M. Sc. Medical Physics

Syllabus

(With effect from the academic year 2026- 2027 onwards)

Program Code: MPHA

DEPARTMENT OF MEDICAL PHYSICS

SCHOOL OF PHYSICAL SCIENCES

BHARATHIAR UNIVERSITY

COIMBATORE 641 046, INDIA

(A State University, Accredited with "A++" Grade by NAAC)

Medical Physics Curriculum

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.

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.

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 in accordance with the standards and guidelines prescribed by the **National Commission for Allied and Healthcare Professions (NCAHP), Ministry of Health and Family Welfare, Government of India**.

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.

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.

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.

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

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.

Entrance & Age Criteria

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

(i) eligibility criteria as mentioned above, and

(ii) 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.

(iii) 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.

Duration and Academic Structure Pattern

The M.Sc. Medical Physics programme shall be over three academic years comprising four semesters (two academic years) followed by one year of mandatory Residency Training.

Medium of Instruction

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

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

Attendance

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

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.

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.

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.

Migration/Transfer

Allowed as per the University norms.

Residency

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

Scheme of Examination

M.Sc., Medical Physics Program

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
	Elective-1	Programming, Data Science, and Computational Methods for Medical Physics	3	2	1	0	25	75	100
		Health Technology Assessment							
	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

	Elective-II	Artificial Intelligence in Medical Physics	3	2	1	0	25	75	100
		Materials for Radiological applications							
	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	3	2	1	0	25	75	100
		Small Field Dosimetry and Calibration Standards							
	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
	Elective-IV	Dosimetric Audit and Clinical Trials in Medical Physics	3	2	1	0	25	75	100
		Montecarlo Techniques in Dosimetry							
	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	2	0	0	4	50	-	50
		Total	**22**	**10**	**3**	**18**	**200**	**300**	**500**
		Grand Total	**100**	**59**	**21**	**40**	**775**	**1875**	**2650**

CIA- Continuous Internal Assessment **ESE- End Semester Examination**

THIRD YEAR

Residency Credits (32)

FIRST YEAR

FIRST SEMESTER

FIRST SEMESTER								
Course Code	Title of the Course	Credits	Hours/ Week				Maximum Marks	
			Theory	Tutorial	Practical	CIA	ESE	Total
	Nuclear and Radiation Physics	**4**	**3**	**1**	**0**	**25**	**75**	**100**
	Non-Ionizing 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 **Health Technology Assessment**	**3**	**2**	**1**	**0**	**25**	**75**	**100**
	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			I YEAR - I SEMESTER					
Subject Code	**Subject Name**	**Category**	**L**	**T**	**P**	**Credits**	**Inst. Hours**	**Marks**
	Nuclear and Radiation Physics	Core	3	1	0	4	60	100

Pre-Requisites
Modern Physics, Atomic and Nuclear Physics, Mathematical Physics – UG level
Learning 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.

UNITS	**Course Details**
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.
TEXT BOOKS & REFERENCE BOOKS	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, WileyVCH, 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.

COURSE OUTCOMES:

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

CO1	Understand nuclear structure, decay mechanisms, and radioactivity principles relevant to radiological sciences.	K1, K2
CO2	Analyze photon, charged particle, and neutron interactions with matter quantitatively.	**K2, K3**
CO3	Compute radiation quantities, dosimetric parameters, and apply appropriate units and relationships.	**K3**
CO4	Identify and evaluate suitable radiation sources used in medical diagnosis and therapy.	**K2, K5**
CO5	Develop analytical and computational proficiency in radiological physics problem-solving.	**K3 ,K4, K5**
K1 - Remember; K2 – Understand; K3 - Apply; K4 - Analyze; K5 – Evaluate		

MAPPING WITH PROGRAM OUTCOMES:

Map course outcomes **(CO)** for each course with program outcomes **(PO)** and program specific outcomes **(PSO)** in the 3-point scale of STRONG (3), MEDIUM (2) and LOW (1)**.**

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	3	2	1	1	3	2	1	1	1	1
CO2	3	3	3	2	3	2	1	1	2	2
CO3	3	2	3	2	3	2	1	1	1	1
CO4	3	3	2	3	3	2	1	1	2	2
CO5	2	2	2	3	3	3	2	2	2	3

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8	PSO9	PSO10
CO1	3	3	2	2	2	1	2	1	1	2
CO2	3	3	3	2	2	2	2	1	2	2
CO3	3	3	2	3	2	2	3	2	3	2
CO4	3	2	2	3	3	2	3	2	2	2
CO5	2	2	3	3	3	3	3	2	3	3

Core 2 - Non-Ionizing Radiation Physics	I YEAR - I SEMESTER

Subject Code	Subject Name	Category	L	T	P	Credits	Inst. Hours	Marks
	Non-Ionizing Radiation Physics in Medicine	Core	3	0	0	3	45	100

Pre-Requisites
Modern Physics, Atomic and Molecular Physics, Optics and Laser Physics –UG level
Learning Objectives
• Gain broad knowledge on the Interaction of Non-Ionizing Radiation with biological systems. • Understand the Applications of lasers 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 theranostic and biosensor technologies. • Grasp the Application of radio waves and microwaves in medicine, including thermography and hyperthermia.

UNITS	Course Details
UNIT I: LASERS AND TISSUE OPTICS (9hrs)	**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: CO2, 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 hrs)	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 hrs)	Overview of NIRP-Study of non-ionizing 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 hrs)	**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 nano preparations – 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 hrs)	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.

TEXT BOOKS & REFERENCE BOOKS	• 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.

COURSE OUTCOMES:

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

CO1	Various sources of Non-Ionizing Radiations and their interaction mechanism.	K1, K2
CO2	The type of laser to be employed for various applications and the fundamentals of optical light microscopy and electron microscopy.	**K2, K3**

CO3	Tissue Optical Properties and apply them for the disease diagnosis and therapy, including current optical imaging technologies and their application in research.	**K3, K4**
CO4	Students will be able to understand the integration of diagnostic and therapeutic strategies in oncology, and biosensors for clinical use and their safety.	**K2, K4**
CO5	The use of thermography and its application in Medicine, as well as the principles and applications of Radio Frequency and Microwaves in medicine.	**K3, K4, K5**
K1 - Remember; K2 – Understand; K3 - Apply; K4 - Analyze; K5 – Evaluate		

MAPPING WITH PROGRAM OUTCOMES:

Map course outcomes **(CO)** for each course with program outcomes **(PO)** and program specific outcomes **(PSO)** in the 3-point scale of STRONG (3), MEDIUM (2) and LOW (1)**.**

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**
CO1	3	2	1	1	2	1	1	1	1	1
CO2	3	3	1	2	3	2	1	1	2	2
CO3	3	3	2	3	3	2	2	1	2	2
CO4	3	2	2	3	3	3	2	2	2	3
CO5	2	2	2	2	3	3	3	2	3	3

	PSO1	**PSO2**	**PSO3**	**PSO4**	**PSO5**	**PSO6**	**PSO7**	**PSO8**	**PSO9**	**PSO10**
CO1	3	3	2	1	2	1	1	1	1	1
CO2	3	3	2	2	2	1	1	1	2	1
CO3	3	3	3	2	3	2	3	2	1	1
CO4	3	2	3	3	3	2	3	2	1	2
CO5	3	3	2	3	2	2	3	2	2	2

Core 3- Medical Electronics and Instrumentation	I YEAR - I SEMESTER

Subject Code	Subject Name	Category	L	T	P	Credits	Inst. Hours	Marks
	Medical Electronics and Instrumentation	Core	3	1	0	4	60	100

Pre-Requisites
Electronics , Digital Electronics , Basic Instrumentation–UG level
Learning 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.

UNITS	Course Details
UNIT I: Fundamentals of Analog and Digital	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

Electronics	to programmable logic devices (PLD, FPGA) and their applications in medical electronics.
UNIT II: Microprocessors, Microcontrollers and Embedded Systems	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	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	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	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.
TEXT BOOKS & REFERENCE BOOKS	1. T.L. Floyd, Electronic Devices (10th edition), Pearson Education Inc., 2017. 2. R.F. Coughlin and F.F. Driscoll, Operational Amplifiers and Linear Integrated Circuits (6th edition), Pearson Education Inc., 2001. 3. T.L. Floyd, Digital Fundamentals (11th edition), Pearson Education Inc., 2015. 4. Khandpur, Handbook of Biomedical Instrumentation (3rd edition), McGraw Hill Education, 2014.

	5. S. Brown and Z. Vranesic, Fundamentals of Digital Logic with Verilog Design (3rd edition), Tata McGraw-Hill, 2013. 6. H. Skalsi, Electronic Instrumentation (3rd edition), Tata McGraw-Hill, 2012. 7. Leslie Cromwell, Fred J. Weibell, Erich A. Pfeiffer, Biomedical Instrumentation and Measurements, Prentice Hall, 1990. 8. M. Arumugam, Biomedical Instrumentation, Anuradha Publishing Co., 2004.

