory Board (AERB) recognizes the professional competence of qualified medical physicists in ensuring that all aspects of ionising radiation use such as facility lay out and planning, installation design, and infrastructure compliance meet national safety standards and align with international best practices.

Medical physicists, through their advanced academic training and technical proficiency, play a pivotal role in bunker planning and infrastructure design for diagnostic, therapeutic, and research installations. They calculate and verify structural shielding parameters, ensuring that radiation levels in controlled, supervised, and public areas remain within permissible limits. Their involvement is essential in limiting radiation exposure to occupational workers, and the general public through meticulous assessment of workload, occupancy factors, and radiation leakage pathways.

Subject to regulatory evaluation and compliance with AERB's requirements, medical physicists are particularly well-suited to discharge their responsibilities as serve as Radiological Safety Officers (RSOs) in institutions handling radiation sources and ensuring safe transport of radioactive material. In this capacity, they oversee the implementation of regulatory provisions for ensuring radiation safety, establishing radiation protection programme, safety protocols, monitor radiation levels in the facility, maintain documentation for regulatory audits, source inventory, and ensure infrastructure integrity throughout the facility's lifecycle. Their expertise reinforces a strong culture of safety, accountability, and regulatory compliance, ensuring adherence to the highest standards of radiation protection and sustainable infrastructure development as envisaged under India's regulatory framework for the peaceful applications of ionising radiation sources.

3.6.6 Research and Development

Medical physicists play a pivotal and indispensable role in the advancement and safe application of radiation-based technologies within the healthcare sector. Their expertise encompasses the design, development, characterization, and optimization of complex imaging systems and radiotherapy treatment equipment, ensuring that such technologies operate with the highest standards of precision, safety, and efficacy.

In the field of oncology, medical physicists contribute extensively to research and innovation in areas such as the theoretical modelling of radiation absorption, accurate dose calculation methodologies, advanced dosimetry techniques, and the development of novel modalities utilizing heat, lasers, and other physical agents in cancer therapy. They also contribute significantly to the field of radiobiology, enhancing the understanding of radiation interactions at cellular and molecular levels, which underpins the safe and effective application of radiation.

In nuclear medicine, medical physicists contribute to research and development in internal dosimetry, quantitative nuclear medicine imaging, and hybrid imaging technologies such as PET/CT and SPECT/CT. They play a key role in the establishment and implementation of quality assurance and quality control programmes, and in ensuring radiation protection of patients, occupationally exposed workers, and the public, in accordance with national and international safety standards.

Within imaging physics, medical physicists are at the forefront of research in image formation theory, detector design and characterization, and the development of methodologies for image quality assessment of CT and MRI. Their work also extends to the systematic investigation and mitigation of potential risks associated with diagnostic and interventional imaging procedures, thereby contributing directly to patient safety and the continual improvement of healthcare quality.

Medical physicists, through their scientific rigor and commitment to excellence, serve as a critical link between technology and medicine ensuring that innovations in radiation science translate into tangible benefits for patients, practitioners, and the nation's healthcare system at large.

3.6.7 Teaching

Medical physicists contribute significantly to the development of human resources and the strengthening of academic excellence in the domain of radiation sciences. Medical Physicists hold distinguished academic appointments in universities, research institutions, and teaching hospitals across the country, where they play a vital role in shaping the next generation of professionals in medical physics and allied disciplines.

They are actively engaged in teaching and mentoring at both undergraduate and postgraduate levels, delivering specialized courses in medical physics, radiation physics, and related scientific fields. In addition, medical physicists provide essential instruction and training to radiology and radiation oncology residents, medical students, medical physics residents, X-ray technologists/radiographers, radiation therapists, and nuclear medicine technologists, ensuring that all categories of healthcare professionals working with radiation possess the requisite knowledge of radiation safety, dosimetry, and equipment operation.

Through their academic leadership and continuous engagement in education and research, medical physicists contribute to the creation of a robust scientific foundation for the safe and effective use of radiation in medicine. Their role in academic and professional training not only advances national self-reliance in medical technology and safety practices but also upholds India's commitment to maintaining global standards of excellence in healthcare delivery and radiation protection.

3.6.8 Others

Medical physicists can play vital roles across a wide range of professional domains that extend beyond traditional clinical practice. They can become entrepreneurs, developing innovative technologies, software, and solutions that enhance medical imaging, radiation therapy, and healthcare efficiency. In sales and as product or application specialists, they can bridge the gap between manufacturers and healthcare providers by explaining complex technologies, ensuring proper implementation, and optimizing clinical use. As designers and project consultants, medical physicists can contribute to the planning, development, and integration of advanced imaging and therapeutic systems within healthcare facilities. They can serve as TSD (Technical Support and Development) experts, providing technical troubleshooting, installation support, and performance optimization.

Through mentorship and training, they can educate healthcare teams, technologists, and students on radiation safety, equipment operation, and quality assurance principles. Acting as QA service providers, they can ensure compliance with safety and regulatory standards, maintaining equipment accuracy and reliability. In leadership capacities such as CTO, technical advisor, or product specialist, medical physicists can guide research and development, lead innovation strategies, and advise on emerging technologies. Altogether, medical physicists can integrate scientific knowledge, technical skill, and clinical understanding to improve healthcare outcomes and promote technological advancement. Medical physicist possesses expertise to conduct probabilistic safety assessment (PSA) of healthcare equipment to minimise potential exposures and associated radiological risk. They can play an efficient role as leaders/co-ordinators during accreditation of health care units by the national /international accreditation such as Joint Commission International (JCI), National Accreditation Board for Hospitals & Healthcare Providers (NABH).

3.7. Importance of Medical Physicists to Healthcare

Medical physicists are integral to the safe and effective delivery of healthcare services involving the use of ionizing and non-ionizing radiation. Their professional expertise bridges the disciplines of physics, medicine, and technology, ensuring that diagnostic and therapeutic procedures are conducted with the highest standards of accuracy, safety, and efficiency.

The responsibilities of medical physicists vary according to their area of specialization such as diagnostic radiology, radiation oncology, nuclear medicine, or radiation protection, but their fundamental role lies in the application of physical sciences and associated instrumentation to improve patient care and clinical outcomes. They establish, implement, and maintain evidence-based protocols that optimize imaging quality, treatment precision, and radiation safety for both patients and healthcare personnel.

Medical physicists also play a pivotal role in addressing operational and technical challenges within healthcare facilities. In circumstances involving complex clinical cases, equipment malfunction, software or computational issues, or human error, they apply their analytical and problem-solving skills to identify root causes, implement corrective measures, and restore safe and efficient functionality. Through these activities, they ensure continuity of services and uphold the integrity of patient safety systems.

As healthcare technologies evolve, the role of medical physicists continues to expand to encompass quality assurance, equipment commissioning, radiation safety management, regulatory compliance, and innovation in clinical practice. Their contributions are essential in aligning institutional operations with national and international safety standards, including those established by the Atomic Energy Regulatory Board (AERB) and other competent authorities.

Recognizing the critical role of medical physicists reinforces a national commitment to safe, effective, and technologically advanced healthcare delivery. Policy frameworks that support their professional development, recruitment, and active participation in institutional decision-making are therefore vital to maintaining quality and safety across all radiation-based medical practices.

3.7.1. Equipment Selection

The medical physicist is required to maintain up-to-date knowledge of advancements in medical devices, technologies, and associated equipment relevant to their area of specialization. They are responsible for critically evaluating manufacturers' technical claims, assessing equipment performance as per BIS and applicable international standards and suitability in accordance with institutional objectives and available resources, and providing informed recommendations for procurement. Furthermore, medical physicists play a key role in negotiating technical specifications with equipment manufacturers and in defining precise performance and safety requirements within purchase and tender documentation to ensure compliance with regulatory and clinical standards. Medical physicists working within a manufacturer's team can play a crucial role in developing and customizing radiation-based equipment and systems to meet the specific requirements of each healthcare institution. By collaborating closely with clinicians, engineers, and administrators, these physicists can help design tailor-made solutions that align with an institution's clinical workload, infrastructure, and safety standards. Their deep understanding of radiation physics, dosimetry, and regulatory compliance enables them to optimize system performance, ensure compatibility with existing facilities, and enhance overall operational efficiency. Through this collaborative approach, manufacturer-team physicists contribute to the personalization of technology, ensuring that each installation not only meets technical specifications but also supports the institution's unique clinical objectives and safety goals.

3.7.2. Facility Design and Shielding

Medical Physicists, who is designated as Radiological Safety Officer (RSO) is characterized by complex infrastructure, installation, and safety requirements. In the process of siting, commissioning and operation of new medical devices, the medical physicist shall ensure that all infrastructural provisions are adequate to support safe and reliable operation. This includes verifying the suitability of electrical power supply, ventilation and climate control systems, emission monitoring arrangements, and radiation shielding & radiation environment, both for optimal equipment performance and for the protection of patients, personnel, and the general public.

RSO shall also ensure the incorporation of appropriate safety systems/sub-systems, interlocks, audiovisual monitoring systems for patient and operator observation, and other engineering and administrative controls necessary to mitigate potential risks associated with the use of radiation-emitting or high-energy equipment.

Where mandated by regulatory provisions, RSO is responsible for preparing and submitting detailed site and facility design report to the competent regulatory authorities for review and approval. Such submissions must include all relevant technical documentation and measurement data obtained through independent verification by the RSO, confirming that the design and final construction conform to prescribed safety and performance standards.

3.7.3. Acceptance Testing

Following the installation of new equipment or the upgrading of existing systems or major repair, the medical physicist shall be responsible for conducting a comprehensive series of acceptance tests and performance measurements to verify that the equipment meets the technical specifications and performance criteria stipulated during the purchase and procurement documents of manufacturer/supplier.

3.7.4. Commissioning

Medical physicists are responsible for conducting comprehensive and precise measurements to fully characterize the operational performance of medical equipment. The data obtained from these measurements shall be systematically analyzed, validated, and documented in a format suitable for routine clinical application, thereby ensuring accurate, safe, and consistent use of the equipment in patient care.

3.7.5. Computer Systems and Networking

Modern imaging and therapeutic equipment under the responsibility of medical physicists frequently involves the transfer and management of large volumes of data across diverse software platforms and hardware systems. These include, but are not limited to, Picture Archiving and Communications Systems (PACS), DICOM, RIS, hospital information systems, treatment control systems such as record-and-verify, and specialized software developed in-house by physicists or programmers.

Medical physicists, often in collaboration with information technology and systems support personnel, may serve as administrators for these integrated systems. In this capacity, they ensure the accurate and secure transfer of data between platforms, as well as the precise and reliable operation of imaging and treatment delivery devices under software control, thereby safeguarding both the quality of patient care and the integrity of clinical data.

3.7.6. Quality Assurance

Medical physicists are responsible for establishing and maintaining comprehensive, continuous quality assurance programs encompassing all aspects of medical device performance including decommissioning. They routinely conduct systematic reviews and evaluations of equipment and system metrics to ensure that the operation of devices is safe, appropriate, and optimized to meet the clinical needs of patients.

3.7.7. Safety

Medical physicists bear primary responsibility for ensuring the safety of staff, patients, comforters/carers and the general public with respect to any emissions originating from imaging or therapeutic equipment. As noted in Section II.B, certified medical physicists are recognized and designated by employer of healthcare facilities as Radiation Safety Officers (RSOs) under the Atomic Energy (Radiation Protection) Rules, 2004.

Besides the roles and responsibilities of RSO, medical physicists play a pivotal role in radiation safety programs. Their responsibilities include, but are not limited to, the application for and management of all regulatory licenses for facilities housing ionising radiation sources (i.e. radiation-emitting devices and radioactive materials); to advise on implementation of terms and conditions of regulatory licences, establishment and oversight of personnel dosimetry programs; performance of radiation protection surveys and wipe tests of sealed radioactive sources; design and verification of shielding and radionuclide storage; staff training in radiation safety and radiological physics; control of radioactive material inventory, acquisition, and disposal; and evaluation of, and communication with, appropriate regulatory authorities regarding any radiation incidents including the investigations. Medical physicists are central to ensuring that all aspects of regulatory compliance are met and maintained.

In parallel, MRI physicists collaborate with technologists and radiologists to develop policies and procedures for the safe conduct of MRI examinations. Certain patients, such as those with implanted medical devices (e.g., cardiac pacemakers), may be at risk, while others may safely undergo scanning only under specific conditions. The physicist evaluates the interaction between the MRI scanner and the medical device by reviewing technical specifications, consulting equipment manufacturers, and surveying relevant literature to determine whether the procedure poses an unacceptable risk to the patient.

3.7.8. Technique Development

Clinical procedures and techniques supported by medical physicists are continually evolving as advances in technology create new capabilities. These developments require an increasingly sophisticated understanding of the physical and biological principles relevant to the diagnosis and treatment of disease. The development, evaluation, and clinical implementation of novel methods and technologies constitute an ongoing and integral component of the professional responsibilities of medical physicists.

3.7.9. Teaching and Research

Medical physicists when designated as Professor/ Associate Professor/ Assistant Professor play a key role in the education and professional development of healthcare personnel. They are actively involved in teaching post-graduate students in medical physics, as well as teaching residents in radiology, nuclear medicine, and radiation oncology, and to technologists in radiology, nuclear medicine, and radiation therapy.

Medical physicists hold academic positions at universities, secure and manage research grants, supervise graduate students, and contribute to the advancement of the field by presenting research at scientific and medical conferences and publishing in peer-reviewed journals. Through these activities, medical physicists help cultivate a highly skilled workforce and contribute to the continuous growth of knowledge and innovation in medical physics and allied healthcare disciplines.

In the field of research, experimental Medical Physicists with their experimental skills and research capabilities contribute by developing precise instrumentation, refining measurement techniques, and validating new diagnostic and therapeutic technologies. While theoreticians strengthen the field by providing robust models, simulations, and analytical frameworks that deepen understanding of radiation interactions and imaging principles. Together they expand the frontiers of medical physics by enabling novel contrast agents, targeted therapies, nanoscale sensors, and innovative imaging platforms. Research in Medical physics and in the fringing fields, enrich both core and emerging areas of medical physics, fostering interdisciplinary growth and driving innovation in healthcare applications.

3.7.10. Sub-Speciality Responsibilities

A. Radiation Oncology

The primary responsibility of Radiation Oncology physicists is to oversee radiation treatment planning and delivery processes. This includes medical imaging, treatment planning, dose calculation, patient immobilization, the operation of treatment delivery devices, radiation interactions with matter, and the biological response of cells and tissues to ionizing radiation. Given the complexity of modern radiotherapy, these processes require oversight by professionals with a broad spectrum of technical and scientific expertise. Medical physicists, with their grounding in fundamental science and problem-solving skills, are ideally suited to this role and are generally recognized as the authoritative technical and scientific resource within a radiotherapy program.

The main responsibilities and functions of Medical Physicists in radiation oncology are described below:

(a) Design and layout of radiotherapy installation, technical specifications, acceptance testing, and commissioning of equipment, including the establishment of criteria for acceptable performance.

- Medical Physicists (MPs) play a vital role in the planning and installation of new or modified radiation therapy facilities. While the overall layout and structural design of the bunker and related rooms are prepared by architects or civil structure engineers, this process is carried out in close consultation with MPs. The MPs are responsible for performing detailed shielding evaluation in accordance with Atomic Energy Regulatory Board (AERB) requirements, and for specifying the appropriate thickness, material composition, and placement of shielding to ensure radiation safety of the public and the environment. This collaborative approach ensures that the final design not only meets functional and structural needs but also complies with national safety standards, thereby protecting patients, staff, and the general public. After installation, MPs further verify the adequacy of shielding by radiometry technique to confirm compliance and safety before clinical use.
- MPs have a leading role in preparing equipment specifications based on applicable national and international standards (e.g. IAEA, ISO, IEC, BIS) and), according to the needs of the radiation therapy facility, and they participate in the technical evaluation and purchase recommendation of the equipment. They analyse the functional requirements for clinical use, and specify the necessary conditions for integration, compatibility and connectivity to existing equipment of the equipment to be purchased.
- Following the installation of new equipment, MPs are responsible for specifying the basic standards to be applied for its acceptance and subsequent commissioning. They ensure that all units and systems function according to their technical specification and provide advice on any deviation of equipment performance from acceptable criteria, including guidance on decommissioning when appropriate. MPs also have, often in collaboration with computer engineers, responsibility for the verification of the computer systems and algorithms associated with the new equipment, and for ensuring that they are adequate for safe and effective clinical use.

(b) Calibration and verification of measurement instruments: CQMPs are responsible for the calibration of the instruments they use or are responsible for following recommended standards or codes of practice and keeping appropriate calibration records. They are responsible for developing procedures to determine the stability of the instruments for clinical use.

(c) Technical supervision of equipment operation, maintenance, modifications, if any and repair: MPs are responsible for authorizing the clinical use of radiation equipment after a maintenance procedure. For this purpose, they perform QC measurements of particular complexity after preventive or corrective maintenance, to ensure that the function of the equipment has not been affected by any alteration made during maintenance or repair. By verifying the proper function of the equipment, they aim to ensure optimal performance as well as patient and staff safety.

(d) Radiation safety and protection of patients, staff, comforters/carers and the general public: MPs have responsibilities in the development and implementation of a clinical radiation safety program for the radiation protection of the patient in radiation therapy. In the majority of cases however, they also have responsibilities with respect to radiation safety of the staff and the public, as it pertains to the radiation therapy service and infrastructure. MPs are responsible for developing the procedures needed for testing the integrity of the equipment and accessories, for the proper operation of interlocks and other safety aspects.

(e) Patient radiation dosimetry: MPs are responsible for establishing procedures for the calculation and verification of the radiation dose to the patient. Their duties include dosimetry measurements using ionization chambers and other detectors for the reference and relative determination of absorbed dose from external beam radiation therapy and brachytherapy sources, development of methods to analyse the results of dose measurements, and verification of the accuracy of dose distributions delivered to patients. Tasks related to patient dosimetry include:

- Acceptance Testing, Commissioning, Treatment Planning, and Dose Calculations: Qualified Medical Physics Specialists (MPs) are responsible for the acceptance testing, commissioning, and clinical integration of radiation generators, radioactive sources, and treatment planning systems (TPSs). This includes the acquisition and validation of all data required for safe and effective clinical use of both imaging and treatment units. In addition, MPs perform or supervise the dose calculations and measurements essential for optimizing patient dose distributions across different treatment modalities. These may involve manual calculations, computer-based simulations, and/or in-phantom measurements. As part of their role, MPs ensure the proper application of these calculations and the accuracy of image and data transfer to and from the TPS.
- They also typically act as administrators of the TPS, overseeing system security, data protection, import/export of data, backups, storage, archival, and system upgrades or updates, thereby ensuring the reliability, integrity, and compliance of the system in clinical practice.

- Patient dose verification: MPSs are responsible for patient specific dose verification measurements. They establish tolerances and action levels. This includes relevant in vivo dosimetry measurements using appropriate detectors.
- Additional tasks in brachytherapy: Subsequent to the calibration of the radioactive sources used for brachytherapy, but still as a component of the commissioning process, MPs are responsible for the comparison with the manufacturer's calibration certificates, resolving any discrepancy that may arise. To initiate treatments with manual after-loading implants, they are responsible for the transfer of the sources from the shielded safe to the patient's room, and for the necessary radiation survey after the sources have been inserted into the applicators. They make periodic QC measurements to ensure that the computer controlled movements of the source are accurate. MPs are responsible for producing policies and procedures to ensure the safety and protection of patients, staff and members of the public for this type of source.

They develop an emergency action plan, indicating the steps to be followed in the case that a source is lost or the computerized brachytherapy treatment system fails. When decommissioning a brachytherapy unit or sources, medical physicists are responsible for their radioactive waste disposal after removal of the source from the equipment.

(f) Optimization of physical aspects of therapeutic procedures: MPs have responsibilities for optimizing the physical and technical aspects of the therapeutic procedures used in their radiation therapy facility. This includes assisting in the selection of the appropriate positioning and immobilization aids for optimization of patient treatment plans according to the delivery techniques envisaged, overseeing the manufacture, QC and verification of beam shaping devices, performing the QA of the intensity modulation used for each treatment, defining the imaging protocols used for treatment planning and image guided radiation therapy (IGRT), and developing the methodologies used in the determination of set-up margins.

(g) Quality management of the physical and technical aspects of radiation therapy: MPs participate as team members in establishing a quality management program and have responsibility for the physical and technical aspects. Related tasks are:

- Developing institutional policies and procedures related to the use of ionising radiation sources, which includes responsibility for documenting and implementing new policies and procedures, or updating existing ones.

- Establishing QA programs and performing QC of all of the radiation generators (all radiation therapy imaging and treatment units), TPSs, radiation therapy networks, e.g. record and verify systems, and dosimetry equipment (ionization chambers and other detectors, electrometers, phantoms, scanners, etc.): One of the major tasks of QA in radiation therapy is the calibration of radiation sources. MPs are responsible for performing the calibration of radiation units and brachytherapy sources according to well established dosimetry protocols or codes of practice, and for ensuring compliance of radiation therapy equipment with national and international regulations and recommendations. They also verify the accuracy of the TPS and perform QC of individual treatment plans using independent dose calculation methods or systems.
- Depending on the frequency and complexity of the task, the QA programme shall be divided as follows: [21]
    - Daily Quality Assurance/Machine check: Performed by Radiotherapy technologists (RTTs), the results of which are to be overlooked and signed off by a medical physicist. RTTs performing the QA should be provided a detailed procedure document indicating how the test needs to be performed. If any test fails it needs to bought into attention of the medical physicist.
    - Monthly Quality Assurance: Performed by medical physicist/s or medical physics trainees, such as students or residents working under the supervision of medical physicists. This also requires assistance of RTTs for machine operation while QA is being done.
    - Annual Quality Assurance: Performed by medical physicist/s. The annual tests are usually more complex and require a greater understanding of the tests, test equipment, and all components of the linac. This also requires assistance of RTTs for machine operation while QA is being done.
    - Patient Specific Quality Assurance (PSQA): When the PSQA requires a phantom setup, that is performed by a medical physicist, while if there is no need for a phantom setup i.e. Portal Dose Imaging Prediction (PDIP), it can be done by RTTs and results of which are overlooked and analysed by the medical physicist.
- Performing risk assessments and identifying potential radiation emergencies, such as incidents resulting from equipment malfunction, human error or loss/missing of radioactive sources: MPs develop plans of action to be followed in the event of such occurrences and carry out drills to verify that they can be implemented correctly and effectively. In general, MPs try to find ways to minimize the risk in each case, adopt mandatory peer review processes, follow continuous quality improvement methods and participate in external audits whenever possible.

- Investigating unintended or accidental medical exposures: MPs have responsibilities in analysing all incidents related to equipment failure, accident, error or other unsolicited event which could result in patients receiving an undesirable exposure that was significantly different, higher or lower, from that prescribed. MPs provide consultation on the doses received by patients or personnel and on their associated risks, and recommend measures to minimize the likelihood of accidents happening again.

(h) Collaboration with other clinical professionals: MPs are key members of the team of clinical professionals, including medical practitioners, therapists and nursing staff, that work together in the treatment of malignant diseases. The contribution of MPs in this respect includes:

- Consultation with radiation oncology medical practitioners on patient cases, in order to establish the optimal treatment technique including patient positioning and immobilization aids and accessories, and beam modifiers that may be needed and manufactured for the best outcome: MPs provide treatment plan assessments and proposals on how to optimize them.
- Collaboration with the technology staff in the set-up, correct treatment delivery and dosimetry of patients: Advanced treatment modalities, especially during initial implementation, may require more intensive collaboration, e.g. intensity modulated radiation therapy (IMRT) and image guided radiation therapy (IGRT). Some modalities, e.g. stereotactic radiosurgery and permanent prostate seed implant brachytherapy, require the physical presence of the MPS during the procedure.
- Comprehensive quality management systems require the input of the MPs in regular peer review meetings, e.g. image review and new patient planning conferences.

B. Diagnostic and Interventional Radiology

In the field of diagnostic radiology and interventional, Medical Physicist focuses on optimizing the use and performance of imaging equipment including conventional x-ray, fluoroscopy, mammography, computed tomography, and ultrasound, ensuring maximum clinically relevant information while minimizing radiological risk to patients, staff, and the public. They are often recognized as the technical authority within a radiology department.

The main responsibilities and functions of MPs in diagnostic and interventional radiology are listed below:

(a) MPs are an essential part of the design team for new installations. They are responsible for shielding and installation design of new or modified radiology rooms, ensuring that all safety and legislative requirements are complied with, including dose limits. They calculate workload of diagnostic and IV procedures, and provide the thickness, material composition and placement of shielding and built-in design safety features needed to protect patients, staff and the general public, and supervise the construction, thus guaranteeing that all requirements of safety and functionality are met. They also verify the adequacy of the shielding after installation of equipment.

(i) MPs have a leading role in preparing equipment specifications and participate in the technical and safety evaluation and preparing procurement recommendation of equipment. They perform analysis of the technical and functional requirements for clinical use, and specify conditions for integration, compatibility and connectivity of the equipment to be purchased.

(ii) Following the installation of new equipment, or after any significant modifications or service, MPs are responsible for specifying the basic standards to be applied for its acceptance and subsequent commissioning. They ensure that all units and systems function according to their technical specifications and provide advice on any deviation of equipment performance from acceptable criteria, including guidance on decommissioning when appropriate. MPs also have, often in collaboration with computer engineers, responsibility for the verification of the computer systems; they assist medical practitioners in evaluating imaging or diagnostic algorithms for their safe and effective clinical use.

(b) Radiation safety and protection of patients, staff and the general public: MPs have responsibilities in the development and implementation of a clinical radiation safety program for the radiation protection of patients in areas where DIR equipment is used. In the majority of cases, however, the QMPS also has responsibilities with respect to the radiation safety of the staff and the public, as it pertains to the radiology service and infrastructure (e.g. stewardship for development of Radiation Management Plans). MPs are responsible for developing procedures for testing the integrity of the equipment and accessories (including personal protective equipment), for the proper operation of dosimetry equipment and other safety features. They also significantly contribute in the investigation of incidents involving radiation exposures and they provide the appropriate reports and documentation including lessons learnt and corrective & preventive measures.

(c) Patient dosimetry: MPs are responsible for establishing procedures for the calculation and verification of the radiation dose received by the patient. Their duties include dosimetry measurements as well as the development of methods to analyse the results of the measurements and verify the accuracy of doses delivered to patients. In special cases, duties also involve individual patient dose calculations. Tasks related to patient dosimetry include:

- Measurements and calculation of absorbed doses: MPs use data acquired during commissioning and information from dosimetry measurements to estimate the absorbed dose to patients during different clinical procedures (including MGD (mammography) and CTDIvol or DLP (CT)). This requires the use of analytical calculations, computerized models or in-phantom measurements. Judgement with respect to the applicability of the models used and the ability to synthesize new models is necessary, as well as knowledge to estimate dosimetry uncertainties.
- Specific patient dose calculations: MPs are responsible for the measurement and/or calculation of individual patient doses for research ethics applications and incidents and foetal doses in cases where a patient is found to be pregnant. This may include detailed measurements and the use of software to calculate effective dose. They establish tolerances and make judgements on the appropriateness of the measured data, including advice to the medical practitioner and the patient on any associated risks, especially those related to the induction of cancer.
- Patient dose estimations to establish diagnostic reference levels (DRLs), or to verify conformity with DRLs recommended by national or international authorities: MPs have responsibilities in reviewing procedures and equipment when DRLs are consistently exceeded in standard procedures. It may also be appropriate to set warning and notification levels for interventional procedures (e.g. angiography and cardiology).

(d) Optimization of physical aspects of diagnostic and interventional procedures: MPs have responsibilities in the optimization of the physical and technical aspects of the different processes used to produce medical images and the necessary imaging equipment (analogue and digital x-ray units, CT, angiography units, etc.). They also assist medical practitioners in the evaluation of examination efficacy and participate in image quality and perception studies.

(e) Quality management of the physical and technical aspects: MPs participate as team members in establishing a quality management program and have responsibility for the physical and technical aspects. They are primarily responsible for developing and implementing procedures for the initial and continuing evaluation of the DIR equipment as well as for the calibration of dosimetry equipment. Related tasks comprise:

- Developing institutional policies and procedures for the continuous optimization of radiation use, which includes responsibility for writing new policies and procedures, or updating existing ones.
- Establishing a QA program for verifying, setting and accepting the initial reference values of parameters for optimal image quality and the initial reference state of the imaging equipment: This includes developing and implementing QC, ensuring that periodic QC measurements are carried out for the x-ray units and associated equipment for image visualization, processing, storage and printing. MPs are also responsible for ensuring compliance of the imaging equipment with government and accreditation agency regulations and recommendations.
- Performing risk assessments and identifying possible radiation emergencies, such as incidents resulting from equipment malfunction or human error: MPs develop action procedures to be followed in the event of such occurrences and carry out drills to verify that procedures can be carried out correctly.
- Investigating unintended or accidental medical exposures, such as sentinel events in interventional radiology: MPs provide consultation on the doses received by patients or personnel and on the associated risks, and recommend measures to minimize the chances for accidents to happen again.

(f) Collaboration with other clinical professionals: MPs are key members of the team of clinical professionals, including radiological medical practitioners and other clinical specialists, radiographers and nursing staff, that work together for the diagnosis and treatment of patients. The contribution of medical physicists in this respect includes:

- Consultations to medical practitioners on special patient cases that may be encountered during diagnostic or interventional procedures that require additional actions to those routinely established: The collaboration between the medical practitioners and the MPs helps in establishing the optimal approach for each case.
- Assistance and providing advice to the radiology personnel in the implementation of new clinical procedures, being key members of the team responsible for the introduction of new clinical procedures in the institution: MPs are also responsible for developing methods for QA of the new procedures.

In addition to the above-described roles and responsibilities of the QMPS in diagnostic and interventional radiology, MPs working in medical imaging, due to their knowledge, training and professional focus, can contribute in MRI, they possess advanced knowledge of the complex physical principles underlying MRI technology. They serve as key technical and scientific resources within the medical team, overseeing equipment procurement, acceptance testing, and quality assurance. Medical physicists develop, evaluate, and optimize pulse sequences to enhance diagnostic image contrast, quality, and acquisition efficiency. Medical physicists develop acquisition and analysis procedures for magnetic resonance spectroscopy (MRS) and assist in interpreting spectra related to tissue chemistry medical physicists evaluate and support the use of higher magnetic field strengths, optimizing image quality while addressing associated technical and safety considerations. For advanced MRI applications, including functional MRI (fMRI), MRS, or dynamic contrast studies, MRGFUS treatment physicists provide expertise in image acquisition, analysis, and patient safety as integral members of the clinical team.

C. Nuclear Medicine

Medical Physicists in Nuclear Medicine focus on the use of unsealed radionuclides for diagnostic and therapeutic purposes. Their responsibilities mirror those in diagnostic radiology, encompassing equipment procurement, testing, radiation protection, dosimetry, teaching, research, and development.

The main responsibilities and functions of MPs in nuclear medicine are listed below:

(a) Installation design, layout and technical specification, acceptance and commissioning of equipment, including the establishment of criteria for acceptable performance: Within the technical specification, acceptance commissioning and supervision of the proper operation of the installation and its equipment, and the establishment of criteria for its acceptable performance, the following roles and duties must be considered:

- MPs are an essential part of the design team for new installations. They are responsible for shielding and installation designs of new or modified nuclear medicine facilities, ensuring that all safety requirements are complied with. They calculate and provide the thickness, material composition and placement of shielding needed to protect patients, staff and the general public, and design the system for the management of isotopes and radioactive wastes, thus ensuring that all requirements of safety and functionality are met. They also verify the adequacy of the shielding after installation.

- MPs have a leading role in preparing equipment specifications according to the needs of the nuclear medicine facility, and they participate in the tender evaluation and purchase recommendation of the equipment. They analyse the functional requirements for clinical use, and specify the necessary conditions for integration, compatibility and connectivity to existing equipment of the equipment to be purchased.
- Following the installation of new equipment, MPs are responsible for specifying the basic standards to be applied for its acceptance and subsequent commissioning. They ensure that all units and systems function according to their technical specification and provide advice on any deviation of equipment performance from acceptable criteria, including guidance on decommissioning when appropriate. MPs also have, often in collaboration with computer engineers, responsibility for the verification of the computer systems; they assist medical practitioners in evaluating imaging or diagnostic algorithms for their safe and effective clinical use.

(b) Radiation safety and protection of patients, staff and the general public: MPs have responsibilities in the development and implementation of a clinical radiation safety program for the radiation protection of the patient in nuclear medicine. In the majority of cases, however, they also have responsibilities with respect to the radiation safety of the staff and the public, as it pertains to the nuclear medicine service and infrastructure. MPs are responsible for developing the procedures needed for testing the integrity of equipment and radioactive sources and for the proper operation of the equipment. They establish policies and procedures for the safe transport of these radionuclides, for precautions in the case of contamination or spillage of unsealed radionuclides, and for the management of radioactive waste as required by regulations. MPs have responsibilities with respect to discharging the patient after radionuclide therapy, based on the potential exposure of the public. They have responsibilities for communicating with the patients to provide instructions that can further minimize the exposure of relatives and the public after discharge.

(c) Patient internal dosimetry: MPs are responsible for establishing procedures for the calculation and verification of the radiation dose received by different internal organs, as well as the total effective dose to the patient, resulting from the administration of radionuclide activity. They are also responsible for verifying the accuracy of such calculations. Tasks related to patient dosimetry include:

- Activity measurements and calculation of absorbed doses: MPs use activity distribution data and internal dosimetry methodology to estimate the dose absorbed by patients during different clinical procedures. This requires the use of manual or computerized models and/or in-phantom measurements. Judgement with respect to the applicability of the models used and the ability to synthesize new models is necessary, as well as knowledge to estimate dosimetry uncertainties.
- Specific patient dose calculations: MPs are responsible for the measurement and/or calculation of individual patient dose, as well as foetal doses in cases where patients are found to be pregnant; this is particularly important in therapeutic applications where dosimetry needs to be done for each patient. They also establish tolerances and make judgements on the appropriateness of the measured data, including advice to the medical practitioner and the patient on any associated risks, especially those related to the induction of cancer.

(d) Dose Estimations for Clinical Trials and Research: QMPS are responsible to provide dose reports and risk assessments to institutional research and ethics committees for clinical trials and research which include imaging procedures involving ionising radiation such as radiology and nuclear medicine procedures.

(e) Optimization of the physical aspects of diagnostic procedures: QMPs have responsibilities for the optimization of the physical aspects of the imaging systems (gamma cameras, single photon emission computed tomography (SPECT), positron emission tomography (PET), the latter two often combined with computed tomography (CT), etc.). They are responsible for the development and maintenance of a quality management program for all imaging equipment, so as to produce images of optimal quality while minimizing the radiation dose delivered to patients. MPs are also responsible for the equipment and instrumentation needed to ensure proper QC, optimal image quality, monitoring of patient exposure, and determination of dose to individual organs from different nuclear medicine imaging procedures, as well as for the use of the appropriate guidelines and techniques. They can also assist medical practitioners in the evaluation of examination efficacy and participate in image quality and perception studies.

(f) Radionuclide Therapy: Nuclear Medicine QMPS play a key role in the development, implementation, delivery, verification and maintenance of radionuclide therapy techniques:

- Ensuring the accuracy of the measured radioactivity;
- Ensuring the dose delivery of in-patient treatment facilities for each patient;
- Ensuring the safety of staff during the administration of the radiopharmaceutical;
- Ensuring the removal of any radioactive contamination of the treatment facilities following the discharge of the patient;
- The measurement of absorbed dose to the tumour(s)/Source Uptake value and to critical organs and determination of the activity to be administered from tracer dose administrations of the radionuclide, accounting for physical effects such as attenuation, scatter and partial volume effects;
- Providing advice on the appropriate radiation safety precautions to ensure that the patient's relatives and friends do not receive radiation doses in excess of the appropriate dose constraints' and
- Development of procedures and protocol for safe and effective introduction and use of novel radionuclide therapy technique. This may include advanced techniques such as Monte Carlo based dose calculations.

(g) Quality management of the physical and technical aspects of nuclear medicine: MPs participate as team members in establishing a quality management program and have responsibility for physical and technical aspects. Related tasks comprise:

- Developing institutional policies and procedures for the continuous optimization of radiation use, which includes responsibility for writing new policies and procedures, or updating existing ones.
- Establishing QA programs ensuring that policies and procedures are in place, with appropriate elements of good practice for handling of radioactive material, for radiation protection of patients, and for QC and regulatory compliance of equipment.
- Performing risk assessments and identifying potential radiation emergencies, such as incidents resulting from equipment malfunction, human error, radioactive spill or losses of radioactive sources: MPs develop action procedures to be followed in the event of such occurrences and carry out drills to verify that procedures can be implemented correctly. In general, MPs try to find ways to minimize the radiation risk in each case, adopt mandatory peer review processes, follow continuous quality improvement methods and participate in voluntary external audits whenever possible.

- Investigating unintended or accidental medical exposures: MPs have responsibilities in analysing all incidents related to equipment failure, accidents, errors or other unsolicited events which could result in patients receiving an exposure significantly different from that intended. MPs provide consultation on the doses received by patients or personnel and on the associated risks, and recommend measures to minimize the chances for accidents to happen again.

(h) Collaboration with other clinical professionals: MPs are key members of the team of clinical professionals, including medical practitioners, nuclear medicine technologists, radiopharmaceutical scientists and nursing staff, that work together for the diagnosis and/or treatment of patients. The contribution of medical physicists in this respect includes:

- Consultations with nuclear medicine medical practitioners on special cases where diagnostic tests or treatment require additional actions to those routinely established: The collaboration between the medical practitioners and the medical physicists helps in establishing the optimal approach for each case.
- Support and guidance to nuclear medicine technologists in the implementation of new clinical procedures, being key members of the team responsible for the introduction of new imaging or therapeutic procedures in the institution: MPs are also responsible for developing methods for QA of the new procedures.

(i) Teaching and training of radiation professionals such as NMTs and regular awareness training on radiation safety aspects for all in the department

3.8 Indicative Career Progression of Medical Physicist

The tables below indicate the various channels of career progression for distinct sectors i.e. clinical institutions, academic and industry where in medical physicists are engaged.

Table 3.1: Career progression in a scientific and research organisation (in absence of reputed growth chart from the institute in line DAE/DRDO/ISRO/ICMR)

Nomenclature	Qualification and experience	Promotion Criteria
Scientist C/Scientific Officer C/Medical Physicist C or equivalent	I.B.Sc. degree in science from a recognized university, with Physics as one of the main subjects. II. M.Sc. in (Medical Physics/Radiological Physics) or Post M.Sc. (Physics) Diploma in Medical Physics/Radiological Physics from an AERB/NCAHP III. Registration as a Medical Physicist under NCAHP and/or AERB	---
Scientific Officer D or equivalent	As above	1.Proficiency Test CR, self-appraisal & HOD Appraisal/DPC report or equivalent. 2. Minimum 4-year experience as scientific officer C or equivalent or PhD in the subject (Medical Physics/Radiological Physics). 3. Research Publications in indexed journal as 1st /2nd /3rd author or corresponding author during the tenure of Scientific Officer C

Nomenclature	Qualification and experience	Promotion Criteria
Scientific Officer E or equivalent	As above	1.Proficiency Test CR, self-appraisal & HOD Appraisal/DPC report or equivalent. 2.Min 5-year experience as scientific officer D or equivalent. 3. Research Publications in indexed journal as 1st /2nd /3rd author or corresponding author during the tenure of Scientific Officer D or equivalent.
Scientific Officer F or equivalent	As above + Ph.D. in Medical Physics/Radiological Physics/Physics	1.Proficiency Test CR, self-appraisal & HOD Appraisal/DPC report or equivalent. 2.Min 6-year experience as scientific officer E or equivalent. 3. Research Publications in indexed journal as 1st /2nd /3rd author or corresponding author during the tenure of scientific officer E or equivalent.

Nomenclature	Qualification and experience	Promotion Criteria
Scientific Officer G /or equivalent	As above	1.Proficiency Test CR, self-appraisal & HOD Appraisal/DPC report or equivalent. 2.Min 6-year experience as scientific officer F or equivalent. 3. Research Publications in indexed journal as 1st /2nd /3rd author or corresponding author during the tenure of scientific officer F or equivalent.
Scientific Officer H or equivalent	As above	1.Proficiency Test CR, self-appraisal & HOD Appraisal/DPC report or equivalent. 2.Min 6-year experience as scientific officer G or equivalent. 3. Research Publications in indexed journal as 1st /2nd /3rd author or corresponding author during the tenure of scientific officer G or equivalent.

Nomenclature	Qualification and experience	Promotion Criteria
Outstanding Scientist or equivalent	As above	1.Proficiency Test CR, self-appraisal & HOD Appraisal/DPC report or equivalent. 2.Min 7-year experience as scientific officer H or equivalent. 3. Research Publications in indexed journal as 1st /2nd /3rd author or corresponding author during the tenure of scientific officer H or equivalent.

Note: The promotion criteria outlined above 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.

Table 3.2: For Academic Stream (Teaching for MD and DNB programs, programs (Radiotherapy, Radio Diagnosis, Nuclear Medicine), Radiotherapy Technology (RTT) programmes, Nuclear Medicine Technology (NMT) courses, or Medical Physics programmes)

Designation	Eligibility and Experience (Direct Recruitment)	Eligibility and Experience (Promotion)	Annual Performance-based Appraisal
Demonstrator /Sr. Demonstraor	1. B.Sc degree in science from a recognized university, with Physics as one of the main subjects. 2. M.Sc. in (Medical Physics/ Radiological Physics) or Post M.Sc. (Physics) Diploma in Medical Physics/Radiological Physics from an AERB/NCAHP recognized institution. 3. Registration as Medical Physicist under NCAHP/AERB.		
Assistant Professor	1. B.Sc. degree in science from a recognized university, with Physics as one of the main subjects. 2. M.Sc. in (Medical Physics/ Radiological Physics) or Post M.Sc. (Physics) Diploma in Medical Physics/Radiological Physics from an AERB/NCAHP recognized institution.	Minimum four years' experience as above position /over all 4 years	• Annual appraisal by IQAC / HOD / Dean. • Minimum two conference presentations as above post • Minimum two presentations/publications as above post (preferably as first author) during tenure

Designation	Eligibility and Experience (Direct Recruitment)	Eligibility and Experience (Promotion)	Annual Performance-based Appraisal
	3. Registration as Medical Physicist under NCAHP/AERB recognized institution. 4. Ph.D. (Medical Physics / Radiological Physics / Physics related discipline) is preferable.		
Associate Professor	As above Educational qualification, + 10 years' experience as (Clinical /research/teaching) + Ph.D. (Medical Physics / Radiological Physics / Physics related discipline) is Mandatory. + Teaching experience is preferable	Minimum five years' experience as above position /over all 10 years + Ph.D. (Medical Physics / Radiological Physics / Physics related discipline) is Mandatory for promotion	• Annual appraisal by IQAC / HOD / Dean. • Minimum two conference presentations as above post • Minimum two presentations/publications as above post (preferably as first author) during tenure
Professor/ Head of Medical Physics Department/ Institute	As above Educational qualification, + 15 years' experience as (Clinical /research/teaching) + Ph.D. (Medical Physics / Radiological Physics / Physics related discipline) is Mandatory.+ Teaching experience is preferable	Minimum four years' experience as above position/over all 12 years.+ Ph.D. (Medical Physics / Radiological Physics / Physics related discipline) is Mandatory for promotion.	• Annual appraisal by IQAC / HOD / Dean. • Minimum 2 Ph.D. students guided and 5 additional publications as above post • Evidence of leadership, funded projects, or guiding Ph.D. students. • Expected to guide Ph.D. / M.Sc. dissertations

Designation	Eligibility and Experience (Direct Recruitment)	Eligibility and Experience (Promotion)	Annual Performance-based Appraisal
Sr. Professor/ Principal / Dean / Director (School of Medical Physics/School of Advance Sciences/School of Science)	As above Educational qualification, + 20 years' experience as (Clinical /research/teaching) + Ph.D. (Medical Physics / Radiological Physics / Physics related discipline) is Mandatory.+ Teaching experience is mandatory + academic and administrative leadership is preferable	Minimum four years' experience as above position/over all 20 years.+ Ph.D. (Medical Physics / Radiological Physics / Physics related discipline) is Mandatory for promotion Professor will be considered for Dean/Principal position.	• Minimum five conference presentations as Professor • Contribution in policy formulation, NAAC/NIRF accreditation, or national curriculum tenure • Publications, funded projects, and collaborations at national / international level.

Notes:

- All teaching faculty must possess NCAHP and AERB Registration
- Annual appraisal includes teaching load, mentorship, research contribution, and institutional duties.
- Promotion based on Academic Performance Indicator (API) as per UGC 7th Pay Commission Regulations/ University/Institution policy
- Publication norms should align with UGC standards.
- Wherever Medical Physicists are involved in teaching such as in MD programs, DNB programs, Radiotherapy Technology (RTT) programs, Nuclear Medicine Technology (NMT) courses, or Medical Physics programs, the institution may follow the guideline that best supports quality education and ensuring that teaching and academic activities for existing students are not adversely affected.
- RSO (Medical) shall be considered equivalent to NET for the purpose of eligibility, wherever applicable.

Table 3.3: For (Non-Academic/ Private/Corporate Hospitals)

Designation	Eligibility and Experience (Direct Recruitment)	Eligibility and Experience (Promotion)	Annual Performance-based Appraisal
Medical Physicist	1. B.Sc degree in science from a recognized university, with Physics as one of the main subjects. 2. M.Sc. in (Medical Physics/ Radiological Physics) or Post M.Sc. (Physics) Diploma in Medical Physics/Radiological Physics from an AERB/NCAHP recognized institution. 3. Registration as Medical Physicist under NCAHP/AERB.		Performance appraisal every year based on: • Teaching/learning activity • Contribution to departmental work • Research proposal or case-based study
Sr Medical Physicist/ Consultant Medical Physicist	As above Educational qualification + 5 years as Clinical Physicist.	Above Post + 5 years	Performance appraisal every year based on: • Teaching/learning activity • Contribution to departmental work • Research proposal or case-based study
Deputy Chief Medical Physicist/Sr. Consultant Medical Physicist	As above Educational qualification + 10 years as Clinical Physicist.	Above Post + 5 years	Performance appraisal every year based on: • Teaching/learning activity • Contribution to departmental work • Research proposal or case-based study

Designation	Eligibility and Experience (Direct Recruitment)	Eligibility and Experience (Promotion)	Annual Performance-based Appraisal
Chief Physicist/Sr. Consultant Medical Physicist	As above Educational qualification +15 years' experience as (Clinical Medical Physicist/research/teaching) + Ph.D. (Medical Physics / Radiological Physics / related discipline) is preferable	Above Post + 5 years	Performance appraisal every year based on: • Teaching/learning activity • Contribution to departmental work • Research proposal or case-based study
Head of Medical Physics/ Director of Physics	As above Educational qualification +20 years' experience as (Clinical Medical Physicist/research/teaching) + Ph.D. (Medical Physics / Radiological Physics / related discipline) is preferable	Above Post + 5 years	Performance appraisal every year based on: • Teaching/learning activity • Contribution to departmental work • Research proposal or case-based study

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Chapter 4

Infrastructure and Resources Requirements

4.1. General Conditions

4.1.1. Eligibility of Institutions

Only those institutions recognized by the Central Government, the University Grants Commission (UGC)/HECI, the Atomic Energy Regulatory Board (AERB), or the National Commission for Allied and Healthcare Professions (NCAHP) Council shall be eligible to conduct the Medical Physics Programme.

4.1.2. Student Intake

The maximum permissible intake for the Programme in existing institutes shall be thirty (30) students, subject to the availability of adequate infrastructure, sanctioned faculty positions, laboratory facilities, and clinical teaching material. Notwithstanding the above, any institution initiating the Programme for the first time shall be permitted to admit not more than ten (10) students during the initial academic year. Such institutions may be permitted to enhance the intake up to a maximum of twenty (20) students only after upgradation of infrastructure and upon verification and approval by the competent regulatory authority.

The University shall assume full responsibility for entering into Memoranda of Understanding (MoUs) with various hospitals for residency intake to accommodate its enrolled students. MoUs covering not less than 75% of the sanctioned student intake shall be in place for the course to be conducted.

4.1.3. Institution–Hospital Linkage

The Institution offering the Programme shall have an attached accredited/ recognised hospital or a valid Memorandum of Understanding (MoU) with a hospital having fully functional Departments of:

- Radiotherapy / Radiation Oncology,
- Nuclear Medicine, and
- Diagnostic Radiology.

4.1.4. Medical Physics Department

Both the Institution and the attached/MoU Hospital shall maintain a dedicated Department of Medical Physics. For fully hospital-based institutions, a single integrated Medical Physics Department may be established. The Head of the Department / Programme Director / Course Director shall be a qualified Medical Physicist possessing the requisite academic qualifications and professional experience as prescribed by the competent regulatory authority under the NCAHP Council.

For a student intake of up to fifteen (15) students per academic year, the University/College shall appoint a Programme Director in Medical Physics. For a student intake of more than fifteen (15) students per academic year, the University/College shall establish a full-fledged Department of Medical Physics with a designated Head of Department.

4.1.5. Medical Physics lab

The Institution and the attached/MoU Hospital shall ensure the availability of adequate laboratory facilities, simulation and modelling lab, medical imaging lab, radiation therapy lab, electronics/instrumentation lab and radiation-measuring instruments necessary for equipment calibration, quality assurance program and radiation protection, in full compliance with the standards and directives issued by the NCAHP Council.

4.2. Eligible Institution

The following entities shall be eligible to apply for permission to establish and conduct a Medical Physics Programme, namely:

1. The Central Government, any State Government, or a Union Territory Administration;
2. An autonomous body constituted or promoted by the Central Government and/or any State Government, whether established by or under an Act for the purpose of health sciences education;
3. A University, a Deemed-to-be University, or a private institution affiliated to a Government University, duly recognized by the competent statutory authorities;
4. An organisation registered under the Societies Registration Act, 1860 (21 of 1860) or any corresponding State legislation, including missionary organisations engaged in health sciences education or healthcare service delivery;
5. A public trust or charitable trust registered under the Indian Trusts Act, 1882 (2 of 1882) or under the relevant State Trusts Act.

4.3. Functional Requirements

4.3.1. Resolution of the Trust / Management

The applicant institution shall submit a duly authenticated Resolution of the Trust, Society, Governing Body, or Management, explicitly indicating:

- the name of the institution, and
- the name of the program proposed to be started or currently being conducted.

All academic matters, including proposals, guidelines, or recommendations, shall first be placed before the Board of Studies (BoS) in Medical Physics/School of Advance Science/School of Science, followed by consideration and approval by the Standing Committee on Academic Affairs (SCAA) of the Institution, and subsequently ratified by the University Syndicate, as per institutional norms.

4.3.2. Land Requirements

The Institution (College/University and Hospital) shall provide details of the land on which the academic programme will be established. The land shall be in the name of the applicant Society, with valid proof such as Sale Deed, Lease Deed, Gift Deed, or equivalent. In case the land is held under a lease agreement, the lease period shall be for a minimum of five years from the date of admission notification.

4.3.3. Regulatory Permissions from Competent Authorities

4.3.3.1. Government Permissions

Both the Institution and the attached/MoU Hospital shall obtain all requisite permissions, recognitions, approvals and No-Objection Certificates (NOCs) from the State/central Government and the Local body authorities, including approvals relating to land use, building compliance, structure stability, institutional operations, and public health requirements, Lift, Licence and as mandated under applicable State statutes and regulations.

4.3.3.2. Fire Safety & NBCI Compliance

Both the Institution and the attached/MoU Hospital shall obtain a valid Fire and Life Safety Clearance from the State Fire and Rescue Services Department, certifying compliance with all prescribed fire safety norms, fire-fighting installations, building safety standards, and emergency response systems. The clearance shall be maintained in force at all times and renewed within the validity periods prescribed by the Fire Safety Authority.

The buildings shall comply with National Building Code of India (NBCI) guidelines and be barrier-free, ensuring accessibility for persons with disabilities.

4.3.3.3. Atomic Energy Regulatory Board (AERB) Permissions

Both the Institution and the attached/MoU Hospital shall obtain all necessary Licences, Approvals and Consents from the Atomic Energy Regulatory Board (AERB) for handling the radiation generating equipment's and radioactive sources, wherever applicable.

All radiation facilities shall possess valid AERB licences and adhere strictly to AERB Safety Codes, Directives, and Regulatory Guidelines.

4.3.3.4. PCPNDT Act Registration

Where diagnostic imaging services fall within the scope of the Pre-Conception and Pre-Natal Diagnostic Techniques (Prohibition of Sex Selection) Act, 1994, the Institution shall obtain mandatory registration under the PCPNDT Act from the Appropriate Authority. Both the Institution and the attached/MoU Hospital shall maintain all statutory records and mandatory reporting in strict conformity with the Act, Rules, and notifications issued by the Central and State Supervisory Boards.

4.3.3.5. Continuous Compliance

Both the Institution and the attached/MoU Hospital shall ensure that all licences, permissions, certificates, and registrations obtained from State, Central, and Statutory Authorities remain valid, current, and compliant at all times.

Any renewal, modification, or compliance requirement mandated by the issuing authorities shall be promptly addressed and documented by the Institution.

4.3.3.6. Approved Site and Building Plan

Both the Institution and the attached/MoU Hospital shall submit attested copies of the approved Site Plan and Building Plan, covering the Academic Block, Administrative Block, Hostels, Playgrounds, and other essential facilities, as sanctioned by the Local Self Government authority.

4.3.3.7. Environmental and Waste Management Compliance

Both the Institution and the attached/MoU Hospital shall implement adequate pollution control and waste management systems, wherever applicable, including

a) biomedical waste disposal mechanisms,
b) solid waste management arrangements and
c) a sewage treatment plant (STP).

4.3.4. Financial Statements

The application shall be accompanied by authenticated financial documentation, as follows:

- For non-governmental organizations: an attested copy of the Audited Balance Sheet for the preceding three (3) financial years;
- For government institutions: a certified statement of the budget allocation from the parent Government authority.

4.3.5. Mandatory Institutional Undertaking

Both the Institution and the attached/MoU Hospital shall furnish a legally binding Undertaking, affirming that it shall:

- Operate the college/institute/hospital and conduct admissions in strict accordance with all Acts, Statutes, Rules, Regulations, Orders, Circulars, and Instructions issued by the Statutory Councils, NCAHP, AERB, University, Central Government, and State Government;
- Appoint and maintain adequate teaching and non-teaching staff in accordance with prescribed norms, ensuring compliance with the stipulated Teacher–Student Ratio;
- Provide complete cooperation for all inspections, whether scheduled or surprise, conducted by the Statutory Councils, NCAHP, AERB, University authorities, or Government agencies;
- Make available all records, documents, facilities, and personnel required for verification, assessment, or audit by competent authorities.
- Submission of the Yearly Submission Checklist Proforma to NCAHP is mandatory for all institutions for continued compliance.

4.3.6. Space, Lab & Faculty Requirements

4.3.6.1. Both the Institution and the attached/MoU Hospital shall have adequate space to have facilities mentioned in clause 4.5 & 4.6 wherever applicable

- Academic Departments and laboratories;
- Faculty and administrative offices;
- Classrooms, seminar halls, and library;
- Hostel and residential facilities; and
- Ancillary facilities & Others

4.3.6.2. Faculty Requirements: Both the Institution and the attached/MoU Hospital shall appoint qualified faculty in accordance with in clause 4.7 wherever applicable

Faculty positions shall be sufficient to maintain the prescribed teacher-to-student ratio**,** ensuring high-quality teaching, supervision, and clinical exposure for students.

4.3.7. Accessibility and Transport

The Institution shall be established either on a unitary campus (College & Hospital) or a maximum of two campuses, with adequate constructed area on each campus as per prevailing building norms.

Where College and Hospital are on separate campuses, the distance shall not exceed a reasonable limit within the 30 km**,** ensuring practical accessibility for students and staff.

4.3.8. Amenities Facilities

Both the Institution and the attached/MoU Hospital buildings shall

- be designed to accommodate the maximum number of students permitted for admission, as prescribed by the Council.
- Adequate parking space, recreational areas, and open spaces for students shall be provided in accordance with applicable Government norms.
- provide continuous electricity supply, including generator backup, and CCTV surveillance for common areas as per prescribed norms.
- Adequate and safe drinking water and toilet/restroom facilities shall be provided for students and staff at all times.
- ensure good connectivity with public transport**,** with bus stops or other public conveyance options available within 500 meters of the campus**.**
- provide adequate facilities for student welfare**,** Common rooms; Cafeteria / Canteen for students, staff, and guests; Cultural and extracurricular activity spaces; Yoga and physical training areas; Gymnasium; Indoor and outdoor games facilities.

4.3.9. Renewal of the Course Licence

The course approval shall require renewal at a frequency of not more than three (3) years.