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.	K1, K2
CO2	Design and analyze basic microprocessor and microcontroller-based circuits for healthcare applications.	**K2, K3**
CO3	Evaluate and implement regulated and noise-free power supply systems for medical and nuclear instrumentation.	**K3**
CO4	Analyze the operation and interfacing of radiation detectors and biomedical sensors with electronic circuits.	**K4, K5**
CO5	Apply knowledge of modern biomedical technologies such as IoT, robotics, and AI in medical instrumentation and patient monitoring systems. Electronics and Biomedical Instrumentation	**K4, K5**
K1 - Remember; K2 – Understand; K3 - Apply; K4 - Analyze; K5 – Evaluate		

MAPPING WITH PROGRAM OUTCOMES:

Map course outcomes **(CO)** for each course with program outcomes **(PO)** and program specific outcomes **(PSO)** in the 3-point scale of STRONG (3), MEDIUM (2) and LOW (1)**.**

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**
CO1	3	2	1	1	3	2	1	1	1	1
CO2	3	3	3	2	3	1	1	1	2	2
CO3	3	2	3	2	3	2	1	1	1	1
CO4	3	3	2	3	3	2	1	1	2	2
CO5	2	2	2	3	3	3	2	2	2	3

	PSO1	**PSO2**	**PSO3**	**PSO4**	**PSO5**	**PSO6**	**PSO7**	**PSO8**	**PSO9**	**PSO10**
CO1	3	3	2	2	2	1	2	1	1	2
CO2	3	3	3	2	2	2	2	1	2	2
CO3	3	3	2	3	2	2	3	2	3	2
CO4	3	2	2	3	3	2	3	2	2	2
CO5	2	2	3	3	3	3	3	2	3	3

Core 4 - Anatomy, Physiology, Tumor Pathology, and Genetics	I YEAR - I SEMESTER

Subject Code	Subject Name	Category	L	T	P	Credits	Inst. Hours	Marks
	Anatomy, Physiology, Tumor Pathology, and Genetics	Core	0	4	0	4	60	100

Pre-Requisites
Anatomy-XII level
Learning 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.

UNITS	Course Details
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.

TEXT BOOKS & REFERENCE BOOKS	• 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.

COURSE OUTCOMES:

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

CO1	Understand human anatomical structures and physiological mechanisms relevant to medical physics.	K1, K2
CO2	Identify normal and pathological anatomy using radiological images and sectional anatomy.	**K2, K3**
CO3	Explain the principles of genetics and their role in tumour initiation and progression.	**K2,K4**
CO4	Correlate clinical oncology principles with imaging and therapeutic applications.	**K3, K4**
CO5	Acquire an integrated understanding of organ-specific cancers, staging, and treatment modalities.	**K2, K4, K5**
K1 - Remember; K2 – Understand; K3 - Apply; K4 - Analyze; K5 – Evaluate		

MAPPING WITH PROGRAM OUTCOMES:

Map course outcomes **(CO)** for each course with program outcomes **(PO)** and program specific outcomes **(PSO)** in the 3-point scale of STRONG (3), MEDIUM (2) and LOW (1)**.**

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**
CO1	3	2	1	1	2	1	1	1	1	1
CO2	3	3	2	2	3	2	1	1	2	2
CO3	3	2	3	2	3	2	2	1	2	2
CO4	3	3	3	3	3	2	2	2	3	2
CO5	3	3	2	3	3	2	2	2	3	3

	PSO1	**PSO2**	**PSO3**	**PSO4**	**PSO5**	**PSO6**	**PSO7**	**PSO8**	**PSO9**	**PSO10**
CO1	3	3	2	1	2	1	1	1	1	1
CO2	3	3	2	2	3	2	1	1	2	2
CO3	3	2	3	2	3	2	2	1	2	2
CO4	3	3	3	3	3	2	3	2	3	2
CO5	3	3	2	3	3	3	3	2	3	3

Core 5- Solid State Physics and Radiation Detectors	I YEAR - I SEMESTER

Subject Code	Subject Name	Category	L	T	P	Credits	Inst. Hours	Marks
	Solid State Physics and Radiation Detectors	Core	3	1	0	4	60	100

Pre-Requisites
Solid State Physics, Semiconductor Physics –UG level
Learning 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.

UNITS	Course Details
UNIT I: **Solid State Physics Fundamentals for Detector Materials**	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**	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**	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**	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**	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.

TEXT BOOKS & REFERENCE BOOKS	1. C. Kittel, Introduction to Solid State Physics, 8th Ed., Wiley, 2005. 2. G. F. Knoll, Radiation Detection and Measurement, 4th Ed., Wiley, 2010. 3. F. H. Attix, Introduction to Radiological Physics and Radiation Dosimetry, Wiley-VCH, 2008. 4. S. R. Cherry, J. A. Sorenson, and M. E. Phelps, Physics in Nuclear Medicine, Elsevier, 2012. 5. Glenn F. Knoll, Practical Gamma-Ray Spectrometry, Wiley, 2008. 6. Price W.J. Nuclear Radiation Detection. 7. Stepanor B.I. Theory of Luminescence 8. Glenn F Knoll. Radiation Detection & Measurement. 9. Albert Paul Malvino. Electronics Principles 10. Robert L. Boylestad. Electronics Devices and Circuit Theory 11. Paul – Horowitz. Art of Electronics 12. Greiner R.A. Semiconductor Devices & Application 13. Crawford R.H. MOSFET in Circuit Design 14. IAEA, Radiation Oncology Physics: A Handbook for Teachers and Students, Vienna, 2005. 15. IAEA Safety Reports and TECDOCs on calibration and instrumentation. 16. ISO 4037 – X and gamma reference radiation calibration standards. 17. AERB Codes and Safety Guides on radiation instrumentation and monitoring. 18. Recent publications on OSL, DIS, diamond, and radiochromic detectors in medical dosimetry.

COURSE OUTCOMES:

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

CO1	Explain solid-state physics principles governing the operation of detector materials.	K1, K2
CO2	Describe the physical principles, modes, and characteristics of various radiation detectors.	**K2**

CO3	Apply radiation detection techniques in measurement, monitoring, and clinical instrumentation.	**K2, K3**
CO4	Perform calibration and quality assurance procedures for dosimetry and monitoring systems.	**K3, K4**
CO5	Correlate material properties and defects with detector response and dosimetric performance	**K4, K5**
K1 - Remember; K2 – Understand; K3 - Apply; K4 - Analyze; K5 – Evaluate		

MAPPING WITH PROGRAM OUTCOMES:

Map course outcomes **(CO)** for each course with program outcomes **(PO)** and program specific outcomes **(PSO)** in the 3-point scale of STRONG (3), MEDIUM (2) and LOW (1)**.**

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	3	2	1	1	2	1	1	2	2	1
CO2	3	2	1	2	3	1	1	2	2	2
CO3	3	3	2	2	3	2	1	1	3	2
CO4	3	3	2	3	3	3	2	2	1	1
CO5	3	3	2	3	2	2	2	3	2	3

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8	PSO9	PSO10
CO1	3	3	2	1	2	1	1	1	1	1
CO2	3	3	2	2	2	1	1	1	2	1
CO3	3	3	3	2	3	2	3	2	1	1
CO4	3	2	3	3	3	2	3	2	1	2
CO5	3	3	2	3	2	2	3	2	2	2

Elective 1.A: Programming, Data Science, and Computational Methods for Medical Physics	I YEAR - I SEMESTER

Subject Code	Subject Name	Category	L	T	P	Credits	Inst. Hours	Marks
	Programming, Data Science, and Computational Methods for Medical Physics	Elective	2	1	0	3	45	100

Pre-Requisites
Computer Programming-XII or similar level
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

UNITS	Course Details
UNIT I: Programming Foundations in Python (6L + 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 (6L + 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 (6L + 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 (6L + 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 (6L + 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
TEXT BOOKS & REFERENCE BOOKS	• 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)

COURSE OUTCOMES:

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

CO1	Write modular, documented Python code and MATLAB scripts for medical physics tasks.	K1, K3
CO2	Load, clean and analyse complex datasets (time-series, QA logs, image metadata) and produce visualisations appropriate for medical physics	**K2, K3**

	research or QA.	
CO3	Apply filtering and segmentation methods to medical image data (DICOM) and interpret the results in a medical-physics context.	**K3,K4**
CO4	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.	**K4, K5**
CO5	Use MATLAB toolboxes effectively for medical image display, processing, analysis and basic machine-learning/fuzzy logic tasks; relate results to clinical/physics practice.	**K4, K5**
K1 - Remember; K2 – Understand; K3 - Apply; K4 - Analyze; K5 – Evaluate		

MAPPING WITH PROGRAM OUTCOMES:

Map course outcomes **(CO)** for each course with program outcomes **(PO)** and program specific outcomes **(PSO)** in the 3-point scale of STRONG (3), MEDIUM (2) and LOW (1)**.**

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**
CO1	3	3	2	2	2	1	1	2	3	1
CO2	3	3	2	3	2	1	1	2	3	1
CO3	3	3	3	3	3	3	2	2	3	2
CO4	3	3	3	3	3	3	2	2	2	2
CO5	3	3	3	3	2	3	3	2	2	3

	PSO1	**PSO2**	**PSO3**	**PSO4**	**PSO5**	**PSO6**	**PSO7**	**PSO8**	**PSO9**	**PSO10**
CO1	3	3	2	2	1	2	2	1	1	1
CO2	3	3	2	3	1	2	2	1	1	1
CO3	3	3	3	2	2	2	2	1	2	3
CO4	3	3	3	3	2	2	3	2	2	2
CO5	3	3	2	3	2	2	3	2	2	3

Elective 1. B: Health Technology Assessment (HTA)	**I YEAR - I SEMESTER**

Subject Code	**Subject Name**	**Category**	**L**	**T**	**P**	**Credits**	**Inst. Hours**	**Marks**
	Programming, Data Science, and Computational Methods for Medical Physics	**Elective**	3	0	0	3	45	100

Pre-Requisites
Computer Programming-XII or similar level
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 decisionmaking. • 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).

UNITS	**Course Details**
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
TEXT BOOKS & REFERENCE BOOKS	• 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

Learning Outcomes

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

CO1	Explain the concept, scope, and evolution of HTA globally and in India.	K1, K3
CO2	Describe the institutional framework and role of HTAIn in India	**K2, K3**
CO3	Demonstrate knowledge of HTA frameworks, processes, and stakeholder engagement.	**K3,K4**
CO4	Apply economic and clinical methods to assess technology value and interpret outcome data.	**K4, K5**
CO5	Analyze ethical, legal, and political dimensions and integrate HTA into health policy.	**K4, K5**
K1 - Remember; K2 – Understand; K3 - Apply; K4 - Analyze; K5 – Evaluate		

MAPPING WITH PROGRAM OUTCOMES:

Map course outcomes **(CO)** for each course with program outcomes **(PO)** and program specific outcomes **(PSO)** in the 3-point scale of STRONG (3), MEDIUM (2) and LOW (1)**.**

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**
CO1	3	3	2	2	2	1	1	2	3	1
CO2	3	3	2	3	2	1	1	2	3	1
CO3	3	3	3	3	3	3	2	2	3	2
CO4	3	3	3	3	3	3	2	2	2	2
CO5	3	3	3	3	2	3	3	2	2	3

	PSO1	**PSO2**	**PSO3**	**PSO4**	**PSO5**	**PSO6**	**PSO7**	**PSO8**	**PSO9**	**PSO10**
CO1	3	3	2	2	1	2	2	1	1	1
CO2	3	3	2	3	1	2	2	1	1	1
CO3	3	3	3	2	2	2	2	1	2	3
CO4	3	3	3	3	2	2	3	2	2	2
CO5	3	3	2	3	2	2	3	2	2	3

Core Lab 1 - Electronics and Radiation Instrumentation Lab	I YEAR – I SEMESTER

Subject Code	Subject Name	Category	L	T	P	Credits	Inst. Hours	Marks
	Electronics and Radiation Instrumentation Lab	Core	0	0	6	3	45	100

Pre-Requisites
Electronics- UG level
Learning 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 (5)** 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 (10)** 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 the Peak-to-Total (P/T) ratio (Npeak/Ntotal) and Peak-to-Compton (P/C) ratio (Npeak/NCompton) from the measured gamma-ray spectrum.
- 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 as a function of distance from a point source and verify that the intensity is inversely proportional to the square of the distance.
- 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 the practical range of beta particles and estimate the maximum beta energy (Emax) by extrapolation.
- 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 the Half Value Layer (HVL) and the linear attenuation coefficient (μ): HVL = ln(2)/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 Thermoluminescent 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

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

Additional References with Links

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

SECOND SEMESTER

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	I YEAR - II SEMESTER

Subject Code	Subject Name	Category	L	T	P	Credits	Inst. Hours	Marks
	Applied Mathematical Physics	Core	0	4	0	4	60	100

Pre-Requisites
Mathematical & Statistical Physics- UG level
Learning Objectives
• Understand numerical methods, error analysis, and their applications in medical physics problem-solving. • Learn probability, descriptive statistics, and statistical distributions for data interpretation in radiation measurements. • Apply statistical techniques for radiation data analysis, regression, correlation, and hypothesis testing. • Analyze counting statistics, detector performance, and uncertainty evaluation in nuclear measurements. • Explore vectors, matrices, eigenvalue problems, and partial differential equations for modeling physical phenomena relevant to medical physics.

UNITS	Course Details
UNIT I: Vectors, Matrices & Eigen Value-Problems	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**	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**	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 **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: **Probability,**	Probability concepts – Addition and multiplication laws – Conditional probability – Population and samples – Data collection, tabulation, and graphical representation –

Descriptive Statistics, and Statistical Distributions	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**	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

TEXT BOOKS & REFERENCE BOOKS	1. Chapra SC, Canale RP. Numerical Methods for Engineers, 8th Edition, McGraw-Hill, 2015. 2. Spiegel MR, Schiller JS. Theory and Problems of Probability and Statistics, McGraw- Hill, 2009. 3. Walpole RE, Myers RH, Myers SL, Ye K. Probability and Statistics for Engineers and Scientists, 9th Edition, Pearson, 2012. 4. Arfken GB, Weber HJ, Harris FE. Mathematical Methods for Physicists, 7th Edition, Academic Press, 2013. 5. Jain AK. Numerical Methods for Scientific and Engineering Computation, New Age International, 2010. 6. 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. 7. A.C. Bajpai, I.M. Calcus and J.A. Fairley Numerical Methods for Engineers and Scientists – A student's course book, John Wiley & Sons. 8. Band W. Introduction to Mathematical Physics. 9. Croxton. Elementary Statistics 10. Dahlberg G. Statistical methods of Medical & Biology Students. 11. Krasnor M.L. Ordinary Diff. Equation. 12. Conte S, de Boor C. Elementary Numerical Analysis: An Algorithmic Approach, 3rd Edition, McGraw-Hill, 2012. 13. Devore JL. Probability and Statistics for Engineering and the Sciences, 9th Edition, Cengage Learning, 2015. 14. Beck J. Numerical Methods in Engineering and Science, 2nd Edition, Springer, 2010. 15. Rao CV. Mathematical Methods of Physics, Universities Press, 2010. 16. Gupta S. Statistical Methods for Engineers and Scientists, New Age International, 2014

COURSE OUTCOMES:

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

CO1	Apply numerical methods for solving equations, integration, differentiation, and differential equations in medical physics problems.	K1, K2
CO2	Analyze experimental data using probability, descriptive statistics, and statistical distributions for measurement, calibration, and radiation detection.	**K3, K4**
CO3	Interpret counting statistics, evaluate detector performance, and estimate uncertainty in nuclear measurements	**K3,K4**
CO4	Solve vector and matrix problems, including eigenvalue and eigenvector calculations relevant to radiation physics.	**K4**
CO5	Formulate and solve partial differential equations for physical phenomena in biomedical and radiation physics applications.	**K4, K5**
K1 - Remember; K2 – Understand; K3 - Apply; K4 - Analyze; K5 – Evaluate		

MAPPING WITH PROGRAM OUTCOMES:

Map course outcomes **(CO)** for each course with program outcomes **(PO)** and program specific outcomes **(PSO)** in the 3-point scale of STRONG (3), MEDIUM (2) and LOW (1)**.**

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**
CO1	3	3	2	2	3	1	2	2	2	1
CO2	3	3	2	3	3	2	3	2	2	2
CO3	3	3	2	3	3	2	2	2	3	2
CO4	3	3	2	2	2	1	3	2	3	1
CO5	3	3	3	1	3	2	2	2	2	3
	PSO1	**PSO2**	**PSO3**	**PSO4**	**PSO5**	**PSO6**	**PSO7**	**PSO8**	**PSO9**	**PSO10**
CO1	3	3	3	2	2	1	2	1	2	2
CO2	3	3	3	2	3	2	2	2	2	2
CO3	3	3	3	2	3	2	1	1	2	2
CO4	3	3	3	3	2	1	2	2	2	2
CO5	3	3	3	3	3	2	2	2	2	3

Core 7- Electro dynamics and Quantum Mechanics	I YEAR - II SEMESTER

Subject Code	Subject Name	Category	L	T	P	Credits	Inst. Hours	Marks
	Electro dynamics and Quantum Mechanics	Core	3	0	0	3	45	100

Pre-Requisites
Electricity & Magmatism, Quantum Mechanics –UG level
Learning Objectives
• To provide a strong foundation in classical electrodynamics and Maxwell's equations relevant to medical physics applications. • To develop an understanding of electromagnetic wave propagation in media and boundary interactions significant to diagnostic and therapeutic systems. • To introduce the fundamental postulates and formalism of quantum mechanics and their physical interpretation. • To enable understanding of atomic structure, radiation emission, and quantum transitions relevant to nuclear and medical radiation processes. • To bridge the principles of electrodynamics and quantum theory with modern instrumentation and radiation detection systems in medical physics.

UNITS	Course Details
UNIT I: Electrostatics and Magnetostatics	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**	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**	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**	One-dimensional potential problems – Free particle, particle in a box, potential barrier and tunnelling phenomena. Quantum harmonic oscillator – Eigenvalues and eigen functions – 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**	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.

TEXT BOOKS & REFERENCE BOOKS	1. David J. Griffiths, Introduction to Electrodynamics, 4th Ed., Cambridge University Press, 2017. 2. Nouredine Zettili, Quantum Mechanics: Concepts and Applications, 2nd Ed., Wiley, 2009. 3. R. P. Feynman, R. B. Leighton & M. Sands, The Feynman Lectures on Physics, Vol. II & III, Addison-Wesley, 2011. 4. J. S. Townsend, A Modern Approach to Quantum Mechanics, University Science Books, 2012. 5. H. C. Ohanian, Classical Electrodynamics, Allyn and Bacon, 1988. 6. J. D. Jackson, Classical Electrodynamics, 3rd Ed., Wiley, 1998. https://doi.org/10.1002/9781118820211 7. E. Merzbacher, Quantum Mechanics, 3rd Ed., Wiley, 1998. https://archive.org/details/quantum-mechanics-merzbacher 8. A. Zangwill, Modern Electrodynamics, Cambridge University Press, 2013. https://doi.org/10.1017/CBO9781139013401 9. P. M. Mathews & K. Venkatesan, A Textbook of Quantum Mechanics, Tata McGraw- Hill, 2010. 10. D. H. Perkins, Introduction to High Energy Physics, Cambridge University Press, 2000.