4.4. Memorandum of Understanding (MOU) Between Hospital and University/Institution/College

4.4.1. Scope of Agreement

The MOU shall cover, without limitation, the following obligations:

a. Allocation of hospital-based Medical Physicists for teaching and clinical training; Minimum number:
b. Teaching-sharing ratio between Hospital and University/College faculty;
c. Engagement of clinical consultants for lectures, demonstrations, and practice-based training;
d. Mode of engagement (Part-Time & ratio of clinical & teaching) for all teaching personnel; As specified in their appointment/work order and the MOU.
e. Duration, renewal, and termination conditions of the MOU;
f. Access to clinical departments, equipment, library and patient care areas for practical training;
g. Compliance with all applicable regulations, guidelines, and statutory requirements, including AERB, NCAHP, University statutes, and Central/State legislation;
h. Detailed teaching plan including lecture hours at hospital, laboratory hours, proposed to taught, assigned teaching team, and academic/clinical allocation ratio.
i. lecture hours at Hospital and Laboratory hours shall be specified in the MOU;
j. Subjects/papers, teaching team composition (Medical Physicists, clinical consultants), and academic/clinical allocation ratio shall be defined
k. Residency students intake shall be specified in the MOU

4.4.2. Obligations

Clinical consultants and Medical Physicists shall fulfil teaching obligations as specified in MOU;

4.4.3. Signing Authorities

All signatories identified herein shall execute this Memorandum of Understanding (MOU), and their signatures shall constitute full and binding acceptance of all terms, obligations, and responsibilities contained herein. No party shall be deemed to have agreed to or be bound by this MOU unless duly signed by all required representatives of both the University/College and the Hospital.

4.4.3.1. University/College Side

- Head of the Institution/ Registrar with the approval of Vice Chancellor or Pro Vice Chancellor, authorized to bind the University/College to the terms of this MOU.
- Head of Department of Medical Physics, responsible for academic and faculty coordination.
- Head of Finance (if applicable) responsible for financial compliance and obligations.

4.4.3.2. Hospital Side

- Head of Institution, authorized to bind the Hospital to the terms of this MOU.
- Head of Finance, responsible for financial compliance and obligations.
- Head of Department, Medical Physics and departmental RSO, responsible for clinical training, radiation safety, and teaching obligations.
- Head of Department, Radiation Oncology, responsible for clinical training, radiation safety, and teaching obligations.
- Head of Department, Nuclear Medicine, and departmental RSO, responsible for clinical training, radiation safety, and teaching obligations.
- Head of Department, Radiology, and departmental RSO, responsible for clinical training, radiation safety, and teaching obligations.
- Head of Department, Medical Physics responsible for coordination of medical physics teaching, QA, and regulatory compliance.

4.4.4. Dispute Resolution

4.4.4.1. Amicable Resolution

Any dispute, difference, or claim arising out of, or in connection with, this Memorandum of Understanding (MOU), including matters affecting the conduct of academic or clinical training, shall first be referred to the respective authorities of the Hospital and the University/Institution for amicable resolution.

During the dispute resolution process, the ongoing education and training of students shall continue without interruption, unless otherwise directed by regulatory authorities.

4.4.4.2. Referral to Regulatory Authorities

If the dispute cannot be resolved amicably within a reasonable period, the matter shall be referred to the National Commission for Allied and Health Professions (NCAHP) or the affiliating University for adjudication.

The decision of NCAHP / affiliating University shall be final and binding on both parties, and shall be exhausted prior to any recourse to courts or other legal forums.

4.4.4.3. Legal Recourse

Only upon exhaustion of the internal and regulatory resolution mechanisms outlined above, either party may approach a competent court of law for enforcement of rights or remedies, in accordance with applicable statutory provisions.

4.5. Institute/College Medical Physics Department Facility Requirements

4.5.1. Medical Physics Laboratory

The Department shall include a Medical Physics, Physics, & Electronics and Instrumentation Laboratory equipped with adequate space of approximately 1000 sq. ft along with following equipment's:

- Multimeters, oscilloscopes, power supplies, signal generators, and associated components;
- Geiger-Muller counters (minimum 2) with sources;
- Alpha counting system with sources;
- Pressurized ion chamber-based survey meters and pocket dosimeters;
- Single-channel and multi-channel analyser-based gamma spectrometer with sources;
- Thermo-luminescence dosimeter (TLD) / Optically Stimulated Luminescence Dosimeter (OSLD) reader systems.

4.5.2. Computer Laboratory / IT Facilities

The Department shall provide computer student ratio 1:3 equipped with simulation and computational software, including but not limited to MATLAB, Python, Geant4, and treatment planning systems.

The computers shall have high-speed internet connectivity and access to workstations with basic computational and simulation software for academic and research purposes.

4.5.3. Library and Learning Resource Centre

4.5.3.1. Library

The Institution shall provide a Library accessible to all students, faculty, and staff of the Medical Physics Programme.

The library shall contain:

a. A minimum of two books of two sets of standard/reference textbooks for each paper prescribed in the syllabus;
b. Reports and publications from major international medical physics organizations, including but not limited to the AAPM Medical Physics, IAEA Reports, ICRU, ICRP.

c. The Institution shall maintain mandatory Essential Journals, with applicable licensing and subscription requirements**:**
    - Medical Physics (AAPM)
    - Physica Medica
    - Physics in Medicine & Biology (PMB)
    - Journal of Applied Clinical Medical Physics (JACMP)
    - Journal of Nuclear Medicine
    - Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment
    - Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms
    - British Journal of Radiology (BJR)

4.5.3.2. Digital Resources and ONOS Access

The Institution shall ensure that the library provides lawful, continuous, and unrestricted access to authenticated online repositories, academic databases, electronic journals, and digital resources from recognized national and international publishers and professional organizations. Such access shall include, but shall not be limited to, resources made available through Wiley, Elsevier, Springer Nature, PubMed, the International Organization for Medical Physics (IOMP), and the International Atomic Energy Agency (IAEA).

The Institution shall maintain mandatory access to the following Journals, without interruption and in accordance with applicable requirements**:**

- Journal of Medical Physics
- Physics and Imaging in Radiation Oncology (phiRO)
- Frontiers in Physics – Medical Physics & Imaging
- Journal of Cancer Research and Therapeutics
- British Journal of Radiology (BJR)
- Indian Journal of Radiology and Imaging (IJRI)
- World Journal of Nuclear Medicine
- Indian Journal of Nuclear Medicine (IJNM)

The Library shall include access to the One Nation One Subscription (ONOS) portal, providing the following resources:

- High-impact international journals and scholarly publications issued by multiple recognized publishers and relevant to Medical Physics and allied health sciences.
- Online academic databases pertaining to Medical Physics, Radiotherapy, Diagnostic Imaging, Nuclear Medicine, Radiation Dosimetry, Radiation Protection, and related scientific disciplines.
- Reports and publications from major international reference organizations, including ICRU and ICRP.

4.5.4. Lecture Hall, Seminar Halls & Others

4.5.4.1. Lecture Hall

The Institution shall provide a minimum of two smart classrooms, each with:

- Seating capacity of at least 50 students;
- Smart board, projector, and audio-visual facilities;
- Proper ventilation, lighting, and furniture arrangements as specified above.

4.5.4.2. Seminar Hall

The Institution shall provide a minimum of one seminar hall with:

- Seating capacity of at least 50 persons;
- Projector and smart audio-visual setup;
- Built-in black/green/white boards;
- Adequate ventilation and proper lighting;
- Desk/dais or large table with chair for the teacher;
- Racks or cupboards for teaching aids and other necessary equipment.

4.5.4.3. Examination Hall

The Institution shall provide an examination hall equipped with:

- A surveillance camera system of required specifications in working condition;
- Communication signal jammer of required specifications in working condition, in compliance with examination security norms.

4.5.4.4. Auditorium / Multipurpose Hall

The Institution shall provide a large auditorium with:

- Seating capacity for 200-300 persons;
- Adequate electrical and seating arrangements;
- Audio-visual system facilities.

4.5.4.5. Faculty Rooms/Office

The University shall provide dedicated office and academic spaces in accordance with the prescribed minimum area requirements.

The Dean/Director/Principal shall be allotted an office of 250 sq. ft., while the Professor (HOD) shall be provided an office of 140 sq. ft. Each faculty member shall be provided a separate office of not less than 100 sq. ft. Visiting Faculty Room of 100 sq. ft

Common Staff Rooms of 100 sq. ft. each, a. Seminar/Conference Room of 700 sq. ft. (adequate for 50 persons), and a Classroom of 350 sq. ft. per year of intake shall be made available. Separate Students' Common Rooms for girls and boys, each measuring 200 sq. ft., shall be provided, along with a Library with Reading Room of 180 sq. ft., a Discussion Room of 180 sq. ft. Each faculty office shall be equipped with a work desk, computer workstation, overhead storage units, and shelving to ensure adequate functional and academic workspace.

4.6 Clinical Hospital Requirements

4.6.1. General Criteria and Ancillary Facilities

The hospital shall have been operational for a minimum of two years prior to submitting the application, with fully functional departments in Medical Physics Radiotherapy, Nuclear Medicine, and Diagnostic Radiology, meeting all applicable regulatory and clinical standards.

The Hospital shall provide the following support facilities:

a. Patient waiting and observation area;
b. Emergency resuscitation facility, including crash cart with oxygen, suction, and essential drugs;
c. Radiation treatment records and Picture Archiving and Communication System (PACS);
d. Immobilization device workshop for fabrication of thermoplastic masks, casts, and related devices;
e. Mould room equipped with:
    i. Water bath;
    ii. Vacuum pump system;
    iii. Plaster and thermoplastic material setup;
    iv. Cutting and finishing tools;
f. Anatomy and Physiology laboratory, including:
    i. Human skeleton model;
    ii. Disarticulated bone set & Specimens

4.6.2. Radiotherapy Department – Clinical Facilities

The Department shall include the following facilities with adequate space as per AERB and other regulatory requirements, with an approximate total area of 3,500 sq. ft

4.6.2.1. Linear Accelerators (LINAC)

a) Linear Accelerator (LINAC) The Hospital shall have preferably two or more LINAC units, Multi-Energy (Photons and Electrons), including C-ARM, Robotic, Ring Gantry, or MR LINAC systems. At least one LINAC shall provide the full range of clinical photon energies (6 MV, 6 FFF, 10 MV, 10 FFF, 15 MV) and electron energies (6 MeV-18 MeV).
b) The LINAC providing the full range shall be less than nine years old from the date of commissioning to the date of admission notification each academic year. If the LINAC exceeds nine years in age, the Hospital shall obtain a formal undertaking from the Original Equipment Manufacturer (OEM) confirming support for a minimum of three years prior to admission notification each academic year.

c) The hospital shall enter into and maintain a valid Comprehensive Maintenance Contract (CMC) with the Original Equipment Manufacturer (OEM) for all applicable equipment, and shall renew or update the contract as required from time to time.
d) Minimum patient treatment: 40 patients/day.
e) Capabilities: 3D-CRT, IMRT, VMAT, IGRT with CBCT, Stereotactic cranial/extra cranial radiotherapy.
f) Deep Inspiration Breath Hold (DIBH) or Automatic Breath Control (ABC).
g) Preferably equipped with a Big Bore CT Scanner dedicated to Radiotherapy.
h) Preferably 4D CT capability with slice thickness ≤ 0.6 mm.
i) Telecobalt unit (optional for training exposure).

4.6.2.2. Brachy therapy Facility

a) HDR (High Dose Rate) Remote After loading Unit: The hospital shall have a minimum of one HDR remote after loading unit, with a work load of four on-couch treatments per week.
b) Brachytherapy Applicators: The hospital shall provide applicators for intracavitary, interstitial, intraluminal, and surface applications, suitable for training and clinical procedures.
c) Quality Assurance and Calibration Tools: The hospital shall maintain all necessary QA and calibration equipment for brachytherapy sources and applicators in proper working condition.
d) Source Storage and Handling Facility: The hospital shall provide shielded and secured storage and handling facilities for radioactive brachytherapy sources, compliant with AERB safety regulations.
e) The hospital shall enter into and maintain a valid Comprehensive Maintenance Contract (CMC) and Source Contract with the Original Equipment Manufacturer (OEM) for all applicable equipment, and shall renew or update the contract as required from time to time.

4.6.2.3. Treatment Planning Systems

The Medical Physics Department shall include the following facilities with adequate space as per AERB and other regulatory requirements, with an approximate total area of 500 sq. ft

a) The hospital shall have a minimum of two treatment planning system (TPS) units.
b) One TPS shall be capable of advanced techniques, including intensity-modulated radiation therapy (IMRT), volumetric-modulated arc therapy (VMAT), stereotactic radiosurgery (SRS), and stereotactic body radiation therapy (SBRT), for training and clinical purposes.
c) The hospital shall provide a Head of Department (HOD) room near TPS with a minimum area of 100 sq. ft.

4.6.2.4. Contouring Stations

The hospital shall have a minimum of two contouring stations with the following capabilities:

a) Basic contouring for clinical and training purposes.
b) Capability of handling CT, MRI, and PET images.
c) Support for deformable and rigid image registration.

4.6.2.5. Quality Assurance and Calibration Equipment

The hospital shall have the following equipment for quality assurance and calibration in compliance with the guidelines:

a) Radiation field analyzers (RFA) and associated software are maintained in proper working condition and not older than nine years from the date of commissioning to the date of admission notification each academic year. If the RFA exceeds nine years in age, the Hospital shall obtain a formal undertaking from the Original Equipment Manufacturer (OEM) confirming support for a minimum of three years prior to admission notification each academic year.
b) The hospital shall enter into and maintain a valid Comprehensive Maintenance Contract (CMC) and Source Contract with the Original Equipment Manufacturer (OEM) for RFA and shall renew or update the contract as required from time to time
c) Ionization chambers and electrometers including at minimum: one Farmer chamber, one plane-parallel chamber, one pin-point chamber, and two semiflex.
d) Two-dimensional/ three-dimensional/four dimensional detector arrays or film dosimetry setups for beam verification
e) One-dimensional water phantom for dosimetric measurements.
f) Phantom (Slab / Rando / Head & Neck) for clinical and educational purposes.
g) Environmental monitoring devices, including barometer, thermometer, and hygrometer, to ensure dosimetry accuracy.
h) Comprehensive QA toolkits for daily, weekly, and monthly verification of LINAC and diagnostic QA Kit for X-ray radiography, CT.

All equipment shall be maintained in proper working condition at all times, and records of calibration, maintenance, and operational checks shall be preserved and made available for inspection by regulatory authorities.

4.6.2.6 Radiation Safety Instruments

The hospital shall have the following for radiation Safety management:

a) Radiation survey meters.
b) Emergency Containers
c) Area monitoring devices and personal dosimeters.
d) Contamination monitors.

e) Radiation warning and interlock systems.
f) Lead-lined doors, where applicable.
g) Controlled and supervised areas in accordance with AERB guidelines.

4.6.3. Nuclear Medicine Department – Clinical Facilities

The hospital shall maintain fully functional Nuclear Medicine facilities in compliance with AERB guidelines, including imaging, radionuclide therapy, radiopharmacy, and radioactive waste management, with an approximate total area of 2,500 sq. ft

4.6.3.1. Imaging Equipment

The hospital shall have the following equipment's for diagnostic and clinical training purposes.

a) PET-CT
b) Gamma Camera / SPECT / SPECT-CT

If the above equipment's are nine years in age, the Hospital shall obtain a formal undertaking from the Original Equipment Manufacturer (OEM) confirming support for a minimum of three years prior to admission notification each academic year.

The hospital shall enter into and maintain a valid Comprehensive Maintenance Contract (CMC) and Source Contract with the Original Equipment Manufacturer (OEM) for all applicable equipment, and shall renew or update the contract as required from time to time.

4.6.3.2. Radionuclide Therapy Facilities

a) High-Dose Radionuclide Facility: Minimum 2-bedded facility, treating at least 30 patients per year.
b) Low-Dose Radionuclide Facility: Minimum 1 unit, treating at least 30 patients per year.

4.6.3.3. Radio pharmacy and Quality Control

a) Radiopharmacy Laboratory: Minimum 1 unit, equipped for preparation and handling of radiopharmaceuticals.
b) Quality Control (QC) Sources:
   - Dose calibrator
   - Tc-99m generator
   - Thyroid uptake probe
   - Well counter
   - QC kits and accessories for Tc-generator eluted ^{99m}Tc radioisotope

4.6.3.4. Radioactive Waste and Safety Management

The hospital shall have the following for radioactive management & Safety management:

a) Properly designed radiation rooms with lead shielding as per AERB layout.
b) Radiation warning lights and signage.
c) Radiation survey meter and contamination monitors.
d) Absorbent sheets and laboratory accessories

e) Lead bricks, L-bench, and lead-lined dust bins.
f) Radioactive waste storage facility.
g) Decontamination room/facility.
h) Long-handled tools for safe handling of radioactive materials.
i) Melting point system.
j) Two-chamber delay tank as per regulatory specifications, with associated monitoring system.

4.6.3. Radiology Department – Clinical Facilities

The hospital shall maintain a fully functional Radiology Department in compliance with AERB regulations, ensuring the availability of diagnostic imaging services, image processing, quality assurance provisions, and radiation safety measures, with an approximate total area of 2,500 sq.ft

4.6.4.1. Imaging Equipment

a) CT Scanner – Minimum 16-slice, preferably equipped with contrast injector and workstation.
b) MRI Scanner – Minimum 1.5 Tesla (3 Tesla preferred for advanced applications).
c) Digital Radiography (DR) / Computed Radiography (CR) unit.
d) Mammography unit.
e) Ultrasound scanner (USG).
f) Fixed and Portable X-ray machine.
g) Dental OPG unit/BMD/DEXA (optional for training purposes).

If the CT & MRI machines are nine years in age, the Hospital shall obtain a formal undertaking from the Original Equipment Manufacturer (OEM) confirming support for a minimum of three years prior to admission notification each academic year.

The Hospital shall maintain valid Comprehensive Maintenance Contracts (CMC) and Source Contracts with the Original Equipment Manufacturer (OEM) for all CT and MRI machines, and shall ensure timely renewal or updating of these contracts as required.

4.6.4.2. Image Processing and Reporting Facilities

a) Picture Archiving and Communication System (PACS).
b) Radiology Information System (RIS).
c) Image reconstruction and post-processing software for CT/MRI.
d) Film printer and dry imager.

4.6.4.3. Radiation Safety and Protection

a) Properly designed X-ray rooms with lead shielding as per AERB-approved layouts.
b) Radiation warning lights and signage.
c) Protective accessories including lead aprons, thyroid shields, gonadal shields, and lead glasses.

d) Lead-lined doors and viewing windows.
e) Controlled and supervised zones with access restricted to authorized personnel only.

4.7. Faculty Requirement for the course

4.7.1. Medical Physics Faculty (University/College)

4.7.1.1. Minimum Designation and Strength

One (1) Professor in Medical Physics Department (Full-Time): with requisite academic qualifications and professional experience as prescribed by the competent regulatory authorities AERB and NCAHP.

The incumbent shall serve as the Programme Director / Head of the Department of Medical Physics, responsible for academic leadership, administrative control, curriculum compliance, and overall programme governance.

For a student intake of up to fifteen (15) students per academic year, the University/College shall appoint a Programme Director in Medical Physics. For a student intake of more than fifteen (15) students per academic year, the University/College shall establish a full-fledged Department of Medical Physics with a designated Head of Department.

Additionally, two (2) faculty member at the level of Associate Professor / Assistant Professor / Demonstrator (Full-Time).

4.7.1.2. Minimum Count

A minimum of three (3) full-time Medical Physics faculty members is mandatory.

4.7.1.3. Mode of Engagement

Full-Time appointment.

4.7.1.4. Counting Norm

Full-time faculty members shall be fully counted toward the statutory core faculty requirement of the programme.

4.7.2. Physics/Allied Faculty (Allied Specializations)

4.7.2.1. Applicability

The Institution may appoint or engage a Physics faculty member at the level of Professor/Associate Professor / Assistant Professor / Demonstrator (Full-Time) to share the teaching responsibilities of Medical Physics courses where specialized expertise is required.

Provided always that the Head of the Department or Programme Director shall be an individual holding a recognized qualification in Medical Physics, as prescribed by the relevant regulatory authorities, and shall be duly registered with the AERB and/or the NCAHP Council, as applicable.

4.7.2.2. Minimum Count

Based on the Requirement, Preferable one

4.7.2.3. Mode of Engagement

Full-Time appointment.

4.7.2.4. Counting Norm

Full-time faculty members shall be fully counted toward the statutory core faculty requirement of the programme

4.7.3. Medical Physicist (Hospital Based)

4.7.3.1. Minimum Designation and Strength

a) One (1) Chief Medical Physicist/Head in Medical Physics Department (Full-Time): with requisite academic qualifications and professional experience as prescribed by the competent regulatory authorities by the AERB and NCAHP Council and the experience of 12 years. Preferable a Ph.D. holder.
b) The incumbent shall serve as the Course Coordinator**/** Programme Director / Head of the Department of Medical Physics**,** control over the course in Hospital.
c) Additionally, two (2) Medical Physicist with the experience of more than 5 years

4.7.3.2. Minimum Count

A minimum of three (3) full-time Medical Physicist members is mandatory for 10 intake of students.

4.7.3.3. Mode of Engagement

Medical Physicists employed on a full-time basis at the affiliated hospital may be engaged on a part-time basis for teaching duties at the Institution/College, in accordance with the approved Teaching Arrangement or Memorandum of Understanding (MoU) executed between the parties.

The Clinically practicing Medical Physicists from the affiliated hospital shall be engaged for academic activities strictly as per the teaching ratio specified in their work order, contract, or appointment order.

Accordingly, Medical Physicists engaged in both clinical services and academic teaching shall be appointed under dual designations, such as:

“Chief Medical Physicist & Professor” or “Senior Medical Physicist & Associate Professor,” in accordance with the proposed career progression framework.

Part-Time, with the teaching allocation clearly defined in the approved Teaching Arrangement / Memorandum of Understanding (MOU) executed between the institution and the affiliated hospital.

All engagements shall comply with regulatory and accreditation requirements, including teaching allocation, documentation, and oversight by the Head of Department / Programme Director.

4.7.3.4. Counting Norm

For regulatory equivalence, the clinically practicing Medical Physicists shall be counted, based on the teaching allocation recorded in the MOU.

The MOU shall explicitly specify the total number of Medical Physicists and the teaching-sharing ratio allocated for the program.

Teaching Allocation: Clinically practicing Medical Physicists from the affiliated hospital shall contribute a minimum of twenty-five percent (25%) of their engagement towards teaching and seventy-five percent (75%) towards clinical responsibilities. Under no circumstance shall the teaching load exceed fifty percent (50%), so as to ensure that clinical duties, regulatory compliance requirements, and patient-care responsibilities remain the primary obligation of the Medical Physicist.

Default Provision: If the teaching allocation percentage is not explicitly mentioned in the MOU, it shall be deemed to be 25% for regulatory and compliance purposes.

4.7.4. Clinical Expert Requirements

4.7.4.1. Minimum Designation and Strength

The Hospital/Institution shall engage a minimum of two (2) part-time Clinical Experts, with teaching included as an explicit responsibility in their contract, work order, or appointment letter.

Eligible Specializations: Radiation Oncologists, Radiologists, Nuclear Medicine Physicians, Cardiologists, Radiation Biology, and Anatomy.

4.7.4.2. Mode of Engagement

Part-Time, with formal teaching allocation defined in the approved Teaching Arrangement / Memorandum of Understanding (MOU) between the Hospital and the Institution.

4.7.4.3. Counting Norm

Clinical Experts shall not be counted under the core faculty requirement.

Their engagement is mandatory for clinical teaching, demonstrations, and practice-based training, in compliance with regulatory and accreditation standards.

4.7.5. Faulty Student Ratio

4.7.5.1. Faulty Student Ratio

a) The faculty-to-student ratio for the Medical Physics programme shall be 1:5.
b) Notwithstanding the above, the minimum qualification and number of faculty as prescribed shall be maintained.
c) For compliance purposes, the higher of the two criteria either the 1:5 ratio or the prescribed minimum faculty number/qualification shall apply.

Table 4.1. Minimum Faculty Requirement for Medical Physics program (10)

Category	Minimum Number	Mode of Engagement	Counting Norm / Notes
Core Medical Physics Faculty (University/ College)	1 Professor (HOD Medical Physics/Programme Director) + 2 Associate/Assistant/ Demonstrator	Full-Time (3)	All three members counted towards mandatory faculty requirement
Physics Faculty / Allied Specializations (University/ College)*	1 Professor/Associate/ Assistant/Demonstrator	Full-Time (1)	May Appoint to share teaching of Medical Physics courses for required specialization. Counted as one (1) full-time faculty .
Medical Physicists (Hospital-Based / Clinical Faculty)**	3 clinically practicing Medical Physicists	Part-Time, as per teaching allocation in MOU Effective (1) FT	Collectively counted as one (1) full-time faculty equivalent. teaching allocation as per MOU: 50% 25% 25% ratio as per MOU
Clinical Experts (Clinical Faculty)	2 Clinicians	Part-Time	Not counted under core faculty. Mandatory for clinical teaching

Note:

- The table provided is illustrative and intended solely for guidance regarding minimum faculty requirements.
- The actual composition and allocation of faculty may vary, subject to the teaching ratio formally defined between the Hospital and the College/University and documented in the approved Teaching Arrangement / Memorandum of Understanding (MOU).
- Refer the all the clauses of 4.7
- * Physics/Allied Faculty is optional and not a mandatory requirement. Allied Faculty may be taken into account only where Medical Physics Faculty is not available or for teaching specialized subjects. The engagement of Allied Faculty shall not exceed the limits prescribed in the relevant table. The number of Medical Physics Faculty may be increased accordingly to meet the prescribed student–faculty ratio.
- ** A fully hospital-based institution shall have a minimum of eight (8) Clinical Physicists for an approved intake of ten (10) students, in order to maintain a student–faculty ratio of 1:5

Table 4.2. Requirement for 30 students/year

Category	Minimum Number	Mode of Engagement	Counting Norm / Notes
Core Medical Physics Faculty (University/ College)	1 Professor (HOD Medical Physics) + 5 Associate/Assistant/ Demonstrator	Full-Time (6)	All six members counted towards mandatory faculty requirement
Physics Faculty / Allied Specializations (University/ College)*	2 Professor/Associate/ Assistant/ Demonstrator	Full-Time (2)	Appoint to share teaching of Medical Physics courses for required specialization. Counted as one (1) full-time faculty
Medical Physicists (Hospital-Based / Clinical Faculty)	6 clinically practicing Medical Physicists	Part-Time, as per teaching allocation in MOU 2 FT	Collectively counted as one (1) full-time faculty equivalent. teaching allocation as per MOU: 50% 50% 25% 25%25%25% ratio as per MOU
Clinical Experts (Clinical Faculty	2 Clinicians	Part-Time	Not counted under core faculty. Mandatory for clinical teaching

Note:

- The table provided is illustrative and intended solely for guidance regarding minimum faculty requirements.
- The actual composition and allocation of faculty may vary, subject to the teaching ratio formally defined between the Hospital and the College/University and documented in the approved Teaching Arrangement / Memorandum of Understanding (MOU).
- Refer the all the clauses/sections of 4.7
- * Physics/Allied Faculty is optional and not a mandatory requirement. Allied Faculty may be taken into account only where Medical Physics Faculty is not available or for teaching specialized subjects. The engagement of Allied Faculty shall not exceed the limits prescribed in the relevant table. The number of Medical Physics Faculty may be increased accordingly to meet the prescribed student–faculty ratio.

4.8 Annual Submission of Proforma Checklist to NCAHP

The teaching institute shall submit the prescribed proforma and undertaking to the NCAHP each year on or before 31st January, or prior to the release of the admission notification, whichever is earlier

INSTITUTIONAL PROGRAMME COMPLIANCE DOCUMENT MEDICAL PHYSICS COURSE

Name of Institution: .....

.....

.....

Address: .....

.....

.....

University Affiliation .....

Academic Year of Submission: .....

Programme: M.Sc. Medical Physics / Post-M.Sc. Diploma Medical Physics / Ph.D. in Medical Physics

MoU Hospital: .....

.....

.....

S. No.	Description	Status (Yes/No)	Remarks
1 General			
1.1	Actual Intake/Approved Intake	YES / NO	
1.3	Is Valid MoU with accredited / recognised hospital as per 4.1.3	YES / NO	
1.3	If intake is > 15/ year, Is there a functional Medical Physics Department at both the Institution and the MoU-linked Hospital? as per 4.1.4	YES / NO	
1.4	IS Medical Physics Laboratory fully functional as per 4.1.5	YES / NO	
2 Functional Requirements			
2.1	If the land is held under a lease agreement, the lease shall have a minimum remaining validity of five (5) years from the date of issuance of the admission notification.	YES/NO	
2.2	Is all permissions, approvals, and no-objection certificates from local government authorities, including land-use and building compliance approvals, obtained and maintained in accordance with Section 4.3.3.1.	YES/NO	
2.3	Is the institution compliant with Fire Safety and NBCI requirements? as per section 4.3.3.2	YES/NO	
2.4	Does the institution have valid AERB licence and all other regulatory approvals as per AE(RP) Rules, 2004 and applicable AERB Safety Codes/Standards?	YES/NO	
2.5	Are all required environmental and waste management approvals valid and up to date? is in compliance with section 4.3.6	YES/NO	

S. No.	Description	Status (Yes/No)	Remarks
2.6	Are the College and the Hospital located within the permissible 30 km distance as required? as per section 4.3.9	YES/NO	
2.7	Does the Institution meet all facility requirements as specified in Section 4.3.10?	YES/NO	
2.8	Have all final-year students passed and secured residency? If not, please mention the number of students still awaiting residency placement.	YES/NO	
3 Facility Requirements			
3.1	Does the Medical Physics Laboratory comply with all requirements specified in Section 4.5.1?	YES/NO	
3.2	Does the Institution provide Computer/IT facilities as specified in Section 4.5.2?	YES/NO	
3.3	Does the Institution comply with Section 4.5.3 regarding Library and Learning Resource facilities?	YES/NO	
4 Built-up Space requirements			
4.1	Is Lecture Hall built up space and all other related requirements are in accordance with section 4.5.4.1	YES/NO	
4.2	Is the Seminar Hall built-up area and all related facilities compliant with Section 4.5.4.2	YES/NO	
4.3	Is the Examination Hall built-up space and all related facilities compliant with Section 4.5.4.3	YES/NO	

S. No.	Description	Status (Yes/No)	Remarks
4.4	Is the Auditorium/Multipurpose Hall built-up space and all related facilities compliant with Section 4.5.4.4?	YES/NO	
4.5	Is the Faculty Rooms/Office built up space and all other related requirements are in accordance with section 4.5.4.5	YES/NO	
5 Requirements for Clinical Hospital			
5.1	All general requirements and ancillary facilities are provided and fulfilled as per section 4.6.1	YES/NO	
5.2	Do the Hospital has Radiotherapy / Radiation Oncology dept, Nuclear Medicine dept, Diagnostic Radiology dept functioning properly	YES/NO	
5.3	Is the LINAC which is having dual photon energies & electron energies less than nine years old as on date, and if not, has the Hospital obtained an OEM support undertaking for the next three years?	YES/NO	
5.4	Is the brachytherapy unit operational?	YES/NO	
5.5	If Ir-192 brachy source, last source change date is within seven-month interval of as on date	YES/NO	
5.6	Is the Radiation Field Analyzer (RFA) and its accessories fully functional & less than nine years old as on date, and if not, has the Hospital obtained an OEM support undertaking for the next three years?	YES/NO	

S. No.	Description	Status (Yes/No)	Remarks
5.7	Is the PET CT machine than nine years old as on date, and if not, has the Hospital obtained an OEM support undertaking for the next three years?	YES/NO	
5.8	Is the CT machine than nine years old as on date, and if not, has the Hospital obtained an OEM support undertaking for the next three years?	YES/NO	
5.9	Is the MRI machine than nine years old as on date, and if not, has the Hospital obtained an OEM support undertaking for the next three years?	YES/NO	
5.7	Is a current OEM-issued Comprehensive Maintenance Contract (CMC) in place for Linac, Brachy, PET CT, CT, MRI & RFA	YES/NO	
5.8	Is all radiation safety related equipment are working and valid calibration as on date	YES/NO	
6 Faculty Requirement			
6.1	Is Faculty and Staff Requirements fulfilled as per section 4.7	YES/NO	
6.2	Is HOD / Programme Director qualified Medical Physicist	YES/NO	
6.3	Is teaching allocation specified in MOU is maintained by Hospital & College/University in last year	YES/NO	
6.4	Is Minimum Hospital Medical Physicists are available as on date as per MoU	YES/NO	
6.5	Is Teaching-sharing ratio with hospital & College is followed last year	YES/NO	

S. No.	Description	Status (Yes/No)	Remarks
6.6	What is the Teacher student ratio last year		
6.7	Name of Faculty and Clinicians		
7 Patient Data Details			
7.1	How many patients treated in Linac by attached hospital in last one year		
7.2	How many patients treated in Brachytherapy by attached hospital in last one year		
7.3	How many fractions/sitting executed in brachy by attached hospital in last one year		
7.4	How many procedure executed in CT & MRI by attached hospital in last one year		
7.5	How many procedure executed in PET/SPECT/Gamma Camera by attached hospital in last one year		
7.6	How many NM Therapy executed in Camera by attached hospital in last one year		

Declaration

We hereby declare that all information and documents submitted herein are true and correct to the best of our knowledge, and that the Institution complies with all requirements prescribed under Section 4 for the commencement and continuation of the Medical Physics Program

Registrar/Principal SEAL Program Director/HOD Medical Physics

Hospital Head of the Institution SEAL HOD-Medical Physics (Hospital)

4.9 Inspection of Institutions / Courses

4.9.1 Inspections

All institutions conducting the Medical Physics program shall be inspected by the central council/state council of the NCAHP at the commencement of the course and at periodic intervals as prescribed by the Council.

The corresponding Council of the NCAHP shall constitute the inspection committee responsible for verifying compliance with academic, staffing, laboratory, and infrastructural requirements.

4.9.2 Composition of the Inspection Committee

The Inspection Committee shall be constituted such that more than 50% of its members are AERB/NCAHP-registered Medical Physicists, drawn from the State Council, the Central Council, or a combination thereof.

The Head/Chairperson shall be an AERB/NCAHP-registered Medical Physicist with not less than twenty (20) years of professional experience in the Clinical, Academic, or Research domains of Medical Physics.

The Committee shall include at least two (2) AERB/NCAHP-registered professionals who are engaged in Academic, Clinical, or Research activities in the field of radiation sciences, or who possess a minimum of ten (10) years of professional experience in the radiation sciences.

In the event that the Inspection Committee, as constituted, comprises less than fifty percent (50%) members with an academic or professional background in Medical Physics, the competent authority shall immediately nominate additional qualified Medical Physicists to ensure compliance with the prescribed composition.

Such nominated members shall be AERB/NCAHP-registered Medical Physicistsand possess the requisite academic or professional qualifications and experience, consistent with the standards for the Head/Chairman and other members, including a minimum of twenty (20) years of professional experience for the Chairman and at least ten (10) years for other members.

The augmented committee shall exercise all powers and responsibilities of the Inspection Committee, including evaluation of infrastructure, faculty, clinical facilities, and academic compliance, and shall submit a consolidated report to the NCAHP Council.

NATIONAL COMMISSION FOR ALLIED AND HEALTHCARE PROFESSIONS
स्वास्थ्यम् सर्वार्थसाधनम्
NCAHP
Since-2021
राष्ट्रीय सहबद्ध और स्वास्थ्य देख-रेख पेशा

Chapter 5

Medical Physics Curriculum

5.1. Vision

To develop a nationally and globally competent Medical Physics workforce by strengthening education, clinical training, research, and professional practices that ensure the safe, effective, and ethical application of radiation and physics-based technologies in healthcare through the Medical Physics program.

5.2. Mission

- To establish a uniform national standard for the Medical Physics program, integrating fundamental sciences with clinical and technological applications.
- To prepare competent and responsible Medical Physicists capable of contributing to Radiotherapy, Medical Imaging, Nuclear Medicine, and Radiation Protection across diverse healthcare settings.
- To promote evidence-based practice, professional ethics, patient safety, and lifelong learning in alignment with national regulations and international guidelines.
- To facilitate structured clinical exposure, skill development, and collaboration among academic institutions, hospitals, regulatory bodies, and professional organizations.
- To encourage innovation, analytical thinking, and adoption of emerging technologies to advance the quality and safety of radiation-based healthcare services.

5.3. Medical Physics – Program Objective

The objective of the Medical Physics program is to provide a standardized national framework of knowledge, practical competence, clinical exposure, and professional skills required for Medical Physicists to operate effectively in clinical, academic, research, industrial, and regulatory environments. The program aims to:

- Provide a strong foundation in radiation physics, radiological sciences, medical imaging, radiotherapy, nuclear medicine, and radiation protection.
- Develop proficiency in dosimetry, instrumentation, calibration, quality assurance, and safety practices in accordance with the National Commission for Allied and Healthcare Professions (NCAHP) and the Atomic Energy Regulatory Board (AERB) norms.
- Apply scientific reasoning, computational methods, and analytical techniques for solving clinical and technological challenges in healthcare.
- Promote adherence to ethical standards, regulatory compliance, communication skills, and multidisciplinary teamwork.
- Support advancement in research, innovation, and emerging technologies such as Artificial Intelligence / Machine Learning (AI/ML), Monte Carlo simulation, Health Technology Assessment (HTA), and precision dosimetry.

5.4. Program Outcomes (POs)

PO1 – Core Knowledge of Medical Physics:
Demonstrate comprehensive knowledge of radiation physics, radiobiology, imaging principles, radiotherapy concepts, nuclear medicine, and radiation protection.

PO2 – Clinical Competence
Perform clinical measurements, dosimetry, imaging quality control (QC), treatment planning support, and radiation safety procedures in compliance with regulatory and professional standards.

PO3 – Analytical and Problem-Solving Skills
Analyze and solve complex clinical physics problems using mathematics, simulations, scientific reasoning, and evidence-based approaches.

PO4 – Proficiency in Modern Tools and Technologies
Use advanced tools including Treatment Planning Systems (TPS), imaging software, dosimetry equipment, Monte Carlo codes, and computational platforms to support clinical and research applications.

PO5 – Ethical and Professional Practice
Demonstrate ethical conduct, professional responsibility, and adherence to national and international standards including those of the Atomic Energy Regulatory Board (AERB), International Atomic Energy Agency (IAEA), and International Commission on Radiological Protection (ICRP).

PO6 – Effective Communication and Collaboration
Communicate clearly and function effectively with multidisciplinary teams involved in radiation therapy, diagnostic imaging, nuclear medicine, and radiation protection.

PO7 – Research Aptitude and Lifelong Learning
Engage in scientific research, evaluate data critically, contribute to technological advancement, and pursue continuous learning to adapt to evolving healthcare technologies.

PO8 – Leadership, Mentorship, and Entrepreneurship
Demonstrate leadership in clinical and academic settings, provide mentorship to trainees and colleagues, and apply principles of innovation and entrepreneurship to improve healthcare services, develop new technologies, and advance the medical physics profession.

5.5. Program Specific Outcomes (PSOs)

PSO1 – Radiotherapy Physics Application
Apply principles of radiotherapy physics to perform dosimetry, calibration, quality assurance (QA), and support treatment planning following national and international protocols.

PSO2 – Radiation Measurement and Calibration
Conduct radiation measurements, detector selection, calibration, uncertainty estimation, and implementation of standardization protocols such as the International Atomic Energy Agency – Technical Reports Series (IAEA TRS).

PSO3 – Medical Imaging Physics Competence
Evaluate, optimize, and perform quality control of imaging modalities including X-ray, Computed Tomography (CT), Magnetic Resonance Imaging (MRI), Ultrasound, Positron Emission Tomography – Computed Tomography (PET-CT), and Single Photon Emission Computed Tomography (SPECT).

PSO4 – Nuclear Medicine Physics and Dosimetry
Perform radionuclide dosimetry, quality control of radiopharmaceuticals, and equipment quality assurance in accordance with national regulations and safety requirements.

PSO5 – Radiation Protection and Safety Management
Implement radiation protection practices, shielding calculations, hazard assessment, and compliance with radiation safety guidelines and statutory regulations.

PSO6 – Computational and Simulation Skills
Use computational tools, Artificial Intelligence / Machine Learning (AI/ML) methods, Monte Carlo simulations, and data analytics for problem-solving and clinical decision support.

PSO7 – Innovation, Quality Assurance, and Professional Development
Contribute to technological innovation, quality assurance programs, clinical audits, and continuous professional development to enhance radiation-based healthcare services.

PSO8 – evaluate HTA and translate evidence on the clinical effectiveness, safety, cost-effectiveness, ethical and social implications of health technologies to support informed healthcare decision-making and policy formulation.

5.6. Pathways

1. M.Sc. in Medical Physics
2. Post M.Sc. Diploma in Radiological Physics / Medical Physics or Advanced Master Degree in Radiological/Medical Physics

5.7. Future Directions

The One India One Curriculum pathway will be: A two-year M.Sc. Medical Physics program

Followed by a one-year structured clinical residency, which will be the mandatory professional training for clinical practice in radiotherapy, diagnostic imaging, and nuclear medicine.

(The Post M.Sc. Diploma in Radiological/Medical Physics or Advanced Master Degree in Radiological/Medical Physics program will be phased out in three years, from the academic/admission year 2029-2030 to ensure in line with national initiatives to standardize and streamline Medical Physics education)

5.8. Eligibility for Admission & Selection Procedure (M.Sc. Medical Physics)

5.8.1 Academic Eligibility criteria for Admission:

Candidates must have obtained:

The candidate must possess a First Class in B.Sc. Physics with Mathematics as Ancillary subject

(OR)

The candidate must possess a B.Sc. (Science) in First Class with Physics as a major (≥ 60% or ≥ 6.5 CGPA) and Mathematics as an ancillary, and must have completed at least five of the following Physics courses: *Mechanics, Electricity and Magnetism, Thermodynamics, Optics, Electronics, Solid State Physics, and Nuclear Physics*. All required details shall be submitted in the application and verified through supporting academic records.

5.8.2 Entrance & Age Criteria:

Admission to the M.Sc. Medical Physics program shall be made strictly on the basis of merit, determined through

- Eligibility criteria as mentioned above, and
- The merit list for the admission process shall be prepared in accordance with the rules and regulations of the respective University/Institution, based on the entrance examination. The syllabus for the entrance examination shall be published by the respective University/Institution along with the admission notification.
- The candidate must have attained the minimum age of 20 years as on the date of admission or as notified for the current academic year.

5.8.3 Duration and Academic Structure Pattern:

The M.Sc. Medical Physics program shall be of 2 years (4 semesters) + one year Residency Program

5.8.4 Medium of Instruction:

English should be the medium of instruction for all subjects and examinations.

5.8.5 Teaching/Learning Methods:

- Competency-based learning will be implemented for both theory and clinical training.
- Methods include classroom teaching, practical lab sessions, self-learning, hybrid/virtual learning, advanced learning tools, simulators, and videos. However, virtual/online teaching/learning should not be more than 10 percent of total program hours

5.8.6 Attendance:

- Minimum attendance 75% in theory subjects.
- Minimum attendance 85% in practical/skills training.
- Any deviation shall be addressed as per Institute norms

5.8.7 Assessment

- Continuous Internal Assessment (CIA) forms the Formative Assessment component, while end-semester examinations constitute Summative Assessment.
- Weightage: 25% Internal Assessment, 75% University/External Examination.

5.8.8 Examination Schedule:

- University examinations shall be conducted at the end of each semester in accordance with the academic calendar and regulations of the University.
- Two internal examinations and one model examination must be conducted before the Semester Examination for each course.
- Internal marks shall be awarded based on the performance in these examinations and other approved academic/technical evaluation components such as assignments, attendance, presentations, and continuous assessment activities.
- Two academic examination cycles will be conducted per academic year.

5.8.9 Maximum Duration of Program:

- Must complete M.Sc. Medical Physics within 4 years. (Excluding Residency)
- Failure to complete within duration will result in discharge, except for exceptional cases reviewed by the university committee.

5.8.10 Migration/Transfer:

Allowed as per university norms.

5.8.11 Residency

- Mandatory one-year rotation post-academic training.
- Up to 2 months may be externship.
- Refer the Residency Guiding document

5.9 Scheme of Examination

M.Sc., Medical Physics Program

Course Code	Title of the Course	Credit	Hours/ Week			Maximum Marks		
			Theory	Tutorial	Practical	CIA	ESE	Total
FIRST SEMESTER								
Core-1	Nuclear and Radiation Physics	4	3	1	0	25	75	100
Core-2	Non-Ionising Radiation Physics	3	3	0	0	25	75	100
Core-3	Medical Electronics and Instrumentation	4	3	1	0	25	75	100
Core-4	Anatomy, Physiology, Tumour Pathology, and Genetics	4	4	0	0	25	75	100
Core-5	Solid State Physics and Radiation Detectors	4	3	1	0	25	75	100
E1ective-1	Programming, Data Science, and Computational Methods for Medical Physics Health Technology Assessment	3	2	1	0	25	75	100
Practical-I	Electronics and Radiation Instrumentation Lab	3	0	0	6	25	75	100
Total		**25**	**18**	**4**	**6**	**175**	**525**	**700**
SECOND SEMESTER								
Core-6	Applied Mathematical Physics	4	0	4	0	25	75	100
Core-7	Electrodynamics and Quantum Mechanics	3	3	0	0	25	75	100
Core-8	Physics of Medical Imaging	4	3	1	0	25	75	100
Core-9	Physics of Radiotherapy	4	3	1	0	25	75	100
Core-10	Nuclear Medicine I: Imaging and Therapy	4	3	1	0	25	75	100

Course Code	Title of the Course	Credit	Hours/ Week			Maximum Marks		
			Theory	Tutorial	Practical	CIA	ESE	Total
Elective-II	Artificial Intelligence in Medical Physics / Materials for Radiological applications	3	2	1	0	25	75	100
Practical- II	Medical Physics Lab I- Medical Imaging	3	0	0	6	25	75	100
Professional Enhancement Course (PEC)	Professional Ethics in Medical Physics	2	2	0	0	50	-	50
Total		**27**	**16**	**8**	**6**	**225**	**525**	**750**
THIRD SEMESTER								
Core-11	Treatment Planning in Radiation Oncology	4	2	1	2	25	75	100
Core-12	Nuclear Medicine II: Dosimetry and Quality Assurance	4	2	1	2	25	75	100
Core-13	Radiation Dosimetry and Standardization	4	3	1	0	25	75	100
Core-14	Radiation Biology	4	3	1	0	25	75	100
Core-15	Research Methodology, Data Analytics and Ethics	4	3	1	0	25	75	100
Elective-III	Advanced Techniques and Emerging Technologies in Medical Physics / Small Field Dosimetry and Calibration Standards	3	2	1	0	25	75	100
Practical- III	Medical Physics Lab II: Radiation Dosimetry lab	3	0	0	6	25	75	100
Total		**26**	**15**	**6**	**10**	**175**	**525**	**700**
FOURTH SEMESTER								
Core-16	Radiation Protection	4	3	1	0	25	75	100
Core- 17	Radiation Hazards evaluation and control	4	3	1	0	25	75	100

Course Code	Title of the Course	Credit	Hours/ Week			Maximum Marks		
			Theory	Tutorial	Practical	CIA	ESE	Total
Elective-IV	Dosimetric Audit and Clinical Trials in Medical Physics Montecarlo Techniques in Dosimetry	3	2	1	0	25	75	100
Seminar	Seminar on Technical Research and Review Paper Analysis	2	2	0	0	50	-	50
Project	Project	7	0	0	14	25	75	100
Professional Enhancement Course (PEC)	Webinars- 4 Nos. (OR) Oral / Poster Presentation in Conference (OR) Field Onsite Training/- 4 weeks (OR) Hand-on workshops- 4 (OR)	2	0	0	4	50	-	50
Total		**22**	**10**	**3**	**18**	**200**	**300**	**500**
Grand Total		**100**	**59**	**21**	**40**	**775**	**1875**	**2650**

THIRD YEAR

Residency Credits (32)

Course Code	Title of the Course	Credits	Hours/ Week			Maximum Marks		
			Theory	Tutorial	Practical	CIA	ESE	Total
FIRST SEMESTER								
	Nuclear and Radiation Physics	**4**	**3**	**1**	**0**	**25**	**75**	**100**
	Non-Ionising Radiation Physics	**3**	**3**	**0**	**0**	**25**	**75**	**100**
	Medical Electronics and Instrumentation	**4**	**3**	**1**	**0**	**25**	**75**	**100**
	Anatomy, Physiology, Tumour Pathology, and Genetics	**4**	**4**	**0**	**0**	**25**	**75**	**100**
	Solid State Physics and Radiation Detectors	**4**	**3**	**1**	**0**	**25**	**75**	**100**
	Programming, Data Science, and Computational Methods for Medical Physics	**3**	**2**	**1**	**0**	**25**	**75**	**100**
	Health Technology Assessment							
	Electronics and Radiation Instrumentation Lab	**3**	**0**	**0**	**6**	**25**	**75**	**100**
	Total	**25**	**18**	**4**	**6**	**175**	**525**	**700**

Core–1: Nuclear and Radiation Physics

Credits: 4 **Lecture:**3 **Tutorial:**1 **Practical:** 0

Course Objectives

- To understand the fundamental concepts of nuclear structure and radioactivity relevant to radiological sciences.
- To study the interaction of various types of radiations with matter and their quantitative descriptions.
- To learn radiation quantities, dosimetric parameters, and radiation protection units.
- To familiarize with natural and artificial radiation sources used in medical applications.
- To develop analytical and problem-solving skills in nuclear and radiological physics.

Detailed Syllabus

Unit I – Nuclear Physics (12 hrs)

Nucleus- Scattering experiment, properties, Discovery of neutrons, Experimental determination of size of the nucleus etc. Nuclear forces- properties, spin dependence, charge independence etc. Liquid drop model-Binding energy, semi-empirical mass formula, mass parabola, application in stability of neutron star- Radioactivity – α decay - general properties of α particles, spectrum, Gamow's theory, Geiger-Nuttal law- Beta decay- general properties, Fermi theory, spectrum, fall of parity, neutrinos – Positron emission- Electron capture-gamma emission-Internal conversion- Laws of radioactivity- Laws of successive transformations and application in dating- Natural radioactive series- Radioactive equilibrium- Nuclear isomerism– Nuclear reactions- Artificial radioactivity- Elementary ideas of fission and its application in nuclear reactors and nuclear weapons – Fusion-energy production in the sun, production of elements in the universe-big bang and stellar nucleo synthesis- Particle Physics.

Tutorial: Students solve numerical problems on binding energy and Q-value determination and analyze isotopic stability using real nuclear data.

Unit II – Interaction of Electromagnetic Radiations and Neutrons with Matter (12 hrs)

Interaction of electromagnetic radiation with matter – Exponential attenuation – Thomson scattering – Photoelectric and Compton process and energy absorption – Pair production – Attenuation and mass energy absorption coefficients – Relative importance of various processes. Interaction of neutrons with matter – Classification of neutrons, slow and fast neutron interactions – Microscopic and macroscopic interaction cross section – Charged particle emission, radiative capture and its significance in radiation dose to humans – Elastic and inelastic scattering – Neutron induced nuclear reactions – Neutron activation – Fission – Neutron attenuation.

Tutorial: Students derive and plot attenuation curves for various materials and energies, and calculate photon attenuation coefficients using real experimental data.

Unit III– Interaction of Charged Particles with Matter (12 hrs)

Interaction of charged particles with matter – Classical theory of inelastic collisions with atomic electrons – Energy loss per ion pair by primary and secondary ionization – Dependence of collision energy losses on the physical and chemical state of the absorber – Cerenkov radiation – Electron absorption process: Scattering, Excitation and Ionization – Radiative collision (Bremsstrahlung) – Range energy relation – Continuous slowing down approximation (CSDA) – Transmission and depth dependence methods for determination of particle penetration – Empirical relations between range and energy – Backscattering.

Interaction of heavy charged particles with matter – Energy loss by collision – Range energy relation – Bragg curve – Spread Out Bragg Peak (SOBP) – Specific ionization – Stopping Power – Bethe–Bloch Formula.

Tutorial: Students calculate attenuation coefficients, HVL, and analyze energy dependence of interaction processes. Comparisons are made between photon and charged particle interactions through plotted graphs.

Unit IV – Radiation Quantities and Units (12 hrs)

Radiometric quantities: Activity, exposure, particle flux, fluence, fluence rate, energy flux and energy fluence.

Interaction quantities: Linear and mass attenuation coefficients, mass energy transfer and mass energy absorption coefficients, stopping power, mass stopping power, LET. Dosimetric quantities: Exposure, absorbed dose, kerma, terma, charged particle equilibrium (CPE), relationship between kerma, absorbed dose and exposure under CPE, radiation chemical yield, W-value.

Radiation protection quantities: Equivalent dose, effective dose, committed equivalent dose, committed effective dose, radiation weighting factor, tissue weighting factor, Annual Limit on Intake (ALI), Derived Air Concentration (DAC). Operational quantities: Dose equivalent, ambient and directional dose equivalents [H*(d), H'(d)], personnel dose equivalents for strongly and weakly penetrating radiation, Hp(10), Hp(0.07) and Hp(3).

Radiation units: Becquerel & Curie, exposure units (C/kg & roentgen), gray & rad, sievert & rem.

Tutorial: Students perform numerical calculations on dose–kerma relationships, unit conversions, and effective dose estimation from radiation protection data.

Unit V – Radiation Sources and their Medical Applications (12 hrs)

Radiation sources – Natural and artificial radioactive sources – Large scale production of isotopes – Reactor produced isotopes (^{60}Co, ^{192}Ir, ^{99}Mo etc.) – Cyclotron produced isotopes (^{18}F, ^{13}N, ^{15}O, ^{11}C) – Fission products (^{137}Cs, ^{99}Mo, ^{131}I, ^{90}Sr), Ga-68 – Teletherapy and brachytherapy sources – Sources for permanent implants (^{198}Au, ^{125}I, ^{103}Pd) – Beta ray applicators – Ophthalmic applicators (^{90}Sr, ^{125}I, ^{106}Ru) – Thermal and fast neutron sources (^{241}Am–Be, ^{252}Cf).

Tutorial: Students identify suitable isotopes for specific medical applications and calculate activity required for therapeutic and diagnostic uses.

Course Outcomes

- Understand nuclear structure, decay mechanisms, and radioactivity principles relevant to radiological sciences.
- Analyze photon, charged particle, and neutron interactions with matter quantitatively.
- Compute radiation quantities, dosimetric parameters, and apply appropriate units and relationships.
- Identify and evaluate suitable radiation sources used in medical diagnosis and therapy.
- Develop analytical and computational proficiency in radiological physics problem-solving.

Text Books & References

- H.E. Johns & J.R. Cunningham – *The Physics of Radiology*, Charles C. Thomas, 1983.
- G.F. Knoll – *Radiation Detection and Measurement*, John Wiley & Sons, 2010.
- F.H. Attix – *Introduction to Radiological Physics and Radiation Dosimetry*, Wiley-VCH, 2004.
- E.B. Podgorsak – *Radiation Physics for Medical Physicists*, Springer, 2016.
- D.J. Dowsett, P.A. Kenny & R.E. Johnston – *The Physics of Diagnostic Imaging*, CRC Press, 2006.
- Faiz M. Khan, The Physics of Radiation Therapy, Lippincott Williams & Wilkins, Philadelphia, 3rd edition, 2003
- R.D. Evans, Atomic Nucleus
- Preston M.A. Physics of Nucleus
- Lapp R.E. Nuclear Radiation Physics
- Segre E. Experimental Nuclear Physics
- Slack L. Radiations from Radioactive Atoms
- Oliver R. Radiation Physics in Radiology
- Crouthamel C.E. Applied Gamma Rays Spectrometry.
- IAEA – *Radiation Oncology Physics: A Handbook for Teachers and Students*, Vienna, 2005. https://www.iaea.org/publications/
- Cember, H. & Johnson, T.E. – *Introduction to Health Physics*, McGraw-Hill, 2009.

- Khan, F.M. & Gibbons, J.P. – *The Physics of Radiation Therapy*, Lippincott Williams & Wilkins, 2014.
- Knoll, G.F. – *Radiation Detection and Measurement*, 4th Edition, Wiley, 2010.
- Podgorsak, E.B. – *Radiation Physics for Medical Physicists*, 2nd Edition, Springer, 2016.

Core 2: Non-Ionizing Radiation Physics in Medicine

Course Objectives

- Gain broad knowledge on the Interaction of Non-Ionizing Radiation with biological systems.
- Understand the Applications of Laser in Medicine and associated safety measures.
- Study the Optical Properties of Tissues and advanced optical imaging techniques for diagnosis and therapy.
- To introduce the principles and applications of theranostics and biosensor technologies.
- Grasp the Application of radio waves and microwaves in medicine, including thermography and hyperthermia.

Detailed Syllabus

UNIT I: LASERS AND TISSUE OPTICS (9)

Optical Radiations Overview and types- UV, Visible, IR-FTIR, Raman spectroscopy-Principles and applications in medical diagnostics and therapy. First law of photochemistry - Law of reciprocity -Lasers: Theory and mechanism. Surgical lasers: CO_2, Nd-YAG, ArF lasers. Measurement of fluence from optical sources. Tissue Optics: Absorption and scattering in turbid media – Theory and experimental techniques. Interaction of laser radiation with tissues – Photo thermal – photo chemical – photo ablation – electromechanical effect – Bio simulation – Integrating Sphere, Monte Carlo Simulation.