COURSE OUTCOMES:

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

CO1	Apply Maxwell’s equations to describe electromagnetic field behavior in medical and biological contexts.	K1, K3
CO2	Solve the Schrödinger equation for basic quantum systems and interpret physical observables.	**K2, K3**
CO3	Explain the quantum mechanical basis of radiation–matter interactions and detector operation.	**K3,K4**
CO4	Relate electrodynamic and quantum principles to technologies used in diagnostic imaging and radiotherapy.	**K4, K5**
CO5	Demonstrate integrated understanding of electromagnetic and quantum phenomena for further study in radiation physics.	**K4, K5**
K1 - Remember; K2 – Understand; K3 - Apply; K4 - Analyze; K5 – Evaluate		

MAPPING WITH PROGRAM OUTCOMES:

Map course outcomes **(CO)** for each course with program outcomes **(PO)** and program specific outcomes **(PSO)** in the 3-point scale of STRONG (3), MEDIUM (2) and LOW (1)**.**

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**
CO1	3	3	2	2	2	1	1	2	3	1
CO2	3	3	2	3	2	1	1	2	3	1
CO3	3	3	3	3	3	3	2	2	3	2
CO4	3	3	3	3	3	3	2	2	2	2
CO5	3	3	3	3	2	3	3	2	2	3

	PSO1	**PSO2**	**PSO3**	**PSO4**	**PSO5**	**PSO6**	**PSO7**	**PSO8**	**PSO9**	**PSO10**
CO1	3	3	2	2	1	2	2	1	1	1
CO2	3	3	2	3	1	2	2	1	1	1
CO3	3	3	3	2	2	2	2	1	2	3
CO4	3	3	3	3	2	2	3	2	2	2
CO5	3	3	2	3	2	2	3	2	2	3

Core 8- Physics of Medical Imaging									I YEAR - II SEMESTER
Subject Code	**Subject Name**	**Category**	**L**	**T**	**P**	**Credits**	**Inst. Hours**	**Marks**	
	Physics of Medical Imaging	Core	3	1	0	4	60	100	

Pre-Requisites- Radiological Physics

Learning 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.

UNITS	Course Details
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 unitsTomosynthesis – 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	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

Resonance (NMR) and MRI (10 hrs)	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.
TEXT BOOKS & REFERENCE BOOKS	• 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: 1. Seeram E. Computed Tomography: Physical Principles, Clinical Applications, and Quality Control, 4th Edition, 2020. 2. Szabo TL. Diagnostic Ultrasound Imaging: Inside Out, 2nd Edition, 2014. 3. Haacke EM, Brown RW, Thompson MR, Venkatesan R. MRI: Physical Principles and Sequence Design, 2nd Edition, 2014. 4. Fauber TL. X-Ray Imaging: Principles and Applications, 2014. 5. Hendee WR, Ritenour ER. Medical Imaging Physics Handbook, 2010.

COURSE OUTCOMES:

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

CO1	Understand X-ray tube physics, imaging technology, and generator accessories.	K1, K2
CO2	Evaluate radiographic images quantitatively for unsharpness, resolution, and magnification.	**K3, K5**
CO3	Understand CT principles, reconstruction algorithms, and artifacts.	**K2,K4**
CO4	Analyze ultrasound physics, transducer properties, and Doppler techniques.	**K3, K4**
CO5	Understand NMR/MRI physics, sequences, instrumentation, and functional imaging.	**K2, K4**
K1 - Remember; K2 – Understand; K3 - Apply; K4 - Analyze; K5 – Evaluate		

MAPPING WITH PROGRAM OUTCOMES:

Map course outcomes **(CO)** for each course with program outcomes **(PO)** and program specific outcomes **(PSO)** in the 3-point scale of STRONG (3), MEDIUM (2) and LOW (1)**.**

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**
CO1	3	2	1	1	3	2	1	1	3	1
CO2	3	3	2	2	3	2	1	1	3	2
CO3	3	3	2	3	3	2	2	1	3	2
CO4	3	3	3	3	3	2	2	2	2	3
CO5	3	3	2	3	3	3	2	2	2	3

	PSO1	**PSO2**	**PSO3**	**PSO4**	**PSO5**	**PSO6**	**PSO7**	**PSO8**	**PSO9**	**PSO10**
CO1	3	3	2	2	1	2	2	1	1	1
CO2	3	3	2	3	1	2	2	1	1	1
CO3	3	3	3	2	2	2	2	1	2	3
CO4	3	3	3	3	2	2	3	2	2	2
CO5	3	3	2	3	2	2	3	2	2	3

Core 9- Physics of Radiotherapy	I YEAR - II SEMESTER

Subject Code	Subject Name	Category	L	T	P	Credits	Inst. Hours	Marks
	Physics of Radiotherapy	Core	3	1	0	4	60	100

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

UNITS	Course Details
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.
TEXT BOOKS & REFERENCE BOOKS	1. Khan FM, Gibbons JP. The Physics of Radiation Therapy, 5th Edition, Lippincott Williams & Wilkins, 2020. 2. Podgorsak EB. Radiation Oncology Physics: A Handbook for Teachers and Students, IAEA, 2005. 3. Das IJ, Ding GX, Ahnesjö A. Advanced Radiation Therapy Physics: Theory and Practice, 2nd Edition, CRC Press, 2019. 4. Hendee WR, Ibbott GS, Hendee EK. Medical Radiation Physics, 4th Edition, Wiley, 2005.

	5. H.E. Johns and Cunningham. The Physics of Radiology. 6. Faiz M. Khan, The Physics of Radiation Therapy, Lippincott Williams & Wilkins, Philadelphia, 3rd edition, 2003. References: 1. IAEA. Absorbed Dose Determination in External Beam Radiotherapy, Technical Report Series No. 398, 2000. 2. AAPM Report No. 85. The Role of In Vivo Dosimetry in Modern Radiotherapy, 2006. 3. ICRU Report 50 & 62. Prescribing, Recording, and Reporting Photon Beam Therapy, 1993, 1999. 4. Jones DG, Hendry JH. Radiobiology for Radiotherapy, 5th Edition, CRC Press, 2018. 5. Podgorsak EB. Radiation Physics for Medical Physicists, Springer, 2016.

COURSE OUTCOMES:

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

CO1	Explain the principles and functioning of kilovoltage X-ray units, telecobalt units, and linear accelerators.	K1, K2
CO2	Analyze dosimetry parameters and interpret isodose charts for photon and electron beams.	**K3, K4**
CO3	Apply beam modifying and shaping devices for clinical photon therapy.	**K3**
CO4	Plan and calculate clinical electron beam treatments considering geometry and heterogeneities.	**K3, K4, K5**
CO5	Describe brachytherapy techniques, source selection, dose rates, and safety compliance.	**K2, K4**
K1 - Remember; K2 – Understand; K3 - Apply; K4 - Analyze; K5 – Evaluate		

MAPPING WITH PROGRAM OUTCOMES:

Map course outcomes **(CO)** for each course with program outcomes **(PO)** and program specific outcomes **(PSO)** in the 3-point scale of STRONG (3), MEDIUM (2) and LOW (1)**.**

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**
CO1	3	2	1	1	3	2	3	1	1	1
CO2	3	3	3	2	3	2	3	1	2	2
CO3	3	3	2	3	3	2	3	2	2	2
CO4	3	3	3	3	3	3	3	2	3	3
CO5	3	2	2	3	3	3	3	2	2	3

	PSO1	**PSO2**	**PSO3**	**PSO4**	**PSO5**	**PSO6**	**PSO7**	**PSO8**	**PSO9**	**PSO10**
CO1	3	3	2	1	2	1	1	1	1	1
CO2	3	3	3	2	3	2	3	2	2	2
CO3	3	3	2	3	3	2	3	2	2	2
CO4	3	3	3	3	3	3	3	2	3	3
CO5	3	2	2	3	3	2	3	2	2	3

Core 10 - Nuclear Medicine I: Imaging and Therapy	I YEAR - II SEMESTER

Subject Code	Subject Name	Category	L	T	P	Credits	Inst. Hours	Marks
	Nuclear Medicine I: Imaging and Therapy	Core	3	1	0	4	45	100

Pre-Requisites
Radiological Physics
Learning Objectives
• To understand the fundamental physics of nuclear medicine and radionuclide production. • To learn principles and applications of radiopharmaceuticals and cyclotron operation. • To gain knowledge of in-vivo non-imaging procedures and basic dosimetry. • To understand radionuclide imaging systems and advanced imaging techniques including SPECT, PET, and fusion modalities. • To learn the principles of radionuclide therapy, room shielding, radiation safety, and QA procedures.

UNITS	Course Details
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, Sr82/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: 1. Prepare flow diagrams for radionuclide production and generator operation. 2. 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 nonimaging 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:** 1. Perform calculations for thyroid uptake, renogram, and RBC lifespan. 2. 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:** 1. Label gamma camera components and explain function. 2. Evaluate collimator performance and detector resolution. 3. Analyze sample imaging outputs and identify artifacts.
UNIT IV: Advanced Imaging Modalities and Quality Assurance	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-

(12 h: 9 L + 3 T))	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:** 1. Analyse sample SPECT/PET data for resolution and contrast. 2. 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:** 1. Design shielding for a radionuclide therapy isolation room. 2. Prepare a mock workflow for radionuclide therapy. 3. Develop contamination-control and waste-management protocols.
TEXT BOOKS & REFERENCE BOOKS	1. Bushberg JT, Seibert JA, Leidholdt EM, Boone JM. The Essential Physics of Medical Imaging. 4th Edition, Lippincott Williams & Wilkins, 2021. 2. Cherry SR, Sorenson JA, Phelps ME. Physics in Nuclear Medicine. 5th Edition, Elsevier, 2012. 3. Ljungberg M, et al. Handbook of Nuclear Medicine Physics: Theory and Practice. Springer, 2017. 4. Simon R. Chery, James A. Sorenson, Michael E. Phelps, Physics in Nuclear Medicine (3rd ed.) SAUNDERS an imprint of Elsevier. 5. Ramesh Chandra, Nuclear Medicine Physics (5th ed.) Lea &Febiger, Philadelphia.

6. Antonio Fernando Goncalves Rocha and John Charles Harbert, Text Book of Nuclear Medicine : Basic Science, Lea &Febiger, Philadelphia.
7. Pail J. Early, M.A. Razzak and D, Bruces Sodee, Text book of Nuclear Medicine Technology. The C.V. Mosby Company.
8. A.L. Baert and K. Sartor, Diagnostic Nuclear Medicine (2nd ed.) Springer.
9. Gopal B. Saha, Fundamental of Nuclear Medicine Pharmacy (5 ed.) Springer.
10. Wagner LK, Loo Jr BW. Nuclear Medicine Physics: Practical Aspects. CRC Press, 2020.
11. Saha GB. Fundamentals of Nuclear Pharmacy. 7th Edition, Springer, 2020.
12. 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.
13. J.F. Fowler, Nuclear Particles in Cancer Treatment, Adam Hilger Ltd., Philadelphia, 1981.

References:

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

COURSE OUTCOMES:

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

CO1	Demonstrate understanding of nuclear medicine physics and radionuclide production principles.	K1, K2
CO2	Perform basic in-vivo non-imaging studies and clinical dose calculations.	**K3**
CO3	Analyze and evaluate imaging systems including gamma camera and PET/SPECT.	**K4, K5**
CO4	Apply QA/QC standards to advanced imaging techniques.	**K3, K4**
CO5	Design safe therapeutic workflows and implement radiation safety measures in nuclear medicine facilities.	**K2, K4, K5**
K1 - Remember; K2 – Understand; K3 - Apply; K4 - Analyze; K5 – Evaluate		

MAPPING WITH PROGRAM OUTCOMES:

Map course outcomes **(CO)** for each course with program outcomes **(PO)** and program specific outcomes **(PSO)** in the 3-point scale of STRONG (3), MEDIUM (2) and LOW (1)**.**

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**
CO1	3	2	1	1	3	2	1	1	1	1
CO2	3	3	3	2	3	2	1	1	2	2
CO3	3	3	3	3	3	2	2	2	3	3
CO4	3	3	2	3	3	3	2	2	2	3
CO5	3	3	3	3	3	3	3	2	3	3

	PSO1	**PSO2**	**PSO3**	**PSO4**	**PSO5**	**PSO6**	**PSO7**	**PSO8**	**PSO9**	**PSO10**
CO1	3	3	2	1	2	1	1	1	1	1
CO2	3	3	3	2	3	2	2	1	2	2
CO3	3	3	3	3	3	2	3	2	3	3
CO4	3	3	2	3	3	3	3	2	2	3
CO5	3	3	3	3	3	3	3	2	3	3

Elective II: Artificial Intelligence in Medical Physics	I YEAR - II SEMESTER

Subject Code	Subject Name	Category	L	T	P	Credits	Inst. Hours	Marks
	Artificial Intelligence in Medical Physics	Elective	2	1	0	3	45	100

Pre-Requisites
Basic understanding of Python programming, medical imaging modalities, and statistical concepts.
Learning Objectives
• To provide foundational knowledge of Artificial Intelligence (AI), Machine Learning (ML), and Deep Learning (DL) techniques used in medical physics. • To enable students to process, analyze, and visualize medical images using AI frameworks. • To impart knowledge on different neural network architectures and their medical applications. • To introduce reinforcement learning and its use in medical decision support and adaptive treatment systems. • To familiarize students with regulatory, ethical, and quality assurance aspects of AI implementation in healthcare.

UNITS	Course Details
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 TG273 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 QNetworks (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.
	Textbooks (Recent Editions) 1. Isaac Bankman, Handbook of Medical Image Processing and Analysis, 3rd Edition, Academic Press, 2020.

TEXT BOOKS & REFERENCE BOOKS	2. Ian Goodfellow, YoshuaBengio& Aaron Courville, Deep Learning, MIT Press, 2021. 3. Charu C. Aggarwal, Neural Networks and Deep Learning: A Textbook, Springer, 2023. 4. Barry Rosenstein et al., Machine Learning and Artificial Intelligence in Radiation Oncology: A Guide for Clinicians, Springer, 2022. 5. Ruijiang Li, Lei Xing, and Daniel L. Rubin, Radiomics and Radiogenomics: Technical Basis and Clinical Applications, CRC Press, 2021. Reference Books 1. Richard S. Sutton & Andrew G. Barto, Reinforcement Learning: An Introduction, 2nd Edition, MIT Press, 2020. 2. Christopher M. Bishop, Pattern Recognition and Machine Learning, Springer, 2023 (Reprint Edition). 3. AAPM Task Group 273, Best Practices for AI and Machine Learning in Medical Physics, AAPM, 2021. 4. Daniel Rueckert&PolinaGolland (Eds.), Machine Learning in Medical Imaging: Advances and Applications, Springer, 2023. 5. Bradford Tuckfield, Dive Into Data Science: Use Python to Tackle Real-World Healthcare Challenges, No Starch Press, 2022.

COURSE OUTCOMES:

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

CO1	Understand the role of AI, ML, and DL in medical imaging, radiation therapy, and diagnostics.	K1, K2
CO2	Develop and evaluate AI/ML models for healthcare applications with proper validation metrics.	**K3, K4, K5**
CO3	Implement CNN and GAN architectures for medical image classification, segmentation, and synthesis.	**K3, K4**
CO4	Apply reinforcement learning principles for adaptive radiation therapy and clinical decision-making.	**K3, K4**

CO5	Demonstrate awareness of data governance, ethical frameworks, and AI quality assurance protocols in medical physics practice.	**K2, K5**
K1 - Remember; K2 – Understand; K3 - Apply; K4 - Analyze; K5 – Evaluate		

MAPPING WITH PROGRAM OUTCOMES:

Map course outcomes **(CO)** for each course with program outcomes **(PO)** and program specific outcomes **(PSO)** in the 3-point scale of STRONG (3), MEDIUM (2) and LOW (1)**.**

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**
CO1	3	2	1	1	3	2	1	1	1	1
CO2	3	3	3	3	3	3	2	2	3	3
CO3	3	3	3	3	3	2	2	2	3	2
CO4	3	3	3	3	3	3	3	2	3	3
CO5	2	2	2	3	3	3	3	3	2	3

	PSO1	**PSO2**	**PSO3**	**PSO4**	**PSO5**	**PSO6**	**PSO7**	**PSO8**	**PSO9**	**PSO10**
CO1	3	3	2	1	2	1	1	1	1	1
CO2	3	3	3	3	3	3	3	2	3	3
CO3	3	3	2	3	3	2	3	2	3	2
CO4	3	3	3	3	3	3	3	2	3	3
CO5	2	2	2	3	3	2	3	3	2	3

Elective II: Materials for Radiological Applications	I YEAR - II SEMESTER

Subject Code	Subject Name	Category	L	T	P	Credits	Inst. Hours	Marks
	Materials for Radiological Applications	Elective	2	1	0	3	45	100

Pre-Requisites
Learning 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 biofunctionality 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.

UNITS	Course Details
UNIT I: Classes of Materials	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,

Used in Medicine	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; biofunctionality. 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.
TEXT BOOKS & REFERENCE BOOKS	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)

COURSE OUTCOMES:

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

CO1	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.	K1, K2
CO2	Critically assess material characterisation data (physical, thermal, electrical, optical surface) and interpret biocompatibility, hemocompatibility and degradation behaviour in a biological environment.	**K3, K4, K5**

CO3	Select appropriate additive manufacturing techniques (3D/4D printing) and material feedstocks for custom medical devices and implants, considering design, printability, biocompatibility and functional performance.	**K3, K4**
CO4	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.	**K3, K4**
CO5	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.	**K2, K5**
K1 - Remember; K2 – Understand; K3 - Apply; K4 - Analyze; K5 – Evaluate		

MAPPING WITH PROGRAM OUTCOMES:

Map course outcomes **(CO)** for each course with program outcomes **(PO)** and program specific outcomes **(PSO)** in the 3-point scale of STRONG (3), MEDIUM (2) and LOW (1)**.**

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**
CO1	3	2	1	1	3	2	1	1	1	1
CO2	3	3	3	3	3	3	2	2	3	3
CO3	3	3	3	3	3	2	2	2	3	2
CO4	3	3	3	3	3	3	3	2	3	3
CO5	2	2	2	3	3	3	3	3	2	3

	PSO1	**PSO2**	**PSO3**	**PSO4**	**PSO5**	**PSO6**	**PSO7**	**PSO8**	**PSO9**	**PSO10**
CO1	3	3	2	1	2	1	1	1	1	1
CO2	3	3	3	3	3	3	3	2	3	3
CO3	3	3	2	3	3	2	3	2	3	2
CO4	3	3	3	3	3	3	3	2	3	3
CO5	2	2	2	3	3	2	3	3	2	3

Core Lab II: Medical Physics Lab I – Medical Imaging	I YEAR - II SEMESTER

Subject Code	Subject Name	Category	L	T	P	Credits	Inst. Hours	Marks
	Lab II: Medical Physics Lab I – Medical Imaging	Core	-	-	6	3	-	100

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 (15)** 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 (<1mGy/hrat1m).
- **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, surveymeter.
- **Procedure:** Perform radiographic exposure; record dose at multiple points; plot scatter profile.

12. **Measurement of Protective Apron Transmission (Mandatory2)**

- **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 <1µSv/hr.