UNIT II: MEDIPHOTONICS AND OPTICAL IMAGING TECHNIQUES (9)

Lasers in ophthalmology, dentistry, dermatology, oncology. Photo Dynamic Therapy (PDT) and laser thermo therapy and cell biology. Application of ultrafast pulsed lasers in medicine and biology. Fiber optics in medicine. **Optical Imaging Techniques:** Principles of optical microscopy. Fluorescence microscope - Confocal microscope - Two-photon microscopy - Optical coherence tomography - Super-resolution imaging. Imaging Techniques: Imaging Techniques based on light transport through tissue, Polarization, phase contrast, and differential interference contrast microscopy (DIC) microscopy.

UNIT III: IR,RW and Microwave in Medical Applications (9)

Overview of NIRP-Study of non-ionising electromagnetic radiation (UV, Visible, IR, Microwave, RF, ELF, Laser, Ultrasound) and its significance in medical science. Understanding mechanisms of interaction and biological effects on tissues- **Infrared Radiation and Applications-**IR sources and sensors for medical use (thermal imaging, non-contact temperature measurement) -Principles of thermography and clinical applications. non-thermal effects FTIR, RAMAN– Applications –Label free disease diagnosis- Treatment of cancer cells. Volatile Organic Compound (VOC) Sensors for Surgical Guidance – electronic nose**.** Radiofrequency (RF) and Microwave Radiation-Introduction, frequency and wavelength ranges, and generation methods. RF/Microwave delivery systems for therapeutic applications.

UNIT IV: THERANOSTICS AND BIOSENSORS (9)

Theranostics: Integration of diagnostics and therapy in oncology using Nuclear Medicine – Personalized treatment strategies. Cancer Pathways & Nanotechnology: Deregulated signalling in cancer. Theranostic nanomedicine – Smart and multifunctional nanopreparations – Controlled release via biomacromolecule-gated mesoporous silica systems. Magnetic nanoparticles – Detection via microscopy and assays – Toxicity and biodistribution evaluation – Magnetic targeting strategies.

Biosensors: Definition, classification, and components (receptor, transducer) – Types: electrochemical, optical, and mass-based biosensors – Principles of surface plasmon resonance (SPR) – Application in point-of-care diagnostics and biomarker detection – Integration of microfluidics with biosensors

UNIT V: Safety standards of Non-Ionizing Radiation in Physics (9)

Hazards of lasers and their safety measures. - Mechanisms of interaction RF, MW with tissues- biological effects on tissues-SAR – Safety standards- International exposure limits and safety standards (ICNIRP, WHO, IEEE). Measurement, monitoring, and shielding techniques for NIR sources-Safety protocols, risk assessment, and regulatory aspects in medical and research settings.

Course Outcomes

CO1: Various sources of Non-Ionizing Radiations and their interaction mechanism.

CO2: The type of laser to be employed for various applications and the fundamentals of optical light microscopy and electron microscopy**.**

CO3: Tissue Optical Properties and apply them for the disease diagnosis and therapy, including current optical imaging technologies and their application in research.

CO4: Students will be able to understand the integration of diagnostic and therapeutic strategies in oncology, and biosensors for clinical use and their safety.

CO5: The use of thermography and its application in Medicine, as well as the principles and applications of Radio Frequency and Microwaves in medicine.

Textbooks & References

- **Biomedical Optics: Principles and Imaging**, Lihong V. Wang and Hsin-I Wu, Wiley Interscience, 1st Edition, 2007.
- **Fundamentals of Light Microscopy and Electronic Imaging**, 2nd Edition, Douglas B. Murphy, Wiley-Liss, ISBN: 0-471-25391-X, 2012.
- **Tissue Optics**, Valery Tuchin, SPIE Press, 3rd Edition, 2014.
- **Laser Fundamentals**, William T. Silfvast, Cambridge University Press, 2004.
- **Nanoparticle-Based Theranostic Agents, Xie J., Lee S., Chen X., *Elsevier*, 2010.**
- **Biosensors: Fundamentals and Applications, Turner A. P. F., *Oxford University Press*, 1987.**
- Bernhardt, J.H., Non-Ionizing Radiation: Protection and Standards, CRC Press, 2020.
- **RF/Microwave Interaction with Biological Tissues**, André Vander Vorst, Arye Rosen, Youji Kotsuka, Wiley Publications, 2006.
- **Biomedical Optics: Introduction**, 2nd Edition, Tuan Vo-Dinh, CRC Press, 2014.
- **Laser Tissue Interactions- Fundamentals and Applications**, Markolf H. Niemz, Springer Publications, 2007.
- **Introduction to Bio photonics**, Paras N. Prasad, Wiley Interscience publications, 2003.
- **Handbook of Biological Confocal Microscopy**, James B. Pawley, 3rd Edition, Springer, 2016.
- **Henderson and A. J. Chatten, Non-Ionizing Radiation:** Physical and Biological Basis of Radiation Protection, Oxford University Press, 2018.

Core 3: Medical Electronics and Instrumentation

Total Duration: 60 hours (12 hours per unit)

Course Objectives

- Provide a comprehensive understanding of analog, digital, and embedded electronic systems used in medical and nuclear instrumentation.
- Introduce the architecture and interfacing of modern microprocessors, microcontrollers, and embedded systems relevant to healthcare devices.
- Develop knowledge on power supply systems, signal conditioning, and noise management in radiation detection and medical equipment.
- Enable understanding of biomedical transducers, sensors, and signal acquisition for diagnostic and therapeutic applications.
- Familiarize students with modern trends such as IoT-enabled healthcare, wearable biomedical devices, and robotic and AI-assisted instrumentation.

Detailed Syllabus

UNIT I – FUNDAMENTALS OF ANALOG AND DIGITAL ELECTRONICS (12)

Semiconductor diodes, BJT, FET, MOSFET – characteristics and applications.

Operational amplifiers – inverting/non-inverting, summing amplifier, integration, differentiation, active filters, and oscillators.

ADCs and DACs – types and performance parameters.

Digital fundamentals – logic gates, Boolean algebra, combinational and sequential circuits, multiplexers, counters, flip-flops.

Introduction to programmable logic devices (PLD, FPGA) and their applications in medical electronics.

UNIT II – MICROPROCESSORS, MICROCONTROLLERS AND EMBEDDED SYSTEMS (12)

Review of 8085 and 8086 architectures and instruction sets.

Introduction to 8051 and ARM-based microcontrollers.

Memory organization, I/O interfacing, and serial communication.

Embedded system design for medical instruments – data acquisition, control, and display modules.

Introduction to IoT in healthcare – wearable sensors, telemetry, and data transmission.

UNIT III – POWER SUPPLIES AND SIGNAL CONDITIONING IN NUCLEAR INSTRUMENTATION (12)

Rectifiers – half-wave, full-wave, bridge; filters and voltage regulators.

SMPS, DC-DC converters, RF power supplies, and isolation techniques.

Grounding, shielding, and noise reduction methods in nuclear systems.

High-voltage and low-noise power supplies for radiation detectors.

Recent developments: micro-power supplies, battery management in portable devices, and smart energy-efficient designs.

UNIT IV – ELECTRONICS FOR RADIATION DETECTION AND SIGNAL PROCESSING (12)

Detector-preamplifier interface – charge-sensitive and voltage-sensitive preamplifiers.

Pulse shaping, discrimination, and amplification.

Analog and digital pulse processing – baseline restoration, linear gating, and time-to-amplitude conversion.

Data acquisition systems, multi-channel analyzers (MCA), and digital signal processors (DSP).

Introduction to FPGA-based nuclear instrumentation and AI-assisted signal interpretation.

UNIT V – BIOMEDICAL INSTRUMENTATION AND EMERGING TECHNOLOGIES (12)

Bioelectric potentials – origin, measurement, and recording (ECG, EEG, EMG).

Biomedical sensors and transducers – optical, piezoelectric, and MEMS-based devices.

Diagnostic and therapeutic instruments – pacemaker, defibrillator, dialysis unit, ventilator, diathermy.

Robotics and automation in surgery, rehabilitation, and prosthetics.
Modern trends – wearable health monitoring, wireless telemetry, IoT-based patient monitoring, and medical AI systems.

Course Outcomes

Upon successful completion of the course, students will be able to:

CO1: Demonstrate understanding of analog, digital, and embedded electronics used in medical and nuclear systems.

CO2: Design and analyze basic microprocessor and microcontroller-based circuits for healthcare applications.

CO3: Evaluate and implement regulated and noise-free power supply systems for medical and nuclear instrumentation.

CO4: Analyze the operation and interfacing of radiation detectors and biomedical sensors with electronic circuits.

CO5: Apply knowledge of modern biomedical technologies such as IoT, robotics, and AI in medical instrumentation and patient monitoring systems. Electronics and Biomedical Instrumentation

Textbooks & References

- T.L. Floyd, *Electronic Devices* (10th edition), Pearson Education Inc., 2017.
- R.F. Coughlin and F.F. Driscoll, *Operational Amplifiers and Linear Integrated Circuits* (6th edition), Pearson Education Inc., 2001.
- T.L. Floyd, *Digital Fundamentals* (11th edition), Pearson Education Inc., 2015.
- Khandpur, *Handbook of Biomedical Instrumentation* (3rd edition), McGraw Hill Education, 2014.
- S. Brown and Z. Vranesic, *Fundamentals of Digital Logic with Verilog Design* (3rd edition), Tata McGraw-Hill, 2013.
- H. Skalsi, *Electronic Instrumentation* (3rd edition), Tata McGraw-Hill, 2012.
- Leslie Cromwell, Fred J. Weibell, Erich A. Pfeiffer, *Biomedical Instrumentation and Measurements*, Prentice Hall, 1990.
- M. Arumugam, *Biomedical Instrumentation*, Anuradha Publishing Co., 2004.

Core-4: Anatomy, Physiology, Tumour Pathology, and Genetics

Credits: 4 **Lecture:** 4 **Tutorial:** 0 **Practical:** 0

Course Objectives

- To provide foundational knowledge of human anatomy and physiology relevant to diagnostic imaging and radiotherapy.
- To understand the structure, function, and interrelationship of major organ systems of the human body.
- To develop the ability to identify normal and pathological anatomy using radiological imaging modalities.

- To understand the biological basis of cancer, tumour classification, and progression.
- To gain insight into clinical aspects of oncology, including staging, grading, and cancer management modalities.

Detailed Syllabus

Unit I – Introduction to Human Anatomy and Physiology (12 hrs)

General anatomical terminology – Levels of structural organization – Cells, tissues, organs, and systems – Overview of organ systems – Anatomical planes and positions – Skeletal system: bones and joints, classification and functions – Muscular system: types of muscles, mechanism of contraction – Cardiovascular system: structure and function of heart, major vessels, and blood circulation – Lymphatic system: lymph nodes, lymph circulation, and clinical significance.

Unit II – Major Organ Systems and Their Physiology (12 hrs)

Respiratory system – anatomy of lungs, mechanism of respiration, regulation of breathing – Digestive system – structure and function of alimentary canal, liver, pancreas – Urinary system – structure of nephron, urine formation and regulation – Endocrine system – pituitary, thyroid, adrenal, and pancreas – Nervous system – brain, spinal cord, peripheral nerves, synaptic transmission, reflex arc – Reproductive system (male and female): structure, function, and hormones – Sensory organs: anatomy and physiology of eye and ear.

Unit III – Radiographic Anatomy and Cross-sectional Imaging (12 hrs)

Radiographic anatomy of head, thorax, abdomen, pelvis, and extremities – Identification of anatomical landmarks on plain X-rays, CT, MRI, and PET/CT images – Surface and sectional anatomy of organs and structures – Radiological interpretation of normal variations – Identification of major vessels, muscles, and bones in imaging modalities – Correlation between imaging anatomy and radiation treatment planning – Radiographic anatomy of CNS, skeletal, and visceral systems.

Unit IV – Genetics and Tumour Pathology (12 hrs)

Basics of human genetics – structure and function of DNA and RNA – gene expression, mutations, chromosomal aberrations, and genetic disorders – Oncogenes, tumour suppressor genes, and molecular basis of cancer – Cell cycle and mechanisms of carcinogenesis – Tumour pathology: types, classification, grading, and staging – Differences between benign and malignant tumours – Mechanisms of tumour spread: local invasion, lymphatic and hematogenous metastasis – Tumour markers and biopsy interpretation – Genetic predisposition and familial cancers.

Unit V – Basics of Radiation Oncology and Cancer Management (12 hrs)

Site-specific cancers: Head and neck, breast, gynaecological, gastrointestinal, genitourinary, lung, lymphomas, and leukemias – AIDS-related cancers – Staging and grading systems (TNM, Ann Arbor, FIGO, etc.) – Curative and palliative approaches – Modalities of cancer treatment: surgery, chemotherapy, radiotherapy, hormone therapy, immunotherapy, radionuclide therapy – Acute and late radiation effects – Radiation tolerance of organs – Side-effect management during treatment – Multidisciplinary cancer care and patient follow-up protocols.

Course Outcomes

- Understand human anatomical structures and physiological mechanisms relevant to medical physics.
- Identify normal and pathological anatomy using radiological images and sectional anatomy.
- Explain the principles of genetics and their role in tumour initiation and progression.
- Correlate clinical oncology principles with imaging and therapeutic applications.
- Acquire an integrated understanding of organ-specific cancers, staging, and treatment modalities.

Text Books & References

- Ross & Wilson – *Anatomy and Physiology in Health and Illness*, Elsevier.
- Chaurasia B.D. – *Human Anatomy (Volumes I–III)*, CBS Publishers.
- Snell R.S. – *Clinical Anatomy by Regions*, Lippincott Williams & Wilkins.
- Robbins & Cotran – *Pathologic Basis of Disease*, Elsevier.
- Hall J.E. – *Guyton and Hall Textbook of Medical Physiology*, Elsevier.
- Moore K.L. & Dalley A.F. – *Clinically Oriented Anatomy*, Lippincott Williams & Wilkins.
- Junqueira L.C. & Carneiro J. – *Basic Histology: Text and Atlas*, McGraw Hill.
- Alberts B. – *Molecular Biology of the Cell*, Garland Science.
- Hendee W.R. & Ritenour E.R. – *Medical Imaging Physics*, Wiley-Liss. Kumar V. et al. – *Robbins Basic Pathology*, Elsevier.

Core–5: Solid State Physics and Radiation Detectors

Credits: 4 (3 Theory + 1 Tutorial)

Total Contact Hours: 60 (45 Lecture + 15 Tutorial)

Course Objectives

- To understand the principles of solid-state physics relevant to radiation detector materials.
- To study energy bands, charge carriers, and defect mechanisms that govern detector performance.
- To acquire knowledge of gas-filled, scintillation, semiconductor, and neutron detectors used in radiation measurement.

- To familiarize with radiation monitoring instruments, spectrometry systems, and calibration methods.
- To apply concepts of material response, signal processing, and calibration to practical medical physics instrumentation.

Unit I – Solid State Physics Fundamentals for Detector Materials (12 h: 9 L + 3 T)

Energy Bands in Solids (4 h): Electrons in periodic potentials; origin of energy bands; classification of materials as metals, semiconductors, and insulators; Bloch's theorem (1-D case); nearly free electron approximation; formation of bands and band gaps; Brillouin zones and their physical significance.

Charge Carriers and Transport (3 h): Electrons and holes in semiconductors; effective mass concept and density of states; mobility and conductivity; influence of temperature, doping, and scattering mechanisms; Hall-effect measurements for carrier and defect characterization.

Defects and Doping in Solids (3 h): Types of defects – point (vacancies, interstitials, antisites), line (dislocations), and planar (stacking faults); methods of observation and characterization; doping mechanisms – substitutional donors/acceptors, isoelectronic impurities, and defect complexes.

Material Response (2 h)**:** Colour centres and F-centres in luminescent materials; trap states in TL/OSL phosphors; link between defect/dopant chemistry and dosimetric response; semiconductor detectors – charge generation, transport, and collection.

Tutorial: Draw band diagrams for metals, semiconductors, and insulators; calculate effective mass and mobility; analyze Hall data and relate trap states to luminescence behaviour.

Unit II – Principles of Radiation Detection and Detector Characteristics (12 h: 9 L + 3 T)

Principles of radiation detection and interaction of radiation with matter relevant to detection- Modes of detector operation – current, pulse, and mean-level modes; pulse height spectra; counting curves and plateaus- Detector performance parameters – energy resolution, sensitivity, efficiency, detector window, dead time, and recovery time- Electronic components of detection systems – detector, preamplifier, amplifier, pulse processing electronics, and display- Noise sources and signal-to-noise ratio improvement; counting statistics and uncertainty analysis; Poisson statistics and propagation of errors.

Tutorial: Exercises on pulse height spectrum analysis, energy resolution and efficiency calculations, dead-time correction, and counting error estimation.

Unit III – Gas-Filled, Scintillation, and Semiconductor Detectors (12 h: 9 L + 3 T)

Gas-Filled Detectors: Regions of operation – ionization, proportional, and Geiger-Müller; principles and construction of ionization chambers (cylindrical, plane-parallel, spherical, well-type, and extrapolation chambers); gas multiplication; proportional and GM counter mechanisms; sealed, flow, high-pressure, multi-wire, and position-sensitive variants- Applications: Radiation dosimeters, survey meters, and contamination monitors used in medical and protection measurements.

Scintillation Detectors: Advantages and properties of ideal scintillators; radiation detection mechanism in organic and inorganic scintillators; photon detection devices – PMT, photodiodes; light collection systems; types of scintillators used in diagnostic, nuclear medicine, and therapy dosimetry.

Semiconductor Detectors: Principles of operation – p-n junction, depletion region, charge collection; materials (Si, Ge, CdTe, CZT); diode and MOSFET dosimeters – calibration, temperature and energy dependence, and clinical applications.

Tutorial: Determine GM counter plateau and operating voltage; compare NaI(Tl) and HPGe detector spectra; perform calibration exercises for ionization chambers and MOSFET dosimeters.

Unit IV – Neutron, Chemical, and Emerging Detectors (12 h: 9 L + 3 T)

Neutron detection mechanisms – nuclear activation, track detection, and proportional counter methods- Self-Powered Neutron Detectors (SPND); BF_3 and ^3He proportional counters; bubble detectors and solid-state nuclear track detectors (SSNTD)- Gel dosimeters – chemical basis, optical readout, and 3-D dose verification- Luminescent dosimeters – thermoluminescent (TLD), optically stimulated (OSLD), and radiophotoluminescent (RPL) dosimeters; radiographic and radiochromic films (Gafchromic)- Emerging detectors – Direct Ion Storage (DIS), diamond detectors, Radiation litmus films: principle, composition, and mechanism of color change under ionizing radiation exposure – applications in rapid dose visualization and qualitative radiation field mapping- advanced OSLD systems- Calorimeters for high-dose measurements and standards.

Tutorial: Comparative study of neutron detection systems; design of moderator for neutron counters; evaluation of TL glow curves and OSL dose-response characteristics.

Unit V – Radiation Measurement, Monitoring, and Calibration Systems (12 h: 9L + 3T)
Measurement Instruments: Condenser and pocket chambers, quartz fibre electrometers, current-based dosimeters, Farmer chamber, secondary standard therapy-level dosimeters, water phantom systems, radiation field analyzer (RFA), isotope calibrators, and beam therapy dosimeters- Personnel Monitoring Instruments: TLD and OSLD badge readers, glass dosimeter readers, electronic pocket dosimeters, image analyzers, and densitometers- Area and Contamination Monitors: Portable/fixed survey meters, beta–gamma zone monitors, hand–foot–clothing and portal monitors, laundry/floor monitors, neutron monitors, REM counters, and whole-body counters for internal activity assessment- Spectrometry and Counting Systems: Alpha–beta counters, gamma spectrometers (NaI(Tl), HPGe), liquid scintillation counters, air monitors, and multichannel analyzers. Calibration of Radiation Instruments: Concepts and requirements of calibration; parameters checked – energy response, linearity, constancy, angular dependence; selection of sources and source strength; traceability to standards; uncertainty estimation; maintenance and periodic QA as per AERB/IAEA/ISO guidelines.

Tutorial: Calibration exercises for survey meters and TLD readers; performance checks of RFA and spectrometers; design of QA schedule for radiation instruments; computation of calibration coefficients.

Course Outcomes

After completing this course, the students will be able to:

- Explain solid-state physics principles governing the operation of detector materials.
- Describe the physical principles, modes, and characteristics of various radiation detectors.
- Apply radiation detection techniques in measurement, monitoring, and clinical instrumentation.
- Perform calibration and quality assurance procedures for dosimetry and monitoring systems.
- Correlate material properties and defects with detector response and dosimetric performance.

Textbooks & References

- C. Kittel, *Introduction to Solid State Physics*, 8th Ed., Wiley, 2005.
- G. F. Knoll, *Radiation Detection and Measurement*, 4th Ed., Wiley, 2010.
- F. H. Attix, *Introduction to Radiological Physics and Radiation Dosimetry*, Wiley-VCH, 2008.
- S. R. Cherry, J. A. Sorenson, and M. E. Phelps, *Physics in Nuclear Medicine*, Elsevier, 2012.
- Glenn F. Knoll, *Practical Gamma-Ray Spectrometry*, Wiley, 2008.
- Price W.J. Nuclear Radiation Detection.
- Stepanor B.I. Theory of Luminescence
- Glenn F Knoll. Radiation Detection & Measurement.

- Albert Paul Malvino. Electronics Principles
- Robert L. Boylestad. Electronics Devices and Circuit Theory
- Paul – Horowitz. Art of Electronics
- Greiner R.A. Semiconductor Devices & Application
- Crawford R.H. MOSFET in Circuit Design
- IAEA, *Radiation Oncology Physics: A Handbook for Teachers and Students*, Vienna, 2005.
- IAEA Safety Reports and TECDOCs on calibration and instrumentation.
- ISO 4037 – X and gamma reference radiation calibration standards.
- AERB Codes and Safety Guides on radiation instrumentation and monitoring.
- Recent publications on OSL, DIS, diamond, and radiochromic detectors in medical dosimetry.

Elective 1.A: Programming, Data Science, and Computational Methods for Medical Physics

Credits: 4 (3 Theory + 1 Tutorial)
Total Contact Hours: 60 (45 Lecture + 15 Tutorial)

Course Objectives

By the end of the course, students will be able to:

- Understand and apply programming fundamentals using Python and MATLAB in the context of medical-physics applications.
- Perform data analysis and visualization of numerical/medical physics data sets to extract meaningful insights.
- Implement image-processing techniques (filtering, segmentation, DICOM handling) as applied to medical imaging and medical physics workflows.
- Develop user interfaces and apply basic machine-learning methods for solving medical-physics problems (e.g., QA automation, image classification).
- Demonstrate proficiency in MATLAB for reading, processing and visualizing medical image data and applying computational methods in medical-physics scenarios.

Unit I: Programming Foundations in Python (9L + 3T)

- Installation of Python and development environment
- Basic syntax and data types (lists, tuples, dicts, sets)
- Control-flow statements (if/else, loops)
- Functions, modules, packages
- Interactive mode, scripting, error-handling and debugging
- Object-oriented programming in Python
- Tutorial/Practical: writing small Python scripts, simple classes, modular code

Unit II: Data Analysis & Visualization in Python (9L + 3T)

- Introduction to numerical computing: NumPy, SciPy
- Data handling with Pandas: data frames, indexing, grouping
- Data visualization with Matplotlib and Seaborn: plotting profiles, histograms, scatter, time-series
- Basic statistics, hypothesis testing (e.g., t-test, chi-square), correlation analysis
- Case studies: medical-physics relevant data sets (e.g., QA logs, time-series of detector outputs)
- Tutorial/Practical: load/clean data, compute summary statistics, generate visualizations

Unit III: Image Processing & Medical Physics Applications in Python (9L + 3T)

- Python libraries for medical physics: e.g., PyDICOM for DICOM, OpenCV for image processing, pymedphys for medical-physics specific tools.
- Basic image operations: reading DICOM series, image arrays, metadata handling
- Image filtering, segmentation, morphological operations
- Digital image processing concepts (noise, resolution, histogram, transforms)
- Handling DICOM RT datasets (RT-Structure, RT-Plan, RT-Dose)
- Case studies: segmentation of CT/MR images, dose distribution visualization, QA images
- Tutorial/Practical: work with DICOM datasets, apply filters/segmentations, script basic analyses.

Unit IV: GUI Development & Machine Learning in Medical Physics (9L + 3T)

- GUI development in Python: e.g., Tkinter, PyQt; event-driven programming; user flows for tools
- User-interface design principles: usability, workflow for a medical physicist
- Introduction to machine learning: supervised vs unsupervised algorithms, overview (e.g., regression, classification, clustering)
- Application of ML in medical physics: QA anomaly detection, image classification, outcome prediction
- Tutorial/Practical: build a simple GUI tool (for e.g., image viewer + segmentation); implement a small ML workflow (train/test) on a medical physics dataset

Unit V: MATLAB for Medical Physics (9L + 3T)

- Introduction to MATLAB: environment, data types, operators, flow control, functions, I/O, array manipulation
- Executing MATLAB programs, scripts, functions
- Data reading, manipulation, display & plotting in MATLAB
- DICOM file functions in MATLAB: reading, displaying medical images, processing & analysis

- Machine learning and fuzzy logic in MATLAB context (basic introduction)
- Tutorial/Practical: MATLAB lab sessions – read DICOM image, process and display, simple ML/fuzzy logic demo

Course Outcomes

On successful completion of the course, students will be able to:

- Write modular, documented Python code and MATLAB scripts for medical physics tasks.
- Load, clean and analyse complex datasets (time-series, QA logs, image metadata) and produce visualisations appropriate for medical physics research or QA.
- Apply filtering and segmentation methods to medical image data (DICOM) and interpret the results in a medical-physics context.
- Design and build a simple GUI tool to support a medical-physics workflow, and apply a machine-learning pipeline to a relevant medical-physics dataset.
- Use MATLAB toolboxes effectively for medical image display, processing, analysis and basic machine-learning/fuzzy logic tasks; relate results to clinical/physics practice.

Textbooks & Reference

- Essential Python for the Physicist – Giovanni Moruzzi (Springer, 2025)
- MATLAB for Medical Physics: Real-life Clinical Scenarios and Projects – Jidi Sun (Springer, 2023)
- Fundamentals of Medical Image Processing Using MATLAB – Dwijesh K. Dutta Majumder&Dipankar Ray (PHI Learning, 2022)
- Applied Medical Image Processing: A Basic Course – Wolfgang Birkfellner (CRC Press, 3rd ed, 2024)
- Numerical Methods in Physics with Python – Alex Gezerlis (Cambridge Univ Press, 2023)
- Python Data Science Handbook: Essential Tools for Working with Data – Jake VanderPlas (O'Reilly, 2016)
- Python Crash Course – Eric Matthes (No Starch Press, 2023)
- Learn More Python 3: The Hard Way – Zed A. Shaw (Addison-Wesley, 2017)
- Statistics for Absolute Beginners: A Plain English Introduction – Oliver Theobald (Scatterplot Press, 2017)
- Digital Signal Processing for Medical Imaging Using MATLAB – E. S. Gopi (Springer, latest)

Elective 1.B: Health Technology Assessment (HTA) (3 Credits, 45 Hours)

Course Objectives

- Understand the concept, scope, and historical evolution of Health Technology Assessment (HTA) globally and in India.
- Learn the principles, frameworks, and methodologies applied in HTA for clinical, economic, and social assessment.
- Analyze ethical, legal, and political considerations in health technology decision-making.
- Apply HTA methods to evaluate healthcare technologies and public health programs.
- Explore global and Indian HTA systems and their integration with health policy and Universal Health Coverage (UHC).

UNIT I: Introduction to Health Technology Assessment (9 Hours)

Health Technology Assessment (HTA) – Scope of HTA in radiotherapy, nuclear medicine, diagnostics, and public health programs – Multidisciplinary nature of HTA: economics, epidemiology, ethics, policy – Historical evolution of HTA in USA, Canada, and Europe – Formation of INAHTA – Emergence of HTA in developing countries and Asia (HITAP, NICE International) – Importance and role of HTA in health systems – Evidence-based policy making – Priority setting and resource optimization – Role in Universal Health Coverage (UHC) – HTA in India: Institutional structure under DHR–ICMR – Role, objectives, and governance structure – HTAIn manual and its relevance – Conducive factors for HTA in Asia: Policy drivers, political commitment, capacity development

Tutorial Exercises: Topic discussion on HTA evolution and evaluation in public health programs

Key Terms / Keywords: Health Technology, Evidence-Based Decision Making, Resource Allocation, HTAIn, INAHTA, UHC, HITAP, NICE, CADTH, WHO HTA Network

UNIT II: Principles and Framework of HTA (9 Hours)

Core principles of HTA – Transparency, accountability, scientific rigor, stakeholder involvement – Relevance, timeliness, ethical soundness – HTA triangle: Clinical, Economic, Social/Ethical dimensions – Relationship with Evidence-Based Medicine (EBM) and Comparative Effectiveness Research (CER) – HTA process steps: Topic nomination and prioritization – Scoping and protocol development – Evidence synthesis and appraisal – Formulating recommendations – Policy uptake and monitoring – Quality assurance and evaluation: Internal and external review – HTAIn quality check guidance (ICMR) – Reporting standards: HTAIn template, PRISMA, CHEERS checklist – Stakeholder engagement: Policymakers, clinicians, economists, patient groups

Tutorial Exercises: Flowchart of HTA process – Evaluation of stakeholder roles in decision-making

Key Terms / Keywords: HTA Framework, Topic Prioritization, Scoping, Evidence Appraisal, PRISMA, CHEERS, Quality Assurance, Stakeholder Involvement

UNIT III: Methodologies in Health Technology Assessment (9 Hours)

Evidence synthesis – Systematic review – Meta-analysis – Critical appraisal – Databases: PubMed, Cochrane Library – Clinical effectiveness and safety evaluation: Clinical trial data – Observational studies – Surrogate and patient-relevant outcomes – Economic evaluation: Cost-Effectiveness Analysis (CEA) – ICER – Cost-Utility Analysis (CUA) – QALY, DALY – Cost-Benefit Analysis (CBA) – WTP – Cost-Minimization and Budget Impact Analysis (BIA) – Modeling techniques: Decision tree – Markov models – Sensitivity analysis – Discounting – Uncertainty analysis – Reporting economic evidence – CHEERS checklist – Interpretation of incremental cost ratios

Tutorial Exercises: Cost-effectiveness calculation – Critical appraisal of systematic review

Key Terms / Keywords: Cost-Effectiveness, QALY, DALY, ICER, Budget Impact Analysis, Decision Tree, Markov Model, Sensitivity Analysis, Discounting, Evidence Synthesis

UNIT IV: Ethical, Legal, and Political Dimensions of HTA (9 Hours)

Ethical dimensions – Patient autonomy – Beneficence – Justice – Non-maleficence – Balancing cost and access – Public acceptability and transparency – Legal framework: Health technology regulations – Approval processes (CDSCO, FDA, CE) – Intellectual property and patent laws – Data privacy, consent, and confidentiality – Political and institutional factors: Power structures – Policy priorities – Role of advocacy, media, political economy – Case discussions: Pricing of cancer drugs – Medical device regulation – Framework for managing conflicts of interest – Transparency protocols – Governance

Tutorial Exercises: Case study on ethical decision-making – Discussion on legal challenges in medical device approval

Key Terms / Keywords: Ethical Analysis, Justice, Autonomy, Legal Compliance, Patent Law, Regulatory Framework, Political Economy, Accountability, Conflict of Interest

UNIT V: HTA in Practice - Global and Indian Perspectives (9 Hours)

HTAIn – India's HTA system – Institutional framework under Department of Health Research – Process: Topic selection – Assessment – Appraisal – Decision – Examples: Cost-effectiveness of dialysis, knee implants, screening programs – International HTA models: NICE (UK), CADTH (Canada), PBAC (Australia), HITAP (Thailand) – HTA and reimbursement systems in developed and developing nations – Integration with health policy: HTA for Universal Health Coverage – National Health Policy linkages – Public health technology prioritization – Future of HTA: Digital health – AI – Genomics – Personalized medicine – Challenges: Capacity building – Sustainability

Tutorial Exercises: Comparison of India vs UK HTA practices – Proposal of HTA plan for AI-based diagnostic tool

Key Terms / Keywords: HTAIn, NICE, CADTH, PBAC, HITAP, UHC, Health Policy, Digital Health, AI in Healthcare

Learning Outcomes

- Explain the concept, scope, and evolution of HTA globally and in India.
- Describe the institutional framework and role of HTAIn in India.
- Demonstrate knowledge of HTA frameworks, processes, and stakeholder engagement.
- Apply economic and clinical methods to assess technology value and interpret outcome data.
- Analyze ethical, legal, and political dimensions and integrate HTA into health policy.

Textbooks & References

- Drummond MF, Sculpher MJ, Claxton K, Stoddart GL, Torrance GW. *Methods for the Economic Evaluation of Health Care Programmes*, 5th Edition, Oxford University Press, 2015.
- Banta D, Jonsson E. *History of Health Technology Assessment*, Academic Press, 2009.
- Oortwijn W, Jansen M, Baltussen R. *Health Technology Assessment: Methods and Applications*, Springer, 2020.
- HTAIn Manual, Indian Council of Medical Research, 2018
- Drummond MF et al., *Key Principles for the Improved Conduct of HTA*, International Journal of Technology Assessment in Health Care, 2008.
- HTAIn Manual (ICMR, 2018)
- Chootipongchaivat S. et al., *Conducive Factors to the Development of HTA in Asia*, 2016
- WHO, *Health Technology Assessment: A Global Overview*
- Luce BR et al., *EBM, HTA, and CER: Clearing the Confusion*, Milbank Quarterly, 2010
- Kieslich K et al., *Accounting for Technical, Ethical, and Political Factors in Priority Setting*, Health Systems & Reform, 2016

Core-Lab I: Electronics and Radiation Instrumentation Lab

Credits: 3 **Lecture:** 0 **Tutorial:** 0 **Practical:** 6

Course Objectives

- To provide hands-on experience in basic and advanced electronic components, circuits, and operational amplifier applications relevant to radiation instrumentation.
- To enable students to develop skills in the operation, calibration, and performance evaluation of radiation detection and measurement systems.
- To train students in the safe handling of ionizing radiation sources and proper use of survey meters, GM counters, scintillation and semiconductor detectors.
- To familiarize learners with essential diagnostic measurements such as energy resolution, efficiency, HVL, attenuation, and dosimeter calibration.
- To equip students with the competence to analyze experimental data, estimate uncertainties, and prepare professional laboratory documentation.

Electronics

Any five out of the following ten practical exercises are recommended

Practical 1

Title: Characteristics of Semiconductor Diode (PN Junction)

Aim & Objective: To study the V-I characteristics of a semiconductor diode and determine its forward and reverse bias behaviour.

Equipment & Components: Semiconductor diode, DC power supply, resistors, voltmeter, ammeter, breadboard, connecting wires.

Procedure:

- Connect the diode in forward bias with series resistor and measure voltage and current.
- Plot forward V-I characteristics.
- Reverse the diode, apply voltage, measure leakage current, and plot reverse V-I characteristics.
- Analyze threshold voltage, breakdown voltage, and diode behaviour.

Practical 2

Title: Input and Output Characteristics of Junction Field Effect Transistor (JFET)

Aim & Objective: To study the input and output characteristics of a JFET.

Equipment & Components: JFET (N-channel), DC power supply, resistors, voltmeter, ammeter, breadboard, connecting wires.

Procedure:

- Connect the JFET in common source configuration.
- Vary gate-source voltage and measure drain current.
- Plot input characteristics (V_GS vs I_G) and output characteristics (V_DS vs I_D).
- Determine pinch-off voltage and operating region.

Practical 3

Title: Input and Output Characteristics of Metal Oxide Semiconductor FET (MOSFET)

Aim & Objective: To study the characteristics of MOSFET in common source configuration.

Equipment & Components: MOSFET (N-channel), resistors, DC power supply, voltmeter, ammeter, breadboard, connecting wires.

Procedure:

- Connect MOSFET in common source configuration.
- Vary gate-source voltage and record drain current for different drain-source voltages.
- Plot input and output characteristics.
- Identify threshold voltage and saturation region.

Practical 4

Title: Study of Operational Amplifier (Op-Amp) Characteristics

Aim & Objective: To determine input offset voltage, input bias current, and gain of an Op-Amp.

Equipment & Components: IC 741 Op-Amp, DC power supply, resistors, voltmeter, breadboard, connecting wires.

Procedure:

- Connect Op-Amp in open-loop configuration.
- Apply small input voltage and measure output voltage.
- Calculate voltage gain.
- Measure offset voltage and input bias current.

Practical 5

Title: Op-Amp Applications – Addition and Subtraction

Aim & Objective: To implement summing and difference amplifiers using Op-Amp and verify the output.

Equipment & Components: IC 741, resistors, DC power supply, function generator, breadboard, connecting wires.

Procedure:

- Build summing amplifier circuit with multiple inputs.
- Apply input voltages and measure output.
- Build difference amplifier, apply input voltages, measure output, and compare with theoretical calculations.

Practical 6

Title: Op-Amp Applications – Integration and Differentiation

Aim & Objective: To design Op-Amp circuits for integration and differentiation and study their output waveform.

Equipment & Components: IC 741, resistors, capacitors, function generator, oscilloscope, breadboard, DC power supply.

Procedure:

- Construct integrator and differentiator circuits.
- Apply sine wave input, observe output waveform on oscilloscope.
- Verify amplitude and phase relationship with theoretical predictions.

Practical 7

Title: Decoder and Encoder Circuits using ICs

Aim & Objective: To study the working of decoder and encoder logic circuits.

Equipment & Components: IC 74138 (decoder), IC 7486 (encoder), LEDs, resistors, DC power supply, connecting wires, breadboard.

Procedure:

- Connect decoder circuit, apply input logic levels, observe outputs.
- Connect encoder circuit, apply multiple inputs, verify encoded output.

Practical 8

Title: Regulated Power Supply using IC

Aim & Objective: To design and test a regulated DC power supply using IC voltage regulators.

Equipment & Components: 7805/7812 voltage regulator IC, transformer, bridge rectifier, capacitors, resistors, DC voltmeter, connecting wires.

Procedure:

- Connect transformer and rectifier to IC regulator.
- Measure output voltage at different loads.
- Verify stability and regulation.

Practical 9

Title: AC Voltage Regulator using IC

Aim & Objective: To design and test an AC voltage regulator circuit using IC and verify output stability.

Equipment & Components: AC voltage regulator IC (e.g., IC 723), resistors, diodes, capacitors, AC supply, oscilloscope, multimeter.

Procedure:

- Construct AC regulator circuit.
- Apply varying AC input, measure regulated output.
- Observe voltage stability and response to load changes.

Practical 10

Title: Op-Amp Comparator Circuit

Aim & Objective: To design and test an Op-Amp as a voltage comparator and observe its output switching behavior.

Equipment & Components: IC 741 Op-Amp, resistors, DC power supply, function generator, oscilloscope, breadboard.

Procedure:

- Connect Op-Amp in comparator configuration.
- Apply varying input voltage and observe output switching.
- Determine reference voltage and analyze response time.

RADIATION INSTRUMENTATION LAB

Any ten out of the following sixteen practical exercises are recommended

1. **Measure the energy resolution of the Gamma ray spectrometer**

   Aim

   To determine the energy resolution (FWHM/peak centroid) of a gamma-ray spectrometer (scintillation or semiconductor) using known gamma sources.

   Objectives

   - To acquire gamma spectra of one or more standard gamma sources (e.g., Cs-137, Co-60, Na-22).
   - To identify photopeaks and measure full width at half maximum (FWHM) and channel centroid.
   - To calculate energy resolution (%) at different energies and assess detector performance.
   - To examine contributors to resolution: statistical broadening, electronic noise, and intrinsic detector effects.
   - To plot resolution vs. energy and interpret the trend.

Components / Apparatus

- Gamma spectrometer (NaI(Tl) scintillator + PMT with preamp & shaping amplifier or HPGe detector with cryostat and preamp).
- Multichannel analyzer (MCA) / digital spectrometer software.
- Standard gamma sources: Cs-137 (662 keV), Co-60 (1173 & 1332 keV), Na-22 (511 & 1275 keV).
- Calibration sources/ check source, lead shielding, source holder, HV supply, amplifier, cables, laptop with acquisition software.

2. **Identify unknown gamma source using the Gamma ray spectrometer (Mandatory 1)**

Aim

To identify an unknown gamma source by acquiring its gamma spectrum and matching photopeak energies to known radionuclides.

Objectives

- To acquire a clean spectrum of the unknown source with sufficient statistics.
- To calibrate the spectrometer (channel-energy).
- To identify characteristic photopeaks (photopeak and escape/sum peaks) and assign energies.
- To match observed energies to radionuclide gamma lines, using databases or reference tables.
- To estimate activity qualitatively or quantitatively (optional) and discuss uncertainties.

Components / Apparatus

Gamma spectrometer with MCA (NaI(Tl) or HPGe), calibration sources (e.g., Cs-137, Co-60), unknown source (sealed, labeled only as unknown), shielding, source holder, laptop and database/reference table.

3. **Activity Estimation of a Gamma Source using SCA (Relative / Absolute)**

Title

Activity Estimation of a Gamma Source using Single Channel Analyser (SCA)

Aim

To estimate the activity of a gamma-emitting source by counting photopeak pulses through an SCA after calibrating detector efficiency (relative or absolute).

Objectives (5)

- To set the SCA window on the chosen photopeak and measure net counts.
- To perform background subtraction and dead-time correction.
- To use a calibrated source or previously measured efficiency curve to determine absolute activity, or to determine relative activity between sources.

- To evaluate uncertainties from counting statistics, efficiency, and geometry.
- To discuss and apply corrections (coincidence summing, self-absorption) if required.

4. **Peak-to-Total and Peak-to-Compton Ratio Measurement using SCA (Effect of Collimation & Windowing)**

   Title

   Measurement of Peak-to-Total (P/T) and Peak-to-Compton (P/C) Ratios with SCA and Study of Collimation / Windowing Effects

   Aim

   To measure the peak-to-total and peak-to-Compton ratios for a gamma photopeak using SCA windows and to study how collimation and SCA window selection influence these figures of merit.

   Objectives (5)

   - To determine the counts in the photopeak, Compton continuum region, and total counts using appropriate SCA windowing.
   - To compute Peak-to-Total (P/T) = Npeak/NtotalN_{\rm peak}/N_{\rm total}Npeak/Ntotal and Peak-to-Compton (P/C) = Npeak/NComptonN_{\rm peak}/N_{\rm Compton}Npeak/NCompton.
   - To study the effect of applying a collimator (narrow beam) on P/T and P/C.
   - To explore impact of window width/position on measured ratios.
   - To report optimal configuration for maximizing spectral quality for given measurement goals.

5. **Verification of inverse square law and finding a hidden source using survey meters**

   Aim

   To verify the inverse square law for gamma radiation intensity with distance and to locate a hidden point source using survey meters.

   Objectives

   - To measure count rate vs. distance from a point source and verify I∝1/r2I\propto 1/r^2I∝1/r2.
   - To quantify deviations due to scattering, attenuation, and finite source/detector size.
   - To practice source localization (triangulation) using count rate measurements.
   - To understand limitations of survey meters and background influence.
   - To evaluate uncertainty and produce best-fit model parameters.

Components / Apparatus

Sealed gamma point source (low-activity for safety), pressurized ion chamber or GM survey meter (preferably calibrated), measuring tape/meter stick, mounting stands, shielding, data sheet, optional second meter for cross-check.

6. **Estimation of efficiency of the alpha counting system (Mandatory 2)**

Aim

To determine the intrinsic and geometric efficiency of an alpha counting system (e.g., ZnS (Ag) scintillation counter, PIPS detector) for a known alpha source.

Objectives

- To measure counting efficiency using a calibrated alpha source (known activity).
- To separate intrinsic detector efficiency from geometric (solid angle) efficiency.
- To understand corrections due to source self-absorption and air attenuation.
- To estimate uncertainty and minimum detectable activity (MDA) for the setup.
- To document procedures for routine efficiency calibration.

Components / Apparatus

- Alpha detector (ZnS (Ag) scintillator + photomultiplier, gas proportional alpha counter, or PIPS silicon detector).
- Calibrated alpha standard source (traceable activity).
- Source holders, distance gauge (micrometer), vacuum/controlled atmosphere if available, lead/aluminum shielding for background reduction, stopwatch/MCA (if energy discrimination), vacuum chuck for PIPS if needed.

7. **Measure the background radiation level using the pressurized ion chamber-based survey meter (Mandatory 3)**

Aim

To measure ambient background gamma dose rate using a pressurized ion chamber survey meter and to analyze variability over time/locations.

Objectives

- To operate a pressurized ion chamber and record dose rates (μSv/h or mR/h).
- To calibrate/check instrument zero and energy response if applicable.
- To compare readings at multiple locations and times and compute statistical parameters.
- To evaluate contributions from cosmic and terrestrial sources and local contamination (if any).
- To determine minimum detectable dose rate and instrument uncertainty.

Components / Apparatus

Pressurized ion chamber (well-calibrated), electrometer/readout, calibration certificate, tripod or holder, environmental log (time, temperature), shielding for controlled tests.

8. **Measure the range and energy of beta particles by feather analysis using the GM counter**

Aim

To measure the continuous energy distribution (range) of beta particles using feather (range-out) analysis with a Geiger–Müller (GM) counter and absorber foils to estimate endpoint energy.

Objectives

- To record beta count rate as function of absorber thickness (feather curve).
- To determine practical range and extrapolate to obtain maximum beta energy EmaxE_{\text{max}}Emax.
- To understand beta attenuation mechanisms and self-absorption.
- To compare results with theoretical range–energy relations.
- To evaluate uncertainties and discuss limitations of GM counters for beta spectrometry.

Components / Apparatus

Beta source (e.g., Sr-90/Y-90 or P-32) with known activity, GM counter with thin window or pancake probe, absorber foils (Al foils of known thickness or Mylar), micrometer, source holder, lead to shield gamma components if present, counting electronics.

9. **Measure the attenuation coefficients of various materials using the GM counter (Mandatory 4)**

Aim

To measure linear and mass attenuation coefficients (μ\muμ and μ/ρ\mu/\rhoμ/ρ) for gamma rays (or X-rays) in different materials using a GM counter and narrow-beam geometry.

Objectives

- To set up a narrow-beam attenuation experiment minimizing scattered radiation.
- To measure transmitted intensity through increasing thicknesses and compute μ\muμ.
- To compare experimental μ/ρ\mu/\rhoμ/ρ with literature values.
- To assess dependence on energy and material composition.
- To evaluate systematic sources of error (scatter, detector response).

Components / Apparatus

Gamma source with monoenergetic gamma (e.g., Cs-137), collimation (lead collimators), GM counter (or NaI spectrometer for energy discrimination), slab samples of test materials (aluminum, lead, concrete, perspex) with known thickness and density, micrometer/caliper, mounting stands, shielding.

10. Measure HVL of various materials using the GM counter

Aim

To measure the half-value layer (HVL) of shielding materials for a given gamma/X-ray beam using measured count rates.

Objectives

- To determine HVL (thickness reducing intensity by half) for materials like lead, aluminum, perspex at the beam energy used.
- To relate HVL to attenuation coefficient: HVL=ln⁡2/μ\text{HVL} = \ln 2 / \muHVL=ln2/μ.
- To compare experimental HVL with reference values and discuss energy dependence.
- To practice narrow-beam measurement techniques and error estimation.
- To demonstrate compound shielding and determine equivalent thicknesses.

Components / Apparatus

Gamma/X-ray source (monoenergetic or known energies), collimation, GM counter or NaI detector, slab samples of materials with stepwise thickness increments, calipers, mountings.

11. Find the resolving time of a GM counter

Aim

To determine the resolving (dead) time of a Geiger–Müller counter using the two-source or double-source method.

Objectives

- To understand and measure the dead time of a GM tube.
- To apply the two-source method to calculate resolving time.
- To correct measured count rates for dead time if needed.
- To compare measured resolving time with manufacturer specification.
- To discuss implications of dead time in high count rate measurements.

Components / Apparatus

GM counter with counting electronics, two similar activity sources (non-coincident), source holders, stopwatch/MCA, distance gauge for count rate control.

12. Study the characteristics of a GM tube

Aim

To measure and plot the characteristic curve (count rate vs. applied voltage) of a Geiger–Müller tube and to determine plateau region and operating voltage.

Objectives

- To record count rate as function of high voltage (V) across the GM tube.
- To identify threshold, plateau region, and onset of continuous discharge.
- To compute plateau slope (% per 100 V) and select recommended operating voltage.
- To study effect of quenching gas and temperature (qualitative).
- To discuss tube behavior: proportional region, avalanche region, and recovery.

Components / Apparatus

GM tube with variable high voltage supply, stabilized source (low-activity), counter/scaler, voltmeter, current monitor (if available), shielding, stand.

13. Calibration of radiochromic film and finding the unknown dose

Aim

To create a calibration curve for radiochromic film (e.g., GafChromic) vs. known doses and use it to determine an unknown dose.

Objectives

- To irradiate film samples to known doses and scan them to obtain optical density (OD) / net pixel values.
- To establish a dose–response calibration curve (OD vs. dose).
- To determine dose for unknown film using the calibration.
- To assess uncertainties and dynamic range of the film.
- To practice film handling, scanning protocol, and post-processing (including background correction).

Components / Apparatus

- Radiochromic film sheets (same lot)
- radiation source (X-ray unit/linear accelerator) with known dose delivery capability or calibrated phantom + ion chamber
- flatbed scanner or film digitizer
- film cutting tools
- positioning phantom
- dosimeter (ion chamber/TLD) for reference doses
- software for pixel analysis (ImageJ or equivalent).

14. Calibrate the TLD/OSLD and find the unknown dose (Mandatory 5)

Aim

To calibrate Thermo luminescent Dosimeters (TLDs) or Optically Stimulated Luminescence Dosimeters (OSLDs) with known doses and use the calibration to measure an unknown dose.

Objectives

- To anneal and prepare TLDs/OSLDs and perform batch homogeneity checks.
- To irradiate dosimeters to known doses under reproducible geometry.
- To readout dosimeters and establish calibration factors (counts or response per unit dose).
- To measure unknown dosimeter(s), apply corrections, and report dose with uncertainty.
- To evaluate fading, energy dependence, and reproducibility.

Components / Apparatus

TLD chips (e.g., LiF:Mg,Ti) or OSLD discs (Al2_22O3_33:C), TLD/OSLD reader (TL reader or OSL reader), annealing oven, calibrated radiation source (Linac/orthovoltage/X-ray or Cs-137), phantom for reproducible geometry, calibrated ion chamber, heat/optical shielding, dosimeter ID system.

15. Reproducibility and Linearity Test of TLD/OSLD Response

Aim

To study the reproducibility and dose-response linearity of TLD/OSLD dosimeters over a range of radiation doses.

Objectives

- To irradiate multiple TLDs/OSLDs with the same dose and assess response variation (reproducibility).
- To expose dosimeters to different dose levels (e.g., 0.5, 1, 2, 3, 5 Gy) to test linearity.
- To perform readout under standardized heating/stimulation conditions.
- To plot response vs. dose and determine the linearity range.
- To compute coefficient of variation (CV%) and correlation coefficient (R^2).

Components / Apparatus Required

- TLD/OSLD chips/discs from the same batch
- TLD/OSLD reader with temperature/optical control
- Radiation source capable of delivering graded doses
- Reference ion chamber for accurate dose delivery verification
- PMMA or water-equivalent phantom
- Lead markers and irradiation template for uniform exposure
- Spreadsheet or data analysis software

16. Determination of Fading Characteristics of TLD/OSLD

Aim

To study the fading behaviour of TLD/OSLD dosimeters by analysing the loss of stored signal over time after irradiation.

Objectives

- To irradiate a batch of TLDs/OSLDs with a known dose under identical exposure conditions.
- To store dosimeters under controlled environmental conditions for different time intervals.
- To measure the residual signal at each time point using a TLD/OSL reader.
- To calculate percentage signal loss as a function of time.
- To assess the effect of temperature, humidity, and storage conditions on fading.

Components / Apparatus Required

- TLD chips (e.g., LiF:Mg,Ti) / OSLD discs (Al_2O_3:C)
- TLD/OSL reader with stable readout system
- Calibrated radiation source (X-ray, Co-60, Cs-137, or Linac)
- Environmental chamber or controlled storage area (optional)
- Dosimeter storage containers with labels
- Stop-watch or digital timer
- Data logging sheets or software

COURSE OUTCOMES

After successful completion of this laboratory course, the student will be able to:

- Demonstrate proficiency in constructing, testing, and analyzing electronic circuits including diodes, FETs, MOSFETs, regulators, and Op-Amp applications.
- Operate and calibrate radiation detection instruments such as GM counters, ion chambers, scintillation detectors, semiconductor spectrometers, TLD/OSLD systems, and radiochromic film setups.
- Perform key radiation measurements including energy resolution, source identification, attenuation coefficients, HVL, beta range, efficiency, and dead-time determination.
- Apply scientific methodology to record data, evaluate statistical and systematic uncertainties, and interpret radiation measurement results with accuracy.
- Adhere to safety protocols for handling radiation sources and demonstrate competency in using appropriate shielding, collimation, and measurement geometries.

REFERENCES

Textbooks

- **Knoll, G. F.**, *Radiation Detection and Measurement*, 4th Ed., Wiley.
- **Tsoulfanidis, N. & Landsberger, S.**, *Measurement and Detection of Radiation*, CRC Press.
- **Boylestad, R. & Nashelsky, L.**, *Electronic Devices and Circuit Theory*, Pearson.
- **Millman, J. & Grabel, A.**, *Microelectronics*, McGraw Hill.
- **Horowitz, P. & Hill, W.**, *The Art of Electronics*, Cambridge University Press.

Additional References with Links

- IAEA Training Material on Radiation Protection & Instrumentation https://www.iaea.org/resources
- ICRU Reports on Dosimetry and Radiation Measurements https://www.icru.org/home/reports
- NCRP Reports on Radiation Safety and Detectors https://ncrponline.org/publications/reports
- NIST X-ray and Gamma-ray Attenuation Database https://www.nist.gov/pml/x-ray-mass-attenuation-coefficients
- Health Physics Society Resources on Radiation Instrumentation https://hps.org/hpspublications/articles/

SEMESTER II

SECOND SEMESTER								
Course Code	**Title of the Course**	**Credits**	**Hours/ Week**			**Maximum Marks**		
			Theory	**Tutorial**	**Practical**	**CIA**	**ESE**	**Total**
	Applied Mathematical Physics	4	0	4	0	25	**75**	**100**
	Electrodynamics and Quantum Mechanics	3	3	0	0	25	**75**	**100**
	Physics of Medical Imaging	4	3	1	0	25	**75**	**100**
	Physics of Radiotherapy	4	3	1	0	25	**75**	**100**
	Nuclear Medicine I: Imaging and Therapy	4	3	1	0	25	**75**	**100**
	Artificial Intelligence in Medical Physics	3	2	1	0	25	**75**	**100**
	Materials for Radiological applications							
	Medical Physics Lab I- Medical Imaging	3	0	0	6	25	**75**	**100**
	Professional Ethics in Medical Physics	2	2	0	0	50	-	**50**
	Total	**27**	**16**	**8**	**6**	**225**	**525**	**750**

Core–6: Applied Mathematical Physics

Credits: 4 **Lecture:** 0 **Tutorial:** 4 **Practical:** 0

Course Objectives

1. Understand numerical methods, error analysis, and their applications in medical physics problem-solving.
2. Learn probability, descriptive statistics, and statistical distributions for data interpretation in radiation measurements.
3. Apply statistical techniques for radiation data analysis, regression, correlation, and hypothesis testing.
4. Analyze counting statistics, detector performance, and uncertainty evaluation in nuclear measurements.
5. Explore vectors, matrices, eigenvalue problems, and partial differential equations for modeling physical phenomena relevant to medical physics.

UNIT I: Vectors, Matrices & Eigen Value-Problems (12 Hours) Unit I

Scalar and vector fields – Gradient, divergence, curl, Laplacian – Line, surface, and volume integrals – Theorems of Gauss, Green, and Stokes – Vector operators in curvilinear coordinates (cylindrical, spherical) – Matrices: eigenvalues, eigenvectors, diagonalisation, symmetric operators – Applications of vectors and matrices in medical physics and radiation problems

Tutorial Exercises: Compute gradients, divergences, curls, line and surface integrals – Solve eigenvalue and eigenvector problems related to radiation and dosimetry systems.

Key Terms / Keywords: Scalar Field, Vector Field, Gradient, Divergence, Curl, Laplacian, Line Integral, Surface Integral, Volume Integral, Gauss Theorem, Green Theorem, Stokes Theorem, Eigenvalues, Eigenvectors, Diagonalisation, Symmetric Operators

UNIT II: Partial Differential Equations in Physics & Engineering (12 Hours)

Wave equation (e.g., transverse vibration of a string) – Diffusion equation (one-dimensional Fourier equation) – Laplace's equation – Method of separation of variables – Fourier Transform- Fourier series solutions in Cartesian coordinates – Boundary and initial conditions – Boltzmann Transport Equation- Physical applications: heat conduction, vibrations, steady-state fields – Recent trends: computational verification, model validation.