14. **Fluoroscopy Dose Rate Measurement (Mandatory3)**

- **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:** Ionchamber 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,pulserate,SSD).
      - **Instruments/Materials:**
      - Calibrated ionization chamber (pencil or flat chamber) or solid-state dosimeter (e.g.,RTI, Unfors)
      - Electrometer/dosimeter read out
      - 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, log sheet

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, log sheet

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 upto clinical range) to simulate patient thicknesses
- Dosemeter(real-time dosimeter/ion chamber)placed at isocentre entrance surface
- Electrometer/readout or dosimeter display, ruler, logsheet

20. CT Number Calibration and UniformityTest

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

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) (Mandatory5)**
    - **Instruments:** CT ion chamber, head/ body phantoms.
    - **Procedure:** Measure dose at central and peripheral holes; calculate CTDIvol and DLP; compare protocols.

24. **MRISNR and Uniformity Measurement**
    - **Instruments:** MRIsystem, standard QA phantom.
    - **Procedure:** Acquire images using spin-echo sequence; compute SNR and uniformity using ROI method.

25. **MRI Geometric Accuracy and Slice Profile (Mandatory6)**
    - **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:** MRIphantom, 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 (Mandatory7)**
    - 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.
- To use a specimen of known 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 aV1orV2 reference block.
  - Scan the specimen containing known/unknown flaws.
  - Observe echo signals corresponding to internal discontinuities.
  - To determine flaw depth using the Time-of-Flight (TOF) method: Depth = $v \times \Delta t / 2$.
  - Estimate flaw size by amplitude drop method (6dB/20dB) or by beam spread technique.

2G. 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 (5–10MHz) 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.

- To calculate specimen thickness: $d = v \times \Delta t / 2$ (using the ultrasonic 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 ($A_1, A_2, A_3\ldots$)from back-wall reflections for each thickness.
  - To plot ln(Amplitude) versus thickness and evaluate the attenuation coefficient of the material. .
  - To determine the attenuation coefficient (α) from the slope of the ln(Amplitude) versus thickness plot based on the attenuation relation $A = A_0 e^{(-\alpha x)}$.
  - 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 valuation 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,3rdEd.,Lippincott Williams CWilkins.
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. KarlRawer, 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. AAPMTG-142,TG-150,TG-175,TG-246(X-ray,Fluoro,CTCMRIQAReports) https://www.aapm.org/pubs
3. ICRP Publications on Diagnostic Doses 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 Resourceshttps://www.nist.gov/pml

Subject Code	Subject Name	Category	L	T	P	Credits	Inst. Hours	Marks
	Professional Enhancement Course: Professional Ethics in Medical Physics (General and Medical Physics)		2	-	-	2	-	50

Pre-Requisites
Learning 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.

UNITS	Course Details
UNIT I: Fundamentals of Professional Ethics(6h:4L+2T)	Concept of ethics, morality, and values –Role of ethics in professional and personal life- Ethical theories and frame works: utilitarianism, deontology, virtueethics, 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 (6h:4L+2T)	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 team work. **Tutorial:** Analyze scenarios involving professional misconduct and propose ethical resolutions.
UNIT III: Medical Physics Professional Ethics and Code of Practice (6h:4L+2T)	Ethical foundations of Medical Physics as a health care 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 guide lines and discuss implications for clinical practice.
UNIT IV: Ethical Issues in Clinical and Research Practice (6h:4L+2T)	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 dataprivacy 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 (6h:4L+2T)	National regulatory frame work: 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.

TEXT BOOKS & REFERENCE BOOKS	Textbooks 1. BeauchampT.L.C ChildressJ.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 Bio ethics, Routledge. 4. AAPM Professional Council, AAPM Code of Ethics and Professional Conduct, AAPM Reports Series. 5. StephenR.Covey,The 7 Habits of Highly Effective People, Simon CSchuster. **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

COURSE OUTCOMES:

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

CO1	Explain the fundamental principles and frame works of professional ethics.	K1, K2
CO2	Apply ethical reasoning and decision-making to academic and clinical contexts.	**K3, K4, K5**
CO3	Demonstrate understanding of ethical codes governing medical physicists	**K3, K4**

	globally and nationally.	
CO4	Identify and resolve ethical dilemmas in clinical, research, and institutional settings	**K3, K4**
CO5	Integrate ethical behavior, accountability, and professional responsibility into medical physics practice.	**K2, K5**
K1 - Remember; K2 – Understand; K3 - Apply; K4 - Analyze; K5 – Evaluate		

MAPPING WITH PROGRAM OUTCOMES:

Map course outcomes **(CO)** for each course with program outcomes **(PO)** and program specific outcomes **(PSO)** in the 3-point scale of STRONG (3), MEDIUM (2) and LOW (1)**.**

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	3	2	1	1	3	2	1	1	1	1
CO2	3	3	3	3	3	3	2	2	3	3
CO3	3	3	3	3	3	2	2	2	3	2
CO4	3	3	3	3	3	3	3	2	3	3
CO5	2	2	2	3	3	3	3	3	2	3

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8	PSO9	PSO10
CO1	3	3	2	1	2	1	1	1	1	1
CO2	3	3	3	3	3	3	3	2	3	3
CO3	3	3	2	3	3	2	3	2	3	2
CO4	3	3	3	3	3	3	3	2	3	3
CO5	2	2	2	3	3	2	3	3	2	3

SECOND YEAR

THIRD SEMESTER

THIRD SEMESTER									
Code	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	II YEAR - III SEMESTER

Subject Code	Subject Name	Category	L	T	P	Credits	Inst. Hours	Marks
	Treatment Planning in Radiation Oncology	Core	2	1	2	4	60	100

Pre-Requisites
Radiological Physics and Physics of Radiotherapy
Learning Objectives
• Explain the principles of teletherapy treatment planning, target volume delineation (GTV, CTV, PTV), SSD/SAD setups, and dose prescription following ICRU protocols. • Apply conventional and advanced radiotherapy techniques, including field arrangements, arc therapy, IMRT, VMAT, and FFF/proton beams for clinical scenarios • Plan and optimize brachytherapy treatments, including HDR, LDR, PDR, electronic brachytherapy, and specialized procedures such as prostate and ocular applications. • Utilize computational algorithms and treatment planning systems for dose calculations, plan optimization, and verification across photon, electron, proton, and heavy ion beams • Implement safety, quality assurance, and verification procedures for advanced and adaptive radiotherapy techniques, integrating multimodality imaging for precise treatment planning

UNITS	Course Details
UNIT I: Fundamentals of Treatment Planning and Target Volume Definition	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

(10 Hours)	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**	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

(10 Hours)	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 TRS430 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

TEXT BOOKS & REFERENCE BOOKS	Textbooks (Recent Editions) 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, TRS430, 2008. 5. Van Dyk J, Mah K. Advanced Treatment Planning and Techniques in Radiotherapy, Semin Radiat Oncol, 2010.

Learning Outcomes:

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

	Explain principles of teletherapy and brachytherapy treatment planning including target volume definition and dose prescription.	
	Apply SSD/SAD setups, field arrangements, and corrections for tissue inhomogeneity in treatment planning.	
	Demonstrate treatment time and monitor unit calculations for conventional, conformal, and arc therapy techniques.	
	Design and optimize brachytherapy plans using CT/MR-based forward and	

	inverse planning techniques.	
	Utilize computers and TPS algorithms for photon, electron, proton, and heavy ion beam treatment planning and perform QA.	
	Plan and evaluate advanced radiotherapy techniques including SRS, SBRT, and adaptive radiotherapy ensuring optimal target coverage and organ-at-risk sparing.	
K1 - Remember; K2 – Understand; K3 - Apply; K4 - Analyze; K5 – Evaluate		

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.

MAPPING WITH PROGRAM OUTCOMES:

Map course outcomes **(CO)** for each course with program outcomes **(PO)** and program specific outcomes **(PSO)** in the 3-point scale of STRONG (3), MEDIUM (2) and LOW (1)**.**

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**
CO1	3	2	1	1	3	2	1	1	1	1
CO2	3	3	3	2	3	2	1	1	2	2
CO3	3	3	3	3	3	2	2	1	3	2
CO4	3	3	3	3	3	3	3	2	3	3
CO5	3	3	3	3	3	3	3	2	2	3
	PSO1	**PSO2**	**PSO3**	**PSO4**	**PSO5**	**PSO6**	**PSO7**	**PSO8**	**PSO9**	**PSO10**
CO1	3	3	2	1	2	1	1	1	1	1
CO2	3	3	3	2	3	2	3	2	2	2
CO3	3	3	3	3	3	2	3	2	3	2
CO4	3	3	3	3	3	3	3	2	3	3
CO5	2	3	3	3	3	2	3	3	2	3

Core 12: Nuclear Medicine II: Dosimetry and Quality Assurance								II YEAR - III SEMESTER
Subject Code	**Subject Name**	**Category**	**L**	**T**	**P**	**Credits**	**Inst. Hours**	**Marks**
	Nuclear Medicine II: Dosimetry and Quality Assurance	Core	3	1	1	4	60	100

Pre-Requisites- Nuclear Medicine I

Learning 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.

UNITS	Course Details
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).
TEXT BOOKS & REFERENCE BOOKS	**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.

Course Outcomes:

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

C01	Perform internal dosimetry and MIRD-based calculations accurately.	K3, K4
C02	Evaluate and calibrate Nuclear Medicine instruments and perform facility monitoring.	K3, K4, K5
C03	Implement radiological safety and emergency protocols	K3
C04	Apply QA/QC protocols in imaging, therapy, and cyclotron operations	K3, K4
C05	Maintain documentation and regulatory compliance in NM facilities.	K2, K5
K1 - Remember; K2 – Understand; K3 - Apply; K4 - Analyze; K5 – Evaluate		

MAPPING WITH PROGRAM OUTCOMES:

Map course outcomes **(CO)** for each course with program outcomes **(PO)** and program specific outcomes **(PSO)** in the 3-point scale of STRONG (3), MEDIUM (2) and LOW (1)**.**

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**
CO1	3	3	3	2	3	2	1	1	2	2
CO2	3	3	3	3	3	3	2	2	3	3
CO3	3	2	3	2	3	3	3	2	2	3
CO4	3	3	3	3	3	3	2	2	3	3
CO5	2	3	2	3	3	3	3	3	2	3
	PSO1	**PSO2**	**PSO3**	**PSO4**	**PSO5**	**PSO6**	**PSO7**	**PSO8**	**PSO9**	**PSO10**
CO1	3	3	3	2	3	2	2	1	2	2
CO2	3	3	3	3	3	3	3	2	3	3
CO3	3	2	3	3	3	3	3	2	2	3
CO4	3	3	3	3	3	3	3	2	3	3
CO5	2	2	2	3	3	3	3	3	2	3

Core 13: Radiation Dosimetry and Standardization	**II YEAR - III SEMESTER**

Subject Code	**Subject Name**	**Category**	**L**	**T**	**P**	**Credits**	**Inst. Hours**	**Marks**
	Radiation Dosimetry and Standardization	Core	3	1	0	4	60	100

Pre-Requisites
Physics of Radiotherapy
Learning 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.

UNITS	**Course Details**
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 intercomparison. **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**	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,

Therapy (12 Hours)	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.
TEXT BOOKS & REFERENCE BOOKS	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,kVerlog 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.

Course Outcomes:

C01	Demonstrate understanding of calibration standards and uncertainty analysis in dosimetry.	K1, K2
C02	Apply cavity theories to derive absorbed dose relationships and determine dose to water.	K3, K4
C03	Standardize external beam and brachytherapy sources according to IAEA/AAPM protocols.	K3, K5
C04	Conduct neutron dosimetry, instrument calibration, and radiotherapy quality assurance.	K3, K4
C05	Implement chemical dosimetry and radiation chemistry techniques for dose verification.	K2, K4, K5
K1 - Remember; K2 – Understand; K3 - Apply; K4 - Analyze; K5 – Evaluate		

MAPPING WITH PROGRAM OUTCOMES:

Map course outcomes **(CO)** for each course with program outcomes **(PO)** and program specific outcomes **(PSO)** in the 3-point scale of STRONG (3), MEDIUM (2) and LOW (1)**.**

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**
CO1	3	2	1	1	3	2	1	1	1	1
CO2	3	3	3	3	3	2	2	1	2	2
CO3	3	2	3	3	3	3	2	2	3	3
CO4	3	3	3	3	3	3	3	2	3	3
CO5	3	3	3	3	3	3	3	3	3	3

	PSO1	**PSO2**	**PSO3**	**PSO4**	**PSO5**	**PSO6**	**PSO7**	**PSO8**	**PSO9**	**PSO10**
CO1	3	3	2	1	2	1	1	1	1	1
CO2	3	3	3	2	3	2	3	2	2	2
CO3	3	3	3	3	3	3	3	2	3	3
CO4	3	3	3	3	3	3	3	2	3	3
CO5	3	3	3	3	3	3	3	3	3	3

Core 14: Radiation Biology	II YEAR - III SEMESTER

Subject Code	Subject Name	Category	L	T	P	Credits	Inst. Hours	Marks
	Radiation Biology	Core	3	1	0	4	60	100

Pre-Requisites
Radiological Physics, Physics of Radiotherapy and its relevant subjects
Learning 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.

UNITS	Course Details
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 reoxygenation, 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 nonuniform 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.
TEXT BOOKS & REFERENCE BOOKS	Textbooks 1. Hall, E. J. & Giaccia, A. J. Radiobiology for the Radiologist, 8th Ed., Lippincott Williams & Wilkins, 2019. 2. Sureka, C. S. Radiation Biology for Medical Physicists, CRC Press, Taylor & Francis, USA, 2017. 3. Joiner, M. & van der Kogel, A. Basic Clinical Radiobiology, 5th Ed., CRC Press, 2018.

	4. Chadwick, K. H. & Leenhouts, H. P. The Molecular Theory of Radiation Biology, Springer, 1981. 5. Curtis, S. B. Biological Effects of Radiation, Taylor & Francis, 2000. 6. Meschan I. *An Atlas of Normal Radiographic Anatomy*. 2nd ed. Philadelphia: W.B. Saunders Company; 1959. 7. Hollinshead WH. *Textbook of Anatomy*. 2nd ed. New York: Harper & Row; 1967 References. 1. Coggle JE. *Biological Effects of Radiation*. 2nd ed. London: Taylor & Francis; 1983. 2. Hall EJ, Giaccia AJ. *Radiobiology for the Radiologist*. 7th ed. Philadelphia: Lippincott Williams & Wilkins (LWW); 2012. 3. Steel GG. *Basic Clinical Radiobiology*. 3rd ed. London: Arnold Publishers; 2002. 4. Hallahan DE, Giaccia AJ, editors. *Radiation Oncology: Radiobiology and Clinical Applications*. Philadelphia: Lippincott Williams & Wilkins; 2006. 5. Alpen EL. *Radiation Biophysics*. 2nd ed. San Diego, CA: Academic Press; 1998.

Course Outcomes:

C01	Understand the molecular, cellular, and systemic effects of ionizing radiation	K1, K2
C02	Apply radiobiological principles in radiation therapy, protection, and dosimetry	K3
C03	Analyze dose–response relationships and survival models for clinical optimization.	K4
C04	Evaluate biological effects using LQ and BED models for treatment planning.	K4, K5
C05	Integrate mechanistic understanding for safe and effective radiation applications in medicine.	K2, K4, K5
K1 - Remember; K2 – Understand; K3 - Apply; K4 - Analyze; K5 – Evaluate		

MAPPING WITH PROGRAM OUTCOMES:

Map course outcomes **(CO)** for each course with program outcomes **(PO)** and program specific outcomes **(PSO)** in the 3-point scale of STRONG (3), MEDIUM (2) and LOW (1)**.**

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	3	2	1	1	3	2	1	1	1	1
CO2	3	3	3	2	3	2	2	1	2	2
CO3	3	2	3	3	3	2	2	2	3	2
CO4	3	3	3	3	3	3	2	2	3	3
CO5	3	3	3	3	3	3	3	2	3	3

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8	PSO9	PSO10
CO1	3	3	2	1	2	1	1	1	1	1
CO2	3	3	3	2	3	2	3	2	2	2
CO3	3	3	3	3	3	2	3	2	3	3
CO4	3	3	3	3	3	3	3	2	3	3
CO5	3	3	3	3	3	3	3	2	3	3

Core 15- Research Methodology, Data Analytics and Ethics	II YEAR - III SEMESTER

Subject Code	Subject Name	Category	L	T	P	Credits	Inst. Hours	Marks
	Research Methodology, Data Analytics and Ethics	Core	3	1	0	4	60	100

Pre-Requisites
Statistical Methods, Computer Application –UG level
Learning Objectives
• Expose students to diverse research methodologies covering problem definition literature review hypothesis development and research design. • Expertise students in mathematical and advanced statistical methods for hypothesis testing regression and correlation techniques. • Train students in multivariate analysis including Analysis of Variance and Principal Component Analysis. • Familiarize students with advanced computing tools like Neural Networks and Fuzzy Logic and their applications in medicine. • Train students to handle and utilize graphical and simulation software such as SPSS OriginPro and Matlab for data processing and visualization.

UNITS	Course Details
UNIT I: Research	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 questions and hypotheses -

Methodology and Ethics	Multimethod research. Defining and formulating the research problem – Selecting the 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.

TEXT BOOKS & REFERENCE BOOKS	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. 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.

COURSE OUTCOMES:

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

CO1	Students will be able to define and formulate a research problem conduct a literature review develop a working hypothesis and design appropriate research methods.	K1, K2
CO2	Students will be able to perform data processing hypothesis testing using various distributions and apply regression and correlation techniques to interpret research findings.	**K2, K3**
CO3	Students will be able to apply advanced ANOVA techniques and utilize Multivariate Analysis methods like Principal Components for complex data sets.	**K3,K4**
CO4	Students will be able to understand the structure and training of Neural Networks and the basic concepts of Fuzzy Logic for potential medical applications.	**K4, K5**

CO5	Students will be proficient in using SPSS OriginPro and Matlab for statistical analysis signal processing and effective data visualization.	**K4, K5**
K1 - Remember; K2 – Understand; K3 - Apply; K4 - Analyze; K5 – Evaluate		

MAPPING WITH PROGRAM OUTCOMES:

Map course outcomes **(CO)** for each course with program outcomes **(PO)** and program specific outcomes **(PSO)** in the 3-point scale of STRONG (3), MEDIUM (2) and LOW (1)**.**

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**
CO1	3	3	1	2	3	2	3	1	1	1
CO2	3	3	1	2	3	2	3	1	2	2
CO3	3	3	1	3	3	2	3	2	3	3
CO4	2	3	1	2	3	3	3	2	2	3
CO5	2	2	1	2	3	3	3	2	2	3

	PSO1	**PSO2**	**PSO3**	**PSO4**	**PSO5**	**PSO6**	**PSO7**	**PSO8**	**PSO9**	**PSO10**
CO1	2	1	3	2	3	1	2	1	1	2
CO2	2	2	3	2	3	2	3	1	1	2
CO3	2	2	3	2	3	2	2	2	3	2
CO4	1	2	3	2	3	3	1	2	2	2
CO5	1	2	3	2	3	3	3	2	2	2

Elective III: Advanced Techniques and Emerging Technologies in Medical Physics	**II YEAR - III SEMESTER**

Subject Code	**Subject Name**	**Category**	**L**	**T**	**P**	**Credits**	**Inst. Hours**	**Marks**
	Advanced Techniques and Emerging Technologies in Medical Physics	Elective	2	1	0	3	45	100

Pre-Requisites
Radiotherapy techniques
Learning 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.