Tutorial Exercises: Solve wave, diffusion, and Laplace equations using separation of variables – Apply Fourier series solutions to physical problems in heat conduction and vibrations.

Key Terms / Keywords: Partial Differential Equation, Wave Equation, Diffusion Equation, Laplace Equation, Separation of Variables, Fourier Series, Boundary Conditions, Initial Conditions, Heat Conduction, Vibrations, Steady-State Fields.

UNIT III: Numerical Methods (12 Hours)

Accuracy and errors in calculations – Round-off errors – Evaluation of mathematical formulae – Iterative methods – Initial approximation and convergence criteria – Newton-Raphson method – Taylor series expansion – Numerical differentiation formulas – Numerical integration: Trapezoidal rule, Simpson's rule, Simpson's three-eighth rule – Differential equation solving: Taylor's method, Euler's method, Modified Euler's method, Runge-Kutta method – Applications in medical physics problem-solving.

Tutorial Exercises: Solve numerical problems on differential equation solutions, numerical integration, and error estimation in radiation physics

Key Terms / Keywords: Numerical Methods, Round-off Error, Convergence, Newton-Raphson, Taylor Series, Euler Method, Runge-Kutta, Trapezoidal Rule, Simpson's Rule

Fourier Transform, Boltzmann Transport Equation, Bivariate analysis

UNIT IV: Probability, Descriptive Statistics, and Statistical Distributions (12 Hours)

Probability concepts – Addition and multiplication laws – Conditional probability – Population and samples – Data collection, tabulation, and graphical representation – Frequency distributions – Measures of central tendency: mean, median, and mode – Measures of dispersion: variance, standard deviation, coefficient of variation – Statistical distributions: Binomial, Poisson, Gaussian, and exponential – Additive property of normal variates – Confidence limits and intervals – Bivariate distribution and analysis – Correlation and regression – Chi-square, t, and F distributions – Law of large numbers and Central Limit Theorem – Applications in measurement, calibration, radiation detection, dosimetry, and imaging data analysis.

Tutorial Exercises: Construct frequency distributions – Calculate mean, median, mode, variance, and standard deviation – Analyze data using Gaussian, Poisson, and binomial distributions – Perform correlation and regression analysis

Key Terms / Keywords: Probability, Conditional Probability, Population, Sample, Central Tendency, Variance, Standard Deviation, Coefficient of Variation, Binomial, Poisson, Gaussian, Exponential, Confidence Interval, Correlation, Regression, Chi-square, t-test, F-test

UNIT V: Counting Statistics, Error Analysis, and Sampling (12 Hours)

Statistics of nuclear counting – Application of Poisson statistics – Random fluctuations – Goodness-of-fit tests – Pearson's chi-square test and Lexis divergence coefficient – Signal-to-noise ratio – Evaluation of detector performance – Efficiency and sensitivity in radiation measurements – Statistical aspects of γ-ray and β-ray counting – Estimation of uncertainty and Minimum Detectable Activity (MDA) – Double isotope technique and statistical accuracy evaluation – Sampling and sampling distributions – Confidence intervals – Hypothesis testing and types of errors – Linear and nonlinear regression – Applications in radiological and biomedical data interpretation – Statistical analysis for calibration, dose-response studies, and clinical trial data – Correlation and regression analysis in dosimetric and radiobiological experiments

Tutorial Exercises: Calculate detector efficiency, signal-to-noise ratio, MDA – Apply chi-square and goodness-of-fit tests – Perform regression analysis and hypothesis testing on sample radiation datasets

Key Terms / Keywords: Counting Statistics, Poisson Statistics, Signal-to-Noise Ratio, Detector Efficiency, Sensitivity, Uncertainty, MDA, Chi-square Test, Lexis Divergence, Sampling, Confidence Interval, Regression, Hypothesis Testing

Learning Outcomes

1. Apply numerical methods for solving equations, integration, differentiation, and differential equations in medical physics problems.
2. Analyze experimental data using probability, descriptive statistics, and statistical distributions for measurement, calibration, and radiation detection.
3. Interpret counting statistics, evaluate detector performance, and estimate uncertainty in nuclear measurements.
4. Solve vector and matrix problems, including eigenvalue and eigenvector calculations relevant to radiation physics.
5. Formulate and solve partial differential equations for physical phenomena in biomedical and radiation physics applications.

Textbooks & References

- Chapra SC, Canale RP. *Numerical Methods for Engineers*, 8th Edition, McGraw-Hill, 2015.
- Spiegel MR, Schiller JS. *Theory and Problems of Probability and Statistics*, McGraw-Hill, 2009.
- Walpole RE, Myers RH, Myers SL, Ye K. *Probability and Statistics for Engineers and Scientists*, 9th Edition, Pearson, 2012.
- Arfken GB, Weber HJ, Harris FE. *Mathematical Methods for Physicists*, 7th Edition, Academic Press, 2013.
- Jain AK. *Numerical Methods for Scientific and Engineering Computation*, New Age International, 2010.
- Hoffman. Numerical Methods for Engineers and Scientists – 2nd Edition Revised and Expanded, Marcel Dekker, Inc., 270 Madison Avenue , New York, NY 10016, Marcel Dekker AG, Hutgasse 4, Postfach 812, CH-4001 Basel, Switzerland.
- A.C. Bajpai, I.M. Calcus and J.A. Fairley Numerical Methods for Engineers and Scientists – A student's course book, John Wiley & Sons.
- Band W. Introduction to Mathematical Physics.
- Croxton. Elementary Statistics
- Dahlberg G. Statistical methods of Medical & Biology Students.
- Krasnor M.L. Ordinary Diff. Equation.
- Conte S, de Boor C. *Elementary Numerical Analysis: An Algorithmic Approach*, 3rd Edition, McGraw-Hill, 2012.
- Devore JL. *Probability and Statistics for Engineering and the Sciences*, 9th Edition, Cengage Learning, 2015.

- Beck J. *Numerical Methods in Engineering and Science*, 2nd Edition, Springer, 2010.
- Rao CV. *Mathematical Methods of Physics*, Universities Press, 2010.
- Gupta S. *Statistical Methods for Engineers and Scientists*, New Age International, 2014.

Core 7: Electrodynamics and Quantum Mechanics

Credit: 3 **Total Hours:** 45 **(3 Credits = 45 Lecture Hours)**

Course Objectives

1. To provide a strong foundation in classical electrodynamics and Maxwell's equations relevant to medical physics applications.
2. To develop an understanding of electromagnetic wave propagation in media and boundary interactions significant to diagnostic and therapeutic systems.
3. To introduce the fundamental postulates and formalism of quantum mechanics and their physical interpretation.
4. To enable understanding of atomic structure, radiation emission, and quantum transitions relevant to nuclear and medical radiation processes.
5. To bridge the principles of electrodynamics and quantum theory with modern instrumentation and radiation detection systems in medical physics.

UNIT I – Electrostatics and Magnetostatics (9 Hours)

Coulomb's law – Electric field and potential due to continuous charge distributions – Gauss's law and applications – Multipole expansion – Boundary conditions at conductor and dielectric surfaces – Image charge method – Capacitance and energy density in electrostatic fields.

Magnetostatics – Biot–Savart law – Magnetic field due to steady currents – Ampere's law – Vector potential – Magnetic boundary conditions – Magnetic dipoles and their fields – Magnetic materials: diamagnetic, paramagnetic, and ferromagnetic behaviour.

UNIT II – Maxwell's Equations and Electromagnetic Waves (9 Hours)

Maxwell's equations in differential and integral forms – Physical interpretation and displacement current – Poynting vector and energy flow – Electromagnetic wave equation and plane wave solutions in free space.

Wave propagation in conducting and dielectric media – Skin depth – Reflection and transmission at dielectric boundaries – Polarization, reflection coefficients, and Brewster's angle – Waveguides and resonant cavities: qualitative discussion.

Applications in microwave diathermy, radiotherapy accelerators, and RF heating systems.

UNIT III – Foundations of Quantum Mechanics (9 Hours)

Limitations of classical physics – Blackbody radiation, photoelectric effect, and Compton effect – de Broglie hypothesis – Wave–particle duality – Heisenberg uncertainty principle – Wave packets and group velocity.

Schrödinger equation (time-dependent and time-independent forms) – Interpretation of the wave function – Probability density and normalization – Operators and expectation values – Commutation relations and observables.

UNIT IV – Solutions of Schrödinger Equation and Quantum Systems (9 Hours)

One-dimensional potential problems – Free particle, particle in a box, potential barrier and tunnelling phenomena.

Quantum harmonic oscillator – Eigenvalues and eigenfunctions – Rigid rotator – Angular momentum operators and commutation relations – Hydrogen atom: energy levels and quantum numbers.

Spin angular momentum and Pauli exclusion principle – Applications to atomic and subatomic systems relevant to nuclear and medical physics.

UNIT V – Quantum Transitions and Applications in Medical Physics (9 Hours)

Time-dependent perturbation theory – Transition probabilities – Fermi's golden rule – Spontaneous and stimulated emission – Einstein's coefficients and relation to laser principles.

Interaction of radiation with matter from a quantum viewpoint – Photoelectric absorption, Compton scattering, and pair production – Quantum origin of X-ray spectra and bremsstrahlung.

Quantum mechanical concepts in MRI, PET, and radiation dosimetry instrumentation – Quantum detectors and solid-state radiation sensors.

Course Outcomes

Upon successful completion of this course, students will be able to:

1. Apply Maxwell's equations to describe electromagnetic field behavior in medical and biological contexts.
2. Solve the Schrödinger equation for basic quantum systems and interpret physical observables.
3. Explain the quantum mechanical basis of radiation–matter interactions and detector operation.
4. Relate electrodynamic and quantum principles to technologies used in diagnostic imaging and radiotherapy.
5. Demonstrate integrated understanding of electromagnetic and quantum phenomena for further study in radiation physics.

Textbooks

- David J. Griffiths, *Introduction to Electrodynamics*, 4th Ed., Cambridge University Press, 2017.
- Nouredine Zettili, *Quantum Mechanics: Concepts and Applications*, 2nd Ed., Wiley, 2009.
- R. P. Feynman, R. B. Leighton & M. Sands, *The Feynman Lectures on Physics*, Vol. II & III, Addison-Wesley, 2011.
- J. S. Townsend, *A Modern Approach to Quantum Mechanics*, University Science Books, 2012.
- H. C. Ohanian, *Classical Electrodynamics*, Allyn and Bacon, 1988.

References

- J. D. Jackson, *Classical Electrodynamics*, 3rd Ed., Wiley, 1998. https://doi.org/10.1002/9781118820211
- E. Merzbacher, *Quantum Mechanics*, 3rd Ed., Wiley, 1998. https://archive.org/details/quantum-mechanics-merzbacher
    - Zangwill, *Modern Electrodynamics*, Cambridge University Press, 2013. https://doi.org/10.1017/CBO9781139013401
- P. M. Mathews & K. Venkatesan, *A Textbook of Quantum Mechanics*, Tata McGraw-Hill, 2010.
- D. H. Perkins, *Introduction to High Energy Physics*, Cambridge University Press, 2000.

Core–8: Physics of Medical Imaging (4 Credits, Lecture: 3, Tutorial: 1, Practical: 0, 60 Hours)

Objectives

1. To understand the physics of X-ray production, characteristics, and generator design.
2. To analyze radiographic image formation, intensifying screens, unsharpness, resolution, and contrast.
3. To understand the principles, instrumentation, and reconstruction techniques of CT imaging.
4. To study the physics of ultrasound, transducers, Doppler techniques, and biological effects.
5. To understand nuclear magnetic resonance and MRI physics, instrumentation, imaging sequences, and safety considerations.
6. Analyze the physics of imaging detectors, their efficiency, noise characteristics, and performance evaluation.
7. Learn the principles of radiography, conventional imaging techniques, and optimization of image quality vs. patient dose.
8. Explore digital imaging, tomographic reconstruction, computed tomography, and dual/multimodality imaging techniques.
9. Comprehend quality assurance, safety protocols, and associated imaging modalities such as MRI and diagnostic ultrasound

Unit I – X-ray Generators and Technology (12 hrs)

Discovery, production, and properties of X-rays – Characteristics and continuous spectra – Design of hot cathode X-ray tubes – Basic requirements of medical diagnostic, therapeutic, and industrial radiographic tubes – Rotating anode and hooded anode tubes – Tube rating, standard exposure charts, limitations on tube loading – Safety devices, insulation and cooling of X-ray tubes – Fault detection in X-ray equipment (pitting of anode, filament evaporation, etc.) – Types of X-ray units: fixed radiography, CT, interventional radiology, C-arm, mammography, bone densitometer, dental X-ray units – Filament and high-voltage transformers, high-voltage circuits, half-wave and full-wave rectifiers, condenser discharge apparatus, three-phase apparatus, voltage doubling circuits – Current and voltage stabilizers – Automatic exposure control (AEC) – Automatic brightness control (ABC) – Measuring instruments for kV and mA, timers, control panels – Complete X-ray circuit – Image intensifiers and flat-panel detectors – Computed Radiography (CR) and Digital Radiography (DR) systems – Modern trends.

Tutorial: Evaluate X-ray tube ratings, simulate tube loading, and analyze AEC/ABC systems.

Unit II – X-ray Imaging, Film, and Radiographic Quality (12 hrs)

Production of a pattern on radiograph, latent image formation, – Construction characteristics, optical density, contrast, gamma, speed, and latitude – Screen films, non-screen films, single-coated films – Fluorescence, intensifying screens: construction, action, types, intensification factor, rare-earth screens, screen unsharpness – Fluoroscopic screens, use of lead screens, artificial contrast and contrast media – Scattered radiation, grids, types of grids, grid ratio, grid factor, Potter-Bucky diaphragms – Unsharpness in radiographs – Exposure timers: hand, synchronous, electronic, mAs, photo, ionization chamber – Timer testing – Image intensifier and CCTV – Tomography – Interlocking and safety devices – Mammography equipment: X-ray tube, screens, accessories – Portable X-ray machines, capacitor discharge units- Tomosynthesis – Xeroradiography principles and working – Automatic film processing – Geometry of radiographic image – Subject contrast and radiographic contrast – Characteristic curves: toe, linear, and shoulder regions – Diagnostic relevance – Fogging and contributing factors – Image quality: dependence on radiographic mottle, sharpness, and resolution – Factors affecting sharpness: geometric, motion, absorption, screen, parallax, total unsharpness – Resolution, line spread function, study of screens – Modulation transfer function and significance – Noise and Wiener spectrum – Dependence of geometric sharpness on focal spot size, FOD, FFD, OFD, slanting beams – Magnification of radiographic image and influencing factors – Estimation of focal spot size by different methods – Quantitative evaluation of resolution.

Tutorial: Compute geometric and total unsharpness, evaluate image magnification and resolution using sample radiographs.

Unit III – Computed Tomography (CT) and Digital Imaging (10 hrs)

Principles of computer tomography – Data accumulation, storage, image reconstruction, and display – CT numbers – Different generations of CT machines, reasons for higher contrast and resolution – Scan configurations – Modern developments: Cone Beam CT, Spiral CT, 3D reconstruction – X-ray tube characteristics in CT units – Detectors and detector configurations in various generations – Mathematics of image reconstruction and display – Algorithms: back projection, interactive, analytical – Image display systems – Image quality, quantum mottle – Resolution: spatial and contrast resolution – Artifacts: motion, streak, beam-hardening, ring artifacts.

Digital radiography systems (CR and DR), digital subtraction techniques, orthopantomography (OPG), interventional radiology- Cone Beam CT (CBCT), Dual Energy CT (DECT) – Detectors for digital imaging: Direct and indirect conversion methods – QA protocols for CT and interventional systems – Dose optimization techniques – Dual and multimodality imaging (PET/CT, SPECT/CT, MR/CT, etc.)- Bone densitometry and absorptiometry (DEXA)

Tutorial: Simulate CT image reconstruction and analyse artifacts; compare contrast and resolution in different CT generations.

Unit IV – Ultrasound Imaging (10 hrs)

Basic principles, nature and production of ultrasound – Intensity interaction with medium – Scan modes: A, B, M, Doppler – Biological effects of ultrasound – Transducers and construction: characteristics of piezoelectric crystals, Curie temperature, resonant frequency, Q factor – Fresnel and Fraunhofer zones: dependence on transducer size and frequency – Interaction between ultrasound and matter: reflection, dependence on angle of incidence, refraction, absorption, quarter-wave matching – Acoustic impedance of various materials – Real-time scanning, gray-scale imaging – Significance of gain and gain compensation – Pulse rate and its significance – Resolution: frequency and depth – Doppler techniques: color Doppler, pulse Doppler, duplex scanner – Real-time measurements – Types of probes: oscillating transducer, rotating wheel, linear array – Thermography: basic principles, scanning techniques – Radiation dose to patients.

Tutorial: Evaluate resolution, depth, and Doppler shift; analyze ultrasound imaging parameters for clinical quality.

Unit V – Nuclear Magnetic Resonance (NMR) and MRI (10 hrs)

Angular momentum of the nucleus: orbital and spin angular momentum – Magnetism and magnetic dipole moment (MDM) – Larmor frequency, energy states for nuclear spin systems – NMR parameters, magnetization vector, RF field, rotating coordinate system – Free induction decay – T1 and T2 relaxation mechanisms – Spin-echo techniques, Fourier transform – MRI instrumentation: resistive, air-core, and superconducting magnets; RF coils, gradient coils – Slice selection, phase encoding, frequency encoding – Spin-echo imaging sequence – Image reconstruction – Multi-slice and multi-echo imaging – Contrast enhancement, T1 and T2-weighted images – Signal-to-noise ratio – Safety considerations, recent developments, functional MRI – Dual and multimodality imaging (PET/MRI).

Tutorial: Analyze NMR spectra, calculate T1/T2 relaxation times, evaluate SNR, and assess image contrast.

Outcomes

- Understand X-ray tube physics, imaging technology, and generator accessories.
- Evaluate radiographic images quantitatively for unsharpness, resolution, and magnification.
- Understand CT principles, reconstruction algorithms, and artifacts.
- Analyze ultrasound physics, transducer properties, and Doppler techniques.
- Understand NMR/MRI physics, sequences, instrumentation, and functional imaging.

Textbooks

- Bushberg JT, Seibert JA, Leidholdt EM, Boone JM. *The Essential Physics of Medical Imaging*, 4th Edition, 2021.
- Hendee WR, Ritenour ER. *Medical Imaging Physics*, 4th Edition, 2021.
- Kremkau FW. *Diagnostic Ultrasound: Principles and Instruments*, 9th Edition, 2020.
- McRobbie DW, Moore EA, Graves MJ, Prince MR. *MRI from Picture to Proton*, 3rd Edition, 2017.
- Fauber TL. *Radiographic Imaging and Exposure*, 6th Edition, 2020.
- Curry, T.S., Dowdey, J.E., Murry, R.C., (1990) Christensen's introduction to the physics of diagnostic radiology (4th ed.), Philadelphia : Lee & Febiger
- Bushberg, S.T., Seibert, J.A., Leidholt, E.M. & Boone, J.M. (1994) The essential physics of medical imaging, Baltimore : Williams & Wilkins.
- Dendy, P.P & Heaton B. (2nd ed), Physics for diagnostic radiology, Bristol &Philadelphia : Institute of Physics Publishing.
- Johns, H.E. & Cunningham, J.R (1983), The physics of radiology (4th ed), Springfield, IL : Charles C. Thomas
- E. Seeram. X-ray imaging equipment, An Introduction (1985), Springfield , IL : Charles C. Thomas
- Hendee, W.R. & Ritenour, R. (1993), Medical Imaging Physics (3rd ed), St. Louis : C.V. Mosbey.
- Chesney , D.N. & Chesney, M.O., X-ray equipment for stuent radiographers (3rd ed). New Delhi : CBS Publishers & Distributors.
- Chesney, D.N. & Chesney, M.O., Radiographic imaging (4th ed.) New Delhi : CBS Publishers & Distributors.
- Hashemi, R.H, Bradley, W.G. & Lisanti, C.J. MRI the basics, Philadelphia : Lippincot Williams & Wilkins.
- Sprawls, P., Magnetic resonance imaging principles, methods and techniques, Madison, Wisconsin : Medical Physics Publishing.

References

- Seeram E. *Computed Tomography: Physical Principles, Clinical Applications, and Quality Control*, 4th Edition, 2020.
- Szabo TL. *Diagnostic Ultrasound Imaging: Inside Out*, 2nd Edition, 2014.
- Haacke EM, Brown RW, Thompson MR, Venkatesan R. *MRI: Physical Principles and Sequence Design*, 2nd Edition, 2014.
- Fauber TL. *X-Ray Imaging: Principles and Applications*, 2014.
- Hendee WR, Ritenour ER. *Medical Imaging Physics Handbook*, 2010.

Core-9: Physics of Radiotherapy (4 Credits, Lecture: 3, Tutorial: 1, Practical: 0, 60 Hours)

Course Objectives

1. Understand the principles and working of therapy beam generators, including kV X-ray units, telecobalt units, and linear accelerators.
2. Learn dosimetry parameters, clinical beam characteristics, and monitor unit calculations for photon and electron beams.
3. Comprehend beam modification and shaping devices integrated with linear accelerators for clinical therapy.
4. Acquire knowledge of clinical electron beam therapy, including depth dose characteristics, collimation, and planning techniques.
5. Understand brachytherapy techniques, sources, dose rate classifications, and afterloading equipment safety requirements.

UNIT I: Therapy Beam Generators – kV X-ray and Telecobalt Units (12 Hours)

Kilovoltage therapy X-ray units – Grenz ray therapy – Contact therapy – Superficial therapy – Deep therapy and Supervoltage therapy – Spectral distribution of kV X-rays and effect of filtration – Thoraeus filter – Telecobalt units: Construction and working, source design, beam shutter mechanisms – Radiation field – Beam collimation, penumbra and its types – Trimmers and breast cones – Beam directing devices – Front and back pointers, pin & arc ODI, laser – Isocentric gantry

Tutorial Exercises: Students analyze kV X-ray and telecobalt unit design parameters, compute field collimation, and evaluate penumbra and dose distribution

Keywords: Kilovoltage X-ray, Grenz ray, Superficial therapy, Deep therapy, Telecobalt unit, Beam collimation, Penumbra, Trimmers, Breast cones, ODI, Isocentric gantry

UNIT II: Linear Accelerators and Beam Modification Devices (12 Hours)

Linear accelerator – Design – Principle and function of klystron and magnetron – Travelling and standing waveguide – Pulse modulators and auxiliary systems – Bending magnet systems – Treatment head – Electron beam, X-rays, beam collimation, asymmetric collimator, multileaf collimator (MLC) – Dose monitoring systems – Interlocks – Output calibration procedure – Relative merits and demerits of kV X-rays, gamma rays, MV X-rays and electron beams – Beam modification and shaping devices: Bolus and its types – Beam spoilers – Wedge filters: Individual, universal, motorized, dynamic wedges – Shielding blocks – Field shaping, custom blocking – Styrofoam cutting machine – Tissue compensators: 2D and 3D compensators – Integration of MLC and compensators for treatment planning

Tutorial Exercises: Students analyze linear accelerator components, explain beam collimation using MLCs, perform output calibration calculations, and simulate beam modification with wedges, bolus, and compensators

Keywords: Linear accelerator, Klystron, Magnetron, Pulse modulator, Bending magnet, Treatment head, Beam collimation, MLC, Beam modifiers, Wedge filters, Bolus, Compensators, Dose monitoring, Output calibration

UNIT III: Dosimetry Parameters and Isodose Characteristics (12 Hours)

Collimator scatter factor, phantom scatter factor, and total scatter factor – Percentage depth dose (PDD) – Factors affecting PDD – Maynard factor – Tissue air ratio (TAR) – Backscatter factor / Peak scatter factor (BSF/PSF) – Tissue phantom ratio (TPR) – Tissue maximum ratio (TMR) – Relationship between TAR and PDD and its applications – Relationship between TMR and PDD and its applications – Scatter air ratio (SAR) – Scatter maximum ratio (SMR) – Off-axis ratio and field factor – Surface dose and buildup region – Isodose chart – Measurements of isodose curves – Characteristics of isodose curves – Dosimetric data resources for treatment calculation – Concept of dose calculation for equivalent square field

Tutorial Exercises: Students calculate TAR, PDD, TPR, TMR, SAR, SMR, and off-axis ratios, and interpret isodose charts for treatment planning

Keywords: Collimator scatter factor, Phantom scatter factor, Total scatter factor, PDD, TAR, BSF, TPR, TMR, SAR, SMR, Isodose chart, Dose calculation

UNIT IV: Electron Beam Therapy (12 Hours)

Energy specification – Depth dose characteristics of electron beam (Dmax, Ds, Dx, dmax, R90, R50, Rp, and Bremsstrahlung tail) – Characteristics of clinical electron beams – Collimation – Electron cutouts, electron applicator – Determination of absorbed dose – Applicator factor, cutout factor – Monitor unit calculations – Output factor formalisms – Planning and dose calculation effects of patient and beam geometry – Internal heterogeneities – Treatment planning techniques – Field abutment techniques – Photon and electron mixed beams – Electron arc therapy – ICRU71

Tutorial Exercises: Students simulate electron beam dose calculations, evaluate applicator and cutout factors, and plan mixed photon-electron treatments

Keywords: Electron beam, Depth dose, Dmax, R90, R50, Rp, Bremsstrahlung tail, Collimation, Cutouts, Applicator, MU calculations, Treatment planning, Electron arc, Mixed beams

UNIT V: Brachytherapy Techniques and Source Management (12 Hours)

Definition and classification of brachytherapy techniques – Surface mould, intracavitary, interstitial and intraluminal techniques – Requirement for brachytherapy sources – Description of radium and radium substitutes – 137Cs, 60Co, 192Ir, 125I and other commonly used brachytherapy sources – Dose rate considerations and classification: Low dose rate (LDR), High dose rate (HDR) and Pulsed dose rate (PDR) – Afterloading techniques – Advantages and disadvantages of manual and remote afterloading techniques – AAPM and IEC requirements for remote afterloading brachytherapy equipment

Tutorial Exercises: Students calculate source strength, dose distributions, and compare LDR, HDR, and PDR techniques, and analyze safety requirements for manual and remote afterloading

Keywords: Brachytherapy, LDR, HDR, PDR, Radium, 137Cs, 60Co, 192Ir, 125I, Afterloading, Dose rate, QA, Safety

Learning Outcomes

- Explain the principles and functioning of kilovoltage X-ray units, telecobalt units, and linear accelerators.
- Analyze dosimetry parameters and interpret isodose charts for photon and electron beams.
- Apply beam modifying and shaping devices for clinical photon therapy.
- Plan and calculate clinical electron beam treatments considering geometry and heterogeneities.
- Describe brachytherapy techniques, source selection, dose rates, and safety compliance.

Textbooks

- Khan FM, Gibbons JP. *The Physics of Radiation Therapy*, 5th Edition, Lippincott Williams & Wilkins, 2020.
- Podgorsak EB. *Radiation Oncology Physics: A Handbook for Teachers and Students*, IAEA, 2005.
- Das IJ, Ding GX, Ahnesjö A. *Advanced Radiation Therapy Physics: Theory and Practice*, 2nd Edition, CRC Press, 2019.
- Hendee WR, Ibbott GS, Hendee EK. *Medical Radiation Physics*, 4th Edition, Wiley, 2005.
- H.E. Johns and Cunningham. The Physics of Radiology.
- Faiz M. Khan, The Physics of Radiation Therapy, Lippincott Williams & Wilkins, Philadelphia, 3rd edition, 2003

References

- IAEA. *Absorbed Dose Determination in External Beam Radiotherapy*, Technical Report Series No. 398, 2000.
- AAPM Report No. 85. *The Role of In Vivo Dosimetry in Modern Radiotherapy*, 2006.
- ICRU Report 50 & 62. *Prescribing, Recording, and Reporting Photon Beam Therapy*, 1993, 1999.
- Jones DG, Hendry JH. *Radiobiology for Radiotherapy*, 5th Edition, CRC Press, 2018.
- Podgorsak EB. *Radiation Physics for Medical Physicists*, Springer, 2016.

Core-10: Nuclear Medicine I: Imaging and Therapy

Credits: 4 **Lecture:**3 **Tutorial:**1 **Practical:**0
Total Hours: 60 (45 L + 15 T)

Course Objectives

1. To understand the fundamental physics of nuclear medicine and radionuclide production.
2. To learn principles and applications of radiopharmaceuticals and cyclotron operation.
3. To gain knowledge of in-vivo non-imaging procedures and basic dosimetry.
4. To understand radionuclide imaging systems and advanced imaging techniques including SPECT, PET, and fusion modalities.
5. To learn the principles of radionuclide therapy, room shielding, radiation safety, and QA procedures.

Detailed content:

Unit I – Fundamentals of Nuclear Medicine and Radionuclide Production (12 h: 9 L + 3 T)

Introduction to Nuclear Medicine and unsealed sources – Physical principles of radioactive decay and interaction processes relevant to nuclear medicine- Production of radionuclides using reactor and accelerator-based methods – Photonuclear activation – Equations for radionuclide production and yield calculation- Radionuclide generators: construction, operation principles, and examples (Mo-99/Tc-99m, Ge-68/Ga-68, Sr-82/Rb-82)- Cyclotron principles: types (self-shielded, unshielded, locally shielded); beam production, extraction, and targetry- Cyclotron auxiliary systems: vacuum pumps, RF power, magnet power supply, cooling systems, control software, and their safety significance- Cyclotron-based therapeutic radionuclide production: beam monitoring, quality control, safety interlocks, and regulatory aspects.

Tutorial:

- Prepare flow diagrams for radionuclide production and generator operation.
- Identify cyclotron safety protocols and describe auxiliary equipment functions.

Unit II – Radiopharmaceuticals and Non-Imaging Applications (12 h: 9 L + 3 T)

Preparation, labeling, and quality control of radiopharmaceuticals – Chemical, biological, and physical characteristics – QA and regulatory aspects- Various clinical usages of radiopharmaceuticals in diagnostic and therapeutic contexts- In-vivo non-imaging techniques**:** thyroid uptake, renogram, RBC lifespan, and blood-volume assessment- Dosimetry for non-imaging procedures**:** calculation principles, data interpretation, and patient-specific dose estimation- Radiation safety and dose optimization in diagnostic nuclear medicine- Prostate-Specific Membrane Antigen (PSMA) imaging using Ga-68: radiochemistry, imaging workflow, and radiation protection.

Tutorial:

- Perform calculations for thyroid uptake, renogram, and RBC lifespan.
- Prepare mock patient reports from sample data.

Unit III – Radionuclide Imaging Systems and Digital Processing (12 h: 9 L + 3 T)

Principles and historical development of radionuclide imaging – Concepts of spatial, temporal, and contrast resolution- Rectilinear scanners: operational principles and limitations- Gamma camera / scintillation camera: detectors, electronics, and system design- Collimators: converging, diverging, parallel-hole, pinhole – performance and resolution- Image display, recording, and digital processing – Noise sources and image artifact analysis- System performance evaluation using standard phantoms and QC metrics- Safety during routine maintenance and service of imaging systems: contamination control and regulatory compliance.

Tutorial:

- Label gamma camera components and explain function.
- Evaluate collimator performance and detector resolution.
- Analyze sample imaging outputs and identify artifacts.

Unit IV – Advanced Imaging Modalities and Quality Assurance (12 h: 9 L + 3 T)

SPECT, PET, PET-CT, and PET-MRI: instrumentation, detectors, coincidence detection, hybrid configurations- Image reconstruction: filtered back projection, Fourier-based, and iterative algorithms- Corrections: attenuation, scatter, and resolution recovery- Image-quality parameters – spatial resolution, contrast, signal-to-noise ratio, quantitative accuracy- QA/QC protocols and SOPs for SPECT/PET systems as per IEC/NEMA standards- Emergency preparedness in imaging facilities: management of radioactive spillage, contamination, power failure, and fire.

Tutorial:

- Analyse sample SPECT/PET data for resolution and contrast.
- Prepare QA checklists and evaluate performance metrics.

Unit V – Radionuclide Therapy: Clinical Applications, Shielding, and Safety (12 h: 9 L + 3 T)

Therapy with I-131: principles, patient selection, dosimetry, inpatient/outpatient management, radiation protection, and follow-up- Palliative radionuclide therapy: using P-32, Sr-89, Sm-153, Re-186/188 for bone metastases; radiopharmaceutical preparation, dose calculation, and care protocols- Beta therapy and intra-articular treatments: Y-90, Re-188, P-32; radiation synovectomy and associated safety measures- Peptide Receptor Radionuclide Therapy (PRRT): Lu-177 and Y-90 labeled peptides; absorbed-dose estimation, therapy planning, and post-therapy imaging- Delay-tank concepts and waste-disposal methods: handling of radioactive effluents, decay-in-storage, and compliance with AERB/IAEA limits- High-dose therapy room shielding: design, ventilation, contamination control, and environmental monitoring- Safety protocols for therapy delivery: workflow, radiation monitoring, patient-release criteria, documentation, and regulatory reporting under AERB Safety Codes.

Tutorial:

- Design shielding for a radionuclide therapy isolation room.
- Prepare a mock workflow for radionuclide therapy.
- Develop contamination-control and waste-management protocols.

Course Outcomes

- Demonstrate understanding of nuclear medicine physics and radionuclide production principles.
- Perform basic in-vivo non-imaging studies and clinical dose calculations.
- Analyze and evaluate imaging systems including gamma camera and PET/SPECT.
- Apply QA/QC standards to advanced imaging techniques.
- Design safe therapeutic workflows and implement radiation safety measures in nuclear medicine facilities.

Textbooks

- Bushberg JT, Seibert JA, Leidholdt EM, Boone JM. *The Essential Physics of Medical Imaging*. 4th Edition, Lippincott Williams & Wilkins, 2021.
- Cherry SR, Sorenson JA, Phelps ME. *Physics in Nuclear Medicine*. 5th Edition, Elsevier, 2012.
- Ljungberg M, et al. *Handbook of Nuclear Medicine Physics: Theory and Practice*. Springer, 2017.
- Simon R. Chery, James A. Sorenson, Michael E. Phelps, Physics in Nuclear Medicine (3rd ed.) SAUNDERS an imprint of Elsevier.
- Ramesh Chandra, Nuclear Medicine Physics (5th ed.) Lea & Febiger, Philadelphia.
- Antonio Fernando Goncalves Rocha and John Charles Harbert, Text Book of Nuclear Medicine : Basic Science, Lea & Febiger, Philadelphia.
- Pail J. Early, M.A. Razzak and D, Bruces Sodee, Text book of Nuclear Medicine Technology. The C.V. Mosby Company.
- A.L. Baert and K. Sartor, Diagnostic Nuclear Medicine (2nd ed.) Springer.
- Gopal B. Saha, Fundamental of Nuclear Medicine Pharmacy (5 ed.) Springer
- Wagner LK, Loo Jr BW. *Nuclear Medicine Physics: Practical Aspects*. CRC Press, 2020.
- Saha GB. *Fundamentals of Nuclear Pharmacy*. 7th Edition, Springer, 2020.
- Dale L. Bailey, David W. Townsend, Peter E. Valk and Michael N. Maisey. Springer. Janet F. Eary and Winfried Brenner, Nuclear Medicine Therapy. Informa Health Care
- J.F. Fowler, Nuclear Particles in Cancer Treatment, Adam Hilger Ltd., Philadelphia, 1981.

References

- International Atomic Energy Agency (IAEA). *Radiation Protection and Safety in Medical Uses of Ionizing Radiation*, Safety Report Series No. 101, 2021.
- National Electrical Manufacturers Association (NEMA). *NU 1-2018 Performance Measurements of Gamma Cameras*.
- IEC 60601-2-44: *Medical Electrical Equipment – Particular Requirements for the Safety of X-ray Equipment for SPECT and PET*.
- ICRP Publication 103: *The 2007 Recommendations of the International Commission on Radiological Protection*.
- AAPM Report No. 108: *PET and PET/CT Acceptance Testing and Quality Assurance*.

Elective II: Artificial Intelligence in Medical Physics

Prerequisite:

Basic understanding of Python programming, medical imaging modalities, and statistical concepts.

Course Objectives

1. To provide foundational knowledge of Artificial Intelligence (AI), Machine Learning (ML), and Deep Learning (DL) techniques used in medical physics.
2. To enable students to process, analyze, and visualize medical images using AI frameworks.
3. To impart knowledge on different neural network architectures and their medical applications.
4. To introduce reinforcement learning and its use in medical decision support and adaptive treatment systems.
5. To familiarize students with regulatory, ethical, and quality assurance aspects of AI implementation in healthcare.

Detailed Content

Unit – I INTRODUCTION TO AI IN MEDICAL PHYSICS AND IMAGE PROCESSING

Overview of AI applications in healthcare – Introduction to DICOM image formats and reconstruction in CT, MRI, PET-CT, and Ultrasound – Image segmentation and feature extraction – Open-source AI and medical imaging platforms (3D Slicer, PyTorch, MONAI, SimpleITK) – Medical imaging data sources (TCIA, Kaggle, UK Biobank) – Machine learning pipelines – Metrics for AI model evaluation (AUC, Dice, IoU, precision-recall) – AAPM TG-273 and IEC standards on AI validation – Ethical use and interpretability of AI in medical imaging.

Unit II MACHINE LEARNING PRINCIPLES AND MODEL DEVELOPMENT

Supervised, unsupervised, and reinforcement learning – Data preparation, normalization, and augmentation – Feature extraction and selection (filter, wrapper, embedded methods) – Machine learning models: Linear and logistic regression, Decision Trees, Random Forests, SVM, k-Nearest Neighbors, Gradient Boosting, and XGBoost – Evaluation metrics: confusion matrix, ROC curves, cross-validation – ML model deployment using cloud tools (AWS SageMaker, Google AutoML) – Introduction to radiomics: feature engineering, segmentation, and model integration for diagnosis and prognosis

Unit III DEEP LEARNING ARCHITECTURES AND NEURAL NETWORK FUNDAMENTALS

Artificial neural networks (ANN): perceptron model, activation functions, loss functions, backpropagation – Hyperparameter optimization and regularization – Feedforward networks and multilayer perceptrons – Overview of Deep Learning in radiology, radiation oncology, and nuclear medicine – Data imbalance and augmentation techniques – Optimization algorithms (SGD, Adam, RMSProp) – Introduction to transfer learning – Visualization of hidden layers and feature maps – Model explainability (Grad-CAM, SHAP).

Unit IV CONVOLUTIONAL, RECURRENT, AND GENERATIVE NETWORKS

Convolution operations and filters – CNN architectures (AlexNet, VGG, ResNet, EfficientNet) for medical image classification – Segmentation networks (U-Net, SegNet, nnU-Net) – Recurrent Neural Networks (RNNs) and LSTMs for time-dependent medical data – Generative Adversarial Networks (GANs) and conditional GANs for image synthesis and denoising – Diffusion models for image reconstruction – Multimodal learning and cross-domain fusion (e.g., PET-CT, MRI-fMRI).

Unit V REINFORCEMENT LEARNING, BIG DATA, AND ETHICAL AI IN HEALTHCARE

Fundamentals of Reinforcement Learning (RL): Q-learning, policy gradients, and Deep Q-Networks (DQNs) – Applications of RL in radiotherapy dose optimization, adaptive planning, and robotic surgery – Sources of healthcare big data – Big Data Analytics frameworks (Hadoop, Spark, TensorFlow Extended) – Data privacy and security frameworks (HIPAA, GDPR) – AI governance, interpretability, and bias mitigation – Quality assurance of AI algorithms and regulatory validation (FDA, AAPM TG-302) – Future trends: Explainable AI (XAI), federated learning, and trustworthy AI in healthcare.Use of Large Language Models like ChatGPT, GROK.

Course Outcomes

After successful completion of this course, students will be able to:

- Understand the role of AI, ML, and DL in medical imaging, radiation therapy, and diagnostics.
- Develop and evaluate AI/ML models for healthcare applications with proper validation metrics.
- Implement CNN and GAN architectures for medical image classification, segmentation, and synthesis.
- Apply reinforcement learning principles for adaptive radiation therapy and clinical decision-making.
- Demonstrate awareness of data governance, ethical frameworks, and AI quality assurance protocols in medical physics practice.

Textbooks (Recent Editions)

- Isaac Bankman, *Handbook of Medical Image Processing and Analysis*, 3rd Edition, Academic Press, 2020.
- Ian Goodfellow, YoshuaBengio& Aaron Courville, *Deep Learning*, MIT Press, 2021.
- Charu C. Aggarwal, *Neural Networks and Deep Learning: A Textbook*, Springer, 2023.
- Barry Rosenstein et al., *Machine Learning and Artificial Intelligence in Radiation Oncology: A Guide for Clinicians*, Springer, 2022.
- Ruijiang Li, Lei Xing, and Daniel L. Rubin, *Radiomics and Radiogenomics: Technical Basis and Clinical Applications*, CRC Press, 2021.

Reference Books

- Richard S. Sutton & Andrew G. Barto, *Reinforcement Learning: An Introduction*, 2nd Edition, MIT Press, 2020.
- Christopher M. Bishop, *Pattern Recognition and Machine Learning*, Springer, 2023 (Reprint Edition).
- AAPM Task Group 273, *Best Practices for AI and Machine Learning in Medical Physics*, AAPM, 2021.
- Daniel Rueckert&PolinaGolland (Eds.), *Machine Learning in Medical Imaging: Advances and Applications*, Springer, 2023.
- Bradford Tuckfield, *Dive Into Data Science: Use Python to Tackle Real-World Healthcare Challenges*, No Starch Press, 2022.

Elective II: Materials for Radiological Applications

Course Objectives

On completion of this course the student will be able to:

1. Analyse and classify the major classes of biomaterials used in medical and radiological applications, understanding their structure-property relationships and biological performance.
2. Evaluate and apply key characterisation techniques for biomaterials (physical, thermal, electrical, optical, surface) and assess biocompatibility and bio-functionality in a radiological context.
3. Describe and employ additive manufacturing (3D/4D printing) technologies and select appropriate materials for patient-specific implants, prosthetics, immobilisation devices, and radio-therapeutic applicators.
4. Design and specify materials for radiation oncology applications (shielding, immobilisation, custom blocks, multi-leaf collimators) with awareness of radiation physics, material interactions and clinical constraints.
5. Appraise materials and devices in brachytherapy, imaging-compatible applicators, dosimetry and implantable systems (including MR-safe/conditional devices), integrating knowledge of radiological requirements, biocompatibility and regulatory aspects.

Detailed Content

Unit I – Classes of Materials Used in Medicine

Definition of biomaterials; structural hierarchy in materials and biology.Major classes of materials in medicine: metals (e.g., titanium, stainless steel), ceramics (e.g., alumina, zirconia, bioactive glass), synthetic polymers (e.g., polyethylene, PEEK, PTFE), composites.Hydrogels, bioresorbable and biodegradable polymers (e.g., PLA, PGA, PCL).

Natural biomaterials (e.g., collagen, chitosan, silk) and self-assembling peptides.

Polymers for drug delivery; nanomaterials for therapy and diagnostics (e.g., nanoparticles, nanoshells, nanofibres).Structure–property relations of biological materials and biomimetic design.

Unit II – Characterisation of Materials and Their Biological Performance

Material properties: physical (density, hardness, modulus), thermal (conductivity, expansion), electrical (conductivity, dielectric), optical (transparency, absorption).Surface properties: roughness, wettability, surface energy, adhesion of biomaterials.Biocompatibility: definitions, evaluation methods; bio-functionality.Haemocompatibility: blood-material interactions, coagulation, thrombosis, complement activation.Tumourigenesis risk, inflammatory responses.Degradation of materials in biological environments (corrosion, hydrolysis, enzymatic, wear); implications for implant longevity and safety.

Unit III – 3D / 4D Printing of Materials for Medical Applications

Fundamentals of additive manufacturing (AM): stereolithography, digital light processing, fused deposition modelling, selective laser sintering/melting, inkjet/bio-printing, microfluidics and lithography as applied to biomedical devices.Design considerations for 3D printed medical devices and anatomical models: patient-specific geometry, compatibility with imaging, functional requirements, regulatory aspects.Material feedstocks for 3D printing in medicine: polymers, composites, metals, ceramics, hydrogels.

Biocompatibility and mechanical/functional requirements of 3D-printed materials.

The concept of 4D printing (time-dependent shape changes, stimulus-responsive materials) and its emerging role in medicine.Applications: implants, prosthetics, surgical guides, anatomical models, tissue scaffolds.

Unit IV – Materials in Radiation Oncology

Materials for radiation shielding: lead, tungsten, steel, concrete, novel composites; theory of attenuation, build-up, secondary radiation, imaging compatibility. Patient immobilisation devices: thermoplastics, vacuum cushions, head-rests, neck supports, custom fixation.Treatment-planning devices and accessories: custom blocks (e.g., Cerrobend alloy), lead alloy blocks, multi-leaf collimators (MLCs), jaws and accessory materials.Interaction of radiation with materials in a therapeutic context: scattering, dose perturbation, imaging artefacts and material-induced dose heterogeneity.

Unit V – Materials in Brachytherapy and Radiological Devices

Radioactive sources and source encapsulation materials; applicator materials and designs (CT/MR compatible, image-guided insertion).Shielding for brachytherapy, contrast agents, fiducial markers, implantable devices.Materials for dosimetry and measurement: ionisation chambers, films, diodes, MOSFETs, OSLDs, scintillators material selection and performance criteria. Materials for cardiac implantable electrical devices (CIEDs): device types (pacemakers, ICDs), MR-safe, MR-conditional, MR-unsafe classifications; biocompatibility, packaging and materials in implantable electronics.

Course Outcomes

By the end of the course the student will be able to:

1. Demonstrate a comprehensive understanding of the various classes of biomaterials (metals, ceramics, polymers, composites, hydrogels, bioresorbable, nanomaterials) and their relevance in medical and radiological applications.
2. Critically assess material characterisation data (physical, thermal, electrical, optical surface) and interpret biocompatibility, hemocompatibility and degradation behaviour in a biological environment.
3. Select appropriate additive manufacturing techniques (3D/4D printing) and material feedstocks for custom medical devices and implants, considering design, printability, biocompatibility and functional performance.

4. Formulate material selections and design strategies for radiation oncology devices including shielding, immobilisation, custom blocks and collimation systems, in accordance with radiation safety and therapeutic requirements.
5. Evaluate materials and device technologies used in brachytherapy applicators, image-compatible instruments, dosimetry detectors and implantable systems (CIEDs), with an informed awareness of MR-safe/conditional classifications and regulatory standards.

Textbooks (Latest Editions):

1. Fundamentals of Biomaterials (Haşirci&Haşirci, 2nd ed., Springer Cham, 2024)
2. Additive Manufacturing for Biomedical Applications: Recent Trends and Challenges (Dixit, Kumar & Pathak, Springer Singapore, 2024)
3. Primer on Radiation Oncology Physics: Video Tutorials with Textbook and Problems (Eric Ford, 2nd ed., CRC Press, 2025)

Additional Reference Books:

1. Biomaterials Science: An Introduction to Materials in Medicine, 4th ed. (Wagner et al., Academic Press, 2020
2. The Physics of Radiation Oncology (K. Thayalan, Jaypee, 2023
3. 3D Printing in Biomedical Engineering (Singh, Prakash & Singh, Springer Singapore, 2020)
4. Radiobiology Textbook (Ed. Sarah Baatout, Springer Cham, 2023)

Core–Lab II: Medical Physics Lab I – Medical Imaging

Credits: 3 **Lecture:** 0 **Tutorial:** 0 **Practical:** 6

Course Objectives

1. To train students in performing standard quality assurance (QA) tests on X-ray, fluoroscopy, CT, MRI, ultrasound, and C-arm systems using appropriate dosimetric and imaging phantoms.
2. To develop competence in measuring radiological parameters such as kVp, mAs, HVL, ESD, dose rates, CTDI, DLP, SNR, uniformity, slice thickness, and shielding efficiency.
3. To familiarize students with radiation protection principles by evaluating leakage radiation, scatter distribution, barrier transmission, and protective device performance.
4. To enable hands-on experience with advanced dosimetry equipment including NOMEX Multimeter, ion chambers, phantoms, CT chambers, and MRI QA tools.
5. To cultivate analytical skills in processing measurement data, interpreting imaging performance metrics, and validating compliance with AERB/IAEA standards.

Any fifteen out of the following thirty practical exercises are recommended

1. **Measurement of X-ray Tube Voltage using NOMEX Multimeter (Mandatory 1)**
   - **Aim:** To verify the accuracy of tube potential (kVp) using a calibrated NOMEX Multimeter.
   - **Instruments:** Diagnostic X-ray unit, NOMEX Multimeter, Al filter.
   - **Procedure:** Position NOMEX at standard SID; perform exposures at selected kVp; record measured vs set kVp; compute deviation and compliance.
2. **Exposure Time Accuracy Test**
   - **Aim:** To check time reproducibility and timer accuracy of X-ray generator.
   - **Instruments:** NOMEX Multimeter or solid-state dosimeter.
   - **Procedure:** Expose at different programmed times (e.g., 10–200 ms); record actual exposure durations; calculate percentage deviation.
3. **Output Linearity Test of X-ray Tube**
   - **Aim:** To determine linearity of radiation output with mAs.
   - **Instruments:** NOMEX Multimeter, dosimeter stand.
   - **Procedure:** Measure dose for increasing mAs at fixed kVp; plot dose vs mAs; verify linear proportionality (within ±10%).
4. **Reproducibility of Exposure Output**
   - **Aim:** To verify consistency of radiation output over repeated exposures.
   - **Instruments:** NOMEX Multimeter.
   - **Procedure:** Record 10 exposures under identical settings; compute coefficient of variation (should be < 0.05).
5. **Measurement of Total Filtration in X-ray Beam**
   - **Aim:** To determine inherent and added filtration.
   - **Instruments:** Aluminum filters, NOMEX Multimeter.
   - **Procedure:** Measure HVL with and without filters; calculate equivalent total filtration.
6. **Measurement of Tube Current Accuracy**
   - **Aim:** To evaluate the mA station accuracy.
   - **Instruments:** NOMEX Multimeter, X-ray console.
   - **Procedure:** Compare measured mA values at different mA stations; verify manufacturer tolerance.
7. **Beam Alignment and Perpendicularity Test**
   - **Aim:** To verify beam perpendicularity with image receptor plane.
   - **Instruments:** Beam alignment test tool, level meter.
   - **Procedure:** Perform exposure; analyze shadow displacement; determine angular misalignment.

8. **X-ray Field Size Accuracy and Collimator Operation**
    - **Aim:** To test accuracy of collimator scale and symmetry.
    - **Instruments:** Beam alignment tool, film or CR cassette.
    - **Procedure:** Compare indicated and actual field dimensions; confirm within ±2% of SID.
9. **Measurement of Leakage Radiation from X-ray Tube Housing**
    - **Aim:** To ensure compliance with AERB leakage limits (<1 mGy/hr at 1 m).
    - **Instruments:** Survey meter (ionization chamber type).
    - **Procedure:** Measure radiation around housing with beam off; record maximum value.
10. **Measurement of Radiation Levels in Control Console Area**
    - **Aim:** To assess protective shielding adequacy.
    - **Instruments:** Survey meter or portable ion chamber.
    - **Procedure:** Record exposure rate at console during standard exposure; compare with permissible limits.
11. **Scatter Radiation Distribution Study**
    - **Aim:** To analyze scattered dose at different distances and angles.
    - **Instruments:** Phantom, survey meter.
    - **Procedure:** Perform radiographic exposure; record dose at multiple points; plot scatter profile.
12. **Measurement of Protective Apron Transmission (Mandatory 2)**
    - **Aim:** To test lead apron attenuation.
    - **Instruments:** Dosimeter, lead apron samples.
    - **Procedure:** Measure exposure with and without apron; compute transmission factor (%).
13. **Measurement of Door and Barrier Shielding Efficiency**
    - **Aim:** To verify structural shielding integrity.
    - **Instruments:** Survey meter, radiation source.
    - **Procedure:** Expose phantom; measure radiation outside door and barriers; ensure values <1 µSv/hr.
14. **Fluoroscopy Dose Rate Measurement (Mandatory 3)**
    - **Aim:** To evaluate patient dose rate during fluoroscopy.
    - **Instruments:** Ion chamber, NOMEX Multimeter.
    - **Procedure:** Measure entrance dose rate at phantom surface; verify against regulatory limits.
15. **Patient Entrance Dose Estimation for Common Radiographic Procedures**
    - **Aim:** To compute dose for chest, abdomen, and skull projections.
    - **Instruments:** NOMEX Multimeter, PMMA phantom.
    - **Procedure:** Perform exposures; record incident air kerma; estimate ESD and effective dose.

16. **Measurement of Entrance Skin Dose (ESD)**
    - **Instruments:** Ion chamber or TLD/ OSLDs, patient phantom.
    - **Procedure:** Place dosimeter on phantom surface; record dose for standard projection; compare with reference values.

17. **Measurement of Entrance Skin Dose (ESD) in C-Arm Fluoroscopy**
    - **Aim:** To measure entrance skin dose (ESD) from a C-arm for selected exposure settings (kVp, mA, pulse rate, SSD).
    - **Instruments / Materials:**
        - Calibrated ionization chamber (pencil or flat chamber) or solid-state dosimeter (e.g., RTI, Unfors)
        - Electrometer / dosimeter readout
        - C-arm fluoroscopy unit with adjustable kVp/mA and pulse rate
        - PMMA phantom or water-equivalent phantom (optional for reproducibility)
        - Ruler / calipers for source-to-skin distance (SSD) measurement
        - Lead shielding / aprons for safety, logsheet

18. **Scatter Radiation Measurement Around C-Arm During Fluoroscopy (Mandatory 4)**
    - **Aim:** To quantify scatter dose rates at operator positions and evaluate shielding effectiveness.
    - **Instruments / Materials**
        - Calibrated survey meter / ion chamber (gamma/broad-energy) or solid-state detector
        - Multiple dosimeters (TLDs or OSLDs) for simultaneous measurements (optional)
        - C-arm unit, anthropomorphic phantom or PMMA stack to simulate patient
        - Lead aprons, thyroid shield, ceiling-suspended screen (if available)
        - Measuring tape, protractor to set angles, logsheet

19. **Assessment of C-Arm Dose Rate and Automatic Exposure Control (AEC) Performance**
    - **Aim**: To assess how the AEC adjusts exposure parameters (kVp, mA) and dose rate as phantom thickness changes.
    - **Instruments / Materials**
        - C-arm unit with AEC enabled
        - Stacks of PMMA slabs (10, 20, 30, 40 mm or larger up to clinical range) to simulate patient thicknesses
        - Dose meter (real-time dosimeter / ion chamber) placed at isocentre entrance surface
        - Electrometer/readout or dosimeter display, ruler, logsheet

20. CT Number Calibration and Uniformity Test

- **Instruments:** CT scanner, water phantom, QA software.
- **Procedure:** Scan phantom at standard protocol; measure CT numbers for ROIs; check variation within ±4 HU.

21. CT Spatial and Contrast Resolution

- **Instruments:** CATPHAN or AAPM CT phantom.
- **Procedure:** Analyze MTF patterns and contrast detectability at different window levels.

22. CT Slice Thickness and Position Accuracy

- **Instruments:** Slice-profile phantom.
- **Procedure:** Perform scans at various slice widths; measure FWHM of slice profile; verify z-axis accuracy.

23. Measurement of Computed Tomography Dose Index (CTDI) and Dose Length Product (DLP) (Mandatory 5)

- **Instruments:** CT ion chamber, head/body phantoms.
- **Procedure:** Measure dose at central and peripheral holes; calculate CTDIvol and DLP; compare protocols.

24. MRI SNR and Uniformity Measurement

- **Instruments:** MRI system, standard QA phantom.
- **Procedure:** Acquire images using spin-echo sequence; compute SNR and uniformity using ROI method.

25. MRI Geometric Accuracy and Slice Profile (Mandatory 6)

- **Instruments:** Grid phantom, QA software.
- **Procedure:** Scan phantom; measure deviation from known dimensions and slice location.

26. Measurement of T_1 and T_2 Relaxation Times

- **Instruments:** MRI phantom, multi-echo and inversion recovery sequences.
- **Procedure:** Acquire data; fit exponential decay curves to determine T_1/T_2.

27. Determination of Ultrasonic Velocity in Solids (Mandatory 7)

- Purpose: To measure longitudinal wave velocity in different solid materials.
- Instrument/ Component required: Ultrasonic Flaw Detector (UFD)
- Principle: Time-of-flight (TOF) measurement of ultrasound pulses.
- Simple Steps
    - Connect a straight-beam (normal incidence) probe to the UFD.
    - Apply a thin layer of couplant on the specimen surface.
    - Place the probe firmly and obtain the back-wall echo.
    - Measure the time difference (Δt) between the initial pulse and back-wall echo.

- Use known specimen thickness (d) to calculate velocity: v = 2d / Delta t
- Repeat for different materials (steel, aluminium, glass) and compare results.

28. Detection and Sizing of Internal Flaws (Cracks, Voids)

- Purpose: To identify, locate, and estimate the size of artificial or natural defects.
- Instrument/ Component required: Ultrasonic Flaw Detector (UFD)
- Principle: Reflection of ultrasonic pulses from discontinuities.
- Simple Steps
  - Use a 2–5 MHz straight-beam probe for surface-parallel defects, or an angle-beam probe for weld-type defects.
  - Calibrate the UFD using a V1 or V2 reference block.
  - Scan the specimen containing known/unknown flaws.
  - Observe echo signals corresponding to internal discontinuities.
  - Determine flaw depth using TOF: Depth = v x Delta t / 2
  - Estimate flaw size by amplitude drop method (6 dB/20 dB) or by beam spread technique.

29. Measurement of Material Thickness (Ultrasonic Thickness Testing)

- Purpose: To measure thickness of plates when access to only one side is available.
- Instrument/ Component required: Ultrasonic Flaw Detector (UFD)
- Principle: Echo-pulse method using a single surface contact.
- Simple Steps
  - Attach a high-frequency (5–10 MHz) probe to the UFD.
  - Apply couplant and place the probe on the test specimen.
  - Identify the first and second back-wall echoes on the A-scan.
  - Measure the time gap between successive echoes.
  - Calculate thickness: d = v x Delta t / 2 (Use velocity of the material obtained from Experiment 1)
  - Perform measurements at multiple points to detect thinning due to corrosion.

30. Acoustic Attenuation Coefficient Measurement

- Purpose: To determine attenuation of ultrasonic waves in materials.
- Instrument/ Component required: Ultrasonic Flaw Detector (UFD)
- Principle: Exponential decay of amplitude as ultrasound travels through the medium.
- Simple Steps
  - Select a straight-beam probe, typically 2–5 MHz.
  - Use specimens of the same material but with different thicknesses.
  - Record echo amplitudes (A_1, A_2, A_3...) from back-wall reflections for each thickness.

- Plot ln (Amplitude) vs. Thickness.
- Determine the attenuation coefficient (α) from the slope: $A=Ae^{-\alpha x}$
- Compare attenuation values for different materials or frequencies.

Course Outcomes

Upon successful completion of this laboratory course, the learner will be able to:

- Perform QA and performance evaluation tests on diagnostic radiology systems, including X-ray, fluoroscopy, CT, MRI, and ultrasound.
- Operate advanced dosimetric instruments (ion chambers, NOMEX, TLD/OSLD systems, CT pencil chambers) and apply them appropriately in clinical imaging measurements.
- Evaluate key imaging performance parameters such as spatial and contrast resolution, CT number uniformity, slice thickness, kVp accuracy, timer accuracy, field size accuracy, and dose output.
- Assess radiation protection aspects including leakage radiation, barrier shielding, apron attenuation, and scatter field mapping in diagnostic and interventional radiology.
- Analyze experimental results, compute uncertainties, record results systematically, and interpret compliance with national and international QA guidelines.

REFERENCES

Textbooks

1. **Bushberg, J. T., Seibert, J. A., Leidholdt, E. M., & Boone, J. M.**, *The Essential Physics of Medical Imaging*, 3rd Ed., Lippincott Williams & Wilkins.
2. **Seeram, E.**, *Physical Principles of Medical Imaging*, Springer.
3. **Hendee, W. R., Ritenour, E. R.**, *Medical Imaging Physics*, Wiley.
4. **AAPM Report Series** – Diagnostic Radiology and CT/MRI QA Protocols, AAPM.
5. **Karl Rawer**, *Handbook of Medical Imaging: Physics and Psychophysics*, SPIE Press.

Additional References with Links

1. **IAEA Diagnostic Radiology Physics** – Equipment, QA Tests, and Safety https://www.iaea.org/resources
2. **AAPM TG-142, TG-150, TG-175, TG-246** (X-ray, Fluoro, CT & MRI QA Reports) https://www.aapm.org/pubs
3. **ICRP Publications on Diagnostic Dose & Protection** https://www.icrp.org/publications.asp
4. **NCRP Reports on Medical Imaging Systems and Shielding** https://ncrponline.org/publications/reports
5. **NIST X-ray and CT Dosimetry Resources** https://www.nist.gov/pml

Professional Enhancement Course: Professional Ethics in Medical Physics (General and Medical Physics)

(2 Credits = 30 Contact Hours: 24 Lecture + 6 Tutorial)

Course Objectives

- To introduce fundamental concepts, principles, and values of professional ethics.
- To understand ethical behavior, integrity, and responsibility expected of medical physicists in clinical, research, and academic settings.
- To analyze real-world ethical dilemmas and decision-making models in medical physics practice.
- To understand national and international codes of ethics, safety, and regulatory responsibilities in radiation medicine.
- To develop a professional attitude integrating ethics, patient-centered care, and interdisciplinary collaboration.

Detailed Content

Unit I – Fundamentals of Professional Ethics (6 h: 4 L + 2 T)

Concept of ethics, morality, and values – Role of ethics in professional and personal life- Ethical theories and frameworks: utilitarianism, deontology, virtue ethics, rights-based and duty-based ethics- Distinction between ethics, etiquette, and law – Moral reasoning and ethical decision-making process- Professional responsibility, honesty, integrity, and accountability.

Tutorial: Discuss case examples of ethical vs. unethical professional conduct in science and medicine.

Unit II – Professional Conduct and Responsibilities (6 h: 4 L + 2 T)

Responsibilities of professionals to society, institution, colleagues, and self- Ethical communication, respect, and confidentiality in workplace and patient care- Conflict of interest, intellectual property, plagiarism, and data integrity- Professional etiquette in academic and clinical environments – Time management and teamwork.

Tutorial: Analyse scenarios involving professional misconduct and propose ethical resolutions.

Unit III – Medical Physics Professional Ethics and Code of Practice (6 h: 4 L + 2 T)

Ethical foundations of Medical Physics as a healthcare profession- Role and responsibilities of a Medical Physicist in radiotherapy, diagnostic imaging, and nuclear medicine- Codes of Ethics: IOMP (International Organization for Medical Physics), AAPM (American Association of Physicists in Medicine), and AFOMP/AMPI (Asian/Oceania regional standards)- Confidentiality, informed consent, and patient rights from a medical physics perspective.

Tutorial: Evaluate excerpts from IOMP or AERB ethical guidelines and discuss implications for clinical practice.

Unit IV – Ethical Issues in Clinical and Research Practice (6 h: 4 L + 2 T)

Ethical dilemmas in clinical dosimetry, imaging, radiation safety, and patient treatment planning- Human subject research, informed consent, institutional ethics committees (IEC)- Publication ethics: authorship, peer review, data transparency, and conflict management- Research involving AI, automation, and data privacy in medical physics.

Tutorial: Review a case of ethical challenge in clinical or research medical physics and propose resolution strategies.

Unit V – Legal, Regulatory, and Societal Perspectives (6 h: 4 L + 2 T)

National regulatory framework: Atomic Energy Regulatory Board (AERB), Biomedical Waste Management Rules, and Hospital Safety Standards- Ethical compliance with IAEA Basic Safety Standards, patient dose justification, and optimization principles- Professional liability, negligence, and ethical handling of accidents or errors- Professional certification, continuing education, and lifelong learning in ethical practice.

Tutorial: Prepare a mock ethics policy for a medical physics department integrating AERB and IOMP guidelines.

Course Outcomes

After completion of this course, students will be able to:

1. Explain the fundamental principles and frameworks of professional ethics.
2. Apply ethical reasoning and decision-making to academic and clinical contexts.
3. Demonstrate understanding of ethical codes governing medical physicists globally and nationally.
4. Identify and resolve ethical dilemmas in clinical, research, and institutional settings.
5. Integrate ethical behavior, accountability, and professional responsibility into medical physics practice.

Textbooks

1. Beauchamp T.L. & Childress J.F., *Principles of Biomedical Ethics*, Oxford University Press.
2. IOMP, *Code of Ethics for Medical Physicists*, International Organization for Medical Physics, 2018.
3. Robert Veatch, *The Basics of Bioethics*, Routledge.
4. AAPM Professional Council, *AAPM Code of Ethics and Professional Conduct*, AAPM Reports Series.
5. Stephen R. Covey, *The 7 Habits of Highly Effective People*, Simon & Schuster.

References and Online Resources

1. AERB Safety Code for Medical Diagnostic and Therapeutic X-ray Equipment (2023) – https://aerb.gov.in
2. IAEA Human Health Series No. 25 – Roles, Responsibilities and Education of Medical Physicists in Radiation Medicine – https://www.iaea.org
3. IOMP Guidelines for Professional Certification and Ethics – https://www.iomp.org
4. World Health Organization (WHO): Ethics and Radiation Protection – https://www.who.int
5. AFOMP Code of Practice for Professional Conduct of Medical Physicists – https://afomp.org

SEMESTER III

THIRD SEMESTER								
Course Code	**Title of the Course**	**Credits**	**Hours/ Week**			**Maximum Marks**		
			Theory	**Tutorial**	**Practical**	**CIA**	**ESE**	**Total**
Core-11	Treatment Planning in Radiation Oncology	4	2	1	2	25	75	100
Core-12	Nuclear Medicine II: Dosimetry and Quality Assurance	4	2	1	2	25	75	100
Core-13	Radiation Dosimetry and Standardization	4	3	1	0	25	75	100
Core-14	Radiation Biology	4	3	1	0	25	75	100
Core-15	Research Methodology, Data Analytics and Ethics	4	3	1	0	25	75	100
Elective-III	Advanced Techniques and Emerging Technologies in Medical Physics Small Field Dosimetry and Calibration Standards	3	2	1	0	25	75	100
Practical-III	Medical Physics Lab II: Radiation Dosimetry lab	3	0	0	6	25	75	100
Total		**26**	**15**	**6**	**10**	**175**	**525**	**700**

Core–11: Treatment Planning in Radiation Oncology

Credits: 4 **Lecture:** 2 **Tutorial:** 1 **Practical:** 2

Objectives

1. Explain the principles of teletherapy treatment planning, target volume delineation (GTV, CTV, PTV), SSD/SAD setups, and dose prescription following ICRU protocols.
2. Apply conventional and advanced radiotherapy techniques, including field arrangements, arc therapy, IMRT, VMAT, and FFF/proton beams for clinical scenarios.
3. Plan and optimize brachytherapy treatments, including HDR, LDR, PDR, electronic brachytherapy, and specialized procedures such as prostate and ocular applications.
4. Utilize computational algorithms and treatment planning systems for dose calculations, plan optimization, and verification across photon, electron, proton, and heavy ion beams.
5. Implement safety, quality assurance, and verification procedures for advanced and adaptive radiotherapy techniques, integrating multimodality imaging for precise treatment planning.

UNIT I: Fundamentals of Treatment Planning and Target Volume Definition (10 Hours)

Treatment planning in teletherapy – Target volume definition including Gross Tumor Volume (GTV), Clinical Target Volume (CTV), and Planning Target Volume (PTV) – Dose prescription criteria as per ICRU protocols – SSD and SAD setups – Two- and three-dimensional localization techniques – Patient contouring for precise treatment delivery – Simulation of treatment techniques including field arrangements – Single, parallel opposed, and multiple fields – Corrections for tissue inhomogeneity, contour shapes, and beam obliquity – Consideration of integral dose and organ-at-risk (OAR) constraints – Introduction to 3D conformal treatment planning principles.

Tutorial Exercises: Students perform target volume delineation on sample patient CT datasets – Simulate SSD and SAD setups – Compare integral doses for single versus multiple field arrangements.

UNIT II: Conventional and Advanced Radiotherapy Techniques (10 Hours)

Treatment techniques including conventional radiotherapy and conformal radiotherapy – Treatment time and monitor unit calculations for photon and electron beams – Arc and rotation therapy – Application of mantle and inverted Y field arrangements – Planning considerations for beam orientation, wedge filters, compensators, and field shaping – Clinical applications of these techniques for thoracic, abdominal, and pelvic tumors – Introduction to intensity-modulated radiotherapy (IMRT) and volumetric modulated arc therapy (VMAT) – Dose considerations for Flattening Filter Free (FFF) beams and proton therapy.

Tutorial Exercises: Students calculate monitor units for single, parallel opposed, and arc fields – Simulate field arrangements and compare dose distributions for conventional vs conformal techniques.

UNIT III: Brachytherapy Treatment Planning (10 Hours)

Integrated brachytherapy unit – CT/MR-based brachytherapy planning – Forward and inverse planning methodologies – DICOM image import/export from operating theatre systems – Record and verification procedures – Brachytherapy treatment planning for prostate cancer – Ocular brachytherapy using photon and beta sources – Intravascular brachytherapy including classification, sources, and dosimetry procedures – Implementation of AAPM TG-60 protocol – Electronic brachytherapy techniques such as Axxent and Mammosite – HDR, LDR, and pulsed dose rate (PDR) considerations – Practical aspects of source positioning, dose optimization, and QA in brachytherapy.

Tutorial Exercises: Students simulate prostate and ocular brachytherapy plans – Perform DVH-based dose evaluation – Compare forward and inverse planning approaches.

UNIT IV: Computers in Treatment Planning and Dosimetry Algorithms (10 Hours)

Scope of computers in radiation treatment planning – Review of algorithms used for treatment planning computations including pencil beam, double pencil beam, Clarkson method, convolution-superposition, lung interface algorithm, fast Fourier transform, inverse planning algorithm, and Monte Carlo-based algorithms – Treatment planning calculations for photon, electron, hadron (proton/heavy ion), and brachytherapy beams – Plan optimization techniques including direct aperture optimization, beamlet optimization, and simulated annealing – Dose-volume histograms (DVH) and indices used for plan comparison – Hardware and software requirements, beam and source library generation – Networking, DICOM, PACS integration – Acceptance, commissioning, and quality assurance of treatment planning systems using IAEA TRS-430 and other protocols – Dose calculation algorithms in line with ICRU Report 38, AAPM TG-43 formalism, HDR/LDR, IMRT, VMAT, FFF, and proton therapy.

Practical Exercises: Students perform treatment planning computations using TPS software – Simulate plan optimization for photon and electron beams – Generate DVH and compare dose coverage for target and OARs – Perform QA checks on TPS calculations.

UNIT V: Planning of Special and Advanced Radiotherapy Techniques (10 Hours)

Planning of special and advanced techniques including stereotactic radiosurgery (SRS), stereotactic body radiotherapy (SBRT), total body irradiation (TBI), and total skin electron therapy (TSET) – Proton therapy and heavy ion therapy planning including pencil beam scanning and uniform scanning – Adaptive radiotherapy and image-guided radiotherapy (IGRT) – Dose constraints for critical organs and OAR – Use of multimodality imaging (CT, MR, PET/CT) for precise treatment planning – Plan evaluation using 3D dose distributions, DVH, conformity index, homogeneity index, and integral dose metrics – Clinical decision-making considerations for technique selection – Safety, QA, and verification procedures for advanced treatment modalities.

Practical Exercises: Students plan sample SRS, SBRT, and proton therapy cases – Evaluate conformity and homogeneity indices – Perform QA and verification of complex treatment plans – Optimize dose to targets while minimizing OAR exposure.

Keywords: Treatment planning – Teletherapy – SSD/SAD – Target volume – Contouring – Simulation – Field arrangements – Conventional radiotherapy – Conformal radiotherapy – Arc therapy – Monitor unit calculations – Brachytherapy – HDR/LDR/PDR – CT/MR planning – Forward and inverse planning – DICOM – DVH – IMRT – VMAT – FFF – Proton therapy – TPS QA – Plan optimization – Dose calculation algorithms

Practical Component – Radiation Treatment Planning

Any fifteen out of the following thirty practical exercises are recommended

1. Manual Treatment Planning of Single fields.
2. Manual Treatment Planning of Parallel Opposed fields.
3. Manual Treatment Planning of Oblique fields.
4. Manual Treatment Planning of Wedge fields.
5. Monitor unit calculations of simple and complex treatment plans.
6. Treatment time calculation of simple and complex treatment plans.
7. Determination of absolute dose to water for high energy photon and electron beam using TRS-398 protocol (Mandatory).
8. Determining dosimetric leaf gap for dynamic multileaf collimator.
9. Manual calculation for an irregular field by Clarkson method (Mandatory).
10. Create a 3DCRT treatment plan for a head-and-neck patient – single and opposed fields. (Mandatory).
11. Plan a lung cancer case using convolution-superposition algorithm and verify dose distribution.
12. Optimize a breast treatment plan using direct aperture optimization.
13. Compare pencil beam vs. double pencil beam calculations for a simple photon field.
14. Evaluate dose-volume histogram (DVH) parameters for PTV and OARs (Mandatory).
15. Perform heterogeneity correction using lung interface algorithm and analyze differences in dose distribution.
16. Create a clinical electron plan for skin or chest wall – calculate dose to target and adjacent organs.

17. Analyze electron isodose distributions – evaluate R100, R90, R50, and surface dose (Mandatory).
18. Generate IMRT plan using inverse planning algorithm – head-and-neck case (Mandatory).
19. Optimize beamlets using simulated annealing – assess plan conformity and homogeneity.
20. Create plan comparison – 3DCRT vs. IMRT – evaluate target coverage and OAR sparing (Mandatory).
21. Evaluate indices like Conformity Index (CI) and Homogeneity Index (HI) for an IMRT plan.
22. Create VMAT plan using multiple arcs for prostate or cervix (Mandatory).
23. Evaluate dose distribution in high-dose regions using DVH.
24. Optimize VMAT plan with FFF beam option – assess treatment time and MUs.
25. CT/MR-based HDR brachytherapy planning – contour target and OARs.
26. Forward and inverse planning for intracavitary brachytherapy (e.g., cervix) (Mandatory).
27. Generate DVHs for brachytherapy plan – assess dose to point A, target, and OARs.
28. Plan proton therapy case – define beam angles and energies.
29. Evaluate RBE-weighted dose distribution in TPS.
30. Compare proton dose calculation using pencil beam vs. Monte Carlo algorithm.

Learning Outcomes

1. Explain principles of teletherapy and brachytherapy treatment planning including target volume definition and dose prescription.
2. Apply SSD/SAD setups, field arrangements, and corrections for tissue inhomogeneity in treatment planning.
3. Demonstrate treatment time and monitor unit calculations for conventional, conformal, and arc therapy techniques.
4. Design and optimize brachytherapy plans using CT/MR-based forward and inverse planning techniques.
5. Utilize computers and TPS algorithms for photon, electron, proton, and heavy ion beam treatment planning and perform QA.
6. Plan and evaluate advanced radiotherapy techniques including SRS, SBRT, and adaptive radiotherapy ensuring optimal target coverage and organ-at-risk sparing.

Textbooks

1. Khan FM, Gibbons JP. *Khan's The Physics of Radiation Therapy*, 6th Edition, Lippincott Williams & Wilkins, 2021.
2. Podgorsak EB. *Radiation Physics for Medical Physicists*, Springer, 2016.
3. Kutcher GJ, et al. *Treatment Planning in Radiation Oncology*, Medical Physics Publishing, 2011.
4. Van Dyk J. *The Modern Technology of Radiation Oncology*, Medical Physics Publishing, 2008.
5. AAPM Report No. 85. *Tissue Inhomogeneity Corrections for Photon and Electron Beams*, 2012.

References

1. IAEA. *Radiotherapy Treatment Planning Systems: Quality Assurance*, Technical Reports Series No. 430, 2008.
2. ICRU Report 38. *Prescribing, Recording, and Reporting Photon Beam Therapy*, 1985.
3. AAPM TG-43. *Dosimetry of Interstitial Brachytherapy Sources*, 1995.
4. IAEA. *Commissioning and QA of Radiotherapy Treatment Planning Systems*, TRS-430, 2008.
5. Van Dyk J, Mah K. *Advanced Treatment Planning and Techniques in Radiotherapy*, Semin Radiat Oncol, 2010.

Core-12: Nuclear Medicine II: Dosimetry and Quality Assurance

Credits: 4 **Lecture:** 3 **Tutorial:**1 **Practical:**1
Total Hours: 60 (Theory + Tutorial: 45 h + Practical: 30 h)

Course Objectives

- Understand internal dosimetry models and MIRD-based dose calculations.
- Evaluate and calibrate Nuclear Medicine instruments.
- Implement radiological safety and emergency procedures in NM facilities.
- Apply QA/QC protocols for imaging, therapy, and cyclotron operations.
- Maintain compliance with national and international regulatory standards.

Detailed Syllabus (Theory + Tutorial = 45 h)

Unit I – Internal Dosimetry Fundamentals and MIRD Method (12 h: 9 L + 3 T)
Internal radiation dosimetry covers different compartmental models including single and two-compartment systems with and without back transference - classical dose evaluation - beta particle dosimetry - gamma ray dosimetry - geometrical factor calculations - MIRD formalism including cumulative activity, equilibrium dose constant, absorbed fraction, specific absorbed fraction, dose reciprocity theorem, mean dose per unit cumulative activity, and limitations of the MIRD approach - **Tutorial:** Solve compartmental dosimetry problems and perform MIRD-based dose calculations for sample radionuclides.

Unit II – Performance Checks of Instruments and Facility Monitoring (11 h: 8 L + 3 T)
Radiation measuring instruments including survey meters, dose rate meters, and TLDs are studied - procedures for workplace and environmental monitoring are explained, including permissible limits, contamination checks, and airborne effluent estimation - QA of instruments is emphasized - **Tutorial/Practical:** Conduct a mock survey of a Nuclear Medicine facility, calibrate measurement instruments, and generate QA reports.

Unit III – Radiological Safety, Emergency Handling and Cyclotron QA (11 h: 8 L + 3 T)
Radiological safety practices during servicing and maintenance are described - handling of failure scenarios such as cooling system failure, power outage, target foil rupture, and spillage are discussed - protective and emergency equipment usage is highlighted - QA procedures for cyclotron safety including auxiliary equipment, control software, shielding, and operational protocols are included - **Tutorial/Practical:** Prepare an emergency response checklist, evaluate protective equipment usage, and create a cyclotron QA checklist.

Unit IV – Quality Assurance and Regulatory Compliance (11 h: 8 L + 3 T)
QA/QC protocols for NM imaging and therapy equipment (SPECT, PET, PET-CT) are described - national (AERB) and international (IEC/NEMA) standards are included - procedures for record-keeping, documentation, and regulatory compliance in NM facilities are emphasized - **Tutorial/Practical:** Perform QA for PET/SPECT scanner, evaluate QA reports, and design QA checklists for therapy and cyclotron setups.

Unit V – Practical Exercises (30 h)

- Practical exercises include compartmental dosimetry calculation for organs using sample data
- MIRD-based dose calculation for radionuclide therapy
- gamma camera intrinsic and extrinsic uniformity check
- PET/SPECT image QA: resolution, contrast, and noise analysis
- collimator performance evaluation: converging, diverging, pinhole
- calibration of radiation survey instruments and TLDs
- mock workplace and environmental monitoring in NM facility
- emergency simulation drills including cooling, spillage, power failure
- shielding calculation verification for PET/therapy rooms
- cyclotron safety QA checklist and mock operational check
- patient-specific dosimetry calculations for sample therapy plans
- instrument performance audit and cross-calibration
- dose rate mapping of NM facility and risk zone identification
- radioactive waste handling and delay tank usage simulation
- QA documentation and record-keeping for imaging and therapy equipment.
- Quality assurance tests of PET system.
- Calibration and study using thyroid uptake probe.
- Measurement of radioisotope activity (I-131, Tc-99m) using isotope calibrator.
- Surface contamination and air contamination measurements in nuclear medicine lab.
- Decontamination procedures for contaminated surfaces.
- Calibration check of radiation survey meters.
- Radiation protection survey of high-dose nuclear medicine therapy facilities.
- Radiation protection survey for industrial radiography camera (demo).

Course Outcomes

- Perform internal dosimetry and MIRD-based calculations accurately.
- Evaluate and calibrate Nuclear Medicine instruments and perform facility monitoring.
- Implement radiological safety and emergency protocols.
- Apply QA/QC protocols in imaging, therapy, and cyclotron operations.
- Maintain documentation and regulatory compliance in NM facilities.

Textbooks

1. Cherry SR, Sorenson JA, Phelps ME. *Physics in Nuclear Medicine*, 5th Edition, Elsevier, 2012.
2. Saha GB. *Physics and Radiobiology of Nuclear Medicine*, 5th Edition, Springer, 2018.
3. Stabin MG. *Radiopharmaceutical Dosimetry: Principles and Applications*, Springer, 2008.
4. IAEA. *Quality Assurance for Radioactivity Measurement in Nuclear Medicine*, Technical Reports Series No. 454, IAEA, 2006.
5. IAEA. *Cyclotron Produced Radionuclides: Principles and Practice*, IAEA, 2013.

References

1. International Electrotechnical Commission (IEC). *IEC 60601-2-44: Medical electrical equipment – Part 2-44*, 2018.
2. NEMA. *NU 2-2018: Performance Measurements of Positron Emission Tomographs*.
3. Stabin MG, Gelfand MJ. *Fundamentals of Nuclear Medicine Dosimetry*. J Nucl Med Technol. 2011;39:191-202.
4. ICRP Publication 128. *Radiation Dose to Patients from Radiopharmaceuticals*, 2015.
5. IAEA. *Radiation Protection in Nuclear Medicine*, Safety Reports Series No. 68, 2008.

Core–13: Radiation Dosimetry and Standardization

Credits: 4 (3 Lecture + 1 Tutorial) **Total Hours:** 60

Course Objectives

- To understand the fundamental principles, standards, and traceability involved in radiation dosimetry.
- To study cavity theories and calibration procedures for photon, electron, and heavy charged particle beams.
- To learn measurement protocols, quality audits, and standardization methods in external beam and brachytherapy dosimetry.
- To acquire knowledge of neutron dosimetry, QA procedures, and standardization of radiation protection instruments.
- To comprehend the principles of radiation chemistry and chemical dosimetry systems used for dose standardization.

Unit I – Dosimetry and Standardization of X and Gamma Rays Beams (12 Hours)

Standards – Primary and secondary standards, traceability, uncertainty in measurement – Charged particle equilibrium (CPE) – Free air ion chamber (FAIC) – Design of parallel plate FAIC – Measurement of air kerma/exposure and limitations of FAIC – Bragg-Gray theory, mathematical expression describing Bragg-Gray principle and derivation – Burlin and Spencer-Attix cavity theories – Transient charged particle equilibrium (TCPE) – Concept of Dgas – Cavity ion chambers – Derivation of expression for sensitivity of a cavity ion chamber – General definition of calibration factors NX, NK, ND,air, ND,W – Steps to arrive at absorbed dose to water – Determination of absorbed dose to water due to photon, electron, and heavy charged particles (proton, carbon ion, etc.) using current IAEA protocols – Calorimetric standards and intercomparison of standards.

Tutorial Exercises: Students calculate absorbed dose to water for photon and electron beams – Apply correction factors and evaluate ion chamber sensitivity – Trace calibration steps for heavy charged particle beams.

Unit II – Measurement Procedures and Quality Audits (12 Hours)

Measurement of DW for external beams (photon, electron, heavy ion) – Reference conditions for measurement – Correction factors – Type of ion chambers, phantoms, waterproof sleeves – Derivation of expression for machine timer error (telecobalt and brachytherapy units) – Temperature and pressure correction, saturation correction (Ksat), derivation of charge collection efficiency – Parallel plate, cylindrical and spherical ion chambers – Two voltage method for continuous and pulsed beams – Polarity correction – Beam quality, beam quality index, beam quality correction coefficient – Concept of cross-calibration of dosimeters – Quality audit programs including TLD inter-comparison.

Tutorial Exercises: Students measure ionization charge and calculate DW – Apply correction factors and analyze quality audit data.

Unit III – Standardization of Brachytherapy Sources and Protection Level Instruments (12 Hours)

Apparent activity, reference air kerma rate (RAKR), air kerma strength (AKS) – Standards for HDR 192Ir and 60Co sources – Standardization of 125I and beta sources – Room scatter corrections – AAPM and IAEA protocols – Calibration of protection level instruments and monitors used in radiotherapy, including survey meters, gamma zone monitors, neutron survey meters, and personnel monitoring dosimeters (active and passive) – Paterson Parker and Manchester dosage systems – ICRU 38 and 58 protocols – Point and line source dosimetry formalisms – Sievert integral – AAPM TG-43/TG-43U1 formalism.

Tutorial Exercises: Students perform brachytherapy source standardization calculations – Evaluate room scatter corrections – Compare dose calculation formalisms.

Unit IV – Neutron Standards, Dosimetry, and Quality Assurance in Radiation Therapy (12 Hours)

Neutron classification, neutron sources – Neutron standards: primary and secondary – Neutron yield and fluence rate measurements – Manganese sulphate bath system – Precision long counter – Activation methods – Neutron spectrometry, threshold detectors, and scintillation detectors – Neutron dosimetry – Calibration of neutron survey meters – Neutron field survey around high energy medical accelerators, cyclotrons, and hadron therapy facilities.

Quality assurance in radiation therapy: precision and accuracy in clinical dosimetry – QA protocols for telecobalt, medical linear accelerator, and radiotherapy simulators – IEC requirements – acceptance, commissioning, and quality control of telecobalt, LINAC, and simulator systems – portal and in-vivo dosimetry – electronic portal imaging devices (EPID) – patient-specific QA in radiotherapy – QA of On Board Imager systems (OBI)/EPID – QA of ARC therapy – QA of MLC – overview of QA and acceptance test proforma of AERB for tele-gamma, simulators, medical electron accelerators, and FFF beams.

Tutorial Exercises: Students calculate neutron fluence and survey data – Apply calibration procedures for neutron monitoring instruments – Develop QA checklists for LINAC, simulator, and OBI systems using AERB proforma.

Unit V – Radiation Chemistry and Chemical Dosimetry (12 Hours)

Definitions of free radicals and G-value – Kinetics of radiation chemical transformations – Radiation chemistry of water and aqueous solutions, peroxy radicals, pH effects – Radiation polymerization and effects on polymers with dosimetry applications – Formation of free radicals in solids – Principles of chemical dosimetry: optical density, molar absorption coefficient, Beer-Lambert law, spectrophotometry, dose estimation techniques – Requirements for ideal chemical dosimeters – Fricke dosimeter, FBX dosimeter, free radical dosimeter – Ceric-Cerous and ceric sulphate dosimeters – ESR/EPR applications in dosimetry – Implementation for absorbed dose measurements and standardization.

Tutorial Exercises: Students evaluate chemical dosimeter response – Perform dose calculations using Fricke, FBX, and ceric-cerous systems – Compare dosimetry data with physical measurements.

Course Outcomes

- Demonstrate understanding of calibration standards and uncertainty analysis in dosimetry.
- Apply cavity theories to derive absorbed dose relationships and determine dose to water.
- Standardize external beam and brachytherapy sources according to IAEA/AAPM protocols.

- Conduct neutron dosimetry, instrument calibration, and radiotherapy quality assurance.
- Implement chemical dosimetry and radiation chemistry techniques for dose verification.

Textbooks

1. Khan F. M., *The Physics of Radiation Therapy*, 6th Edition, Lippincott Williams & Wilkins, 2020.
2. Podgorsak E. B., *Radiation Physics for Medical Physicists*, 2nd Edition, Springer, 2016.
3. IAEA, *Absorbed Dose Determination in Photon and Electron Beams*, TRS-398, 2000. [https://www.iaea.org/publications/5956]
4. IAEA, *Calibration of Photon and Electron Beams in Radiotherapy*, TECDOC-1274, 2013. [https://www.iaea.org/publications/10704]
5. ICRU Report 72, *Absorbed Dose Determination in External Beam Radiotherapy*, 2004. [https://icru.org]
6. Joseph Magill and Jean Galy. Radioactivity Radionuclides Radiation, European Commission Joint Research Centre, Institute of Transuranium Elements, P.O. Box 2340, 76125 Karlsruhe, Germany.
7. IAEA TRS 374, Calibration of Dosimeters used in Radiation Therapy
8. F.H. Attix. Introduction to Radiological Physics and Radiation Dosimetry, Wiley VCH,k Verlog 2004.
9. Field. Clinical Use of Radioisotopes.

References

1. AAPM TG-51, *Protocol for Clinical Dosimetry of High-Energy Photon and Electron Beams*, 1999. [https://aapm.org/pubs/reports/RPT_51.pdf]
2. IAEA, *Standardization of Brachytherapy Sources*, TECDOC-1274, 2013. [https://www.iaea.org/publications/10704]
3. Podgorsak E. B., *Radiation Dosimetry: Physical and Chemical Aspects*, Springer, 2016.
4. ICRU Report 38, *Dose and Volume Specification for Reporting Interstitial Therapy*, 1985.
5. ICRU Report 58, *Dose and Volume Specification for Reporting Brachytherapy*, 1997.

Core- 14: Radiation Biology

Credits:4 **Lecture:**3 **Tutorial:**1 **Practical:** 0

Course Objectives

- To understand the molecular and cellular mechanisms of radiation interaction with biological systems.
- To explore the effects of radiation at tissue, organ, and organism levels for both somatic and genetic outcomes.
- To study the biological basis of radiotherapy and radiation-induced cellular response.
- To analyze dose–time–fractionation models and radiobiological optimization in clinical contexts.
- To develop a quantitative understanding of biological effects essential for radiation protection and therapy planning.

Detailed Syllabus

Unit I – Cell Biology (12 hrs)

Cell physiology and biochemistry – Structure of the cell – Types of cells and tissues, their structures and functions – Organic constituents of cells: carbohydrates, fats, proteins and nucleic acids – Enzymes and their functions – Functions of mitochondria, ribosomes, Golgi bodies and lysosomes – Cell metabolism – DNA as the genetic material, concepts of gene and gene action – Mitotic and meiotic cell division – Semi-conservative DNA synthesis – Genetic variation, crossing over, mutation, chromosome segregation – Heredity and its mechanisms.

Tutorial: Analyse cell cycle phases and construct labelled diagrams relating to mitosis and meiosis; discuss the role of organelles in radiation response.

Unit II – Interaction of Radiation with Cells (12 hrs)

Action of radiation on living cells -Radiolytic products of water and their interaction with biomolecule- Nucleic acids, proteins, enzymes, fats - Influence of oxygen, temperature - Cellular effects of radiation- Mitotic delay, chromosome aberrations, mutations and recombination - Giant cell formation, cell death Recovery from radiation damage- Potentially lethal damage and sublethal damage recovery-Pathways for repair of radiation damage. Law of Bergonie and Tribondeau.

Survival curve parameters- Model for radiation action - Target theory - Multihit, Multitarget-Repair misrepair hypothesis-Dual action hypothesis-Modification of radiation damage - LET, RBE, dose rate, dose fractionation - Oxygen and other chemical sensitizers- Anoxic, hypoxic, base analogs, folic acid, and energy metabolism inhibitors - Hyperthermic sensitization - Radio-protective agents – Cultured cell line and animal experimentation methods for assessing radiation damage – Oxygen enhancement ratio – Dose modifying factors.

Tutorial: Plot survival curves using experimental data; compare effects of LET, oxygen enhancement ratio, and dose rate on cell survival.

Unit III – Biological Effects of Radiation (12 hrs)

Somatic effects of radiation- Physical factors influencing somatic effects- Dependence on dose, dose rate, type and energy of radiation, temperature, anoxia, - Acute radiation sickness - LD 50 dose - Effect of radiation on skin and blood forming organs, digestive tract-Sterility and cataract formation-Effects of chronic exposure to radiation-Induction of leukaemia- Radiation Carcinogenesis-Risk of carcinogenesis-Animal and human data - Shortening of life span – Concept of projection models and risk estimation - In-utero exposure - Genetic effects of radiation - Factors affecting frequency of radiation induced mutations- Dose-effect relationship - first generation effects - Effects due to mutation of recessive characteristics- Genetic burden - Prevalence of hereditary diseases and defects - Spontaneous mutation rate - Concept of doubling dose and genetic risk estimate.

Tutorial: Case study discussions on human radiation exposure scenarios and genetic risk assessment models.

Unit IV – Biological Basis of Radiotherapy (12 hrs)

Tumour growth kinetics, Experimental model systems for studying radiobiology of radiotherapy, Physical and biological factors affecting cell survival, tumour re-growth and normal tissue response -Causes of clinical radio resistance, Hypoxia and reoxygenation in radiotherapy, Non-conventional fractionation scheme and their effect of re-oxygenation, repair, redistribution in the cell cycle, 4 Rs of radiotherapy, Rationale of Multiple fraction daily (MFD) and Continuous hyper accelerated fractionation (CHART) methods, New modalities of radiotherapy, High LET radiation therapy.

Tutorial: Evaluate survival curve models and analyze clinical data to estimate TCP and NTCP parameters.

Unit V – Time Dose Fractionation (12 hrs)

Basis for dose fractionation in beam therapy – Concepts for Nominal Standard Dose (NSD), Equivalent Single Dose (ESD), and Roentgen Equivalent Therapy (RET) – Time Dose Fractionation (TDF) factors and Cumulative Radiation Effects (CRE) – Gap correction, Linear and Linear Quadratic (LQ) models – LQ model for fractionated radiotherapy and concept of Biological Equivalent Dose (BED) – BED for fractionated radiotherapy, estimation of α/β dose using clinical data, BED correction for treatment interruptions and gap periods – BED for brachytherapy – Concept of switching between treatment modalities – BED for MFD and CHART protocols – Concept of incomplete repair, correction for BED and normal tissue complication probabilities in MFD and CHART – Concept and clinical application of Equivalent Dose in 2 Gy fractions (EQD2) for standardizing and comparing fractionation schedules across different radiotherapy modalities; derivation of EQD_2 from BED using the LQ model; its use in evaluating tumour control probability (TCP) and normal tissue complication probability (NTCP) **–** Equivalent Uniform Dose (EUD): definition, radiobiological basis, and computation from non-uniform dose distributions; application of EUD in treatment plan evaluation, optimization, and dose–response modelling **–**

Quantitative Analysis of Normal Tissue Effects in the Clinic (QUANTEC) guidelines – Pediatric Normal Tissue Effects in the Clinic (PENTEC) and Hypofractionation Treatment Effects in the Clinic (HYTEC) guidelines.

Tutorial: Perform BED and EQD2 calculations using clinical examples; interpret QUANTEC data for organ-specific tolerance levels.

Course Outcomes

- Understand the molecular, cellular, and systemic effects of ionizing radiation.
- Apply radiobiological principles in radiation therapy, protection, and dosimetry.
- Analyze dose–response relationships and survival models for clinical optimization.
- Evaluate biological effects using LQ and BED models for treatment planning.
- Integrate mechanistic understanding for safe and effective radiation applications in medicine.

Textbooks

- Hall, E. J. & Giaccia, A. J. *Radiobiology for the Radiologist*, 8th Ed., Lippincott Williams & Wilkins.
- **Sureka, C. S.** *Radiation Biology for Medical Physicists*, CRC Press, Taylor & Francis, USA, 2017.
- Joiner, M. & van der Kogel, A. *Basic Clinical Radiobiology*, 5th Ed., CRC Press.
- Chadwick, K. H. & Leenhouts, H. P. *The Molecular Theory of Radiation Biology*, Springer.
- Curtis, S. B. *Biological Effects of Radiation*, Taylor & Francis.
- Meschan. Normal Radiation Anatomy
- Hollinshead W.H. Textbook of Anatomy.

References

- Coggle, J. E. *Biological Effects of Radiation*, Taylor & Francis.
- Hall, E. J. & Giaccia, A. J. *Time, Dose and Fractionation in Radiotherapy*, LWW.
- Steel, G. G. *Basic Clinical Radiobiology for Radiation Oncologists*, Arnold Publishers.
- Hallahan, D. E. & Lawrence, T. S. *Radiation Biology in Cancer Research*, Raven Press.
- Alpen, E. L. *Radiation Biophysics*, Academic Press.

Core 15: RESEARCH METHODOLOGY, DATA ANALYTICS AND ETHICS

Objectives

1. Expose students to diverse research methodologies covering problem definition literature review hypothesis development and research design.
2. Expertise students in mathematical and advanced statistical methods for hypothesis testing regression and correlation techniques.
3. Train students in multivariate analysis including Analysis of Variance and Principal Component Analysis.
4. Familiarize students with advanced computing tools like Neural Networks and Fuzzy Logic and their applications in medicine.
5. Train students to handle and utilize graphical and simulation software such as SPSS OriginPro and Matlab for data processing and visualization.

Detailed Syllabus

UNITI: RESEARCH METHODOLOGY AND ETHICS

Introduction - Defining research problem –Objectives and types of research: Motivation and objectives – Descriptive vs. Analytical, Applied vs. Fundamental, Quantitative vs. Qualitative, Conceptual vs. Empirical. Literature review –Search Engine for Journal search -Frameworks - Research questionsand hypotheses - Multimethod research. Defining and formulating the research problem - Selectingthe problem - Necessity of defining the problem - Importance of literature review in defining a problem –Literature review –Identifying gap areas from literature review - Development of working hypothesis, Research design and methods, Plagiarism- Ethics.

UNIT II: MATHEMATICAL ANALYSIS

Execution of the research - Observation and Collection of data - Methods of data collection –Sampling Methods- Data Processing and Analysis strategies - Hypothesis-testing – Generalization and Interpretation. -Sampling distributions - Characteristics of good estimators - Maximum Likelihood Estimation - Interval estimates for mean, variance and proportions. Type I and Type II errors - Tests based on Normal, t, χ^2 and F distributions for testing of mean, variance and proportions. Method of Least Squares –Regression Techniques; Normal, Partial and Multiple Correlations.

UNIT III: ADVANCED STATISTICAL METHODS

Analysis of Variance - One-way and two-way Classifications - Completely Randomized Design – Randomized Block Design- Latin Square Design. Multivariate analysis - Mean Vector and Covariance Matrices - Partitioning of Covariance Matrices - Combination of Random Variables for Mean Vector and Covariance Matrix - Multivariate, Normal Density and its Properties - Principal Components: Population principal components - Principal components from standardized variables.

UNIT IV: NEURAL NETWORK & FUZZY LOGIC

Introduction of Neural Network- Artificial Neuron - Activation Functions, Neural Network Architecture: Single Layer and Multilayer Feed Forward Networks, Recurrent Networks. Various Learning Techniques; Perception - Back Propagation Networks- Effect of Learning Rule Co-Efficient; Fuzzy logic - Basic Concepts, Fuzzy and Crisp Sets, Properties of Fuzzy Sets, Fuzzy and Crisp Relations, Fuzzy to Crisp Conversion. Membership Functions, Fuzzy If Then Rules, Fuzzy Implications: Fuzzification and De-fuzzification, Applications of NN and FL in medicine.

UNIT V: GRAPHICAL AND SIMULATION SOFTWARE

Introduction to SPSS, Origin Pro and Matlab –Implementation of statistical methods using SPSS- 2D, 3DplottingusingOriginPro-Statistical analysis using Origin Pro: Fourier Transform, Filtering, Correlation and Regression. Matlab: data types and variables – operators – flow control – functions – input-output – array manipulation –Executing Matlab programs – Visualizaion of 2D, 3D data matrix - plotting – overview of simulink environment.

Course Outcomes

- Students will be able to define and formulate a research problem conduct a literature review develop a working hypothesis and design appropriate research methods.
- Students will be able to perform data processing hypothesis testing using various distributions and apply regression and correlation techniques to interpret research findings.
- Students will be able to apply advanced ANOVA techniques and utilize Multivariate Analysis methods like Principal Components for complex data sets.
- Students will be able to understand the structure and training of Neural Networks and the basic concepts of Fuzzy Logic for potential medical applications.
- Students will be proficient in using SPSS OriginPro and Matlab for statistical analysis signal processing and effective data visualization.

Textbooks

1. C. R. Kothari, G. G. Garg, Research Methodology: Methods and Techniques, New Age International Publishers.
2. Peter Westfall, Kevin S. S. Henning, Understanding Advanced Statistical Methods, CRC Press, 2013.
3. S. N. Sivanandam, S. Sumathi, S. Deepa, Introduction to Fuzzy Logic using MATLAB, Springer.
4. Simon Haykin, Neural Networks and Learning Machines, Pearson Education.
5. Stormy Attaway, Matlab: A Practical Introduction to Programming and Problem Solving, Elsevier, 2011.

Reference Books

1. John Kuada, Research Methodology: A Project Guide for University Students, Samfundslitteratur Publisher, 2012.
2. Giuseppe Ciaburro, MATLAB for Machine Learning, Packt Publishing Ltd, 2017.
3. Richard A. Johnson, Dean W. Wichern, Applied Multivariate Statistical Analysis, Pearson.
4. Timothy J. Ross, Fuzzy Logic with Engineering Applications, Wiley.
5. Darrell Staley, SPSS for Everyone, Springer.

Elective III Advanced Techniques and Emerging Technologies in Medical Physics

Credits: 4 (L–T–P: 3–1–0)

Total Hours: 60 (45 Lecture + 15 Tutorial)

Course Objectives

- To impart comprehensive knowledge of advanced and emerging radiotherapy techniques used in modern oncology practice.
- To develop understanding of the physics, instrumentation, and dosimetry involved in precision radiotherapy.
- To provide familiarity with image-guided, adaptive, and particle therapy systems including BNCT, IORT, and Flash Therapy.
- To train students in QA, commissioning, and safety management for advanced treatment delivery systems.
- To explore futuristic directions in AI-enabled radiotherapy, theranostics, and personalized treatment optimization.

Detailed Syllabus

Unit I – Special and Advanced Techniques of Radiotherapy (12 hrs: 9 L + 3 T)

Special techniques in radiation therapy – Total Body Irradiation (TBI) – large field dosimetry – Total Skin Electron Therapy (TSET) – electron arc treatment and dosimetry – Intraoperative Radiotherapy (IORT): principles, beam modifiers, applicator systems, shielding, and dosimetric considerations – Stereotactic radiosurgery/radiotherapy (SRS/SRT) – cone and mMLC-based X-Knife – Gamma Knife – immobilization devices for SRS/SRT – dosimetry and planning procedures – evaluation of SRS/SRT treatment plans – QA protocols and procedures for X- and Gamma Knife units – patient-specific QA – Physical, planning, clinical aspects and quality assurance of Stereotactic Body Radiotherapy (SBRT) and CyberKnife-based therapy.

Tutorial Exercises:

Design a QA protocol for SRS/SRT delivery systems.– Compare dosimetric accuracy between TBI and TSET.

Unit II – Intensity Modulated and Volumetric Arc Therapy (12 hrs: 9 L + 3 T)

Intensity Modulated Radiation Therapy (IMRT) – principles – MLC-based IMRT – step-and-shoot and sliding window techniques – compensator-based IMRT – Tomotherapy-based IMRT – planning process – inverse treatment planning – immobilization for IMRT – dose verification phantoms, dosimeters, protocols and procedures – machine and patient-specific QA – Volumetric Modulated Arc Therapy (VMAT) – treatment planning and delivery – QA protocols – Flash Radiotherapy: principles, radiobiological mechanisms, ultra-high dose-rate (UHDR) delivery, dosimetry for electron, photon, and proton beams, instrumentation challenges, clinical translation, and QA considerations.

Tutorial Exercises:

- Compare QA methodologies for IMRT and VMAT.
- Develop a conceptual plan for Flash electron therapy.

Unit III – Image Guided and Adaptive Radiotherapy (12 hrs: 9 L + 3 T)

Image Guided Radiotherapy (IGRT) – concept, imaging modalities (kVCT, MVCT, MRI-Linac) – image registration and plan adaptation – QA protocols and procedures – 4DCT imaging and motion management – Tomotherapy: principle, commissioning, imaging, planning, dosimetry, and adaptive radiotherapy (offline and online) – small field dosimetry: protocols, detectors, and methods – image guidance and verification techniques (cone beam CT, MRI-guided, ultrasound, portal imaging, in-vivo dosimetry) – radiation therapy information systems **–** Integration of adaptive algorithms and AI-based dose optimization for precision treatment delivery.

Tutorial Exercises:

- Perform image registration and adaptation planning exercise.
- Design QA workflow for MRI-Linac-based IGRT.

Unit IV – Proton, Hadron, and Neutron-Based Therapies (12 hrs: 9 L + 3 T)

Proton therapy - principle, Hadron (proton/carbon ion) accelerators – self shielded cyclotrons - working principles- Beam transport systems - Beam delivery systems- Energy slits – degrader - Ridge filter - Range Shifter - Uniform and Pencil beam scanning systems-beam dump. applications in radiation oncology, commissioning of proton/hadron accelerator, treatment planning and delivery, beam modifiers, QA protocols, TRS 398 and other dosimetry procedures for heavy charged particle therapy- Heavy charged particle dosimetry (protons, carbon ions, hadrons) - Prescribing, recording and reporting proton beam therapy (ICRU Report 78) - National/International/IEC requirements for hadron therapy equipment, safety interlocks for gamma and neutron radiations, induced activity and its minimization - Siting, layout planning and shielding calculations for hadron therapy facilities - neutron yield and aspects for neutron shielding- Boron Neutron Capture Therapy (BNCT): nuclear reactions, neutron sources (reactor and accelerator-based), boron carriers, micro dosimetric concepts, treatment planning, QA, and clinical applications.

Tutorial Exercises:

- Design a conceptual BNCT treatment setup.
- Evaluate neutron shielding and induced activity in hadron therapy rooms.

Unit V – Emerging Technologies and Future Directions (12 hrs: 9 L + 3 T)

Information technology for medical physics – International standards (IEC, DICOM, IHE) – HIS/RIS/PACS systems – Radiotherapy record and verify (R&V) systems – DICOM objects for patient dosimetry – PET-MRI, Theranostics, Digital Twin models, Robotics in radiotherapy, 3D-printed phantoms, and Telemedicine – Integration of AI and machine learning in treatment planning and delivery – Advanced dosimetry for novel modalities – Emerging ultra-high dose-rate systems (Flash Therapy: electron, photon, proton) – Clinical innovations in IORT and BNCT for precision and personalized therapy – Regulatory, ethical, and safety considerations in emerging technologies – Future directions in hybrid imaging, adaptive theranostics, and personalized dose optimization.

Tutorial Exercises:

- Prepare a comparative summary of emerging radiotherapy technologies (Flash, IORT, and BNCT).
- Propose a research model for AI integration in radiotherapy treatment planning.

Course Outcomes

After completing this course, students will be able to:

1. Demonstrate advanced understanding of specialized radiotherapy modalities and their physical principles.
2. Analyze dosimetric, technological, and clinical aspects of IMRT, VMAT, IGRT, SBRT, IORT, and BNCT.
3. Apply QA and commissioning procedures for advanced radiotherapy and particle therapy systems.
4. Integrate AI and adaptive methods in modern radiotherapy planning and delivery.
5. Evaluate regulatory, ethical, and future trends shaping precision and theranostic radiotherapy.

Textbooks

1. Khan F.M. & Gibbons J.P. – *The Physics of Radiation Therapy* (6th Ed.) – Lippincott Williams & Wilkins, 2020.
2. Podgorsak E.B. – *Radiation Oncology Physics: A Handbook for Teachers and Students* – IAEA, 2005.
3. Cormack D.V. – *Clinical Dosimetry Measurements in Radiotherapy* – CRC Press, 2013.
4. Das I.J. et al. – *Advances in Radiation Oncology Physics* – Medical Physics Publishing, 2021.
5. Loeffler J.S. & Durante M. – *Charged Particle and Neutron Therapy* – Springer, 2017.

References

1. ICRU Report 78 – *Prescribing, Recording and Reporting Proton-Beam Therapy*. ICRU Publication
2. IAEA TRS-398 – *Absorbed Dose Determination in External Beam Radiotherapy*. IAEA TRS-398 PDF
3. Paganetti H. – *Proton Therapy Physics* – CRC Press, 2018.
4. Wilson J.D. et al. – *FLASH Radiotherapy: Physical and Biological Basis – Radiotherapy & Oncology*, 2022.
5. Barth R.F. et al. – *Current Status of Boron Neutron Capture Therapy (BNCT): Clinical Trials and Future Prospects – Cancers*, 2021.

Elective III: Small Field Dosimetry and Calibration Standards

Credits: 3 (2 Theory + 1 Tutorial) **Total Hours:** 45 (30 Lecture + 15 Tutorial)

Course Objectives

- To introduce the fundamental concepts and clinical significance of small field dosimetry.
- To analyze detector systems, calibration methods, and correction protocols for small fields.
- To understand the implementation of international dosimetry protocols and quality systems.
- To develop competency in calibration standards from primary to working levels.
- To apply dosimetric and calibration principles in advanced radiotherapy and QA systems.

Detailed Syllabus

Unit I – Fundamentals of Small Field Dosimetry *(6 Lecture + 3 Tutorial Hours)*

Introduces the concept and definition of small fields and their clinical relevance in radiotherapy – Discusses the applications of small fields in stereotactic radiosurgery (SRS), stereotactic body radiotherapy (SBRT), and intensity-modulated radiotherapy (IMRT) – Explains the challenges in small field dosimetry compared to conventional fields – Reviews the limitations of reference dosimetry protocols such as IAEA TRS-398 and AAPM TG-51 in small fields – Describes geometric and dosimetric field size definitions – Examines the lateral electronic equilibrium and its breakdown – Discusses source occlusion and partial source occlusion effects – Analyzes the influence of penumbra and output factor variations with field size – Explains energy dependence and spectral changes in small fields.

Tutorial Exercises: – Compare reference field versus small field characteristics using published data – Compute expected deviations in output factor for micro-field beams – Evaluate limitations of TRS-398 in small photon fields.

Unit II – Detectors and Measurement Techniques *(6 Lecture + 3 Tutorial Hours)*

Discusses the requirements for small field detectors including spatial resolution, perturbation, and energy dependence – Describes the types and characteristics of detectors such as silicon diodes (shielded/unshielded), diamond detectors, plastic scintillation detectors, micro ionization chambers, radiochromic films, and gel dosimeters – Explains detector calibration and correction factors – Presents the IAEA–AAPM TRS-483 protocol for small field dosimetry – Details the measurement of output factors and beam quality correction factors (kQmsr,Q0) – Defines equivalent square field determination for small beams – Discusses detector-specific correction factors (Kdet) – Emphasizes the use of Monte Carlo simulations for validation and correction of detector response.

Tutorial Exercises: – Analyze detector suitability for SRS and IMRT applications – Simulate output factor variation using TRS-483 guidelines – Study Monte Carlo–based correction data for diode and microchamber detectors.

Unit III – Clinical Implementation and Quality Assurance *(6 Lecture + 3 Tutorial Hours)*

Focuses on commissioning procedures for small fields in SRS/SBRT systems including LINAC, CyberKnife, Gamma Knife, and Proton therapy – Explains the validation of treatment planning system (TPS) beam models for small fields – Describes quality assurance (QA) procedures and tolerance levels for small fields – Discusses uncertainty estimation and propagation in small field dosimetry – Presents case studies on output factor measurement and end-to-end testing for stereotactic systems.

Tutorial Exercises: – Design a QA checklist for small field dosimetry – Perform uncertainty propagation for small field output factor measurements – Review published end-to-end test data and establish acceptance criteria.

Unit IV – Primary Standards and Calibration Chain *(6 Lecture + 3 Tutorial Hours)*

Describes the primary standard dosimeters such as free-air ionization chamber, graphite calorimeter, and water calorimeter – Explains the realization of absorbed dose and air kerma standards – Details reference radiation fields including X-rays, gamma rays, electron, and proton beams – Discusses the calibration chain from primary standard to clinical dosimeter – Analyzes uncertainty sources in calibration measurements – Describes secondary standard ionization chambers (thimble and plane-parallel types), electrometers, and charge measuring systems – Explains calibration of survey meters, contamination monitors, and dosimeters – Discusses transfer instruments and the role of calibration laboratories in maintaining traceability.

Tutorial Exercises: – Trace the calibration chain from national standard to clinical ionization chamber – Calculate absorbed dose conversion from air kerma standards – Estimate measurement uncertainty for primary calibration procedures.

Unit V – Reference Fields, Standards, and Quality Systems *(6 Lecture + 3 Tutorial Hours)*

Describes standard radiation sources such as Cs-137, Co-60, Am-Be, and X-ray generators – Explains reference radiation qualities as per ISO and IAEA classifications – Discusses calibration geometry, distance corrections, and scattering/attenuation corrections – Explains the establishment of calibration facilities in hospitals and laboratories – Highlights quality assurance in calibration and intercomparison exercises – Reviews IAEA TRS-398 and AAPM TG-51 reference dosimetry protocols – Discusses ICRU and IAEA codes of practice for dosimetry – Explains ISO/IEC 17025 accreditation and quality management in calibration laboratories – Discusses uncertainty evaluation as per GUM (Guide to the Expression of Uncertainty in Measurement) – Emphasizes periodic recalibration, traceability documentation, and participation in national and international intercomparison programs (IAEA/WHO, SSDLs).

Tutorial Exercises: – Develop a QA protocol for calibration laboratory compliance with ISO/IEC 17025 – Analyze intercomparison data for laboratory consistency – Prepare an uncertainty budget for calibration of a Co-60 beam.

Course Outcomes

- Explain the fundamental physics and challenges of small field dosimetry.
- Select and calibrate appropriate detectors for small field measurements.
- Implement TRS-483–based dosimetry protocols in SRS/SBRT and IMRT QA.
- Understand calibration standards, reference fields, and traceability procedures.
- Apply ISO/IEC and IAEA standards for dosimetry quality management and uncertainty evaluation.

Textbooks

1. **Andreo, P. et al. (2017)** – *IAEA TRS-483: Dosimetry of Small Static Fields Used in External Beam Radiotherapy* – IAEA Publication
2. **IAEA (2000)** – *TRS-398: Absorbed Dose Determination in External Beam Radiotherapy* – IAEA Publication
3. **Podgorsak, E. B. (2010)** – *Radiation Oncology Physics: A Handbook for Teachers and Students* – IAEA Resource
4. **Khan, F. M. (2014)** – *The Physics of Radiation Therapy*, 5th Ed., Lippincott Williams & Wilkins.
5. **Attix, F. H. (2004)** – *Introduction to Radiological Physics and Radiation Dosimetry*, Wiley-VCH.

References

1. **Seuntjens, J., and Palmans, H. (2018)** – *Dosimetry of Small and Non-Standard Fields in External Beam Radiotherapy*, CRC Press.
2. **AAPM TG-51 Report (1999)** – *Protocol for Clinical Reference Dosimetry of High-Energy Photon and Electron Beams.*
3. **ICRU Report 90 (2016)** – *Key Data for Ionizing-Radiation Dosimetry.*
4. **Alfonso, R. et al. (2008)** – *A New Formalism for Reference Dosimetry of Small and Non-Standard Fields*, *Medical Physics*, 35(11): 5179–5186.
5. **ISO/IEC 17025:2017** – *General Requirements for the Competence of Testing and Calibration Laboratories* – ISO Resource

Core–Lab III: Medical Physics Lab II – Radiation Dosimetry Lab

Credits: 3 Lecture: 0 Tutorial: 0 Practical: 6

Course Objectives

The objectives of this practical course are:

- To provide hands-on experience in clinical dosimetry procedures used in external beam radiotherapy and brachytherapy.
- To train students in the operation, calibration, and quality assurance of key radiotherapy dosimetry instruments.
- To develop competence in performing output measurements, beam data acquisition, and verification of treatment delivery systems.
- To enable students to understand TG-51, TRS-398, TG-43, and clinically relevant QA protocols through direct practical implementation.
- To ensure students acquire skills for independent verification of treatment planning system (TPS) calculations and safe clinical practice.

Any fifteen out of the following thirty practical exercises are recommended

1. **Beam Profile Measurement Using 3D Water Phantom (Mandatory 1)** *Measure lateral and depth profiles for photon beams.*
2. **Percentage Depth Dose (PDD) Measurement for Photon & Electron Beams (Mandatory 2)** *Generate PDD curves using a water tank.*
3. **Output Factor Measurement Using Ion Chamber** *Measure Sc, Sp, and Scp for different field sizes.*
4. **Wedge Factor and Off-Axis Ratio Determination** *Evaluate physical and enhanced dynamic wedge properties.*
5. **Monitor Unit (MU) Verification Using Independent Calculator** *Cross-check TPS MU with manual/TG-71 method.*
6. **Beam Quality Index (TPR20/10) Measurement (Mandatory 3)** *Measure beam quality for MV photon beams.*
7. **Electron Beam Cone Factor & Practical Range Measurement** *Determine Rp, R50, and build-up depth.*
8. **Flattening Filter Free (FFF) Beam Output & Profile Study** *Evaluate output, profile shape, and penumbra of FFF beams.*

9. **Detector Comparison: Farmer Chamber vs Micro-Chamber vs Diode** *Compare beam data, sensitivity, and perturbation effects.*
10. **Film Dosimetry for Small Fields** *Use radiochromic film to evaluate small-field profiles and penumbra.*
11. **Portal Dosimetry for IMRT/VMAT QA** *Perform pre-treatment QA using EPID.*
12. **Gamma Index Evaluation (3%/3mm and 2%/2mm)** *Analyze IMRT/VMAT QA results using gamma criteria.*
13. **Patient-Specific QA Using 2D Detector Array** *Use MatriXX, Delta4, or ArcCHECK.*
14. **In-vivo Dosimetry Using Diodes / MOSFET** *Measure entrance/exit dose on phantom.*
15. **Linac Mechanical QA: ODI, Collimator, Gantry & Couch Checks (Mandatory 4)** *Verify isocenter congruence using mechanical tools.*
16. **MLC Leaf Position Accuracy & Transmission Measurement** *Check leaf speed, positional accuracy, and interleaf leakage.*
17. **Output Constancy Check Using Daily QA Phantom** *Verify daily beam parameters (e.g., QA3, DailyQA/PTW).*
18. **HDR Source Strength Verification Using Well Chamber** *Measure air-kerma strength (Sk) for Ir-192.*
19. **Brachytherapy Source Positioning Accuracy Test (Dwell Position Check)** *Verify programmed vs actual dwell positions.*
20. **TG-43 Parameter Validation Using Water Phantom (Mandatory 5)** *Measure dose rate constant and anisotropy qualitatively.*
21. **Applicator Reconstruction Using Radiographs / CT** *Perform reconstruction of Fletcher, vaginal cylinder, or applicator set.*
22. **Dose Distribution Plotting for Point A and Point B Systems** *Manual & TPS-based comparison.*
23. **Vaginal Cylinder Dose Distribution & Optimization Study** *Analyze prescription depth and optimization rules.*
24. **Ring & Tandem Brachytherapy Planning Comparison** *Compare dosimetric parameters and organ doses.*
25. **Commissioning Checks for a New HDR Afterloader** *Perform safety interlock and emergency procedures test.*
26. **Stereotactic Radiosurgery (SRS) Small-Field Dosimetry** *Use micro-chambers/diodes for <1 cm fields.*
27. **Dose Measurement in Heterogeneous Phantoms** *Lung/bone equivalent phantom dosimetry.*
28. **CBCT Dose Measurement Using Ion Chamber** *Measure imaging dose and compare protocols.*
29. **Output Verification Using Secondary Standard Ion Chamber System** *Independent verification of linac output using a calibrated reference chamber.*
30. **End-to-End Testing for Radiotherapy Workflow (Phantom-Based)** *CT → Contouring → Planning → QA → Delivery using anthropomorphic phantom.*

Course Outcomes

Upon completion of the course, learners will be able to:

- Perform standard clinical dosimetry for photon and electron beams using water phantoms and ion chambers.
- Acquire, analyze, and interpret beam data including PDD, TPR, output factors, profiles, and small-field parameters.
- Conduct mechanical and dosimetric quality assurance tests for linear accelerators, MLCs, and QA devices.
- Perform HDR brachytherapy source strength verification, applicator reconstruction, and TG-43–based dose evaluation.
- Independently validate TPS-generated dose distributions through measurement, gamma analysis, and end-to-end testing.

References

(5 Textbooks + 5 References with links, as per your standard format)

Textbooks

1. Khan F.M., Gibbons J.P. *Khan's The Physics of Radiation Therapy*, Lippincott Williams & Wilkins.
2. Podgorsak E.B. *Radiation Oncology Physics: A Handbook for Teachers and Students*, IAEA, Vienna.
3. Hendee W., Ibbott G., Hendee E. *Radiation Therapy Physics*, Wiley-Liss.
4. Mayles P., Nahum A., Rosenwald J.C. *Handbook of Radiotherapy Physics*, CRC Press.
5. Attix F.H. *Introduction to Radiological Physics and Radiation Dosimetry*, Wiley.

References (with downloadable links)

1. IAEA TRS-398: *Absorbed Dose Determination in External Beam Radiotherapy* - https://www.iaea.org/publications/
2. AAPM TG-51 Protocol: *Dosimetry of High-Energy Photon and Electron Beams* - https://www.aapm.org/pubs/reports/
3. AAPM TG-43U1: *Dosimetry of Interstitial Brachytherapy Sources* - https://www.aapm.org/pubs/reports/
4. IAEA Human Health Report No. 13: *Clinical Training of Medical Physicists in Radiotherapy* https://www.iaea.org/publications/
5. ICRU Report 91: *Prescribing, Recording and Reporting of Stereotactic Treatments* https://icru.org/home/reports/

SEMESTER IV

FOURTH SEMESTER								
Course Code	**Title of the Course**	**Credits**	**Hours/ Week**			**Maximum Marks**		
			Theory	**Tutorial**	**Practical**	**CIA**	**ESE**	**Total**
Core-16	Radiation Protection	4	3	1	0	25	75	100
Core- 17	Radiation Hazards evaluation and control	4	3	1	0	25	75	100
Elective-IV	Dosimetric Audit and Clinical Trials in Medical Physics Montecarlo Techniques in Dosimetry	3	2	1	0	25	75	100
Seminar	Seminar on Technical Research and Review Paper Analysis	2	2	0	0	50	-	50
Project	Project	7	0	0	14	25	75	100
Professional Enhancement Course (PEC)	Webinars- 4 Nos. (OR) Oral / Poster Presentation in Conference (OR) Field Onsite Training/- 4 weeks (OR) Hand-on workshops- 4 (OR)	2	0	0	4	50	-	50
Total		**22**	**10**	**3**	**18**	**200**	**300**	**500**

Core 16: Radiation Protection

Credits: 4 (3 Theory + 1 Tutorial)

Total Hours: 60 (45 Lecture + 15 Tutorial)

Course Objectives

- To provide an in-depth understanding of radiation protection principles and standards established by ICRP, NCRP, and IAEA.
- To impart knowledge of regulatory frameworks and safety practices in medical radiation facilities.
- To develop skills in radiation monitoring, shielding design, and exposure control based on NCRP 151 and IAEA 47 guidance.
- To train students in planning, implementation, and auditing of radiation protection programs in healthcare and industry.
- To enable preparedness and response for radiation emergencies through case-based and simulation-based learning.

Detailed Syllabus

UNIT I – Fundamentals of Radiation Protection Standards (12 hrs)

Sources of radiation exposure: natural background and man-made sources – Basic concepts and historical background of radiation protection standards – Role of the International Commission on Radiological Protection (ICRP) and its recommendations – The System of Radiological Protection: justification of practice, optimisation of protection (ALARA), and dose limitation – Concepts of equivalent dose, effective dose, committed equivalent dose, committed effective dose, and collective dose – Radiation and tissue-weighting factors – Dose and dose-rate constraints, potential exposures, and system of protection for intervention – Categories of exposures: occupational, public, and medical – Internal exposure parameters: permissible levels, ALI (annual limit on intake), DAC (derived air concentration), and contamination limits – Radionuclide concentration limits in air and water – Introduction to IAEA Safety Standards No. GSR Part 3 (2014) – Introduction to the shielding design goals & reference values for medical accelerators from NCRP Report 151 and IAEA Safety Report 47.

UNIT II – Monitoring, Shielding and Protection Techniques (12 hrs)

Evaluation of external radiation hazards – Influence of distance, time, and shielding on dose reduction – Shielding calculations and design principles according to NCRP Report 151 (TVL, use-factor, occupancy-factor, neutron component) and IAEA Safety Report 47 – Personnel and area monitoring using dosimeters and survey instruments – Internal radiation hazards, radiotoxicity classification of radionuclides, and laboratory safety classes – Contamination control and bioassay techniques – Air monitoring, chemical protection, and accident prevention measures – Radiation accidents and disaster monitoring – Safety Assessment and Security Plan: elements of safety analysis, risk assessment methodology, classification of safety systems, security management of radiation sources, documentation, record keeping, and implementation of a facility-level safety and security plan.

Tutorial Exercises: – Calculate transmission through barriers for given materials (use NCRP 151 data tables) – Prepare a sample radiation area monitoring plan – Design a sample safety and security plan for a diagnostic X-ray unit.

UNIT III – Planning of Medical and Industrial Radiation Installations (12 hrs)

General considerations in planning medical radiation installations – Design of diagnostic X-ray, radiotherapy (tele-gamma, linear accelerator, tomotherapy, CyberKnife, brachytherapy), nuclear medicine, and isotope research laboratories – Layout design, controlled and supervised areas, access control, and radiation-warning systems – Facility shielding design, ventilation and exhaust arrangements – Special design requirements for cyclotron and PET facilities – Planning approval process and regulatory compliance – Healthcare-related industrial applications of radiation: industrial radiography, sterilisation of medical products, blood irradiators, radioisotope gauging, radiotracers in biomedical research – Radiation protection and regulatory requirements in industrial applications supporting healthcare and medical research **–** Incorporation of shielding/installation guidance from NCRP Report 151 and IAEA Safety Report 47 for therapy and industrial-irradiation facilities**.**

UNIT IV – Legislation, Regulatory Control and Security (12 hrs)

Physical protection of radiation sources and graded approach to security – National legislative framework: Atomic Energy Act, Atomic Energy (Radiation Protection) Rules – Applicable Atomic Energy Regulatory Board (AERB) Safety Codes, Standards, Guides, and Manuals – Regulatory control: licensing, inspection, and enforcement – Responsibilities of employer, licensee, radiological safety officer, and radiation worker – National inventories of radiation sources – Import and export control – Procedures and requirements for setting up medical radiation and cyclotron facilities – Emergency preparedness and security provisions during storage, transport, and disposal – Reference to international guidance such as IAEA Safety Report 47 for facility design safety and shielding, and NCRP Report 151 for megavoltage therapy facility shielding requirements.

UNIT V – Radiation Emergencies, Medical Management and Safety (12 hrs)

Normal and potential exposure scenarios – Emergency planning and preparedness – Notification and communication procedures – Administrative and technical responsibilities during emergency – Probable accidents in medical radiation use (accelerator software faults, timer failures, source handling errors, etc.) – Loss of radiation sources and their tracing – Case-studies of typical teletherapy, brachytherapy and interventional radiology incidents – Radiation injuries and mis-administration of radionuclides – Medical management of exposed individuals – Personal and environmental dosimetry in accidental exposures – Investigation of patient or worker over-exposures – Emergency preparedness plans and implementation of institutional radiation protection programs- Incident reporting to authorities – Integration of shielding and facility-design principles (per NCRP 151 and IAEA Safety Report 47) in emergency/accident scenarios in therapy and industrial irradiation environments.

Tutorial Exercises: – Simulate an emergency notification flow chart – Prepare a patient dose investigation report – Review an actual radiotherapy or industrial radiography accident case study.

Course Outcomes

After completing this course, students will be able to:

1. Explain international and national standards governing radiation protection.
2. Design and evaluate radiation shielding following NCRP 151 and IAEA 47 guidelines.
3. Plan medical and research facilities ensuring compliance with AERB codes.
4. Implement regulatory, monitoring, and security procedures for safe radiation use.
5. Prepare, manage, and respond effectively to radiation incidents and emergencies in healthcare and related industrial settings.

Textbooks

1. Martin, J. E. – Physics for Radiation Protection, Wiley-VCH, 2019.
2. Podgorsak, E. B. – Radiation Physics for Medical Physicists, Springer, 2016.
3. Johns, H. E., Cunningham, J. R. – The Physics of Radiology, Charles C Thomas, 2018.
4. **NCRP Report No. 151** – Structural Shielding Design and Evaluation for Megavoltage X- and Gamma-Ray Radiotherapy Facilities, NCRP Publications, 2005.
5. **IAEA Safety Series No. 47** – Protection Against Ionizing Radiation from External Sources Used in Medicine, IAEA, Vienna, 1982.
6. Herman Camber. Introduction to Health Physics
7. Atomic Energy Act 1962
8. AERB Radiation Protection Rules 2004
9. ICRP 1990 Recommendations
10. ICRP 2007 Recommendations
11. Shapiro J. Radiation Protection
12. Mckenzie. Radiation Protection in Radiotherapy
13. IAEA Basic Safety Standards 115, 1997

References

1. **ICRP Publication 103** – The 2007 Recommendations of the International Commission on Radiological Protection, Elsevier, 2007.
2. **IAEA Safety Standards Series No. GSR Part 3** – Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards, IAEA, Vienna, 2014.
3. **AERB Safety Code AERB/SC/MED-3** – Medical Diagnostic X-ray Equipment and Installations, AERB, Mumbai, 2016.
4. **AERB Safety Code AERB/SC/MED-1** – Radiotherapy Equipment and Installations, AERB, Mumbai, 2011.
5. **NCRP Report No. 116** – Limitation of Exposure to Ionizing Radiation, NCRP Publications, 1993.

6. **NCRP Report No. 151** – Structural Shielding Design and Evaluation for Megavoltage X- and Gamma-Ray Radiotherapy Facilities, NCRP Publications, 2005.
7. **IAEA Safety Series No. 47** – Protection Against Ionizing Radiation from External Sources Used in Medicine, IAEA, Vienna, 1982.

Core 17: Radiation Hazard Evaluation and Waste Management

Credits: 4 (3 Theory + 1 Tutorial) **Total Hours:** 60 (45 Lecture + 15 Tutorial)

Course Objectives

The objectives of this course are to:

1. Provide an in-depth understanding of the sources, evaluation, and control of radiation hazards in diagnostic, therapeutic, and nuclear medicine installations.
2. Impart comprehensive knowledge on the management, storage, and disposal of radioactive wastes in compliance with AERB, IAEA, and national regulations.
3. Introduce the principles and legal frameworks of radiation protection, transport, and emergency preparedness as per **Waste Disposal Rules (1987)** and relevant safety codes.
4. Develop skills in radiation hazard assessment, calibration, and implementation of quality assurance programs for safe clinical operations.
5. Enable learners to interpret and apply the principles of regulatory control, safety audit, and waste management practices in healthcare and research facilities.

Detailed Syllabus

UNIT I – Radiation Hazard Evaluation in Medical Installations (12 hrs)

Evaluation of radiation hazards in diagnostic radiology, radiotherapy, and nuclear medicine facilities – Radiation survey methods and measurement of leakage radiation through treatment heads, X-ray tube housings, and radionuclide storage areas – Measurement and interpretation of radiation levels around treatment rooms, hot labs, and imaging suites – Protective measures for minimizing exposure to staff, patients, and the public – Radiation hazards in brachytherapy, teletherapy, and isotope laboratories – Hazards in particle accelerators, cyclotron facilities, and associated safety systems – Personnel protection and patient handling protocols – Design and operation of waste disposal facilities and safety during source transfer and decommissioning operations – Integration of Waste Disposal Rule, 1987 provisions for institutional waste control – Special safety interlocks and emergency shutdown systems in linear accelerators and high-energy installations.

UNIT II – Radioactive Waste Management and Disposal (12 hrs)

Sources, nature, and classification of radioactive wastes: solid, liquid, and gaseous – Treatment methods and effluent control – Waste management requirements as per Atomic Energy (Safe Disposal of Radioactive Wastes) Rules, 1987 and AERB Safety Code AERB/SC/MED-2 – Concepts of authorized discharge, effluent dilution, and permissible limits for environmental release – Nuclear Medicine Waste Disposal: segregation of short-lived and long-lived isotopes (e.g., I-131, Tc-99m, Lu-177, Y-90); delay-and-decay method; delay tanks; decontamination of syringes, vials, and spills; disposal of patient excreta and contaminated materials; monitoring of sewer effluents; regulatory reporting and record maintenance – Sampling techniques for air, water, and solids – Geological, hydrological, and ecological considerations in waste storage – Design, operation, and shielding of temporary and permanent waste storage facilities – Documentation, surveillance, and regulatory approval for waste disposal and discharge.

Tutorial Exercises: – Calculate permissible discharge limits for medical radionuclides – Prepare a waste classification and segregation chart – Design a waste storage and decay facility layout for a nuclear medicine laboratory.

UNIT III – Transport of Radioactive Materials (12 hrs)

Historical development of transport safety standards – IAEA and AERB transport regulations – Classification, packaging, and labeling of radioactive consignments – Transport index, contamination limits, and activity limits – Transport documents, markings, and emergency instructions – Regulations for road, rail, air, sea, and postal transport – Transport emergencies and response planning – Special provisions for large sealed sources, generators, and radiopharmaceuticals – Responsibilities of consignor, carrier, and consignee – Waste transport and return-to-origin policies for medical sources – Security considerations and physical protection of radioactive consignments during transit and temporary storage.

UNIT IV – Calibration and Standards in Radiation Safety (12 hrs)

Primary and secondary standards for radiation measurements – Calibration of dosimeters, contamination monitors, and survey meters – Reference radiation fields (X-ray, gamma, neutron) and calibration geometry – Corrections for scattering, attenuation, and background – Traceability of calibration to national standards (SSDL, BARC) – Intercomparison and proficiency testing for radiation laboratories – Uncertainty estimation and documentation in compliance with ISO/IEC 17025 – Quality control of contamination monitoring instruments – Records, traceability, and audit requirements for calibration facilities handling radioactive sources.

UNIT V – Quality Assurance, Audits and Regulatory Framework in Hazard Control (12 hrs)

Establishment of institutional radiation safety programs – Periodic recalibration and verification of instruments – ICRU, IAEA, and AAPM codes of practice for radiation safety and hazard evaluation – Application of uncertainty evaluation per GUM – Integration of hazard assessment and waste management within the institutional radiation protection program – Audit and inspection requirements under AERB and Waste Disposal Rule, 1987 – National and international intercomparison program (IAEA/WHO, SSDL networks) – Environmental monitoring, compliance audits, and periodic reporting – Continuous improvement and corrective actions through safety review committees – Interface of QA programs with medical, industrial, and nuclear medicine waste management systems.

Tutorial Exercises: – Perform uncertainty estimation for calibration readings – Prepare a QA audit checklist for radiation hazard monitoring – Draft a compliance report for waste disposal authorization under AERB.

Course Outcomes

Upon successful completion of this course, the students will be able to:

1. Evaluate radiation hazards in medical and industrial installations and apply appropriate control measures for staff, patients, and the public.
2. Classify, treat, and dispose of radioactive wastes following Waste Disposal Rule 1987, AERB, and IAEA guidelines with emphasis on nuclear medicine practices.
3. Apply the principles of radiation transport regulations and safety standards for packaging, labeling, and secure handling of radioactive materials.
4. Implement and maintain calibration, traceability, and quality assurance procedures in radiation safety instrumentation and monitoring.
5. Demonstrate competency in establishing institutional radiation protection programmes, including waste management, audits, and regulatory documentation.

Textbooks

1. Martin, J. E. – *Physics for Radiation Protection*, Wiley-VCH, 2019.
2. Podgorsak, E. B. – *Radiation Physics for Medical Physicists*, Springer, 2016.
3. Cember, H., & Johnson, T. E. – *Introduction to Health Physics*, McGraw-Hill, 2023.
4. IAEA Safety Standards Series No. GSG-9 – *Regulatory Control of Radioactive Discharges to the Environment*, IAEA, Vienna, 2018.
5. Atomic Energy (Safe Disposal of Radioactive Wastes) Rules, 1987 – Government of India, amended 2016.

References

1. IAEA Safety Standards Series No. WS-G-2.7 – *Management of Radioactive Waste from the Use of Radioisotopes in Medicine, Industry, Agriculture, Research and Education*, IAEA, Vienna, 2005.
2. ICRP Publication 103 – *The 2007 Recommendations of the International Commission on Radiological Protection*, Elsevier, 2007.
3. AERB Safety Code AERB/SC/MED-2 – *Nuclear Medicine Facilities*, AERB, Mumbai, 2011.
4. AERB Safety Guide AERB/RF-RS/GD-1 – *Management of Radioactive Waste in Medical, Industrial and Research Establishments*, AERB, Mumbai, 2015.
5. IAEA Safety Standards Series SSR-6 – *Regulations for the Safe Transport of Radioactive Material*, IAEA, Vienna, 2018.
6. Waste Disposal Rule, 1987 (Atomic Energy Act, 1962) – *Safe Disposal of Radioactive Wastes Rules*, Government of India, 1987 (amended 2016).
7. Mawson C.A. Management of Radioactive Wastes

Elective IV: Dosimetric Audit and Clinical Trials in Medical Physics

Credits: 3 (2 Lecture + 1 Tutorial) **Total Hours:** 45 (30 Lecture + 15 Tutorial)

Course Objectives

The objectives of this course are to:

1. Provide foundational understanding of clinical and dosimetric audits as integral components of medical physics quality assurance systems.
2. Familiarize students with international frameworks, including IAEA, WHO, EURATOM, and **AAPM TG-113 Guidance**, governing dosimetric audit methodologies.
3. Develop skills in designing, conducting, and documenting clinical audits in diagnostic imaging, nuclear medicine, and radiotherapy.
4. Strengthen knowledge of organizational safety governance, human factors, and safety culture in radiation practices.
5. Equip students to align institutional audit programs with **AERB, NABH, ISO**, and other international accreditation standards.

Detailed Syllabus

Unit I – Principles and Framework of Audit (9 Hours: 6 Lecture + 3 Tutorial)

Definition, purpose, and scope of clinical audit in healthcare – Distinction between audit, inspection, and research – Stages of an audit: topic selection, standard formulation, data collection, analysis, implementation, and re-audit – Characteristics of an effective audit: independence, documentation, and reproducibility – Roles of medical physicists within audit teams – International guidelines (IAEA, WHO, EURATOM) shaping medical audit practice – Aligning audit objectives with institutional quality and accreditation standards – Ethical considerations and confidentiality in audit data handling.

Tutorial Exercises:

- Draft an outline for a departmental audit cycle with measurable indicators.
- Prepare a checklist aligning institutional policy with IAEA audit guidance.

Unit II – Methodology and Implementation of Audit (9 Hours: 6 Lecture + 3 Tutorial)

Audit design methods: prospective, retrospective, and peer-review models – Development of audit tools and data templates – Sampling strategies and quality metrics – Evaluation of process and outcome indicators in diagnostic imaging, nuclear medicine, and radiotherapy – Communication of audit findings and corrective-action planning – Integration of clinical audit within hospital information systems – Electronic documentation, data security, and traceability – Benchmarking of results and re-audit for sustained improvement.

Levels of Dosimetric Audit (as per AAPM TG-113):

- **Level I:** Basic reference dosimetry audits – verification of beam output calibration.
- **Level II:** End-to-end dosimetry audits – assessment of dose delivery accuracy using phantoms and clinical setups.
- **Level III:** Advanced audits – 3D and patient-specific treatment verification, including IMRT, VMAT, and SBRT audits.
- **Level IV:** Remote or postal audits – TLD/OSLD/film-based dose verification programs.
- **Level V:** Comprehensive clinical audits integrating dosimetric accuracy, clinical workflow, and outcome assessment.

Tutorial Exercises:

- Prepare a mock audit tool for verifying treatment planning accuracy.
- Interpret sample audit data and propose corrective actions.

Unit III – Safety Governance and Institutional Management Systems (9 Hours: 6 Lecture + 3 Tutorial)

Concept of organizational safety governance – Structure of institutional safety committees and their reporting hierarchy – Linking quality assurance with risk management and incident prevention – Development of standard operating procedures (SOPs) for safety and quality control – Internal audits, management reviews, and documentation retention – Competency-based roles and accountability in radiation-using departments – Harmonization of audit outcomes with hospital accreditation systems such as NABH and ISO – Record keeping, traceability, and performance metrics for safety programs.

Tutorial Exercises:

- Design an internal audit schedule for a radiation therapy department.
- Map the reporting pathway between safety committees and hospital management.

Unit IV – Leadership, Human Factors, and Safety Culture (9 Hours: 6 Lecture + 3 Tutorial)

Principles of leadership in safety management – Role of communication, teamwork, and motivation in maintaining safe operations – Understanding human factors and error analysis in clinical environments – Tools for root-cause analysis, incident investigation, and corrective action tracking – Concept of "just culture" and balancing accountability with learning – Methods to measure and strengthen safety culture – Continuous professional development, mentoring, and knowledge sharing among radiation staff – Success stories and lessons learned from international safety culture initiatives.

Tutorial Exercises:

- Conduct a case-study analysis of an incident investigation using root-cause methodology.
- Develop a training module to improve safety communication among staff.

Unit V – Regulatory Compliance and Performance Evaluation (9 Hours: 6 Lecture + 3 Tutorial)

Overview of national and international frameworks guiding medical-radiation governance (AERB, IAEA, WHO, ICRP) – Linking institutional quality systems to legal obligations – Compliance assessment, documentation, and readiness for regulatory inspection – Performance indicators for safety management systems – External quality audits and peer-review networks – Auditing contractors and outsourced services – Evaluation of sustainability, resource efficiency, and continuous improvement – Emerging trends: digital audit dashboards, AI-based compliance tracking, and integrated safety analytics.

Tutorial Exercises:

- Evaluate compliance gaps using an example AERB audit checklist.
- Design a performance-indicator matrix for a hospital's radiation-safety program.

Course Outcomes

Upon completion of this course, students will be able to:

1. Differentiate between clinical, dosimetric, and safety audits, and apply appropriate frameworks in medical physics practice.
2. Design and conduct dosimetric audits at various levels (I–V) following AAPM TG-113 and IAEA guidance.
3. Implement audit methodologies and analyze findings to ensure quality and patient safety in radiotherapy and imaging.
4. Integrate safety governance, leadership, and human factor principles into institutional quality management systems.
5. Demonstrate competence in meeting regulatory compliance requirements and contributing to continuous institutional quality improvement.

Suggested References

1. IAEA, *Comprehensive Audits of Radiotherapy Practices: A Tool for Quality Improvement*, IAEA Human Health Series No. 22, 2015.
2. AAPM Task Group 113, *Guidance on Dosimetric Audits and Clinical Implementation*, Medical Physics, 2011.
3. WHO, *Quality Assurance in Radiotherapy*, WHO Technical Report Series No. 566, 2016.
4. EURATOM, *European Commission Guidelines on Clinical Audit for Medical Radiological Practices*, Radiation Protection 159, 2009.
5. ICRP Publication 103, *The 2007 Recommendations of the International Commission on Radiological Protection*, Annals of the ICRP, 2007.

Elective IV: Monte Carlo Techniques in Dosimetry

Credits:3 **Lecture:**2 **Tutorial:**1 **Practical:** 0

Course Objectives

By the end of this course, students will be able to –

- Understand the stochastic principles underlying Monte Carlo simulations for radiation transport and dosimetry applications.
- Acquire knowledge of random number generation, sampling techniques, and variance reduction concepts.
- Develop practical skills to construct and execute Monte Carlo simulations using standard codes for photon, electron, and neutron dosimetry.
- Analyze simulation results, quantify statistical uncertainty, and interpret physical accuracy.
- Appreciate recent advancements, including GPU-based Monte Carlo algorithms, hybrid methods, and clinical quality-assurance applications.

Unit I – Fundamentals of Monte Carlo Methods *(6 hrs: 4 Lecture + 2 Tutorial)*

This unit introduces the basic concept of the Monte Carlo method as a stochastic approach for solving physical problems that are otherwise intractable analytically. Students learn how random sampling and probability theory underpin radiation-transport simulations. The concept of random numbers, uniform and non-uniform distributions, and transformation of probability density functions are explained in detail. Methods of generating pseudo-random numbers such as linear congruential and Mersenne Twister algorithms are described. The idea of statistical estimators, mean and variance determination, confidence intervals, and convergence behavior of Monte Carlo results are presented with examples. Common sources of bias and statistical error are identified, along with variance-reduction concepts such as importance sampling and Russian roulette.

Tutorial Exercises: – Generate and test uniform random numbers using spreadsheet or Python tools – Perform simple Monte Carlo integration for estimating π or exponential integral – Compute sample mean, standard deviation, and 95 % confidence interval.

Unit II – Radiation Transport and Interaction Modeling *(9 hrs: 6 Lecture + 3 Tutorial)*

The unit focuses on applying Monte Carlo sampling to simulate the transport of photons, electrons, and neutrons through matter. Students review fundamental radiation-interaction processes such as photoelectric absorption, Compton scattering, pair production, elastic and inelastic electron scattering, and nuclear interactions. The concept of macroscopic cross-sections, mean free path, and the probability of interaction are linked to exponential attenuation laws. Techniques for sampling step length and interaction type using cumulative probability distributions are illustrated. The physics of energy transfer and angular distribution of secondary particles are explained with reference to realistic material data. Detailed and condensed-history schemes for charged-particle transport, energy cut-offs, and boundary conditions are analyzed to ensure efficiency and accuracy in simulations.

Tutorial Exercises: – Simulate photon attenuation through a water slab using random sampling – Estimate build-up factor and analyze scatter contribution – Compute statistical uncertainty and relative error as a function of number of particle histories.

Unit III – Monte Carlo Codes and Applications *(9 hrs: 6 Lecture + 3 Tutorial)*

This unit familiarizes students with widely used general-purpose Monte Carlo codes. The structure, input syntax, and operational features of **EGSnrc**, **MCNP**, **GEANT4**, **FLUKA**, and **PENELOPE** are reviewed. Students learn how to define geometry using constructive solid geometry (CSG) and voxelized phantoms, assign material compositions and densities, and specify source distributions such as parallel beams, isotropic point sources, and isotopes. The concept of tally or scoring is introduced to calculate dose, flux, energy deposition, or particle current in selected regions. The workflow of input file preparation, simulation execution, and output interpretation is demonstrated with sample problems. Code verification, benchmarking, and statistical testing of results against analytical solutions are emphasized to ensure reliability.

Tutorial Exercises: – Develop a simple photon beam simulation in EGSnrc or MCNP – Define material geometry and scoring regions – Calculate depth-dose distribution and compare with empirical data – Interpret statistical output and identify sources of variance.

Unit IV – Applications in Medical Dosimetry *(12 hrs: 8 Lecture + 4 Tutorial)*

Monte Carlo techniques find extensive applications in clinical and research dosimetry. This unit explains their role in radiotherapy dose calculation for photon, electron, and proton beams, particularly for heterogeneous and small-field geometries where analytical algorithms fail. Modeling of linear-accelerator head components, beam modifiers, and patient CT-based phantoms is discussed. Applications in brachytherapy include simulation of sealed sources, anisotropy functions, and dose-rate constants following AAPM TG-43 and TG-186 guidelines.

In diagnostic radiology, Monte Carlo methods aid in estimating organ and effective doses for patient and staff exposure, while in nuclear medicine they help model radionuclide transport, SPECT/PET detection, and internal dose assessment. Students learn methods for uncertainty propagation, sensitivity analysis, and validation of simulation results with ionization-chamber or film measurements.

Tutorial Exercises: – Model a Cs-137 brachytherapy seed and obtain dose-rate distribution – Simulate small-field photon beams through lung and bone interfaces – Estimate organ dose from a diagnostic x-ray procedure – Perform uncertainty analysis using statistical resampling.

Unit V – Recent Developments and Quality Assurance *(9 hrs: 6 Lecture + 3 Tutorial)*

The final unit introduces advanced developments in Monte Carlo simulation technology. GPU-based parallelization and variance-reduction algorithms for high-speed dose computation are discussed along with examples from modern treatment-planning systems. Hybrid deterministic–stochastic approaches, coupled photon–electron transport, and track-structure Monte Carlo methods for micro- and nano-dosimetry are reviewed. The integration of Monte Carlo engines into clinical workflows for independent dose verification and quality assurance is emphasized. Students also study QA procedures recommended in AAPM TG-105 and TG-219, verification audits, and regulatory compliance for simulation-based dosimetry. Emerging areas such as Monte Carlo–assisted machine learning, automated optimization, and uncertainty visualization are highlighted to encourage research exploration.

Tutorial Exercises: – Review GPU-accelerated Monte Carlo dose engines (e.g., gDPM, GPUMCD) – Evaluate AAPM TG-105 and TG-186 recommendations – Prepare a mini-project proposal for clinical QA validation using Monte Carlo simulations.

Course Outcomes

After completing this course, students will be able to –

- Explain the theoretical foundations and statistical basis of Monte Carlo simulations in radiation dosimetry.
- Design and execute Monte Carlo simulations for photon, electron, and neutron transport.
- Apply simulation tools to solve complex dosimetric problems in radiotherapy, diagnostic imaging, and radiation protection.
- Assess and minimize uncertainties in simulation results through proper statistical and physical validation.
- Integrate Monte Carlo–based methods into clinical quality-assurance and research protocols with awareness of regulatory standards.

Textbooks

1. Rogers, D. W. O., & Walters, B. R. B. (2011). *DOSXYZnrc User's Manual*. National Research Council of Canada.
2. Briesmeister, J. F. (Ed.). (2000). *MCNP - A General Monte Carlo N-Particle Transport Code (Version 4C)*. Los Alamos National Laboratory.
3. Kawrakow, I., & Rogers, D. W. O. (2010). *The EGSnrc Code System: Monte Carlo Simulation of Electron and Photon Transport*. NRC Canada.
4. Agostinelli, S., et al. (2003). *GEANT4 - A Simulation Toolkit*. *Nuclear Instruments and Methods in Physics Research A*, 506(3), 250–303.
5. Andreo, P. (2018). *Monte Carlo Techniques in Radiotherapy Dosimetry*. CRC Press.

References

1. International Atomic Energy Agency (IAEA). (2004). *Dosimetry in Diagnostic Radiology: An International Code of Practice* (TRS 457).
2. International Commission on Radiation Units and Measurements (ICRU). (2019). *Report 93: Key Data for Ionizing-Radiation Dosimetry*.
3. Ma, C. M., & Rogers, D. W. O. (2001). *Monte Carlo Calculations in Radiotherapy Dosimetry*. CRC Press.
4. Verhaegen, F., & Seuntjens, J. (2003). *Monte Carlo Modeling of Radiotherapy Treatment Units*. *Physica Medica*, 19(3), 107–118.
5. Reynaert, N., et al. (2007). *Monte Carlo Dose Calculations in Radiotherapy: Advantages and Challenges*. *Radiation Physics and Chemistry*, 76, 643–654.

Seminar

Evaluation: Continuous Assessment (Seminar Report, Presentation, Viva-Voce)

Course Objectives

On completion of this course, students will be able to:

1. Identify and select current, high-impact technical research topics relevant to their field from reputed journals and conferences.
2. Critically review and interpret scientific literature to develop a structured understanding of contemporary developments.
3. Organize and present technical content effectively using professional presentation and communication tools.
4. Demonstrate analytical and evaluative thinking by assessing the novelty, limitations, and applicability of research findings.
5. Exhibit professionalism, time management, and audience engagement during oral presentations and discussions.

Course Content (Five Equal Units – Uniform Weightage)

Unit I – Topic Selection and Literature Survey

- Identification of emerging and impactful research areas (last 3–5 years).
- Guidelines for selecting peer-reviewed journal or conference papers (IEEE, Elsevier, Springer, Nature, etc.).
- Understanding the structure of scientific papers: Abstract, Introduction, Methodology, Results, Discussion.
- Techniques for conducting literature reviews using digital libraries (Scopus, PubMed, Web of Science, Google Scholar).
- Defining seminar scope and formulating research questions.

Unit II – Presentation Framework and Content Organization

- Structuring a seminar logically: title, introduction, background, objectives, methods, results, discussion, conclusion.
- Building context and identifying research gaps.
- Summarizing prior works and highlighting innovation in the chosen paper.
- Drafting outlines and flowcharts to ensure coherence.
- Ethical referencing and citation formats (IEEE/APA).

Unit III – Visual Design and Technical Communication Skills

- Slide design principles: readability, color contrast, minimal text, use of infographics.
- Integration of figures, graphs, tables, and animations to improve clarity.
- Effective use of PowerPoint, LaTeX-Beamer, or Google Slides.
- Voice modulation, pace, posture, and audience interaction techniques.
- Time management for 15–20 minute seminars with Q&A.

Unit IV – Critical Analysis and Discussion of Research

- Evaluating methodology, experimental setup, data interpretation, and conclusions.
- Identifying strengths, weaknesses, novelty, and real-world impact.
- Benchmarking with other studies and discussing reproducibility.
- Formulating personal insights and critical viewpoints.
- Discussing future directions and potential for translational research.

Unit V – Professional Delivery and Evaluation

- Rehearsal techniques and dealing with stage anxiety.
- Handling audience questions and constructive criticism.
- Professional ethics, plagiarism checks, and data integrity.
- Preparation of seminar abstracts and summary reports.
- Self-assessment and peer feedback for continuous improvement.

Evaluation Criteria (Uniform Weightage – 20% each)

Component	Description	Weightage
Topic Selection & Relevance	Novelty, scientific depth, and suitability of chosen topic	20%
Technical Content & Understanding	Quality of review, depth of comprehension, interpretation of data	20%
Presentation Structure & Slide Design	Logical flow, visual quality, and clarity of information	20%
Critical Analysis & Discussion	Insightfulness, comparative assessment, originality of viewpoints	20%
Delivery & Interaction	Confidence, timing, clarity, Q&A response	20%

Course Outcomes

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

- Select and justify a recent and relevant research topic based on emerging trends in their field.
- Conduct a comprehensive literature survey, synthesizing current advancements and research gaps.
- Prepare technically sound, visually engaging presentations that effectively communicate research objectives, methodologies, and findings.
- Critically analyse research papers by evaluating results, comparing methods, and identifying future research potential.
- Deliver professional oral presentations demonstrating clarity, confidence, and the ability to respond effectively during technical discussions.

Suggested Learning Resources

Books & Guides

1. Alley, M. (2023). *The Craft of Scientific Presentations: Critical Steps to Succeed and Critical Errors to Avoid*, 3rd Edition, Springer Nature.
2. Davis, M. (2024). *Scientific Papers and Presentations*, 4th Edition, Academic Press.
3. Reynolds, G. (2023). *Presentation Zen: Simple Ideas on Presentation Design and Delivery*, 4th Edition, New Riders.
4. O'Hair, D., Stewart, R., & Rubenstein, H. (2023). *A Pocket Guide to Public Speaking*, 8th Edition, Bedford/St. Martin's.
5. Alley, M. & Adair, D. (2022). *Designing Science Presentations: A Visual Guide to Figures, Papers, Slides, Posters, and More*, Elsevier.

Online Resources

- IEEE Author Center: *Guide to Technical Presentations*
- Elsevier Researcher Academy: *Effective Scientific Communication*
- Coursera/edX: *Effective Communication in STEM*
- Grammarly and Turnitin: *Academic Integrity & Plagiarism Tools*

Field Training

Credits: 2 Lecture: 0 Tutorial: 0 Practical: 4

Course Objectives

1. Gain hands-on experience in clinical departments including radiology, radiotherapy, and nuclear medicine.
2. Understand hospital workflow, radiation safety practices, and medical equipment operation under clinical supervision.
3. Develop competency in handling dosimeters, QA tools, and imaging systems.
4. Correlate theoretical knowledge from the first two semesters with clinical applications.
5. Prepare a detailed training report reflecting learning outcomes and practical exposure.

Training Structure and Duration

1. Total Duration: 4 weeks (equivalent to 4 practical credits = 120 hours).
2. Location: Recognized medical institutions, cancer hospitals, or diagnostic centers with approved radiological facilities.
3. Supervision: Conducted under the supervision of a qualified medical physicist approved by the AERB and the University.
4. Components of Training: Orientation, departmental rotation, logbook maintenance, and mentor evaluation.

Suggested Training Activities

Radiology Section (1 Week)

1. Familiarization with X-ray, CT, and MRI systems.
2. Observation of QA tests (kVp, mA linearity, film–screen contact, CTDI measurement).
3. Demonstration of dose area product (DAP) and patient dose optimization methods.
4. Review of equipment calibration and maintenance logs.

Radiation Therapy Section (2 Weeks)

1. Exposure to teletherapy units (Cobalt-60, Linear Accelerator).
2. Beam data acquisition and patient setup techniques.
3. Observation of treatment planning and QA (output check, field verification, wedge/tray factor validation).
4. Exposure to brachytherapy source handling, dose calculation, and TPS workflow.

Nuclear Medicine Section (1 Week)

1) Familiarization with gamma camera and PET-CT systems.
2) Study of dose preparation, radiopharmaceutical quality control, and activity measurement.
3) Observation of patient imaging and radiation safety procedures.

Documentation and Evaluation

1. Each student shall maintain a Daily Logbook approved by the supervising physicist.
2. A Training Report must be submitted summarizing objectives, activities, observations, and learning outcomes.
3. Evaluation Components: Logbook – 25%, Report – 50%, Viva-voce – 25%.

Expected Outcomes

1. Demonstrate familiarity with clinical radiation instruments and procedures.
2. Apply radiation protection principles in hospital settings.
3. Understand workflow and QA procedures in diagnostic and therapeutic departments.
4. Integrate theoretical knowledge with clinical applications.
5. Exhibit professional conduct and documentation skills in medical settings.

References

1. IAEA Human Health Series No. 25: Postgraduate Medical Physics Training Curriculum.
2. AERB Safety Code No. AERB/RF-MED/SC-1: Medical Diagnostic X-ray Equipment and Installations.
3. IAEA Training Course Series No. 37: Clinical Training of Medical Physicists Specializing in Radiation Oncology.
4. WHO: Quality Assurance in Diagnostic Radiology Services.
5. AAPM Report No. 249: Essentials and Guidelines for Clinical Medical Physics Residency Training.

5.10 Fairness in Assessment:

Assessment is an integral part of system of education as it is instrumental in identifying and certifying the academic standards accomplished by a student and projecting them far and wide as an objective and impartial indicator of a student's performance. Thus, it becomes bounden duty of a University to ensure that it is carried out in fair manner. In this regard, UGC recommends the following system of checks and balances which would enable Universities effectively and fairly carry out the process of assessment and examination.[22]

- At least 50% of core/elective courses must be evaluated by external examiners.
- Projects/Dissertations: Evaluated by internal and external examiners.
- Non-credit courses: Satisfactory/Unsatisfactory.
- Universities may decide pass marks and CGPA requirements as per statutory councils.

Table 5.1: Grades and Grade Points

Grade Letter	Grade Point
O (Outstanding)	10
A+(Excellent)	9
A(Very Good)	8
B+(Good)	7
B(Above Average)	6
C(Average)	5
D (Below Average/Fail)	4
Ab (Absent)	0

A student obtaining Grade D/Ab is considered failed and must reappear.
Computation of SGPA and CGPA:

The UGC recommends the following procedure to compute the Semester Grade Point Average (SGPA) and Cumulative Grade Point Average (CGPA):

- The SGPA is the ratio of sum of the product of the number of credits with the grade points scored by a student in all the courses taken by a student and the sum of the number of credits of all the courses undergone by a student,

  i.e SGPA (Si) = $\sum(Ci \times Gi) / \sum Ci$

  where Ci is the number of credits of the ith course and Gi is the grade point scored by the student in the ith course.

- The CGPA is also calculated in the same manner taking into account all the courses undergone by a student over all the semesters of a programme,

  i.e. CGPA = $\sum(Ci \times Si) / \sum Ci$

  where Si is the SGPA of the ith semester and Ci is the total number of credits in that semester.

- The SGPA and CGPA shall be rounded off to 2 decimal points and reported in the transcripts.

Illustration of CGPA:

Course	Credit (Ci)	Grade letter	Grade point (Gi)	Credit Point = Credit (Ci)x Grade point (Gi)
Course 1	4	A	8	4x8 = 32
Course 2	4	B+	7	4x7 = 28
Course 3	4	B	6	4x6 = 24
Course 4	4	O	10	4x10 = 40
Course 5	4	C	5	3x5 = 15
Course 6	3	B	6	3x6 = 18
Course 7	3	B	6	3x6 = 18
Total	26			175
SGPA (Si) = Credit points/Total credit		175/26 =6.95		6.73
Residency Credits (32)		32		

Sem 1: **26 credits × 6.73 = 174.98**

Sem 2: **27 credits × 7.78 = 210.06**

Sem 3: **26 credits × 6.54 = 169.78**

Sem 4: **22 credits × 6.82 = 150.04**

Total = 704.86

Total Credits = 100

CGPA = 704.86/100 = 7.05

Post MSc Diploma in Radiological / Medical Physics or Advance Master Degree in Radiological / Medical Physics

(This second pathway will be discontinued after three years, with effect from the academic/admission year 2029–2030 in order to align with national initiatives to standardize the Medical Physics education)

5.11 Eligibility for Admission & Selection Procedure (Post MSc Diploma in Radiological / Medical Physics or Advance Master Degree in Radiological / Medical Physics)

5.11.1 Academic Eligibility criteria for Admission: Candidates must have obtained:

M.Sc. (Physics) with not less than 60% marks in aggregate or a CGPA of ≥ 6.5. In addition, the candidate should possess the B.Sc. (Physics as a main subject) Degree with not less than 60% marks in aggregate or or a CGPA of ≥ 6.5

5.11.2 Entrance & Age Criteria:

Admission to the program Post M.Sc. Diploma in Radiological/Medical Physics or Advanced Master Degree in Radiological/Medical Physics shall be made strictly on the basis of merit, determined through

- eligibility criteria as mentioned above, and
- The merit list for the admission process shall be prepared in accordance with the rules and regulations of the respective University/Institution, based on the entrance examination. The syllabus for the entrance examination shall be published by the respective University/Institution along with the admission notification.
- The candidate must have attained the minimum age of 22 years as on the date of admission or as notified for the current academic year.

5.11.3 Duration and Academic Structure Pattern:

The program shall be of 1 year (2 semesters) + one year Residency Program

5.11.4 Medium of Instruction:

English should be the medium of instruction for all subjects and examinations.

5.11.5 Teaching/Learning Methods:

- Competency-based learning will be implemented for both theory and clinical training.
- Methods include classroom teaching, practical lab sessions, self-learning, hybrid/virtual learning, advanced learning tools, simulators, and videos. However, virtual/online teaching/learning should not be more than 10 percent of total program hours

5.11.6 Attendance:

- Minimum attendance 75% in theory subjects.
- Minimum attendance 85% in practical/skills training.
- Any deviation shall be addressed as per Institute norms

5.11.7 Assessment

- Continuous Internal Assessment (CIA) forms the Formative Assessment component, while end-semester examinations constitute Summative Assessment.
- Weightage: 25% Internal Assessment, 75% University/External Examination.

5.11.8 Examination Schedule:

- University examinations shall be conducted at the end of each semester in accordance with the academic calendar and regulations of the University.
- Two internal examinations and one model examination must be conducted before the Semester Examination for each course.
- Internal marks shall be awarded based on the performance in these examinations and other approved academic/technical evaluation components such as assignments, attendance, presentations, and continuous assessment activities.
- Two academic examination cycles will be conducted per academic year.

5.11.9 Maximum Duration of Program:

- Must complete the program within 2 years. (Excluding Residency)
- Failure to complete within duration will result in discharge, except for exceptional cases reviewed by the university committee.

5.11.10 Migration/Transfer:

Allowed as per university norms.

5.11.11 Residency

- Mandatory one-year rotation post-academic training.
- Up to 2 months may be externship.
- Refer the Residency Guiding document 5.13

5.12 Scheme of Examination

Course type	Subject title	Lectures + Tutorials (each of 1 hour)	Credits	Marks	
				Internal	External
Semester – I					
Core-1	Radiation Physics & Radiation Generators	55+5	4	25	75
Core-2	Applied Mathematics & Counting and Medical Statistics	57+5	4	25	75
Core-3	Radiation Dosimetry	44+4	3	25	75
Core-4	Standardization of Radiation Beams and Sources	30+3	2	25	75
Core-5	Radiation Detection, Measurement and Nuclear Instrumentation	56+6	4	25	75
Elective-1	Computational Medical Physics & Artificial Intelligence / Concept of Health Technology	41+4	3	25	75
Lab-1	Practical – I	60	2	25	75
Total of Semester-I		**370**	**22**	**175**	**525**
Semester – II					
Core-1	Anatomy Physiology Pathology and Clinical Aspects of Medical Imaging and Therapy	41+4	3	20	75
Core-2	Radiation Biology	42+4	3	20	75
Core-3	Diagnostic Radiology and Non-ionizing Radiation Physics	46+5	3	20	75

Course type	Subject title	Lectures + Tutorials (each of 1 hour)	Credits	Marks	
				Internal	External
Core-4	Nuclear Medicine and Internal Dosimetry	45+5	3	20	75
Core-5	Radiation Therapy and Treatment Planning	77+8	5	20	75
Core-6	Radiation Safety and Regulatory Aspects	68+7	5	25	75
Lab-2	Practical – II	63	2	25	75
Total of Semester – II		**415**	**24**	**175**	**525**
FIELD TRAINING (6 weeks)		**180**	**5**	**100**	--
SEMINAR		**30**	**1**	**100**	--

SECOND YEAR

Residency Credits 32

Semester – I					
Course type	**Subject title**	**Lectures + Tutorials (each of 1 hour)**	**Credits**	**Marks**	
				Internal	**External**
Core-1	Radiation Physics & Radiation Generators	55+5	4	25	75
Core-2	Applied Mathematics & Counting and Medical Statistics	57+5	4	25	75
Core-3	Radiation Dosimetry	44+4	3	25	75
Core-4	Standardization of Radiation Beams and Sources	30+3	2	25	75
Core-5	Radiation Detection, Measurement and Nuclear Instrumentation	56+6	4	25	75
Elective-1	Computational Medical Physics & Artificial Intelligence / Concept of Health Technology	41+4	3	25	75
Lab-1	Practical – I	60	2	25	75
Total of Semester-I		**370**	**22**	**140**	**175**

CORE COURSES

CORE-1: Radiation Physics & Radiation Generators

[55 Lectures+5 Tutorials (60 hrs); 4 Credits]

Course Outcomes:

- Refresh the knowledge of nuclear and radiation physics
- Understand the concept of interaction of radiation with matter
- Understand the mechanism and technology of various particle accelerators used in medicine and research
- Understand the mechanism of X-ray generation and technology of X-ray equipment used in medicine, and research.

Course Details:

Unit-1: Nuclear Physics

Nucleus-Scattering experiment, properties, Discovery of neutrons, Experimental determination of size of the nucleus etc. Nuclear forces- properties, spin dependence, charge independence etc. Liquid drop model-Binding energy, semi-empirical mass formula, mass parabola, application in stability of neutron star Radioactivity – α decay - general properties of α particles, spectrum, Gamow's theory, Geiger-Nuttal law

Beta decay- general properties, Fermi theory, spectrum, fall of parity, neutrinos – Positron emission- Electron capture - gamma emission - Internal conversion Laws of radioactivity - Laws of successive transformations and application in dating - Natural radioactive series - Radioactive equilibrium - Nuclear isomerism – Nuclear reactions - Artificial radioactivity – Elementary ideas of fission and its application in nuclear reactors and nuclear weapons – Fusion- energy production in the sun, production of elements in the universe-big bang and stellar nucleosynthesis.

Unit 2: Particle Accelerators

Historical development of particle accelerators; basic principles of charged particle acceleration; classification of accelerators as electrostatic, circular, and linear; relativistic effects in accelerator physics; fundamental beam dynamics including transverse and longitudinal motion, emittance, and phase space;

Principle and operation of the cyclotron and its limitation due to relativistic mass increase; concepts of the synchrocyclotron and the azimuthally varying field (AVF) cyclotron; Principle of electron linear acceleration and design of accelerating structures; traveling-wave and standing-wave configurations in electron LINACs; RF cavities as accelerating resonators, and waveguides for RF power transmission and beam acceleration; Particle sources including ion sources for protons and heavy ions and electron guns of thermionic and photocathode type with their injection systems and beam characteristics; RF power generation using klystrons, magnetrons, and solid-state amplifiers; Principles of synchrotron and synchro-cyclotron acceleration; beam extraction methods such as electrostatic deflectors and magnetic kickers; systems for energy variation and selection; magnet systems in high-energy accelerators including dipoles, quadrupoles, and superconducting magnets; beam optics, transport lines, scanning magnets, and beamline design; and engineering aspects of vacuum systems required for stable accelerator operation.

Unit-3: X-ray Generators

Discovery - Production - Properties of X-rays - Characteristics and continuous spectra - Design of hot cathode X-ray tube - Basic requirements of medical diagnostic therapeutic and industrial radiographic tubes - Rotating anode tubes - Hooded anode tubes - Industrial X-ray tubes - X-ray tubes for crystallography - Rating of tubes - Safety devices in X-ray tubes – Ray proof and shock proof tubes- Insulation and cooling of X-ray tubes - Mobile and dental units - Faults in X-ray tubes - Limitations on loading. Portable battery-operated X-ray generators.

Electric Accessories for X-ray tubes - Filament and high voltage transformers - High voltage circuits- Half- wave and full-wave rectifiers - Condenser discharge apparatus - Three phase apparatus – High frequency generator - Voltage doubling circuits - Current and voltage stabilizers - Automatic exposure control- Automatic Brightness Control- Measuring instruments - Measurement of kV and mA - timers- Control Panels - Complete X-ray circuit - Image intensifiers and closed circuit TV systems - Modern Trends.

Unit-4: Interaction of Radiation with Matter

Interaction of electromagnetic radiation with matter Exponential attenuation - Thomson scattering- Rayleigh Scattering- Photoelectric and Compton process and energy absorption - Pair production- Attenuation and mass energy absorption coefficients - Relative importance of various processes. - Concept of linear and mass attenuation coefficient – Energy dependence of coefficient - Build up factors and its dependence on energy. Interaction of charged particles with matter - Classical theory of inelastic collisions with atomic electrons. Energy loss per ion pair by primary and secondary ionization - Dependence of collision energy losses on the physical and chemical state of the absorber - Cerenkov radiation - Electron absorption process- Scattering Excitation and Ionization - Radiative collision - Bremsstrahlung - Range energy relation- Continuous slowing down approximation (CSDA) - straight ahead approximation and detour factors- transmission and depth dependence methods for determination of particle penetration - empirical relations between range and energy - Back scattering.

Passage of heavy charged particles through matter - Energy loss by collision - Range energy relation- Bragg curve - Specific ionization - Stopping Power - Bethe Bloch Formula- relativistic corrections – Basic concept of proton and other heavy ion therapy. Interaction of neutrons with matter - Sources of neutrons from different interactions- Basic idea of neutron spectra- Compound nucleus theory- Neutron cross-section- theory of elastic scattering- Neutron induced nuclear reactions.

Suggested Text Books and References:

1. K.S. Krane. Introductory Nuclear Physics, 2008.
2. J.S. Lilley, Nuclear Physics: Principles and Applications, 2013.
3. R. Eisberg and R. Resnick. Quantum Physics of Atoms, Molecules, Solids, Nuclei and Particles, 2014.
4. J. E. Turner. Atoms, Radiation, and Radiation Protection, 2022.
5. A. Beiser, S. Mahajan, S. Rai Choudhury. Concept of Modern Physics, 2020.
6. Tatjana Jevremovic. Nuclear Principles in Engineering, 2009.
7. J. T. Bushberg, J. A. Seibert, E. M. Leidholdt, J. M. Boone. The Essential Physics of Medical Imaging, 2021.
8. IAEA. Diagnostic Radiology Physics: A Handbook for Teachers and Students, 2014.
9. Rolf Behling. Modern Diagnostic X-ray Sources, 2021.
10. Wangler T.P. RF Linear Accelerators, 2008.

11. C. J. Karzmark, C.S. Nunan, E. Tanabe. Medical Electron Accelerators, 1993.
12. G. David, Williams P. C., Linear Accelerators for Radiation Therapy, 2017.
13. Barker R. J., Schamiloglu Edl. High power microwave sources and Technologies, 2001.

CORE-2: Applied Mathematics & Counting and Medical Statistics

[57 Lectures + 5 Tutorials (62 hrs); 4 Credits]

Course Outcomes:

- Understand the theory of probability, counting and medical statistics and errors with special reference to radiological/medical physics
- Application of Numerical methods and Monte Carlo simulation in radiation physics
- To strengthen the knowledge and skill in use of computational techniques and tools for solving the practical problems of radiological sciences

Course Details:

Unit-1: Probability, Statistics and Errors

Probability - addition and multiplication laws of probability, conditional probability, population, variates, collection, tabulation and graphical representation of data.

Basic ideas of statistical distributions frequency distributions, averages or measures of central tendency, arithmetic mean, properties of arithmetic mean, median, mode, geometric mean, harmonic mean, dispersion, standard deviation, root mean square deviation, standard error and variance, moments, skewness and kurtosis.

Binomial distribution, Poisson distribution, Gaussian distribution, exponential distribution-additive property of normal variates, confidence interval & p-value, Bivariate distribution, Correlation & Regression, Chi- Square distribution, t-distribution, F-distribution, null hypothesis & alternate hypothesis with examples.

Unit-2: Numerical Methods

Why numerical methods, accuracy and errors on calculations - round-off error, evaluation of formulae. Iteration for Solving x = g(x), Initial Approximation and Convergence Criteria, Newton-Raphson Method. Taylor series, approximating the derivation, numerical differentiation formulas. Introduction to numerical quadrature, Trapezoidal rule, Simpson's rule, Simpson's Three-Eighth rule, Boole rule, Weddle rule. Initial value problems, Picard's method, Taylor's method, Euler's method, the modified Euler's method, Runge-Kutta method.

Unit-3: Monte Carlo Methods

Random variables, discrete random variables, continuous random variables, probability density function, discrete probability density function, continuous probability distributions, cumulative distribution function, accuracy and precision, law of large number, central limit theorem, random numbers and their generation, tests for randomness, inversion random sampling technique including worked examples, integration of simple 1-D integrals including worked examples.

Unit – 4: Counting and Medical Statistics

Statistics of nuclear counting - Application of Poisson's statistics - Goodness-of-fit tests - Lexie's divergence coefficients Pearson's chi-square test and its extension - Random fluctuations Evaluation of equipment performance - Signal-to-noise ratio - Selection of operating voltage - Preset of rate meters and recorders - Efficiency and sensitivity of radiation detectors - Statistical aspects of gamma ray and beta ray counting - Special considerations in gas counting and counting with proportional counters - Statistical accuracy in double isotope technique. Medical data, descriptive statistics – measure of central tendency - mean, median mode and percentile, Measure of dispersion – range, quartile deviation, standard deviation and coefficient of variation, Sampling techniques and sample size determination, Testing of hypothesis, Test of significance – level of significance, Calculation and interpretation of p value – statistical significance, correlation and regression analysis, sample size calculation, parametric and non-parametric tests.

Suggested Text Books and References:

1. J. D. Hoffman, S. Frankel. Numerical Methods for Engineers and Scientists, 2001.
2. M.T. Vaughn. Introduction to Mathematical Physics, 2007.
3. Band W. Introduction to Mathematical Physics, 2010.
4. R.Y. Rubinstein and D.P. Kroese. Simulation and the Monte Carlo Method, 2016.
5. Oleg N. Vassiliev, Monte Carlo Methods for Radiation Transport, 2017.
6. W. L. Dunn and J. K. S. Shultis. Exploring Monte Carlo Methods, 2012.
7. M. H. Kalos and P. A. Whitlock. Monte Carlo Methods, 2008.
8. E. B. Podgorsak, Radiation Physics for medical physicists. 2006.

CORE-3: Radiation Dosimetry

[44 Lectures + 4 Tutorials (48 hrs); 3 Credits]

Course Outcomes:

- Understanding of radiation quantities and units
- Detailed knowledge of various radiation sources including their production process application aspects
- Competency to perform absolute, reference and relative radiation dosimetry with various radiation generators and sources

- Knowledge and skill in dosimetry of neutron and standardisation of radionuclides
- Understanding radiation chemistry and use of chemical dosimetry techniques

Course Details:

Unit-1: Radiation Quantities and Units

Radiation quantities and units – Radiometry – Particle flux and fluence – Energy flux and fluence – Cross Section – Linear and mass attenuation coefficients - Mass energy transfer and mass energy absorption coefficients - Stopping power - LET - Radiation chemical yield - W value - Dosimetry - Energy imparted- Absorbed dose - Kerma - Exposure - Air Kerma rate constant - Charged particle equilibrium (CPE)- Relationship between Kerma, absorbed dose and exposure under CPE - Dose equivalent - Ambient and directional dose equivalents [(H*(d) and H'(d)] - Individual dose equivalent penetrating Hp(d) - Individual dose equivalent superficial Hs(d).

Unit-2: Radiation Sources

Radiation sources - Natural and artificial radioactive sources - large scale production of isotopes - Reactor produced isotopes - Cyclotron produced isotopes - Fission products – Telecobalt and Brachytherapy sources - ^{125}I Sources – ^{192}Ir and ^{60}Co high dose rate sources, Beta ray applicators - ^{106}Ru eye plaques, Radioisotopes used in nuclear medicine – ^{99m}Tc, ^{131}I, ^{177}Lu, Thermal and fast neutron sources - Preparation of tracers and labeled compounds - Preparation of radio colloids.

Unit-3: Dosimetry of X- and Gamma Ray Beams

Dosimetry of beam therapy equipment - IAEA TRS 398 and IAEA TRS 398 (Rev). Measurement of D_w for External beams from ^{60}Co teletherapy machines: Reference conditions for measurement, Type of ion chambers, Phantom, Waterproof sleeve, Derivation of an expression for Machine Timing error, Procedure for evaluation of Temperature and pressure correction: Thermometers and pressure gauges. Measurement of temperature and pressure. Saturation correction: derivation of expression for charge collection efficiency of an ion chamber based on Mie theory. Parallel plate, cylindrical and spherical ion chambers, K_{sat}, Two voltage method for continuous and pulsed beams, Polarity correction. Reference dosimetry for high-energy photon beams from medical Linear accelerators: Beam quality, beam quality index, beam quality correction coefficient, Cross calibration. Measurement of absorbed dose to water for high energy Electron beams from linear accelerators: Beam quality, beam quality index, beam quality correction coefficient, Cross calibration using intermediate beam quality. Small Field Dosimetry: IAEA TRS 483 and other protocols – Dosimetry of small field from gamma knife, x-knife and cyber knife, dosimetry of tomotherapy beams. Calibration of brachytherapy sources - Apparent activity - Reference Air Kerma Rate - Air Kerma Strength – IAEA TRS 492 - Calibration of HDR ^{192}Ir and ^{60}Co sources - Calibration of ^{125}I and beta sources - room scatter correction.

Unit-4: Radiation Chemistry and Chemical Dosimetry

Definitions of free radicals and G-value - Kinetics of radiation chemical transformations - LET and dose rate effects - Radiation Chemistry of water and aqueous solutions, peroxy radicals, pH effects. adiation Chemistry of gases and reactions of dosimetry interest - Radiation polymerization, effects of radiation on polymers and their applications in dosimetry - Formation of free radicals in solids and their applications in dosimetry. Dosimetry principles - Definitions of optical density, molar absorption coefficient, Beer-Lambert's law, spectrophotometry - Dose calculations - Laboratory techniques - Reagents and procedures - Requirements for an ideal chemical dosimeter - Fricke dosimeter - FBX dosimeter - Free radical dosimeter - Ceric sulphate dosimeter - Other high and low level dosimeters – Use of chemical dosimeters in radiotherapy and other applications of radiations.

Suggested Text Books and References:

1. Joseph Magill and Jean Galy. Radioactivity Radionuclides and Radiation, 2005.
2. IAEA TRS 374, Calibration of Dosimeters used in Radiation Therapy, 1994.
3. IAEA TRS 398, Absorbed Dose Determination in External Beam Radiotherapy, 2000.
4. IAEA TRS 483, Dosimetry of Small Static Fields Used in External Beam Radiotherapy, 2017.
5. IAEA TRS 492, Dosimetry in Brachytherapy, 2023.
6. P. Andreo, D.T. Burns, A.E. Nahum, J. Seuntjens, F.H. Attix. Fundamentals of Ionizing Radiation Dosimetry, 2017.
7. F. H. Attix. Introduction to Radiological Physics and Radiation Dosimetry, 2004.
8. J. W. T. Spinks, R. J. Woods. An Introduction to Radiation Chemistry, 1990.
9. A. Mozumder. Fundamentals of Radiation Chemistry. 1999.
10. Karl-Heinrich Beckurts, Karl Wirtz, Neutron Physics, 2013.

CORE-4: Standardization of Radiation Beams and Sources

[30 Lectures + 3 Tutorials (33 hrs); 2 Credits]

Unit-1: Radiological Standards for X-rays and Gamma rays

Radiological Standards– Primary Standard, Secondary Standard, Tertiary Standard, National Standard, Reference Standard, Imperfections in measurement, Uncertainty in measurement, Traceability, Properties of dosimeters – Accuracy and precision - Linearity – Dose rate dependence – Energy dependence - directional dependence, Ionometric standards - Charged Particle Equilibrium (CPE), Free Air Ion Chamber (FAIC), Design of parallel plate FAIC, Measurement of Air Kerma/ Exposure. Limitations of FAIC. Bragg-Gray cavity theory, Mathematical expression describing Bragg-Gray principle and its derivation. Burlin and Spencer Attix Cavity theories. Transient Charged Particle Equilibrium (TCPE), Concept of D_{gas}, Cavity ion chambers, Derivation of an expression for sensitivity of a cavity ion chamber.

General definition of calibration factor - N_X, N_K, $N_{D,\,air}$, $N_{D,\,W}$. Various steps to arrive at the expression for D_W starting from N_X. $K_{Q,Q0}$ and K_Q, Derivation of an expression for $K_{Q,\,Q0}$. Standards for Beam Therapy: Description in detail about the Air Kerma standards for Co-60 beams – design features, characteristics, maintenance of the standards. Absorbed dose to water standards – Ionometric standards, Calorimetric standards, Chemical standards, Intercomparison of standards. Standards for Brachytherapy: HDR ^{192}Ir and ^{60}Co sources, Standards for low energy photon emitting brachytherapy sources (^{125}I and ^{103}Pd), Standards for beta sources.

Unit – 2: Neutron and Radionuclide Standards

Classification of neutrons, neutron sources, Activation method. Neutron spectrometry, threshold detectors, scintillation detectors & multispheres, Neutron dosimetry, Neutron survey meters – calibration - neutron field around medical accelerators (LINAC, Proton accelerator and medical cyclotrons). Neutron standards - primary standards, secondary standards, Neutron yield and fluence rate measurements, Manganese sulphate bath system, precision long counter, Tissue Equivalent Proportional Counter (TEPC), Methods of measurement of radioactivity - Defined solid angle and 4π counting - Beta gamma coincidence counting. Standardization of beta emitters and electron capture nuclides with proportional, GM and scintillation counters, Standardization of gamma emitters with scintillation spectrometers - Ionization chamber methods – Extrapolation chamber - Routine sample measurements,Liquid counter – Windowless counting of liquid samples – Scintillation counting methods for alpha, beta and gamma emitter – Reentrant ionization chamber methods - Methods using (n, γ) and (n, p) reactions - Determination of yield of neutron sources - Space integration methods - Solid state detectors.

Unit – 3: Calibration of Beam and Brachytherapy Dosimeters

Calibration procedure for cylindrical and parallel plate ionization chambers: Thimble Ionization chamber dosimetry systems – Cavity ionization chambers (thimble type and plane-parallel) and electrometers, Beam quality specification, Absorbed dose to water calibration coefficient ($N_{D,\,W}$), beam quality correction factor $K_{Q,Q0}$, Determination of absorbed dose to water under reference condition from telecobalt machine as per IAEA TRS-398, Correction for influence quantities, Procedure for determination of calibration coefficient of hospital ionization chamber, Procedure for cross calibration. Calibration Procedure for Well Type Ionization Chamber: Specification of brachytherapy source strength- Reference Air Kerma Rate - Air Kerma Strength - Standards for HDR ^{192}Ir and ^{60}Co sources; Well type ionization chambers - reference sources – maximum response point of the well type chamber – source strength measurement using well type ionization chamber (IAEA TECDOC 1274) –correction for influence quantities - procedure for determination of calibration coefficient of hospital well type chamber.

Unit – 4: Calibration of NM Dose Calibrators and Radiation Survey meters

Calibration of Nuclear Medicine Dose Calibrators - Design features of nuclear medicine dose calibrators - performance characteristics – linearity, reproducibility, stability in response - calibration process for NM dose calibrators – estimation of uncertainty – quality control and maintenance of dose calibrators.

Calibration of Radiation Protection Instruments: Fundamental concepts in calibration of radiation survey meters, Basic requirements for calibration, Various parameters checked during calibration, Selection of radioactive sources and source strength for calibration check – details of applicable standard.

1. Joseph Magill and Jean Galy. Radioactivity Radionuclides and Radiation, 2005.
2. IAEA TRS 374, Calibration of Dosimeters used in Radiation Therapy, 1994.
3. P. Andreo, D.T. Burns, A.E. Nahum, J. Seuntjens, F.H. Attix. Fundamentals of Ionizing Radiation Dosimetry, 2017.
4. F. H. Attix. Introduction to Radiological Physics and Radiation Dosimetry, 2004.
5. Karl-Heinrich Beckurts, Karl Wirtz, Neutron Physics, 2013.

CORE-5: Radiation Detection, Measurement and Nuclear Instrumentation

[56 Lectures + 6 Tutorials (62 hrs); 4 Credits]

Course Outcomes:

- Understanding the principles of radiation detection and measurement instrumentation
- Working and operational principle of radiation detectors used for various types of radiation
- Electronics involved in various radiation detectors and its instrumentation
- Understanding and use of various radiation monitoring instruments

Course Details:

Unit-1: Radiation Detectors

Principles of radiation detection and general properties of detectors: Principles of radiation detection, modes of detector operation, Pulse height spectra, Counting curves and plateaus, Energy resolution, Detector efficiency, Dead time, detector window.

Gas filled radiation detectors: Various regions of operation of gas filled detectors - Ionization chambers, Proportional counters and GM counters - basic detection mechanism, types of radiation detected, mode of operation, different variants of detectors (e.g. sealed, flow type, high pressure, multi- wire, position sensitive), Types of instruments which uses gas filled detectors – radiation dosimeters, survey meters, contamination monitors - Cylindrical, plane parallel, spherical and well-type ionization chambers, Extrapolation chamber, Scintillation (organic/inorganic) and semiconductor detectors: Advantages of scintillation detectors, properties of ideal scintillator, basic electronic blocks in scintillation detector setup.

Radiation detection mechanism of organic and in-organic scintillators, types of scintillators for various applications. Photon detection devices - PMT, Photo diodes. Principles of detection mechanism in semiconductor detectors and its application for gamma and alpha spectrometry, Diode and MOSFET dosimeters Neutron detectors: Neutron detection by activation, Nuclear track detectors, Self-powered neutron detectors (SPND), BF3, He3, Bubble detectors. New types of detectors: Radiation detection by direct ion storage (DIS), OSL, Diamond, Gel dosimeter, Radiation litmus, Radiographic and radiochromic films. Micro dosimeters / Tissue Equivalent Proportional Counters (TEPCs), Fast response detectors for used in ultra-high dose rate (FLASH)-Plastic Scintillators & Cherenkov Detectors, Faraday Cup for absolute beam current measurement of electrons, protons, and heavy ions.

Unit-2: Nuclear Electronics

Analog electronics: Operational amplifiers (ideal characteristics, different operational circuits - inverting, non-inverting amplifiers, adder, sub-tractor, integrator. Interfacing concepts: Fundamental concepts of interfacing an instrument to PC/Computer, interfacing methods.

Power Supply: Low voltage and high voltage power supplies for radiation instruments, Generation of low and high voltages and their specifications, Types of batteries and their specifications.

Basic building blocks used in nuclear measurements: Pre amplifiers, types of preamplifiers and selection of proper preamplifier for specific detector, Types of amplifier - linear, bias amplifier, log amplifier, shaping amplifier, Counters, rate meters - diode pump and IC rate meters, SCA, MCA, Coincidence and anti-coincidence circuit blocks.

Unit 3: Radiation Measuring and Monitoring Instruments

Radiation Monitoring Instruments: Dosimeters based on condenser chamber, quartz fiber electrometer, dosimeter based on current measurement, secondary standard dosimeter, Farmer dosimeter, beam therapy dosimeter, clinical dosimeter, isotope calibrator, Radiation field analyzer (RFA). Instruments for personal monitoring: TLD Reader for medical & research applications, TLD Badge Reader, OSLD badge reader, Image analyser for track counting, Densitometer, Electronic pocket dosimeter.

Area monitoring instruments: Portable and fixed area monitors, fixed area monitors, beta-gamma zone monitor, Survey meters, wide range survey instrument, teletector. Contamination monitoring instruments: portable contamination monitor, hand &foot surface contamination monitor, portal monitor, laundry monitor, floor monitor. Method of estimating activity present inside the body - whole body counter.Neutron monitoring instruments - REM counters.

Unit-4: Principles of Personnel Monitoring

Design aspects of x-ray, gamma ray and beta TLD personnel monitoring badge used in India – TLD Badge Reader - Occupational dose assessment procedures – audit of personnel monitoring laboratories - national occupational dose registry system.

Occupational extremity dosimetry – design and characteristics of extremity dose monitors, Eye lens dose measurements – design and characteristics of the eye lens dosimeters.

Neutron personnel monitoring in India – CR39 personnel monitoring badge – calibration and dose assessment procedure.

Global trends in personnel monitoring and Newer developments in personnel monitoring.

Suggested Text Books and References:

1. P. Horowitz, W. Hill: Art of Electronics. 2015.
2. Serigo Franco. Design with Operational Amplifiers & Analog Integrated Circuits. 2017.
3. Texas Instruments Application Report SBOA092A: Handbook of Operational Amplifier Applications, 2016.
4. N. Widmer, G. Moss, R. Tocci. Digital Systems - Principles and Applications, 2022.
5. M. M. Mano, M. D. Ciletti. Digital Design-With an Introduction to the Verilog HDL, VHDL, and System Verilog, 2018.
6. IAEATECDOC-363. Selected topics in Nuclear Electronics, 1986.
7. Glenn F Knoll. Radiation Detection & Measurement, 2010.
8. A. Martin, S. Harbison, K. Beach, P. Cole. An Introduction to Radiation Protection, 2019.
9. J. E. Turner. Atoms, Radiation, and Radiation Protection, 2007.
10. N. Tsoulfanidis, S. Landsberger. Measurement and Detection of Radiation, 2021.

ELECTIVE – 1A: Computational Medical Physics and Artificial Intelligence

Unit -1: Computational Packages

Familiarization with mathematical packages such as MATLAB, Mathematica. MATLAB - environment, data types, operators, flow control, functions, I/O, array manipulation - Executing MATLAB programs, scripts, functions. Data reading, manipulation, display & plotting in MATLAB.

DICOM file functions in MATLAB: reading, displaying medical images, processing & analysis Machine learning and fuzzy logic in MATLAB context

Tutorial/Practical: MATLAB lab sessions – read DICOM image, process and display, simple ML/fuzzy logic demo

Unit-2: Python programming

Fundamentals of Python; Basic operators in Python; Working with Data - Data Types (Numeric, String, Set, List, Tuple, Dictionary); Operators in python; Python Keywords and Identifiers; Python program flow - If statement, Else statements, Range statement, While loop, For loop, Break, Pass, Continue etc.; Object and class; Python user defined and built-in Functions; Python Modules – Import statement and built-in; File manipulation – Open, close, write, read; Python arrays; Python packages for data science – Numpy and Matplotlib (in depth) - for data analysis and visualization; Handling of excel files using python library.

Unit-3: Basics of Artificial Intelligence

Historical background pertaining to the development of AI;

Logistic regression for predictive modeling -definition and interpretation of the logistic and logit function, Problem, data, model, fit, and evaluation for logistic regression;

Regression, classification and decision boundary definition - difference between regression and classification, converting problem between problem types, interpretation of output of model;

Receiver operating characteristic (ROC) analyses - basic concept and interpretation, True positive, true negative, false positive, false negative, Type I and Type II errors, sensitivity and specificity, area under the curve (AUC));

Co-variance, correlation, regression, R2 – definitions, interpretations, analysis;

Unit-4: Machine Learning

Machine learning categories - supervised learning, unsupervised learning, reinforcement learning, hybrid learning categories, semi-supervised learning, self-supervised learning);

Machine learning models and data analytics tools - Linear and logistic regression, neural networks, dimensionality reduction, support vector machine, decision trees and random forests, gradient boosting, K-means cluster analysis, metrics of evaluation);

Training and validation of machine learning models - mathematics of training, data augmentation, model selection and regularization, forward and backward stepwise predictor selection, ridge regression, LASSO, training methods, hyper parameter optimization, required sample size, bias-variance trade-off, over fitting, handling co-linearity of predictors (Variance inflation factor, VIF), model validation, cross-validation (K-fold, leave-one-out), bootstrap, generalizability, external validation, calibration;

Deep learning - deep learning and neural networks, convolutional neural networks, recurrent neural networks, long short-term memory (LSTM) networks, transformer networks, transformer networks for text, vision and swin transformer networks for image processing, generative adversarial networks - synthetic images; transfer learning, domain adaptation, augmentation, metrics of evaluation (DICE)

Data management - data collection including data retrieval, data quality assessment, data curation, anonymization and de-identification, labeling and segmentation, harmonization, standardization, robustness, overview of AI-based clinical applications, AI-related ethical issues.

Suggested Text Books and References:

1) J. D. Hoffman, S. Frankel. Numerical Methods for Engineers and Scientists, 2001.
2) M.T. Vaughn. Introduction to Mathematical Physics, 2007.
3) Band W. Introduction to Mathematical Physics, 2010.
4) Abhishek Singh. Essential Python for Machine Learning, 2023.
5) John Whittington. Python from the Very Beginning, 2023.
6) R.Y. Rubinstein and D.P. Kroese. Simulation and the Monte Carlo Method, 2016.
7) Oleg N. Vassiliev, Monte Carlo Methods for Radiation Transport, 2017.
8) W. L. Dunn and J. K. S. Shultis. Exploring Monte Carlo Methods, 2012.
9) M. H. Kalos and P. A. Whitlock. Monte Carlo Methods, 2008.
10) E. B. Podgorsak, Radiation Physics for medical physicists. 2006.
11) Gilmer Valdes, Lei Xing Artificial Intelligence in Radiation Oncology and Biomedical Physics 2023
12) Iori Sumida, Artificial Intelligence in Radiation Therapy, 2022
13) Issam El Naqa, Martin J. Murphy, Machine and Deep Learning in Oncology, Medical Physics and Radiology, 2022

ELECTIVE – 1B: Health Technology Assessment, HTA (3 Credits, 45 Hours)

[41 Lectures + 5 Tutorials, 46 hrs, 3 credits]

UNIT I: Introduction to Health Technology Assessment

Health Technology Assessment (HTA) – Scope of HTA in radiotherapy, nuclear medicine, diagnostics, and public health programs – Multidisciplinary nature of HTA: economics, epidemiology, ethics, policy – Historical evolution of HTA in USA, Canada, and Europe – Formation of INAHTA – Emergence of HTA in developing countries and Asia (HITAP, NICE International) – Importance and role of HTA in health systems – Evidence-based policy making – Priority setting and resource optimization – Role in Universal Health Coverage (UHC) – HTA in India: Institutional structure under DHR–ICMR – Role, objectives, and governance structure – HTAIn manual and its relevance – Conducive factors for HTA in Asia: Policy drivers, political commitment, capacity development

UNIT II: Principles and Framework of HTA

Core principles of HTA – Transparency, accountability, scientific rigor, stakeholder involvement – Relevance, timeliness, ethical soundness – HTA triangle: Clinical, Economic, Social/Ethical dimensions – Relationship with Evidence-Based Medicine (EBM) and Comparative Effectiveness Research (CER) – HTA process steps: Topic nomination and prioritization – Scoping and protocol development – Evidence synthesis and appraisal – Formulating recommendations – Policy uptake and monitoring – Quality assurance and evaluation: Internal and external review – HTAIn quality check guidance(ICMR) – Reporting standards: HTAIn template, PRISMA, CHEERS checklist – Stakeholder engagement: Policymakers, clinicians, economists, patient groups

UNIT III: Methodologies in Health Technology Assessment

Evidence synthesis – Systematic review – Meta-analysis – Critical appraisal – Databases: PubMed, Cochrane Library – Clinical effectiveness and safety evaluation: Clinical trial data – Observational studies – Surrogate and patient-relevant outcomes – Economic evaluation: Cost-Effectiveness Analysis (CEA) – ICER – Cost-Utility Analysis (CUA) – QALY, DALY – Cost-Benefit Analysis (CBA) – WTP – Cost-Minimization and Budget Impact Analysis (BIA) – Modeling techniques: Decision tree – Markov models – Sensitivity analysis – Discounting – Uncertainty analysis – Reporting economic evidence – CHEERS checklist – Interpretation of incremental cost ratios

UNIT IV: Ethical, Legal, and Political Dimensions of HTA

Ethical dimensions – Patient autonomy – Beneficence – Justice – Non-maleficence – Balancing cost and access – Public acceptability and transparency – Legal framework: Health technology regulations – Approval processes (CDSCO, FDA, CE) – Intellectual property and patent laws – Data privacy, consent, and confidentiality – Political and institutional factors: Power structures – Policy priorities – Role of advocacy, media, political economy – Case discussions: Pricing of cancer drugs – Medical device regulation – Framework for managing conflicts of interest – Transparency protocols – Governance

UNIT V: HTA in Practice - Global and Indian Perspectives

HTAIn – India's HTA system – Institutional framework under Department of Health Research – Process: Topic selection – Assessment – Appraisal – Decision – Examples: Cost-effectiveness of dialysis, knee implants, screening programs – International HTA models: NICE (UK), CADTH (Canada), PBAC (Australia), HITAP (Thailand) – HTA and reimbursement systems in developed and developing nations – Integration with health policy: HTA for Universal Health Coverage – National Health Policy linkages – Public health technology prioritization – Future of HTA: Digital health – AI – Genomics – Personalized medicine – Challenges: Capacity building – Sustainability

Suggested Text Books and References

1) Drummond MF, Sculpher MJ, Claxton K, Stoddart GL, Torrance GW. *Methods for the Economic Evaluation of Health Care Programmes*, 5th Edition, Oxford University Press, 2015.
2) Banta D, Jonsson E. *History of Health Technology Assessment*, Academic Press, 2009.
3) Oortwijn W, Jansen M, Baltussen R. *Health Technology Assessment: Methods and Applications*, Springer, 2020.
4) HTAIn Manual, Indian Council of Medical Research, 2018
5) Drummond MF et al., *Key Principles for the Improved Conduct of HTA*, International Journal of Technology Assessment in Health Care, 2008.
6) HTAIn Manual (ICMR, 2018)
7) Chootipongchaivat S. et al., *Conducive Factors to the Development of HTA in Asia*, 2016
8) WHO, *Health Technology Assessment: A Global Overview*
9) Luce BR et al., *EBM, HTA, and CER: Clearing the Confusion*, Milbank Quarterly, 2010
10) Kieslich K et al., *Accounting for Technical, Ethical, and Political Factors in Priority Setting*, Health Systems & Reform, 2016

LABORATORY WORK

PRACTICAL -I (20 experiments each of 3 hours' duration, 2 Credits)

Course Outcomes:

- Understanding radiation physics and mathematical concepts applied to radiological processes
- Construction, characterisation and calibration of various radiation detectors and use of spectrometry techniques in radiological physics
- Preparation, standardisation and uses of chemical dosimeters
- Preparation, standardisation and safety aspects of sealed/unsealed radiation sources

List of the experiments:

1. Study of production and attenuation of bremsstrahlung radiation.
2. Study of absorption and backscattering of gamma rays in different materials
3. Measurement of range of beta particles by Feather analysis.
4. Study of backscattering of beta particles and its applications.
5. Study of voltage and current characteristics of an ionization chamber.
6. Calibration of survey meters and pocket dosimeters.
7. Familiarization with construction and testing of radiation protection monitors.
8. Calibration and cross calibration of cylindrical and plane parallel ionization chambers used in external beam therapy
9. Calibration of thermoluminescent dosimeter (TLD) and its use in radiation dose measurements.

10. Determination of plateau and resolving time of a G.M. counter and its application in estimating the shelf-ratio and activity of a beta source.
11. Output measurement of a gamma chamber using Fricke dosimeter
12. Calibration of a TLD personnel monitoring badge and evaluation of personnel doses.
13. Calibration of Gamma ray spectrometer [HPGe] and identification of unknown sources using multichannel analyser.
14. Determination of HVT and TVT in different materials for gamma rays.
15. Calibration of neutron personnel monitoring badge and personnel dose evaluation
16. Study of REM counter response with distance and energy of neutron source.
17. Assessing Deep Learning based segmentation in radiotherapy applications.
18. Radiation protection survey around neutron irradiation installation/facility
19. Measurement of reference output of megavoltage x-rays generated by medical electron linear accelerator
20. Measurement of output of high energy electron beams used in radiotherapy

SEMESTER – II

Semester – II					
Course type	**Subject title**	**Lectures + Tutorials (each of 1 hour)**	**Credits**	**Marks**	
				Internal	**External**
Core-1	Anatomy Physiology Pathology and Clinical Aspects of Medical Imaging and Therapy	41+4	3	25	75
Core-2	Radiation Biology	42+4	3	25	75
Core-3	Diagnostic Radiology and Non-ionizing Radiation Physics	46+5	3	25	75
Core-4	Nuclear Medicine and Internal Dosimetry	45+5	3	25	75
Core-5	Radiation Therapy and Treatment Planning	77+8	5	25	75
Core-6	Radiation Safety and Regulatory Aspects	68+7	5	25	75
Lab-2	Practical - II	63	2	25	75
Total of Semester – II		**415**	**24**	**140**	**175**

CORE COURSES

CORE – 1: Anatomy Physiology Pathology and Clinical Aspects of Medical Imaging and Therapy [41 Lectures + 4 Tutorials; (45 hrs); 3 Credits)

Course Outcomes:

- Knowledge of cell biology, human anatomy, physiology and tumour pathology
- Understanding of mechanism and outcome of interaction of radiation with human cells and associated biological effects
- Basic knowledge of clinical aspects of medical imaging and radiation oncology and detailed knowledge of biological basis of radiotherapy
- Thorough knowledge of dose fractionation in radiotherapy and time-dose models.

Course Details:

Unit-1: Cell Biology

Cell physiology and biochemistry - Structure of the cell - Types of cells and tissue, their structures and functions - Organic constituents of cells - Carbohydrates, fats, proteins and nucleic acids - Enzymes and their functions - Functions of mitochondria, ribosomes, Golgi bodies and lysosomes - Cell metabolism- DNA as concepts of gene and gene action - Mitotic and meiotic cell division - Semi conservative DNA synthesis, Genetic variation Crossing over, mutation, chromosome segregation - Heredity and its mechanisms.

Unit-2: Anatomy, Physiology and Tumour Pathology

Anatomy and physiology as applied to radiodiagnosis and radiotherapy - General anatomical terminology – Levels of structural organization – Cells, tissues, organs, and systems – Overview of organ systems – Anatomical planes and positions – Skeletal system: bones and joints, classification and functions – Muscular system: types of muscles, mechanism of contraction – Cardiovascular system: structure and function of heart, major vessels, and blood circulation – Lymphatic system: lymph nodes, lymph circulation, and clinical significance. Respiratory system – anatomy of lungs, mechanism of respiration, regulation of breathing – Digestive system – structure and function of alimentary canal, liver, pancreas – Urinary system – structure of nephron, urine formation and regulation – Endocrine system – pituitary, thyroid, adrenal, and pancreas – Nervous system – brain, spinal cord, peripheral nerves, synaptic transmission, reflex arc – Reproductive system (male and female): structure, function, and hormones – Sensory organs: anatomy and physiology of eye and ear. Basics of human genetics – structure and function of DNA and RNA – gene expression, mutations, chromosomal aberrations, and genetic disorders – Oncogenes, tumour suppressor genes, and molecular basis of cancer – Cell cycle and mechanisms of carcinogenesis – Tumour pathology: types, classification, grading, and staging – Interpretation of clinico-pathological data - Differences between benign and malignant tumours – Mechanisms of tumour spread: local invasion, lymphatic and hematogenous metastasis – Tumour markers and biopsy interpretation – Genetic predisposition and familial cancers.

Unit-3: Radiographic Anatomy and Cross-sectional Imaging

Radiographic anatomy of head, thorax, abdomen, pelvis, and extremities – Identification of anatomical landmarks on plain X-rays, CT, MRI, and PET/CT images – Surface and sectional anatomy of organs and structures – Radiological interpretation of normal variations – Identification of major vessels, muscles, and bones in imaging modalities – Correlation between imaging anatomy and radiation treatment planning – Radiographic anatomy of CNS, skeletal, and visceral systems.

Unit- 4: Clinical Aspects of Radiation Oncology

Radiation Therapy, Surgery, Chemotherapy, Hormone Therapy, Immunotherapy & Radionuclide therapy, Benign and malignant disease, Methods of spread of malignant disease, Staging and grading systems, Treatment intent - Curative & Palliative, Cancer prevention and public education and Early detection & Screening. Site specific signs, symptoms, diagnosis and management: Head and Neck, Breast, Gynaecological, Gastro-Intestinal tract, Genito-Urinary, Lung & Thorax, Lymphomas & Leukemias & Other cancers including AIDS related cancers. Patient management on treatment - side effects related to radiation and dose - Acute & Late - Monitoring and common management of side effects - Information and communication. Professional aspects and role of medical physicists: General patient care - Principles of professional practice - Medical terminology - Research & Professional writing - Patient privacy - Ethical & cultural issues. Legal aspects - Confidentiality, Informed consent, Health and Safety.

CORE – 2: Radiation Biology [42 Lectures + 4 Tutorials; (45 hrs); 3 Credits)

Unit-1 Interaction of Radiation with Cells

Action of radiation on living cells - Radiolytic products of water and their interaction with biomolecule- Nucleic acids, proteins, enzymes, fats - Influence of oxygen, temperature - Cellular effects of radiation- Mitotic delay, chromosome aberrations, mutations and recombinations - Giant cell formation, cell death Recovery from radiation damage - Potentially lethal damage and sublethal damage recovery - Pathways for repair of radiation damage. Law of Bergonie and Tribondeau.

Survival curve parameters - Model for radiation action - Target theory - Multihit, Multitarget - Repair misrepair hypothesis - Dual action hypothesis - Modification of radiation damage - LET, RBE, dose rate, dose fractionation - Oxygen and other chemical sensitizers - Anoxic, hypoxic, base analogs, folic acid, and energy metabolism inhibitors - Hyperthermic sensitization - Radio-protective agents – Cultured cell line and animal experimentation methods for assessing radiation damage – Oxygen enhancement ratio – Dose modifying factors.

Unit-2: Biological Effects of Radiation

Somatic effects of radiation - Physical factors influencing somatic effects - Dependence on dose, dose rate, type and energy of radiation, temperature, anoxia, - Acute radiation sickness - LD 50 dose - Effect of radiation on skin and blood forming organs, digestive tract - Sterility and cataract formation - Effects of chronic exposure to radiation - Induction of leukaemia - Radiation Carcinogenesis - Risk of carcinogenesis - Animal and human data - Shortening of life span – Concept of projection models and risk estimation - In-utero exposure - Genetic effects of radiation - Factors affecting frequency of radiation induced mutations- Dose-effect relationship - first generation effects - Effects due to mutation of recessive characteristics- Genetic burden - Prevalence of hereditary diseases and defects - Spontaneous mutation rate - Concept of doubling dose and genetic risk estimate.

Unit-3: Biological Basis of Radiotherapy

Tumour growth kinetics, Experimental model systems for studying radiobiology of radiotherapy, Physical and biological factors affecting cell survival, tumour re-growth and normal tissue response -Causes of clinical radioresistance, Hypoxia and reoxygenation in radiotherapy, Non-conventional fractionation scheme and their effect of re-oxygenation, repair, redistribution in the cell cycle, 4 Rs of radiotherapy, Rationales of Multiple fraction daily (MFD) and Continuous hyper accelerated fractionation (CHART) methods, New modalities of radiotherapy, High LET radiation therapy.

Unit-4: Time Dose Fractionation

Time dose fractionation - Basis for dose fractionation in beam therapy - Concepts for Nominal Standard Dose (NSD), Equivalent Single Dose (ESD), Roentgen equivalent therapy (RET) - Time dose fractionation (TDF) factors and cumulative radiation effects (CRE) - Gap correction, Linear and Linear Quadratic (LQ) models, LQ model for fractionated radiotherapy and concept of Biological Equivalent Dose (BED), BED for fractionated radiotherapy, Estimation of α/β dose using clinical data, BED correction for gap, BED for brachytherapy, Concept of switching between treatment modalities, BED for MFD and CHART protocols, Concept of incomplete repair, correction for BED and normal tissue complication in MFD and CHART.

Suggested Text Books and References:

1. A. Waugh, A. Grant. Ross and Wilson Anatomy and Physiology in Health and Illness, 2022.
2. E. J. Hall, A.J. Giaccia. Radiobiology for the radiologist, 2018.
3. Edward L Alpen. Radiation Biophysics, 1998.
4. Hollinshead W.H., C. Rosse, P. Gaddum-Rosse. Text Book of Anatomy, 2008.
5. G. Gordon Steel. Basic Clinical Radiobiology, 2002.
6. Irene Harris. Clinical Aspects of Radiation Oncology, 2015.
7. Hasan Murshed. Fundamentals of Radiation Oncology: Physical, Biological and Clinical Aspects, 2019.

CORE-3: Diagnostic Radiology and Non-ionizing Radiation Physics

[45 Lectures + 5 Tutorials, (50 hrs); 3 Credits]

Course Outcomes:

- Understanding the process of X-ray based imaging using both conventional and advanced imaging systems such as digital X-ray imaging systems (radiography and mammography), dental imaging systems and computed tomography (CT) scanners
- Concepts of magnetic resonance imaging (MRI) and ultrasound imaging in diagnosis of various types of cancer
- Understanding of non-ionizing radiation physics

Course Details:

Unit-1: Principles and Techniques Conventional X-ray Imaging

Physical principle of diagnostic radiology: Interactions of X-rays with human body, differential transmission of x-ray beam, spatial image formation, visualization of spatial image, limitations of projection imaging technique Viz. superimposition of overlying structures and scatter, application of contrast media and projections at different angles to overcome superimposition of overlying structures.

Radiography techniques: Prime factors (kVp, mAs and SID/SFD), influence of prime factors on image quality, selection criteria of prime factors for different types of imaging, different type of projection and slices selected for imaging, objectives of radio-diagnosis, patient dose Vs image quality.

Filters: inherent and added filters, purpose of added filters, beryllium filter, filters used for shaping X- ray spectrum (K-edge filters: holmium, gadolinium, molybdenum).

Scatter reduction: Factors influencing scatter radiation, objectives of scatter reduction, contrast reduction factor, scatter reduction methods; beam restrictors (diaphragms, cones/cylinders & collimators), grids (grid function, different types of stationary grids, grid performance evaluation parameters, moving grids, artifacts caused by grids, grid selection criteria), air gap technique.

Intensifying screens: Function of intensifying screens, screen function evaluation parameters, emission spectra and screen film matching, conventional screens Vs rare earth screens Radiographic Film: Components of radiographic film, physical principle of image formation on film, double and single emulsion film, sensitometeric parameters of film (density, speed, latitude etc.), QA of film developer.

Image quality parameters; sources of un-sharpness, reduction of un-sharpness, factors influencing radiographic contrast, resolution, factors influencing resolution, evaluation of resolution (point spread function (PSF), line spread function (LSF), edge spread function (ESF), modulation transfer function (MTF)), focal spot size evaluation.

QA of conventional diagnostic X-ray equipment: Purpose of QA, QA protocols, QA a test method for performance evaluation of x-ray diagnostic equipment.

Unit-2: Digital Imaging, Interventional Radiology and Mammography

Digital x-ray imaging**: S**torage phosphor (computed radiography-CR) and DR systems, digital detector technology-indirect conversion digital detectors and direct conversion digital detectors.

Fluoroscopy including interventional procedures: Equipments, fluoroscopic imaging chain components, detector systems, automatic exposure rate control, mode of operation, image quality and radiation dose in fluoroscopy.

Mammography: Mammography equipment, screen-film mammography, digital mammography detectors, digital detector technology-indirect conversion digital detectors and direct conversion digital detectors, digital breast tomosynthesis and three-dimensional imaging, QA of mammography equipments.

Unit – 3: Computed Tomography

Principles of X-ray Computed Tomography, CT Generations, Reconstruction Algorithms, CT Equipment and Instrumentation: X-ray tube Design, Filtration, Collimation, Detectors. CT Numbers, Modes of CT Acquisition, Cardiac CT, Dual Energy CT, CT Angiography, CT Dosimetry, Image Quality Assurance tests for CT, CT Image Artefacts.

Images in the Fourier Domain, Object Segmentation – Thresholding, K-means and Region Growing, Filtering: Edge Enhancement and Smoothing Filters, Edge Detection, 2D Morphological Operators. Image Registration: Rigid and Non-Rigid Techniques, Affine And Non-Affine Methods, Applications In Multi-Modality Imaging.

Unit – 4: Non-ionizing radiation Physics and Imaging

Sources of non-ionizing radiation - their physical properties. Various types of optical radiations - UV, Visible, FTIR, Raman. IR Sources - IR Sensors for Medical Applications (e.g., thermal imaging, non-contact temperature sensing). First law of photochemistry - Law of reciprocity - Electrical Impedance and Biological Impedance - Principle and theory of thermography - Applications. Safety in use of non-ionizing radiation sources.

Magnetic Resonance Imaging (MRI) : Introduction-overview-basic concepts of MRI and historical perspective; Spin physics: nuclear spin, interactions with applied magnetic field, RF excitation, FID, magnetic resonance, Larmor condition; Basic Sequence: T1, T2, $T2^*$ relaxation, Bloch equations, Spin echo, Saturation and recovery, inverse recovery; Imaging principles: Magnetic field gradients, Gradient echo, Contrast to noise ratio, Diffusion imaging; MRI techniques: T1/T2/$T2^*$/PD weighting, Diffusion/Perfusion weighting, Functional MRI; Imaging Considerations: SNR, Image quality, Artifacts, Inhomogeneities, Susceptibility, Contrast agents, Phase contrast, Chemical shift. Gradient eddy current, respiratory motions, voluntary motion, water/fat separation; MRI Machine: MRI system components, Scanner magnet and coils, gradient coils, Bo homogeneity and shimming, detector design, resonance circuit, MR Safety: RF safety, SAR, Power dissipation, tissue heating, magnetic field shielding; Advance applications: Cardio-vascular MRI, MR angiography.

Ultrasound Imaging: Interaction of sound waves with body tissues, production of ultrasound - transducers – acoustic coupling- image formation - modes of image display - colour Doppler.

Suggested Text Books and References

1. Carolyn A. MacDonald. An Introduction to X-Ray Physics, Optics, and Applications, 2017.
2. E. Bezak, A.H. Beddoe, L.G. Marcu, M. Ebert and R. Price. Johns and Cunningham's The Physics of Radiology, 2021 (5th Edition).
3. IAEA. Diagnostic Radiology Physics: A Handbook for Teachers and Students, 2014 (http://www-pub.iaea.org/books/IAEABooks/8841/Diagnostic-Radiology-Physics)
4. J. T. Bushberg, J.A. Seibert, E. M. Leidholdt Jr., J. M. Boone. The Essential Physics of Medical Imaging, 2020 (4th Edition).
5. W. R. Hendee, E.R. Ritenour. Medical Imaging Physics, 2002 (4th Edition).
6. S. C. Bushong, and G. Clarke. Magnetic Resonance Imaging, 2014 (4th Edition).
7. R. W. Brown, Y. Chung N. Cheng, E.M. Haacke, M. R. Thompson, R. Venkatesan. Magnetic Resonance Imaging: Physical Principles and Sequence Design, 2014.

CORE-4: Nuclear Medicine and Internal Dosimetry

[45 Lectures + 5 Tutorials, (50 hrs); 3 Credits]

Course Outcomes*:*

- Knowledge of working principles and use of open isotope-based imaging systems such as Gamma Camera, Single Photon Emission Tomography (SPECT), Positron Emission Tomography (PET)
- Understanding of the technology and use of medical cyclotron and
- Understanding the technique of Internal dosimetry techniques

Course Details

Unit-1: Physics of Nuclear Medicine

Introduction to Nuclear Medicine (NM), Unsealed Sources, Production of Radionuclide used in NM; Reactor based Radionuclides, Accelerator based Radionuclides, Photonuclear activation, Equations for Radionuclide Production, Radionuclide Generators and their operation principles. Production of radiopharmaceuticals from Short lived positron emitters, Various usages of Radiopharmaceuticals.

In-vivo Non-imaging procedures; Thyroid Uptake Measurements, Blood Volume studies. Life Span of RBC, Blood Volume studies, Life Span of RBC, Renography, etc. General concept of Radionuclide Imaging and Historical developments. Digital Image Acquisition, Display and Processing Systems. Frame mode acquisition, List mode acquisition. Choice of Matrix size, Image Display systems, Different Imaging Techniques: Basic Principles, Planar / 2D Imaging Techniques. Static, Dynamic, Gated. 3D Imaging Techniques - Basic Principles and Problem, Focal Plane Tomography, Emission Computed Tomography, Single Photon Emission Computed Tomography, Positron Emission Tomography.

Various Image Reconstruction Techniques during Image formation such as Back Projection and Fourier based Techniques, Iterative Reconstruction method and their drawbacks. Attenuation Correction, Correction Scatter, Resolution Correction, Artifacts or Sources of Error.Image Quality Parameters: Uniformity, Spatial Resolution, Factor affecting Spatial Resolution, Methods of Evaluation of Spatial Resolution, Contrast, Noise, Recovery Coefficient. NEMA Protocols followed for Quality Assurance / Quality Control of Imaging Instruments.Working of Medical Cyclotron, Radioisotopes Produced and their characteristics. In-vitro Technique: RIA/IRMA techniques and its principles.

Unit-2: NM Imaging Equipment

The Rectilinear Scanner and its operational principle, Basic Principles and Design of the Anger Camera / Scintillation Camera; System components, Detector System and Electronics, Different types of Collimators, Design and Performance Characteristics of the Converging, Diverging and Pin hole Collimator, Image Display and Recording Systems, Scanning camera, Limitation of the Detector System and Electronics.Physics and working principles of SPECT, PET, SPECT-CT, PET-CT, PET-MRI imaging, PET Instrumentations, Annihilation Coincidence Detection, PET Detector ad Scanner Design, Data Acquisition for PET, 2D/3D, Time of Flight imaging, Data corrections and Quantitative Aspect of PET, Image reconstruction techniques: back projection, Fourier-based, iterative methods - Attenuation, scatter, and resolution correction - Image quality parameters: spatial resolution, contrast, noise - QA/QC protocols as per national and international standards (IEC/NEMA) - Standard operating procedures for imaging equipment.Working of Medical Cyclotron, Radioisotopes Produced and their characteristics. Radiation safety aspects of medical cyclotron facility.Planning and Shielding Calculations during the installation of SPECT, PET/CT and Medical Cyclotron in the Nuclear Medicine Department.

Unit-3: Radionuclide Therapy

Treatment of Thyrotoxicosis, Thyroid cancer with ^{131}I, use of ^{32}P and ^{90}Y for palliative treatment, Radiation Synovectomy and the isotopes used. Peptide Receptor Radionucleide Therapy (PRRT), applications of ^{177}Lu & ^{225}Ac. Concept of Delay Tank and various Waste Disposal Methods used in Nuclear Medicine. High-dose therapy room shielding calculations, Radiological safety aspects during servicing and maintenance - Emergency preparedness: spillage, personnel contamination, power failure - Cyclotron auxiliary equipment and control software as applied to therapy - Safety protocols for therapy delivery.

Unit-4: Internal Dosimetry

Biodistribution and kinetic analysis of radiotracer concentration, Compartmental Modelling, Single Compartmental Model, Two Compartmental Model with Back Transference, Two Compartmental Model without Back Transference. Catenary & Mammillary models.

Classical Methods of Dose Evaluation; Beta particle Dosimetry; Equilibrium Dose Rate Equation, Beta Dose Calculation Specific Gamma Ray Constant, Gamma Ray Dosimetry, Geometrical Factor Calculation, Dosimetry of Low Energy Electromagnetic Radiation. Internal Radiation Dosimetry, MIRD Schema for Dose calculations; Basic procedure and some practical problems, Cumulative Activity, Equilibrium Dose Constant, Absorbed Fraction, Specific Absorbed Fraction, Dose Reciprocity Theorem, Mean Dose per unit Cumulative Activity and Problems related to the Dose Calculations. Limitation of MIRD Technique. individual dose calculations using Monte Carlo technique, Voxel based dosimetry.

Suggested Text Books and References:

1) C. Shah, M. Bradshaw, I. Dalal. Nuclear Medicine: A Core Review, 2021.
2) S. R. Cherry, J. A. Sorenson and M.E. Phelps. Physics in Nuclear Medicine. 2012.
3) H. A. Ziessman, J. P. O'Malley, J. H. Thrall. Nuclear Medicine: The Requisites (Requisites in Radiology), 2013.
4) Henry N. Wagner. A Personal History of Nuclear Medicine, 2006.

CORE-5: Radiation Therapy and Treatment Planning

(77 Lectures + 8 Tutorials, (85 hrs); 5 Credits)

Course Outcomes:

- Understanding the technology and working principles of various beam therapy equipment such as Telecobalt machine, Medical electron linear accelerators (LINAC), and medical proton accelerator
- Understanding the technology and use of brachytherapy equipment, sources and techniques as well as dosimetry and treatment planning in brachytherapy
- Competence in medical radiation dosimetry, quality assurance of various radiotherapy equipment and use of computers in radiation treatment planning including optimisation and associated radiation safety
- Thorough knowledge and competence in applying special and advanced techniques of radiation therapy such as total body irradiation (TBI), total skin electron therapy (TSET), stereotactic radiosurgery/radiotherapy (SRS/SRT), stereotactic body radiotherapy (SBRT), intensity modulated radiotherapy (IMRT), image guided radiotherapy (IGRT), volumetric modulated radiotherapy (VMAT) and associated patient specific quality assurance

Course Details:

Unit-1: Beam Therapy

Description of low kV therapy x-ray units. Construction and working of telecobalt units - source design - beam collimation and penumbra - trimmers and breast cones. Design and working of medical electron linear accelerators - beam collimation- asymmetric collimator - multileaf collimator - dose monitoring - electron contamination. Flattening filter free (FFF) beam, Output calibration of ^{60}Co gamma rays, high energy x-rays and electron beams using IAEA TRS 398, AAPM TG 51 and other dosimetry protocols. Relative merits and demerits of kV x-rays, gamma rays, MV X-rays, and electron beams. Radiotherapy simulator and its applications. CT and virtual simulations.

Central axis dosimetry parameters - Tissue air ratio (TAR) Back scatter/ Peak scatter factor (BSF/PSF)- Percentage depth doses (PDD) - Tissue phantom ratio (TPR) - Tissue maximum ratio (TMR) - Collimator, phantom and total scatter factors. Relation between TAR and PDD and its applications - Relation between TMR and PDD and its applications. SAR, SMR, Off axis ratio and Field factor. Build-up region and surface dose. Tissue equivalent phantoms. Radiation filed analyzer (RFA) and measurement capabilities, commercially available systems. Description and measurement of isodose curves/charts. Dosimetry data resources.

Beam modifying and shaping devices - wedge filters - universal, motorized and dynamic wedges- shielding blocks and compensators. Treatment planning in teletherapy - target volume definition and dose prescription criteria - ICRU 50 & 62 - SSD & SAD set ups – 2 & 3-dimensional localization techniques - contouring - simulation of treatment techniques - field arrangements - single, parallel opposed and multiple fields - corrections for tissue inhomogeneity, contour shapes and beam obliquity - integral dose. Arc/ rotation therapy and Clarkson technique for irregular fields - mantle and inverted Y fields and extended/ magna fields. Conventional and conformal radiotherapy. Treatment time and Monitor unit calculations.

Clinical electron beams - energy specification - electron energy selection for patient treatment - depth dose characteristics (Ds, Dx, R100, R90, R50, Rp etc.) - beam flatness and symmetry - penumbra - isodose plots - monitor unit calculations - output factor formalisms - effect of air gap/ virtual source position method on beam dosimetry - effective SSD.

Hadron therapy - General concept, specifications of the equipment, beam calibration and dosimetry, immobilization, positioning and alignment systems, acceptance & commissioning, QA/QC, Record & verify, Networking, Oncology information system, Relative merits of proton, electron, neutron, heavy ions, x-ray and gamma ray beams - Neutron capture therapy - Heavy ion therapy, Preview of IMPT.

Quality assurance in radiation therapy - precision and accuracy in clinical dosimetry - quality assurance protocols for telecobalt, medical linear accelerator and radiotherapy simulators - IEC requirements - acceptance, commissioning and. quality control of telecobalt, medical linear accelerator and radiotherapy simulators. Exit dosimetry/Portal and in-vivo dosimetry. Electronic portal imaging devices.

Unit-2: Brachytherapy

Definition and classification of brachytherapy techniques - surface mould, intracavitary, interstitial and intraluminal techniques. Requirement for brachytherapy sources - Description of radium and radium substitutes - ^{137}Cs, ^{60}Co, ^{192}Ir, ^{125}I and other commonly used brachytherapy sources. Dose rate considerations and classification of brachytherapy techniques - Low dose rate (LDR), high dose rate (HDR) and pulsed dose rate (PDR). Paterson Parker and Manchester Dosage systems. ICRU 38, 58 & 89 protocols. Specification and calibration of brachytherapy sources – RAKR/AKS and Absorbed dose to water calibration - IAEA TRS 492 and ICRU 72 recommendations – Point and line source dosimetry formalisms - Sievert Integral - AAPM TG43/43U1 and other dosimetry formalisms, AAPM TG 186.

Afterloading techniques - Advantages and disadvantages of manual and remote afterloading techniques. AAPM and IEC requirements for remote afterloading brachytherapy equipment. Acceptance, commissioning, quality assurance, safety of remote after loading brachytherapy equipment. ISO requirements and QA of brachytherapy sources. advances in brachytherapy unit.

Brachytherapy treatment planning - CT/MR/USG based brachytherapy planning - GEC ESTRO recommendations - forward and inverse planning, normalization & optimization methods, plan evaluation, DICOM image import / export from OT - Record & verification. Brachytherapy treatment for Prostate cancer. Ocular brachytherapy using photon and beta sources. Intravascular brachytherapy - classification - sources - dosimetry procedures - AAPM TG 60 protocol. Electronic brachytherapy.

Unit-3: Radiotherapy Treatment Planning

Scope of computers in radiation treatment planning - Review of algorithms used for treatment planning computations - Pencil beam, double pencil beam, Clarkson method, convolution superposition, lung interface algorithm, fast Fourier transform, Inverse planning algorithm, Monte Carlo based algorithms and equivalent dose calculation algorithms. Data acquisition & beam modeling, site specific planning.

Treatment planning calculations for photon beam, electron beam, proton and brachytherapy - Factors to be incorporated in computational algorithms. Plan optimization - direct aperture optimization - beamlet optimization - simulated annealing - biological optimization, multi-criterion optimizations, dose volume histograms - (qualitative and quantitative) dosimetry. Indices used for plan comparisons - Hardware and software requirements - beam & source library generation.

Networking, DICOM and PACS, archieval and restore, big data management, role of cloud-based solutions. Acceptance, commissioning and quality assurance of radiotherapy treatment planning systems using IAEA TRS 430 and other protocols. Basic concept of AI for radiotherapy treatment planning and dosimetry.

Unit-4: Special and Advanced Techniques of Radiotherapy

Special techniques in radiation therapy - Total body irradiation (TBI) - large field dosimetry - total skin electron therapy (TSET), Total Marrow Lymphoid Irradiation (TMLI) - electron arc treatment and dosimetry - intraoperative radiotherapy, AAPM and IAEA task group reports.

Stereotactic radiosurgery/radiotherapy (SRS/SRT) - cone and mMLC based X-Knife - Gamma Knife immobilization devices for SRS/SRT - including baseplate, masks (open/close), positioning devices and alignment devices -dosimetry and planning procedures - Evaluation of SRS/SRT treatment plans - QA protocols and procedures for X- and Gamma Knife units - Patient specific QA, Film dosimetry for SRS/SRT, various films available for QA, EBT and EBT-XD. Physical, planning, clinical aspects and quality assurance of stereotactic body radiotherapy (SBRT) and Cyber Knife based therapy. Preliminary concepts of ZAP-X solutions for SRS/SRT, IAEA TRS 483.

Intensity modulated radiation therapy (IMRT) - principles - MLC & compensator based IMRT - step and shoot and sliding window techniques - Compensator based IMRT - planning process - inverse & forward treatment planning-immobilization, patient positioning, setup and alignment devices for IMRT - dose verification phantoms, dosimeters, protocols, ICRU 83, machine and patient specific QA, AAPM TG reports and protocols. Concept of Volumetric Modulated Arc Therapy (VMAT), Image Guided Radiotherapy (IGRT) - concept, definitions, protocols and recommendations, 4DCBCT/4DMVCT, gated CBCT, Hybrid Medical Linac: CBCT-Linac, MR-Linac, PET/CT-Linac for adaptive radiotherapy, Concept of Adaptive Radiotherapy-image registration, dose accumulation and adaptation, QA protocol and procedures - special motion management phantom, 4DCT, Ring gantry accelerators (Radixact, Halcyon, Tomotherapy) - principle - commissioning - imaging - planning and dosimetry - delivery - plan adaptation - QA protocol and procedures. Concepts of radiomics and dosiomics - principles of quantitative feature extraction from imaging and 3D dose distributions

Surface guided/optically guided RT - concepts, mechanism, hardware, software, imaging techniques, Prospective & retrospective imaging and respiratory waveforms, integration with 4DCT, treatment planning system and treatment machine, phase based and amplitude-based gating, DIBH, DEBH, posture corrections, face recognition & safety, suitability for photons and protons, AAPM TG recommendations.

Suggested Text Books and References:

1. E. Bezak, A. H. Beddoe, L.G. Marcu, M. Ebert, R. Price. Johns and Cunningham's the Physics of Radiology, 2021 (5th edition).
2. J. P. Gibbons. Khan's The Physics of Radiation Therapy, 2019 (6th Edition).
3. T. Pawlicki, D. J. Scanderbeg, G. Starkschall. Hendee's Radiation Therapy Physics, 2016 (4th Edition).
4. Jacob Van Dyk. The Modern Technology of Radiation Oncology, Vol 1, 1999.
5. Jacob Van Dyk. The Modern Technology of Radiation Oncology, Vol 2, 2005.
6. Jacob Van Dyk. The Modern Technology of Radiation Oncology, Vol 3, 2013.
7. Jacob Van Dyk. The Modern Technology of Radiation Oncology, Vol 4, 2020.
8. D. Greene, P.C. Williams. Linear Accelerators for Radiation Therapy, 2017.
9. P.W. Sperduto and J. P. Gibbons. Khan's Treatment Planning in Radiation Oncology (5th edition), 2021.
10. P. Xia, A. Godley, C. Shah, G. M.M. Videtic, J. Suh (Editors). Strategies for Radiation Therapy Treatment Planning, 2018.
11. G.M.M. Videtic and N. M. Woody (Editors). Handbook of Treatment Planning in Radiation Oncology, 2014
12. T. Bortfeld, R. Schmidt-Ullrich, W. De Neve, D. E. Wazer. Image Guided IMRT, 2006.
13. D. Baltas, L. Sakelliou and N. Zamboglou. The Physics of Modern Brachytherapy for Oncology, 2006.
14. S. H. Levitt, J. A. Purdy, C. A. Perez and S. Vijayakumar. Technical Basis of Radiation Therapy Practical Clinical Applications, 2012 (4th Revised Edition).
15. IAEA TRS 398, Absorbed Dose Determination in External Beam Radiotherapy, 2000.
16. IAEA TRS 483, Dosimetry of Small Static Fields Used in External Beam Radiotherapy, 2017.
17. IAEA TRS 492, Dosimetry in Brachytherapy, 2023.
18. ICRU Report 97: MRI-Guided Radiation Therapy Using MRI-Linear Accelerators, 2022
19. ICRU Report 93: Prescribing, Recording, and Reporting Light Ion Beam Therapy, 2016
20. ICRU REPORT 89: Prescribing, Recording, and Reporting Brachytherapy for Cancer of the Cervix, 2013.
21. ICRU Report 83: Prescribing, Recording, and Reporting Photon-Beam Intensity-Modulated Radiation Therapy (IMRT), 2010.
22. ICRU Report 62: Prescribing, Recording and Reporting Photon Beam Therapy (Supplement to ICRU Report 50), 1999.
23. ICRU Report 50, Prescribing, Recording, and Reporting Photon Beam Therapy, 1993.

CORE-6: Radiation Safety and Regulatory Aspects

[68 Lectures + 7 Tutorials, (75 hrs); 5 Credits)

Course Outcomes:

- Comprehensive knowledge of radiation protection standards and recommendations towards occupational and public safety
- Competence in radiation monitoring, evaluation of external/internal radiation hazard, assessment of safety status of a radiation facility and control of contamination
- Thorough knowledge of radiation safety in the medical uses of radiation which involves planning of medical radiation installations, evaluation of hazard and radiation waste disposal
- Knowledge of the concepts of radioactive waste disposal like sources of waste including classification, treatment techniques of waste and disposal of used radiation sources and radiation generators
- Detailed knowledge in transportation of radioactive substances including packaging, documentation, shipment, emergencies and regulations
- Familiarization with National Legislations (acts, rules, standards, and guides) for the use of radiation in various applications
- Knowhow of radiation emergencies and their medical management

Course Details:

Unit-1: Radiation Protection Standards

Radiation dose to individuals from natural radioactivity in the environment and man-made sources. Basic concepts of radiation protection standards - Historical background - International Commission on Radiological Protection and its recommendations – The system of Radiological Protection – Justification of Practice, Optimisation of Protection and individual dose limits – Radiation and tissue weighting factors, equivalent dose, effective dose, committed equivalent dose, committed effective dose – Concepts of collective dose- Potential exposures, dose and dose constraints – Exposure Situations- Planned, Emergency and Existing Categories of exposures – Occupational, Public and Medical Exposures - Factors governing internal exposure - Radionuclide concentrations in air and water - ALI, DAC and contamination levels. Brief introduction to IAEA Safety Standards (Part 1 to7).

Unit-2: Principles of Monitoring and Protection

Evaluation of external radiation hazards - Effects of time, distance and shielding - Shielding calculations - Personnel and area monitoring - Internal radiation hazards – Radio toxicity of different radionuclides and the classification of laboratories – Control of contamination – Bioassay and air monitoring – chemical protection – Radiation accidents – disaster monitoring.

Unit-3: Safety in Medical and Research Applications of Radiation

Planning of medical radiation installations – General considerations – Design of diagnostic, deep therapy, telegamma, standard medical accelerator, Cyberknife, Halcyon, Tomotherapy, Proton Therapy Accelerator installations, brachytherapy facilities, Nuclear medicine (Gamma Camera, SPECT, PET, HDT) facilities, diagnostic radiology (General x-ray, CT, Cathlab, etc.) facilities.

Evaluation of radiation hazards in medical diagnostic and therapeutic installations - Radiation monitoring procedures - Protective measures to reduce radiation exposure to staff and patients - Radiation hazards in brachytherapy departments and teletherapy departments and radioisotope laboratories - Particle Accelerators Protective equipment - Handling of patients - Waste disposal facilities - Radiation safety during source transfer operations Special safety features in accelerators, reactors.

Planning of radiation installations and isotope laboratories for biomedical research - Radiation protection measures and hazards evaluation in biomedical research establishments -

Unit-4: Radioactive Waste Disposal

Radioactive wastes – sources of radioactive wastes - Classification of waste - Treatment techniques for solid, liquid and gaseous effluents – Permissible limits for disposal of waste - Sampling techniques for air, water and solids – Geological, hydrological and meteorological parameters – Ecological considerations.

Disposal of radioactive wastes - General methods of disposal - Management of radioactive waste in medical, industrial, agricultural and research establishments. Atomic Energy (radioactive Waste Disposal) Rules, 1987.Environmental impact assessment for discharge of radioactive wastes, interim storage, safe management of disused sources.

Unit-5: Transport of Radioisotopes

Transportation of radioactive substances - - General packing requirements - Transport documents - Labeling and marking of packages - Regulations applicable for different modes of transport - Transport by post - Transport emergencies - Special requirements for transport of large radioactive sources and fissile materials - Exemptions from regulations – Shipment approval – Shipment under exclusive use – Transport under special arrangement – Consignor's and carrier's responsibilities types of transport package, category of package, TREM card, transport index.

Unit-6: Legislation

National legislation – Regulatory framework – Atomic Energy Act – Atomic Energy (Radiation Protection) Rules – Applicable Safety Codes, Standards, Guides and Manuals, relevant international standards such as IEC, ISO etc. – Regulatory Control – Licensing, Inspection and Enforcement – Responsibilities of Employer, Licensee, Radiological Safety Officer and Radiation Worker– IAEA Code of conduct-Import & Export of radioactive sources- Graded approach of regulation-Exemption, exclusion and clearance. AERB Safety Directives.

Physical protection of sources – Categorization of radioactive sources, Safety and security of sources during storage, use, transport and disposal – Security provisions: administrative and technical – Security threat and graded approach in security provision, preparation of security plans for cat-1&2 sources.

Unit-7: Radiation Emergencies and their Medical Management

Radiation accidents and emergencies in the use of radiation sources and equipment in industry and medicine -Industrial radiography devices, GIC, GRAPF etc. and teletherapy, Brachytherapy, Nuclear Medicine- Loading and unloading of sources in teletherapy, brachytherapy, GRAPF etc.- Loss of radiation sources and their tracing - Typical accident cases. Radiation injuries, their treatment and medical management- Case histories. Prophylaxis and decorporating agents. Orphan and vulnerable sources, emergency handling accessories, emergency preparedness plan and its familiarization, estimation of doses while handling emergency situations, reporting emergency to regulatory body and other relevant authority.

Suggested Text Books and References:

1. H. Cember, T.E. Johnson. Introduction to Health Physics, 2008.
2. Atomic Energy Act 1962.
3. AERB Radiation Protection Rules 2004.
4. ICRP 60 Recommendations, 1990.
5. ICRP 103 Recommendations, 2007.
6. Shapiro J. Radiation Protection: A Guide for Scientists, Regulators and Physicians, 2002.
7. IAEA Safety Standards – General Safety Requirements Part 3:2014
8. Atomic Energy (Radioactive Waste Disposal) Rules, 1987.
9. J. V. Trapp and T. Kron. An Introduction to Radiation Protection in Medicine, 2008.
10. IAEA Safety Standards Series No. SSG-46: Specific Safety Guides - Radiation Protection and Safety in Medical Uses of Ionizing Radiation, 2018.

LABORATORY WORK

Practical -II (21 experiments each of 3 hours' duration, 2 Credits)

Course Outcomes:

- Study and evaluation of parameters involved in X-ray diagnostic and associated radiation safety
- Practical knowledge of measuring the strength of open isotopes, thyroid uptake, patient monitoring and safety assessment of nuclear medicine imaging and therapy facilities
- Skill of radiation dose measurement in beam therapy, brachytherapy, and nuclear medicine
- Practical knowledge of architecture and capabilities of radiotherapy treatment planning systems
- Practical competence in radiation protection survey of various medical installations and safety assessment

List of the Experiments:

1. QA of a medical diagnostic x-ray machine and radiation protection survey of its installation
2. Calibration and study with thyroid uptake probe
3. Radiation protection survey including air contamination measurement of high dose therapy facility
4. Measurement of reference output of a telecobalt machine used in external beam therapy
5. Measurement of total scatter factor of Co-60 gamma rays used in beam therapy
6. Measurement and analysis of PDD curve of high energy photon beams used in radiotherapy
7. Measurement and analysis of PDD curve of high energy electron beams used in radiotherapy
8. Measurement of source strength of HDR brachytherapy source using well chamber
9. Integrity test of a brachytherapy source
10. Study with contaminated surfaces and procedures for decontamination
11. Calibration check of a radiation survey meter
12. Radiation protection survey for an industrial radiography camera
13. Radiation protection survey of teletherapy installations
14. Analysis of patient specific QA plan for IMRT/VMAT
15. Measurement of shift in mechanical isocentre and its coincidence with radiation isocentre of a teletherapy machine
16. Measurement of inter- and intra-leaf transmissions of a multileaf collimator (MLC)
17. Quality assurance (QA) tests of a PET machine
18. Measurement of TG 43 dosimetry parameters of a brachytherapy source
19. 3DRCT/IMRT/VMAT treatment planning using a computerized RTPS
20. Radiation protection survey of a medical cyclotron
21. Imaging and dosimetry quality assurance of a computed tomography scanner

Fairness in Assessment:

Assessment is an integral part of system of education as it is instrumental in identifying and certifying the academic standards accomplished by a student and projecting them far and wide as an objective and impartial indicator of a student's performance. Thus, it becomes bounden duty of a University to ensure that it is carried out in fair manner. In this regard, UGC recommends the following system of checks and balances which would enable Universities effectively and fairly carry out the process of assessment and examination. [22]

1. At least 50% of core/elective courses must be evaluated by external examiners.
2. Projects/Dissertations: Evaluated by internal and external examiners.
3. Non-credit courses: Satisfactory/Unsatisfactory.
4. Universities may decide pass marks and CGPA requirements as per statutory councils.

Table 1: Grades and Grade Points

Grade Letter	Grade Point
O (Outstanding)	10
A+(Excellent)	9
A(Very Good)	8
B+(Good)	7
B(Above Average)	6
C(Average)	5
D (Below Average/Fail)	4
Ab (Absent)	0

A student obtaining Grade D/Ab is considered failed and must reappear.

Computation of SGPA and CGPA:

The UGC recommends the following procedure to compute the Semester Grade Point Average (SGPA) and Cumulative Grade Point Average (CGPA):

- The SGPA is the ratio of sum of the product of the number of credits with the grade points scored by a student in all the courses taken by a student and the sum of the number of credits of all the courses undergone by a student,

  i.e SGPA (Si) = ∑(Ci x Gi) / ∑Ci

  where Ci is the number of credits of the ith course and Gi is the grade point scored by the student in the ith course.

- The CGPA is also calculated in the same manner taking into account all the courses undergone by a student over all the semesters of a programme,

  i.e. CGPA = ∑(Ci x Si) / ∑ Ci

  where Si is the SGPA of the ith semester and Ci is the total number of credits in that semester.

- The SGPA and CGPA shall be rounded off to 2 decimal points and reported in the transcripts.

Illustration of CGPA:

Course	**Credit (Ci)**	**Grade letter**	**Grade point (Gi)**	**Credit Point = Credit (Ci)x Grade point (Gi)**
Course 1	4	A	8	4x8 = 32
Course 2	4	B+	7	4x7 = 28
Course 3	3	B	6	3x6 = 18
Course 4	2	O	10	2x10 = 20
Course 5	4	C	5	4x5 = 20
Course 6	3	B	6	3x6 = 18
Course 7	2	B	6	2x6 = 18
Total	22			136
SGPA (Si) = Credit points/Total credit		136/22 =6.18		6.18
Residency Credits (32)		32		

Sem 1: **22 credits × 6.18 = 135.96**

Sem 2: **30 credits × 7.78 = 233.4**

Total = **369.36**

Total Credits = 52

CGPA = 369.36/52 = 7.10

5.13 Medical Physics Residency Program

5.13.1 Objective:

Students enrolled in the Medical Physics program shall be required to undergo a compulsory one-year Clinical Residency at a well-equipped and duly recognized cancer hospital which has radiation oncology equipped with minimum one linac and one brachy therapy, Diagnostic Radiology (Equipped with minimum one CT), NM facility (Equipped with one PET CT) approved for such training.

It shall be the responsibility of the admitting University to ensure that every student enrolled in the M.Sc. Medical Physics program is provided with a residency placement meeting the above criteria. The residency shall constitute an essential component of the program curriculum and shall be designed to impart practical, hands-on training in clinical medical physics and radiation safety practices.

5.13.2 Infrastructure:

Minimum 12 months' residency in a recognised well-equipped institution has been specified as a mandatory requirement for a qualified Medical Physicist and Radiological Safety Officer. The academic education of medical physicists must include all clinical disciplines, i.e. radiation oncology, diagnostic radiology, and nuclear medicine, and include radiation protection as it is applied to the clinical environment.

The centre having all the following facilities is defined as well-equipped centre

- A well-equipped equipped Radiotherapy centre (30 Weeks)
  - One Linear Accelerator (with photon and electron beams)
  - One HDR Brachytherapy Unit with Adequate dosimetry
  - Dosimetry, QA and Radiation Monitoring instruments/devices as per the regulatory norms needed to run the clinical facilities
- A well-equipped equipped Diagnostic Radiology Department (6 Weeks)
  - Fixed Radiography Machine(s)
  - A Diagnostic CT equipment/ Magnetic Resonance Imaging Equipment/ Mammography/ Ultrasonography/ Interventional Radiology Facilities
  - QA devices such as for x-ray beam alignment, perpendicularity tests, kVp mA meters, image quality and dose assessment phantoms for radiography and CT/MRI/USG.
- A well-equipped equipped Nuclear Medicine department (10 Weeks)
  - Gamma Camera /SPECT / PET Scanner/ Iodine/ Isotope Therapy

QA, dosimetry and radiation monitoring devices/instruments such as Flood phantom with source, spatial resolution and linearity phantoms, isotope calibrator, contamination monitor as per the regulatory norms needed to run the NM facilities.

During the period of internships, stipend amount must be paid to the students by the institute as decided by the respective State Allied and Healthcare Councils. Interns shall also be eligible for leave and other benefits as per institute policy to any other worker.

During the residency, the host institute shall ensure systematic rotational postings of residents across the following departments and units, to ensure comprehensive exposure to all aspects of clinical medical physics:

- Radiation Oncology
- Nuclear Medicine
- Diagnostic Radiology and Magnetic Resonance Imaging (MRI)
- Other relevant departments such as Catheterization Laboratory (Cath Lab), Biomedical Engineering, and Cyclotron Facility, if available

Note: If the 4th Other relevant departments facility lacks the above mentioned the allotted time for those can be adjusted into Radiation Oncology/ Nuclear Medicine/ Diagnostic Radiology & MRI as per on the will of supervisor/program director.

The residency institution shall maintain structured training schedules, supervision protocols, and performance evaluation systems, ensuring that residents acquire the competencies necessary for independent professional practice in medical physics.

Supervisor:

The Residency supervisor is a medical physicist with at least 3 years of working experience in a Radiotherapy Department subject to availability of at least one Medical Physicist having minimum 5 years of working experience.

Following section mentions the qualifications required to become a residency supervisor

Essential Educational Qualification of Supervisor:

- M.Sc. (Medical Physics/ Radiological Physics) or Post M.Sc. Diploma in Radiological Physics / Medical Physics + Certification of Radiological Safety Officer (Medical) from AERB

Ratio of Supervisor to Medical Physics Residents

- The ratio of Medical Physics Residents Supervisor to Medical Physics Residents shall be 1:1 in case the supervisor is having working experience of at least 3 years but less than 5 years.
- The ratio of Medical Physics Residents Supervisor to Medical Physics Residents shall be 1:2 in case the supervisor is having working experience of 5 years or more.

5.13.3 Assessment Plan:

To match evolving technology needs implication of a well-defined assessment plan is the need of the hour for achieving the goal of competency-based training.

Assessment plan includes record keeping of all activities done during residency, regular feedback over performance of resident from supervisor, and a thorough evaluation of the experience and knowledge gained during residency.

As part of the Assessment plan upon completion of the residency, each student shall be required to submit a detailed Residency Logbook to the respective University with which they are enrolled. The Logbook shall be duly completed by the resident and must comprehensively document all clinical, technical, and academic activities undertaken, along with the knowledge and competencies acquired during the residency period.

The format of the Residency Logbook, as prescribed and annexed to this policy document, shall be followed strictly and without alteration. The resident shall ensure that all sections of the Logbook are accurately and completely filled in accordance with the prescribed guidelines.

The Logbook must be authenticated with the signatures of the designated Supervisor from the residency institution and the Program Director responsible for the residency training.

Award of the course completion certificate or degree shall be contingent upon the successful submission and verification of the duly completed and signed Residency Logbook to the residency institute which then issues a certificate of residency completion and a marksheet for residency. Failure to submit the Logbook in the prescribed format or obtain the required endorsements shall render the candidate ineligible for course completion certification until due compliance is achieved.

In certain cases where the student is supposed to complete their residency after the University's annual convocation then the student is eligible for receiving a provisional degree certificate as earliest as possible after completion of residency.

5.13.4 Residency Log Book & Assessment Sheets

University Logo	Residency Institute Logo

Residency Duration	From		To	
Resident's Name			Registration No./ID	
Name of Enrolled University				
University Enrollment Number				
Name of Residency Institute				
Name of Supervising Medical Physicist				
Name of Programme Director				

1. **Rotation Summary:**

Department	Duration (Weeks)	Supervisor	Date		Remarks
			From (DD/MM/YYYY)	To (DD/MM/YYYY)	
Radiation Oncology	30 weeks				
Nuclear Medicine	10 weeks				
Diagnostic Radiology & MRI	6 weeks				
Others Please Specify:	2 weeks				

2. Worksheet

Radiation Oncology				
Week No.	**Dates**		**Description**	**Supervisor Signature**
	From (DD/MM/YYYY)	**To (DD/MM/YYYY)**		
Week 1				
Week 2				
Week 3				
Week 4				
Week 5				
Week 6				
Week 7				
Week 8				
Week 9				
Week 10				
Week 11				
Week 12				
Week 13				
Week 14				
Week 15				
Week 16				
Week 17				
Week 18				
Week 19				
Week 20				
Week 21				
Week 22				
Week 23				
Week 24				
Week 25				
Week 26				
Week 27				

Radiation Oncology				
Week No.	**Dates**		**Description**	**Supervisor Signature**
	From (DD/MM/YYYY)	**To (DD/MM/YYYY)**		
Week 28				
Week 29				
Week 30				

Module Based Evaluation

Radiation Oncology						
Module	**Module Code**	**Module Description**	**Activity Code**	**Activity Description**	**Completion Date**	**Signature of Supervisor**
External Beam Radio-therapy	RO1	Reference Dosimetry including Instrumen-tation and Calibration for MV Photons	A1	Instrument QC, calibration and cross-calibration of field dosimetry systems		
			A2	Reference field mechanical QC		
			A3	Beam quality		
			A4	Reference field mechanical QC		
			A5	Reference dose calibration		
			A6	Other calibration methods		
			A7	Reference dose calibration		
			A8	Constancy measurements		
	RO2	Reference Dosimetry including Instrumentation and Calibration for MeV Electrons	A1	Instrument QC, calibration and cross-calibration		
			A2	Beam quality		
			A3	Reference dose calibration		
			A4	Other calibration methods		

Radiation Oncology						
Module	**Module Code**	**Module Description**	**Activity Code**	**Activity Description**	**Completion Date**	**Signature of Supervisor**
			A5	Reference dose calibration		
			A6	Constancy measurements		
	RO3	Relative Dosimetry for MV Photons	A1	Safety mechanical checks		
			A2	Relative dosimetry measurements: scatter correction factors, TMR, PDD, penumbra, uniformity, symmetry, open field & wedge data, asymmetric collimation		
	RO4	Electron Relative Dosimetry MeV Electrons	A1	Safety mechanical checks		
			A2	Relative dosimetry measurements: applicator factors, PDD, irregular fields, uniformity and symmetry		
			A3	Virtual source position		
	RO5	Positioning & Immobilization	A1	Observe methods of		

Radiation Oncology						
Module	**Module Code**	**Module Description**	**Activity Code**	**Activity Description**	**Completion Date**	**Signature of Supervisor**
				patient positioning and immobilization to ensure optimal field arrangement and minimize setup uncertainty		
	RO6	Beam Modification & Shaping Devices	A1	Manufacture		
			A2	QC and verification		
			A3	Safety aspects		
	RO7	Contours (manual/single slice) & Hand Planning	A1	Clinical examples		
	RO8	Techniques: Clinical Mark-up, Direct Setup, 2D Simulation	A1	Develop technique, setup instructions, and calculate times (clinical examples)		
	RO9	PTV Margin Establishment	A1	Clinical examples for different sites and techniques		
	RO10	3D Computerized Treatment Planning System (TPS)	A1	Acceptance		
			A2	Acquisition of beam data, commissioning (geometric, dosimetry, networking, CT validation)		
			A3	End-to-end testing		

Radiation Oncology						
Module	**Module Code**	**Module Description**	**Activity Code**	**Activity Description**	**Completion Date**	**Signature of Supervisor**
			A4	Algorithms (e.g., TRS-430 [16])		
	RO11	3D TPS Cases	A1	ICRU volume definition, QUANTEC [7] application, dose plan modeling, DVH evaluation and approval		
			A2	Dose plan verification, setup instruction		
			A3	DRR generation		
			A4	Shielding and accessories (QC)		
			A5	Data transfer		
	RO12	Patient Specific Quality Assurance	A1	In-vivo dosimetry (IVD)		
			A2	Portal imaging: calibration, image transfer, comparison, evaluation, QC		
			A3	Recording and reporting		
Brachy-therapy	RO13	Brachytherapy	A1	Acceptance testing procedures (ATP)		
			A2	Commissioning		
			A3	Quality control		
			A4	Source calibration and exchange		
			A5	Image, applicator, and source data for		

Radiation Oncology						
Module	**Module Code**	**Module Description**	**Activity Code**	**Activity Description**	**Completion Date**	**Signature of Supervisor**
				treatment planning		
			A6	Treatment planning		
			A7	Source preparation		
	RO14	Safety of Sources	A1	Stock, acquisition, transport, and waste management		
			A2	Emergency procedures		
	RO15	HDR Techniques	A1	Intraluminal, ICRT, interstitial, surface mould techniques		
	RO16	Quality Assurance Brachytherapy	A1	In-vivo dosimetry (IVD)		
			A2	Recording and reporting		
Radiation Protection & Safety	RO17	Facility Design (i.e. Radiotherapy, Brachytherapy and CT Simulation)	A1	Hypothetical exercise: siting, structures, infrastructure, workflow, efficiency		
	RO18	Shielding Calculations	A1	Calculate effective dose rates to staff and public using layouts		
			A2	Verify shielding calculations using survey instruments		

Radiation Oncology						
Module	**Module Code**	**Module Description**	**Activity Code**	**Activity Description**	**Completion Date**	**Signature of Supervisor**
	RO19	Special Procedures	A1	Fetal dose calculations		
Department Needs Assement	RO20	Equipment Specification & Acquisition	A1	Workload, functionality, compatibility, siting		
	RO21	Technology Assessment	A1	Technical specifications: dosimetry		
			A2	Treatment units		
			A3	Treatment planning		
			A4	Information technology & networking		
			A5	Procurement process		
Quality Manage-ment	RO22	Performing & Documenting QC	A1	Dosimetry instrumentation, equipment calibration, adherence to international codes of practice, redundancy systems		
			A2	Clinical aspects		
	RO23	Auditing	A1	Internal (peer review)		
			A2	External		

Nuclear Medicine				
Week No.	**Dates**		**Description**	**Supervisor Signature**
	From (DD/MM/YYYY)	**To (DD/MM/YYYY)**		
Week 1				
Week 2				
Week 3				
Week 4				
Week 5				
Week 6				
Week 7				
Week 8				
Week 9				
Week 10				

Modules Checklist:

Nuclear Medicine						
Module	**Module Code**	**Sub-Modules**	**Activity Code**	**Activity Description**	**Completion Date**	**Signature of Supervisor**
Radiation Protection & Safety	NM1	Facility standards & workflow	A1	International/ local standards & workflow assessment		
		Designation for unsealed sources	A2	Designation of areas for unsealed radioactive material		
		Shielding calculations	A3	Calculation of shielding barriers		
		Shielding verification	A4	Verifying shielding using survey instruments		
		Handling unsealed sources	A5	Handling unsealed radioactive sources		
		Radiation hazard assessment	A6	Hazard assessment of facilities and procedures		
		Personal dose measurement	A7	Methods for measuring personal dose		
		Operational dosimeter use	A8	Operational use of personal dosimeters		
		Accidental exposure response	A9	Respond to unintended or accidental exposure		

Nuclear Medicine						
Module	**Module Code**	**Sub-Modules**	**Activity Code**	**Activity Description**	**Completion Date**	**Signature of Supervisor**
Technology Management	NM2	Tender & procurement	A1	Prepare specifications & tender acquisition		
		Quality management	A2	Understanding QMS requirements		
		Acceptance & commissioning	A3	Concept & principles of acceptance and commissioning		
		Routine QC	A4	Methods for QC programme supervision		
		Imaging informatics	A5	Practice basic imaging informatics		
Radioactivity Measurements	NM3	Traceable standards	A1	QA principles for radioactivity measurements		
		Quantification calibration	A2	Activity quantification calibration		
		Acquisition parameters	A3	Effect of acquisition parameters		
Performance Testing	NM4	Dose calibrator	A1	System performance assessment & QC		
		Gamma probe/well counter	A2	Performance assessment & QC		

Nuclear Medicine						
Module	**Module Code**	**Sub-Modules**	**Activity Code**	**Activity Description**	**Completion Date**	**Signature of Supervisor**
		Planar gamma camera	A3	Performance assessment & QC		
		SPECT gamma camera	A4	Performance assessment & QC		
Radiopharm aceutical QC	NM5	Radio-pharma--ceutical QC tests	A1	Physical, radionuclide, radiochemical & chemical purity tests		
		Therapy principles	A2	Principles & procedures of radionuclide therapy		
Radionuclide Therapy	NM6	Safety precautions	A1	Radiation safety precautions for unsealed source therapy		
Clinical Application and Awreness	NM7	Routine clinical protocols	A1	Effect of technical factors & acquisition protocol		
		Image artefacts	A2	Common artefacts, causes, mitigation		
		Clinical activities and patient care	A3	Understanding role of multi-disciplinary professionals		

Diagnostic Radiology & MRI				
Week No.	**Dates**		**Description**	**Supervisor Signature**
	From (DD/MM/YYYY)	**To (DD/MM/YYYY)**		
Week 1				
Week 2				
Week 3				
Week 4				
Week 5				
Week 6				

Modules Checklist:

Diagnostic Radiology & MRI						
Module	**Module No.**	**Module Description**	**Activity Number**	**Activity**	**Date of Completion**	**Signature of Supervisor**
Clinical awareness	IMG1	Patient related experience	A1	Understanding patient workflow in a diagnostic radiology department and the role of multi-disciplinary professionals involved in diagnostic radiology.		
Performance testing of imaging equipment	IMG2	Screen-film systems	A1	Measurement and assessment of system performance, periodic QC of screen film systems		
	IMG3	Film processing and darkroom	A1	Measurement and assessment of system performance, periodic QC of processor and dark room		
	IMG4	General radiography	A1	Measurement and assessment of system performance, periodic QC of general radiography installations and equipment		

Diagnostic Radiology & MRI						
Module	**Module No.**	**Module Description**	**Activity Number**	**Activity**	**Date of Completion**	**Signature of Supervisor**
	IMG4	Conventional and digital fluoroscopy	A1	Measurement and assessment of system performance, periodic QC of simple fluoroscopic systems.		
	IMG4		A2	QC of complex fluoroscopic / angiographic systems		
	IMG5	Computed radiography and digital radiography	A1	Measurement and assessment of system performance, periodic QC for computed and digital radiography systems		
	IMG6	Mammography	A1	Measurement and assessment of system performance, periodic QC of conventional (screen film) systems.		
	IMG6		A2	Measurement and assessment of system performance, periodic QC of digital systems		
	IMG7	Computed tomography	A1	Measurement and assessment of		

Diagnostic Radiology & MRI						
Module	**Module No.**	**Module Description**	**Activity Number**	**Activity**	**Date of Completion**	**Signature of Supervisor**
				system performance, periodic QC of axial systems		
	IMG7		A2	Measurement and assessment of system performance, periodic QC of helical systems and MDCT		
	IMG8	Ultrasound	A1	Measurement and assessment of system performance, periodic QC of ultrasound systems		
	IMG9	Dental radiography	A1	Measurement and assessment of system performance, periodic QC		
	IMG9	Display and printing devices and viewing conditions	A1	Measurement and assessment of system performance, periodic QC of display and printing devices.		
	IMG9		A2	Evaluation of viewing conditions.		
Radiation protection and safety.	IMG10	Design of a facility	A1	International and local standards,		

Diagnostic Radiology & MRI						
Module	**Module No.**	**Module Description**	**Activity Number**	**Activity**	**Date of Completion**	**Signature of Supervisor**
				safety review, surrounding structures, dose and risk assessment, expansion needs, workflow and efficiency		
	IMG10		A2	Calculation of shielding barriers		
	IMG10		A3	Verifying shielding		
	IMG10		A4	Calculations using survey instruments		
	IMG11	Radiation hazard assessment	A1	Hazard assessment of facilities and radiological procedures		
	IMG12	Personnel dosimetry	A1	Methods for measuring personal dose		
	IMG12		A2	Operational use of personal dosimeters		
	IMG13	Unintended and accidental exposure in diagnostic radiology	A1	Respond to an unintended or accidental exposure occurring in a radiology		

Diagnostic Radiology & MRI						
Module	**Module No.**	**Module Description**	**Activity Number**	**Activity**	**Date of Completion**	**Signature of Supervisor**
				department affecting staff, patients or members of the public.		
Dosimetry, instrumentation and calibration.	IMG14	Ionising radiation dosimetry and principles of measurement	A1	Dose measurements and uncertainties in clinical practice		
Patient dose audit.	IMG15	Dose Assessment	A1	Dosimetric principles Concept of diagnostic reference levels.		
	IMG15		A2	Patient dose surveys		
	IMG16	Patient Dose Audit	A1	Dosimetry of adult and paediatric patients,		
	IMG17	Foetal dose estimation	A1	Foetal dosimetry		
Technology management in diagnostic radiology.	IMG18	Tender and procurement process	A1	The ability to prepare the specifications and acquire suitable equipment through a tendering process		
	IMG18	Quality management of systems in radiology	A1	To develop an understanding of the principal requirements and elements for a quality management system in		

Diagnostic Radiology & MRI						
Module	**Module No.**	**Module Description**	**Activity Number**	**Activity**	**Date of Completion**	**Signature of Supervisor**
				diagnostic radiology.		
	IMG18	Acceptance Testing / Commissioning	A1	Understanding of the concept and principles of acceptance and commissioning of equipment.		
	IMG18	Routine testing / Quality control	A1	Understanding of the methods for the clinical implementation and supervision of a quality control programme		
	IMG18	Imaging informatics	A1	Skills to practice basic imaging informatics in digital imaging environments.		

Others (Please Specify: .....)				
Week No.	**Dates**		**Description**	**Supervisor Signature**
	From (DD/MM/YYYY)	**To (DD/MM/YYYY)**		
Week 1				
Week 2				

5.13.4 Seminars, Case Presentations & Research

Date	**Topic**	**Type (Seminar/Case/QA)**	**Duration**	**Faculty / Evaluator**	**Remarks**

5.13.5 Supervisor's Monthly Feedback

Month	Technical Skill	Professional Conduct	Documentation	Initiative	Comments / Signature

5.13.6 Evaluation – Radiation Oncology (30 Weeks of posting)

Area	Maximum Marks	Marks Obtained	Remarks
Knowledge and Skills Based on Modules	40		
Treatment Planning Skills	15		
QA & Dosimetry Skills	15		
Documentation & Record-Keeping	10		
Professionalism / Team Interaction	10		
Viva / Oral Examination	10		
Total	**100**		

5.13.7 Evaluation – Nuclear Medicine (10 Weeks of posting)

Area	Maximum Marks	Marks Obtained	Remarks
Knowledge and Skills Based on Modules	20		
QA & Dosimetry Skills	15		
Documentation & Record-Keeping	5		
Professionalism / Team Interaction	5		
Viva / Oral Examination	5		
Total	**50**		

5.13.8 Evaluation – Diagnostic Radiology , MRI & Others (6+2 Weeks of posting)

Area	Maximum Marks	Marks Obtained	Remarks
Knowledge and Skills Based on Modules	20		
QA & Dosimetry Skills	15		
Documentation & Record-Keeping	5		
Professionalism / Team Interaction	5		
Viva / Oral Examination	5		
Total	**50**		

5.14 Residency Exit Evaluation:

The supervisor will assess the above points either with the help of members of the hospital team or with external evaluators.

The candidate must achieve a minimum of 50% in each module and an overall score of at least 60% to successfully complete the residency program. If the candidate does not meet these criteria, the supervisor may extend the residency program for up to two months.

Upon successful evaluation of the student, the supervisor will submit a formal recommendation to the college/university in the prescribed format confirming that the candidate has satisfactorily completed the residency.

5.15 Instructions for Filling the Logbook

- A copy of the prescribed Residency Logbook, in the exact format specified within this document, duly incorporating the details of the University/college/Institute and the Residency Host Institution, shall be provided to each student prior to the commencement of the residency period.
- It shall be the responsibility of the admitting University/college/Institute, in coordination with the host institution, to ensure that every resident is issued an official copy of the Logbook at the outset of their clinical posting. The Logbook shall serve as the primary record of training activities, competencies acquired, and assessments performed throughout the residency.
- The description within the worksheet shall include any learning activities performed in that week, codes of modules completed that week.

5.16 Final Recommendation for Award of the degree

- Upon successful completion of the Residency Program, each resident shall submit a duly completed logbook. The logbook must be verified and signed by the designated Supervisor. Based on the resident's final cumulative score and overall fulfilment of programme requirements, the Program Director shall forward a formal recommendation to the degree-awarding institute for issuance of the Course Completion Certificate or Degree Certificate.
- In instances where the issuance of the Degree Certificate is delayed by the awarding institute, the resident shall be provided with a Provisional Course Completion Certificate, enabling them to proceed with professional engagements and regulatory requirements with NCAHP & AERB.

5.17 Award of the degree and Registration

Residents who have successfully completed all components of the Residency Program shall be deemed eligible to undertake professional duties as a Medical Physicist, subject to fulfillment of the following mandatory criteria:

1. Registration with the National Commission for Allied and Healthcare Professions (NCAHP) as a Healthcare Professional.
2. Registration as a Radiation Professional with the Atomic Energy Regulatory Board (AERB).

These regulatory requirements may also be completed after the professional has joined an institution as a Medical Physicist; however, the individual must ensure timely compliance to maintain professional validity in accordance with national regulations time to time.

NATIONAL COMMISSION FOR ALLIED AND HEALTHCARE PROFESSIONS
स्वास्थ्यम् सर्वार्थसाधनम्
NCAHP
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Chapter 6

Regulatory Framework for the Ph.D. Degree in Medical Physics

6.0. Institutional Regulations & Minimum Standards for Award of Ph.D. Degree in Medical Physics

(to be adopted by Universities / Higher Education Institution (HEIs) offering Ph.D. in Medical Physics)

6.1. Discipline-Specific Scope and Objectives for Ph.D. in Medical Physics

Purpose

The doctoral education in Medical Physics is aimed at preparing scholars who will contribute to both development and application of knowledge in the field of Medical Physics, including radiation physics, imaging physics, radiation therapy, dosimetry, nuclear medicine physics, biomedical instrumentation and allied areas, to enhance quality of research, clinical practice, education and dissemination of knowledge.

These regulations are intended to ensure that the Ph.D. programme in Medical Physics is rigorous, transparent, and aligned with national minimum standards (such as UGC's "University Grants Commission (Minimum Standards and Procedures for Award of Ph.D. Degree) Regulations, 2022and tailored to the specific requirements of the Medical Physics discipline. Institutions may frame their own ordinances/Statutes/Regulations incorporating these provisions and any additional discipline-specific norms as approved by the governing body

Objectives

By the end of the Ph.D. programme a scholar in Medical Physics will be able to:

1. Conduct original research aimed at advancing understanding in Medical Physics (for example: development of Artificial Intelligence based techniques for ease of radiotherapy, novel imaging modalities, dosimetric techniques, radiation therapy planning, Monte Carlo modelling, radiation protection).
2. Contribute new knowledge to the field of Medical or Radiation Physics through experimentation, modelling, data analysis, and clinical/industrial applications.
3. Translate scientific findings into improved diagnostic, therapeutic and radiation safety protocols in healthcare settings.
4. Develop innovative methodologies, techniques or technologies for improved patient care, medical imaging, radiation therapy, and radiation protection.
5. Collaborate with experts from multi-disciplinary domains (e.g., physics, engineering, radiology, oncology, biomedical sciences) to gain comprehensive understanding of medical physics science.
6. Publish research findings in peer-reviewed, only Hybrid/non-paid open access journals and present at national/international conferences to contribute to the broader scientific community and advance the field.

7. Acquire advanced skills in research methodology, data/statistical analysis, critical thinking, scientific communication and technical writing, preparing for careers in academia, research institutions, healthcare industry, regulatory bodies or radiation protection agencies.

6.2. Applicability

These regulations apply to

- Every University established or incorporated by or under a Central Act, a Provincial Act or a State Act;
- Every Institution deemed to be a University under Section 3 of the University Grants Commission (UGC) Act, 1956;
- Every degree-granting autonomous college and every affiliated college allowed to offer Ph.D. programmes in Medical Physics;
- Provided that the institution is recognized/approved by the relevant statutory authority (for example, professional/health sciences regulatory body) to conduct research in Medical Physics.

6.3. Eligibility Criteria for Admission to the Ph.D. Programme in Medical Physics

Candidates for admission to the Ph.D. programme in Medical Physics shall have successfully completed:

- A regular on-campus Master's degree (2 years) in Medical Physics/Radiological Physics or Post M.Sc (Physics)+Diploma in Radiological Physics after a regular Bachelor's degree in Physics
- The candidate must have obtained at least 55% marks in aggregate or its equivalent grade in a point scale wherever grading system is followed in the Master's degree or equivalent qualification from a foreign educational institution accredited by an assessment and accreditation agency approved / recognized or authorized by an authority established or incorporated under law in its home country to assess/accredit or assure quality and standards of the educational institution.
- 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 Sections (EWS) and other categories of candidates as per the decision of the Commission from time to time. Note: The eligibility marks of 55% (or equivalent grade) and the relaxation are permissible based only on the qualifying marks without including grace-mark procedures, if any.
- A relaxation of 0.5 score in CGPA or equivalent grade may be allowed for those belonging to SC/ST/OBC (non-creamy layer)/Differently-Abled/EWS etc., as per decision of the Commission from time to time.

Entrance eligibility

- All universities shall admit Ph.D. scholars through a National Eligibility Test (NET) or National Entrance Test or an Entrance test conducted by the relevant statutory professional body (if any) or by the University/HEI, as per norms of the University offering PhD admissions.
- The institution must adopt the entrance test and interview process in line with national norms.

6.4. Duration of the Programme

- Full-time Ph.D. programme: Minimum duration of three (3) years from the date of Ph.D. registration, including coursework; maximum duration of six (6) years from the date of admission to the Ph.D. programme. Extensions beyond above limits shall be governed by the relevant clauses in statutes/ordinances of the institution, but typically not beyond two (2) additional years.
- Female Ph.D. scholars may be provided maternity/child-care leave up to 240 days if required; during this period they may be relieved from duties such as coursework.
- Part-time Ph.D. programme: Minimum duration of four (4) years, including coursework; maximum of six (6) years.
- Part-time candidate should complete research work and submit the thesis within four years from the date of provisional registration, subject to usual extension up to six years.
- Under extraordinary circumstances (such as illness, official deputation, relocation etc.), the candidate may apply (via Research Advisory Committee and approved by University) for an extension beyond the maximum period. The decision of the Vice-Chancellor or designated university authority shall be final.
- Mode restriction: No HEI or research institution of the Central Government or a State Government shall conduct Ph.D. programmes through distance and/or online mode for Medical Physics (given the experimental/practical nature of the discipline).

Ph.D. through Part-time Mode:

- Ph.D. programmes 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. programme 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. Notwithstanding 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. programmes through distance and/or online mode.

6.5. Procedure for Admission

- The admission shall be based on the criteria notified by the Institution/University, keeping in view the guidelines/norms issued by UGC (or other regulatory bodies) and taking into account the reservation policy of the Central/State Government from time to time.
- Entrance Test: The syllabus shall consist of 50% Research Methodology & Biostatistics (or relevant quantitative methods for Medical Physics) and 50% subject-specific domain (Medical Physics / Radiation Physics / Radiological Physics) knowledge.
- Students who secure at least 50% marks in the entrance test are eligible to be called for the interview/viva-voce. A relaxation of 5% may be allowed for reserved category candidates.
- The institution may decide the number of eligible students to be called for the interview based on available Ph.D. seats.
- For selection (in case of university-conducted entrance), a weightage of 70% for the entrance test and 30% for performance in the interview/viva-voce shall be given.
- The HEI/University shall:
    - Notify in advance, via its website, a prospectus specifying number of seats, criteria for admission, procedure for admission, and other relevant information.
    - Adhere to the National/State-level reservation policy, as applicable.
- The HEI shall maintain on its website a list of Ph.D. supervisors (with name, designation, department/school/centre) and the details of registered Ph.D. scholars (name of scholar, topic of research, date of admission) updated each academic year.

6.6. Guidelines to Institution

- The institution shall publicise Ph.D. admission notifications sufficiently in advance.
- The institution shall maintain records of registered scholars, research topics, guide allocations, progress reports, publications and annual updates.
- The institution must ensure that research involving radiation, imaging devices or human/clinical subjects is carried out only after appropriate approvals (e.g., Institutional Ethics Committee, Radiation Safety Committee, Institutional Review Board).
- The institution shall ensure availability of financial provisions, library access, computing facilities, research instrumentation and workshops required for Medical Physics research.
- The Supervisors and scholars shall abide by research integrity norms, plagiarism checking, data management standards, safety protocols and professional ethics.
- The institution must ensure that the Ph.D. programme is full-time (for full-time category) with the scholar physically available on campus for requisite period of research, experiments and data collection.

6.7. Eligibility Criteria for Guide / Research Supervisor & Co-Guide / Co-Supervisor

- Regular faculty members working at the institution (or recognized by the University) who possess the basic qualification of Medical Physicist as prescribed by NCAHP/AERB, along with a Ph.D. in Medical Physics or Ph.D. in Radiation Physics or Ph.D. in Allied Physics, with a minimum of ten (10) years of teaching experience in an accredited institution, and having at least five (5) research publications as first author in peer-reviewed and refereed indexed journals (UGC-CARE List / Scopus / Web of Science), shall be eligible to act as Research Supervisor.
- Only full-time regular teachers of the University/College concerned can act as Research Supervisor. Adjunct faculty are not permitted to act as Research Supervisor (they may act only as co-supervisors).
- In case of formal institutional collaboration (based on MoUs) the University/College may approve a faculty member with similar eligibility as Co-guide/Co-Supervisor for a Ph.D. candidate from the collaborating institution.
- For interdisciplinary topics: The Department may appoint a Research Supervisor (from the Department) and a Co-Supervisor (from outside the Department/Faculty/College/University) as agreed by the institutions.

- In case of non-availability of a Co-Supervisor as per above, a non-teaching Medical Physicist who possess the basic qualification of Medical Physicist as prescribed by NCAHP/AERB, (e.g., from a clinical setting) with Ph.D., minimum 15 years of clinical/research experience and at least five research publications (first author) in peer-reviewed indexed journals may be considered as Co-Supervisor (valid only for a specified period, e.g., next 5 years).
- The allocation of Supervisor for a selected scholar shall be decided by the Department/School depending on: number of scholars per Supervisor, specialization of Supervisors, research interests of the scholar.
- A Ph.D. awarded under supervision of a faculty not employed by the University/College institute would be in violation of these Regulations.

Number of Ph.D. Scholars permissible per Supervisor

- A Professor acting as Research Supervisor may guide up to eight (08) Ph.D. scholars at any given point, including up to 2 international Ph.D. scholars on a supernumerary basis.
- An Associate Professor may guide up to **six (06)**Ph.D. scholars (including co-supervision).
- An Assistant Professor / Lecturer may guide up to four (04) Ph.D. scholars. One additional scholar may be allotted (above the limit) if the Supervisor is implementing a major sponsored research project.
- Each Research Supervisor/Co-Supervisor can guide maximum two international students on a supernumerary basis. At any point, total number of candidates under a Research Supervisor shall not exceed the prescribed number including co-supervision.
- The Research Supervisor must declare the number of registered Ph.D. scholars under them periodically to the University/College. Multiple registrations via different affiliations should not be used to circumvent the limit.
- University teachers after superannuation, if re-appointed (as contract/honorary/emeritus/distinguished) may continue as Research Supervisors up to age 70, subject to University's decision on research track record and fitness.
- Faculty members with less than three years of service remaining before superannuation shall not be allowed to take new research scholars. They may continue supervising existing Ph.D. scholars until superannuation and act as Co-supervisor after superannuation up to age 70.
- Change of Supervisor / Co-Supervisor: May be allowed within less than two years of registration. In extraordinary circumstances requiring change after two years, the scholar and supervisor/co-supervisor must place facts before Research Advisory Committee (RAC) for opinion. The decision of RAC is final.
- Registration of Supervisors/Co-Supervisors: The University/HEI must obtain and maintain a list of recognized Supervisors/Co-Supervisors as per minimum standards.

6.8. Admission of International Students

- International candidates applying for Ph.D. in Medical Physics must have a relevant Master's degree (2 years regular on-campus) in Medical Physics or equivalent from India or international university. If from an international institution, the qualification must be accredited by an approved assessment/accreditation agency in its home country or be recognized by the University equivalence process.
- Each Supervisor may guide up to two (02) international research scholars on a supernumerary basis above the prescribed limit.
- Universities/HEIs may decide their own selection procedure (entrance test/interview) for international students, keeping in view guidelines/norms issued by statutory/regulatory bodies.

6.9. Coursework: Credit Requirements, Number, Duration, Syllabus, Minimum Standards for Completion

1. The credit requirement for the Ph.D. coursework in Medical Physics is a minimum of 12 credits, including:
    - Research & Publication Ethics (as notified by UGC)
    - Research Methodology & Quantitative Methods for Medical Physics
    - Domain-specific advanced topic: "Advances in Medical Physics processes & practice" or equivalent.Example distribution:
    - Research Methodology & Biostatistics for Medical Physics – 4 credits
    - Research & Publication Ethics – 4 credits
    - Advances in Medical Physics Process & Practice – 4 credits – Additional course(s) may be recommended by RAC as part of credit requirement.
2. A Ph.D. scholar must obtain a minimum of 55% marks or equivalent grade in the UGC 10-point scale (or applicable grading scale) in the coursework to be eligible to continue in the programme and submit thesis.
3. 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. Scholars may be assigned 4–6 hours per week of teaching/research assistantship for tutorials, laboratory work or evaluations.

6.10. Research Advisory Committee (RAC) and its Functions

1. For each Ph.D. scholar there shall be a Research Advisory Committee (RAC) or equivalent body as defined in the Statutes/Ordinances of the HEI. The Research Supervisor shall be the Convener of the RAC. Other members shall satisfy the minimum eligibility for a Supervisor as specified in section 5.
2. The RAC shall have the following responsibilities:
    - To review the research proposal and finalize the research topic, study design and methodology.
    - To guide the scholar in developing the research, identify necessary courses, experiments, data collection methods etc.
    - To periodically review and assist in the progress of the scholar's work.
    - Every six (6) months, the scholar shall appear before the RAC to make a presentation and submit a brief report on progress. The RAC shall submit its recommendations, along with a copy of the progress report, to the HEI concerned; a copy also provided to the scholar.
3. The half-yearly progress report shall include:
    - Progress in literature review
    - New data acquired or theoretical background/techniques developed
    - Progress/standardization in research methodology
    - Discussion of the work done
4. If the candidate fails to submit two consecutive half-yearly progress reports in time, his/her provisional registration shall stand cancelled.
5. If progress is unsatisfactory, the RAC shall record reasons and suggest corrective measures. RAD shall provide three months' time for corrective measures. If the scholar fails to implement these, the RAC may recommend the cancellation of registration.

6.11. Evaluation and Assessment Methods; Minimum Standards for Award of Degree

- Upon satisfactory completion of coursework (and obtaining required grade/marks), the Ph.D. scholar shall undertake research and produce a draft dissertation/thesis.
- There may be requirement for at least two presentations in national/international conferences and at least two research publications of original work from the Ph.D. research work as first author in peer-reviewed & indexed journals (Scopus / PubMed / Web of Science) prior to submission of thesis - or the HEI may specify similarly while aligning with their discipline-specific norms.
- Number of publications – Mandatary – Two in Scopus/Web of Science indexed Hybrid or non-paid open access journals, with Ph.D. candidate as first author, with Guide and co-guide (if applicable) as co-author. Preferable: To have another two publications which may include multiple authors, also should be in hybrid/ non-paid open access journals.

- The Journals should be hybrid/non-paid journals, no publication in open access journals have a provision of article processing charges (APC) will be accepted for Ph.D. thesis submission.
- Before submission of thesis, the scholar shall make a presentation before the RAC of the HEI, which shall also be open to faculty and other research scholars.
- The HEI shall use well-developed software applications to detect plagiarism in the research work and ensure research integrity.
- The scholar shall submit the thesis for evaluation, along with: a) Undertaking from the scholar that there is no plagiarism and b) Certificate from the Research Supervisor attesting to originality of the thesis and that it has not been submitted for award of any other degree/diploma.
- The thesis shall be evaluated by the Research Supervisor and at least two external examiners who are experts in the field and not employed by the HEI concerned. Examiners should have a good publication record (e.g., minimum five publications as first author) in the field. Wherever possible, at least one external examiner should be from outside India.
- The viva-voce board shall consist of the Research Supervisor and at least one of the external examiners and may be conducted online. The viva-voce shall be open to the members of RAC, faculty members, research scholars and students.
- The viva-voce shall be conducted only if both external examiners recommend acceptance of the thesis after any corrections. If one examiner recommends rejection, the thesis shall be sent to an alternate external examiner. If alternate also recommends rejection, the thesis shall be rejected and the scholar declared ineligible for the award of Ph.D.
- The HEI concerned shall complete the entire evaluation process including declaration of viva-voce result within six (6) months from the date of submission of thesis.
- The HEI may frame appropriate rules/ordinances to operationalize these provisions.

6.12. Academic, Research, Administrative and Infrastructure Requirements for Offering Ph.D. in Medical Physics

- Institutions (Colleges/Inter-disciplinary Centres) providing postgraduate programmes in Medical Physics and/or allied disciplines may offer Ph.D. programmes provided they satisfy eligibility of Supervisors, required infrastructure, administrative support and research facilities.

- The institutions shall have:
    - There shall be a separate Department of Medical Physics / Radiological Physics / Radiation Physics for the purpose of enrolling research scholars and conducting the research degree programme.

- At least two faculty members with Ph.D. in Medical Physics (or Physics/allied) in the college, or two Ph.D.–qualified scientists in the research institution.
- Adequate infrastructure: research laboratories in Medical Physics (radiation measurement labs, dosimetry, imaging physics, computational modelling), library resources, access to clinical/radiological facilities (where applicable).
- Administrative support: Office for Research, Ethics committee, access to statistical and computing facilities, appropriate safety & radiation regulatory compliance.
- Institutional Ethics Committee (IEC) / Institutional Radiation Safety Committee as relevant, registered under appropriate authority (e.g., national radiation regulatory body) or with recognized status.

- The HEI shall ensure that all Supervisors/Co-Supervisors, research scholars and research project activities abide by radiation safety, ethical standards and regulatory/statutory requirements for Medical Physics research in clinical and applied contexts.

6.13. Issuing a Provisional certificate

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

6.14. Award of Ph.D. degrees

The degree shall be awarded by the University after the candidate successfully completes the Viva-Voce examination. The Chairperson shall consolidate the recommendations for the award of the Ph.D. degree based on the following:

- The reports of the examiners who adjudicated the thesis.
- The evaluation of the candidate's performance in the Viva-Voce examination.

The Chairperson shall forward the consolidated and individual reports, along with the recommendation, to the University. Based on these reports, the University shall award the Ph.D. degree after obtaining the approval of the Vice-Chancellor.

6.15. Depository with INFLIBNET/Thesis Repository

Following successful completion of evaluation and before announcement of award of Ph.D. degree(s), the HEI shall submit an electronic copy of the Ph.D. thesis to the INFLIBNET Centre or equivalent national digital repository (such as Shodhganga) for hosting so as to make it accessible to all HEIs and research institutions.[23]

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