UNITS	**Course Details**
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 Cyber Knife-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 (12hrs:GL+3T)**	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–QAprotocols– FlashRadiotherapy:principles,radiobiologicalmechanisms, 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, MRILinac) – 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.
	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

UNIT IV: **Proton, Hadron, and Neutron-Based Therapies** **(12 hrs: 9 L + 3 T)**	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.
TEXT BOOKS & REFERENCE BOOKS	Textbooks 1. Khan F.M.C Gibbons J.P.–The Physics of Radiation Therapy (6^{th} Ed.)– Lippincott Williams C Wilkins, 2020. 2. Podgorsak E.B. – Radiation Oncology Physics: A Hand book for

	Teachers and Students – IAEA, 2005. 3. Cormack D.V.–Clinical Dosimetry Measurements in Radiotherapy–CRCPress, 2013. 4. DasI.J.etal.–Advances in Radiation Oncology Physics– Medical Physics Publishing, 2021. 5. Loeffler J.S.C 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.

Course Outcomes:

After completing this course, students will be able to:

C01	Demonstrate advanced understanding of specialized radiotherapy modalities and their physical principles.	K1, K2
C02	Analyze dosimetric, technological, and clinical aspects of IMRT, VMAT, IGRT, SBRT, IORT, and BNCT.	K3
C03	Apply QA and commissioning procedures for advanced radiotherapy and particle therapy systems.	K4
C04	Integrate AI and adaptive methods in modern radiotherapy planning and delivery.	K4, K5
C05	Evaluate regulatory, ethical, and future trends shaping precision and theranostic radiotherapy.	K2, K4, K5
K1 - Remember; K2 – Understand; K3 - Apply; K4 - Analyze; K5 – Evaluate		

MAPPING WITH PROGRAM OUTCOMES:

Map course outcomes **(CO)** for each course with program outcomes **(PO)** and program specific outcomes **(PSO)** in the 3-point scale of STRONG (3), MEDIUM (2) and LOW (1)**.**

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**
CO1	3	2	1	1	3	2	1	1	1	1
CO2	3	3	3	2	3	2	2	1	2	2
CO3	3	2	3	3	3	2	2	2	3	2
CO4	3	3	3	3	3	3	2	2	3	3
CO5	3	3	3	3	3	3	3	2	3	3

	PSO1	**PSO2**	**PSO3**	**PSO4**	**PSO5**	**PSO6**	**PSO7**	**PSO8**	**PSO9**	**PSO10**
CO1	3	3	2	1	2	1	1	1	1	1
CO2	3	3	3	2	3	2	3	2	2	2
CO3	3	3	3	3	3	2	3	2	3	3
CO4	3	3	3	3	3	3	3	2	3	3
CO5	3	3	3	3	3	3	3	2	3	3

Elective III: Small Field Dosimetry and Calibration Standards	**II YEAR - III SEMESTER**

Subject Code	**Subject Name**	**Category**	**L**	**T**	**P**	**Credits**	**Inst. Hours**	**Marks**
	Small Field Dosimetry and Calibration Standards	Elective	2	1	0	3	45	100

Pre-Requisites
Radiation Dosimetry
Learning 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.

UNITS	**Course Details**
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.
TEXT BOOKS & REFERENCE BOOKS	Textbooks • Andreo, P. et al. (2017) – IAEA TRS-483: Dosimetry of Small Static Fields Used in External Beam Radiotherapy – IAEA Publication • IAEA (2000) – TRS-398: Absorbed Dose Determination in External Beam Radiotherapy – IAEA Publication • Podgorsak, E. B. (2010) – Radiation Oncology Physics: A Handbook for Teachers and Students – IAEA Resource • Khan, F. M. (2014) – The Physics of Radiation Therapy, 5th Ed., Lippincott Williams & Wilkins.

	• Attix, F. H. (2004) – Introduction to Radiological Physics and Radiation Dosimetry, Wiley-VCH. References • Seuntjens, J., and Palmans, H. (2018) – Dosimetry of Small and Non-Standard Fields in External Beam Radiotherapy, CRC Press. • AAPM TG-51 Report (1999) – Protocol for Clinical Reference Dosimetry of HighEnergy Photon and Electron Beams. • ICRU Report 90 (2016) – Key Data for Ionizing-Radiation Dosimetry • Alfonso, R. et al. (2008) – A New Formalism for Reference Dosimetry of Small and Non-Standard Fields, Medical Physics, 35(11): 5179–5186. • ISO/IEC 17025:2017 – General Requirements for the Competence of Testing and Calibration Laboratories – ISO Resource.

Course Outcomes:

C01	Explain the fundamental physics and challenges of small field dosimetry.	K1, K2
C02	Select and calibrate appropriate detectors for small field measurements.	K3
C03	Implement TRS-483–based dosimetry protocols in SRS/SBRT and IMRT QA	K4
C04	Understand calibration standards, reference fields, and traceability procedures.	K4, K5
C05	Apply ISO/IEC and IAEA standards for dosimetry quality management and uncertainty evaluation.	K2, K4, K5
K1 - Remember; K2 – Understand; K3 - Apply; K4 - Analyze; K5 – Evaluate		

MAPPING WITH PROGRAM OUTCOMES:

Map course outcomes **(CO)** for each course with program outcomes **(PO)** and program specific outcomes **(PSO)** in the 3-point scale of STRONG (3), MEDIUM (2) and LOW (1)**.**

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	3	2	1	1	3	2	1	1	1	1
CO2	3	3	3	2	3	2	2	1	2	2
CO3	3	2	3	3	3	2	2	2	3	2
CO4	3	3	3	3	3	3	2	2	3	3
CO5	3	3	3	3	3	3	3	2	3	3

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8	PSO9	PSO10
CO1	3	3	2	1	2	1	1	1	1	1
CO2	3	3	3	2	3	2	3	2	2	2
CO3	3	3	3	3	3	2	3	2	3	3
CO4	3	3	3	3	3	3	3	2	3	3
CO5	3	3	3	3	3	3	3	2	3	3

Core–Lab III: Medical Physics Lab II – Radiation Dosimetry Lab	II YEAR - III SEMESTER

Subject Code	Subject Name	Category	L	T	P	Credits	Inst. Hours	Marks
	Medical Physics Lab II – Radiation Dosimetry Lab	Core	0	0	6	3	-	100

Course Objectives

The objectives of this practical course are:

- To provide hands-on experience in clinical dosimetry procedures used in external beam radiotherapy and brachy therapy.
- 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 (Mandatory1)

   Measure lateral and depth profiles for photon beams.
2. Percentage Depth Dose (PDD) Measurement for Photons and Electron Beams (Mandatory2)

   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 (Mandatory3)

   Measure beam quality for MV photon beams.

7. Electron Beam Cone Factors Practical Range Measurement

   Determine Rp, R50,and build-up depth.

8. Flattening Filter Free (FFF) Beam Outputs Profile Study

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%/3mmand2%/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, Gantrys Couch Checks (Mandatory4)

    Verify isocenter congruence using mechanical tools.

16. MLC Leaf Position Accuracy and 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)forIr-1S2.

19. Brachytherapy Source Positioning Accuracy Test (Dwell Position Check)

    Verify programmed vs actual dwell positions.

20. TG-43 Parameter Validation Using Water Phantom (Mandatory5)

    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 Distributions 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–baseddoseevaluation.
- 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*. 5th ed., Lippincott Williams & Wilkins, Philadelphia, 2014.
2. Podgorsak, E. B. *Radiation Oncology Physics: A Handbook for Teachers and Students*. International Atomic Energy Agency (IAEA), Vienna, 2005.
3. Hendee, W. R., Ibbott, G. S., & Hendee, E. G. *Radiation Therapy Physics*. Wiley-Liss, New York, 2005.
4. Mayles, P., Nahum, A., & Rosenwald, J. C. *Handbook of Radiotherapy Physics: Theory and Practice*. CRC Press, Boca Raton, 2007.
5. Attix, F. H. *Introduction to Radiological Physics and Radiation Dosimetry*. Wiley-VCH, New York, 1986.

References (with downloadable links)

1. IAEA TRS-398: *Absorbed Dose Determination in External Beam Radiotherapy*- https://www.iaea.org/publications/
2. AAPMTG-51Protocol:*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 Report91: *Prescribing, Recording and Reporting of Stereotactic Treatments* https://icru.org/home/reports/

FOURTH SEMESTER

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**
	Elective-IV	**Dosimetric Audit and Clinical Trials in Medical Physics**	**3**	**2**	**1**	**0**	**25**	**75**	**100**
		Montecarlo Techniques in Dosimetry							
	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	**II YEAR - IV SEMESTER**

Subject Code	**Subject Name**	**Category**	**L**	**T**	**P**	**Credits**	**Inst. Hours**	**Marks**
	Radiation Protection	Core	3	1	0	4	60	100

Pre-Requisites
Radiological Physics, Physics of Radiotherapy, Radiation Dosimetry and its related subjects
Learning 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 casebased and simulation-based learning

UNITS	**Course Details**
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,	Physical protection of radiation sources and graded approach to security – National legislative framework: Atomic Energy Act, Atomic Energy (Radiation Protection)

Regulatory Control and Security (12 hrs)	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.
TEXT BOOKS & REFERENCE BOOKS	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.

Course Outcomes:

After completing this course, students will be able to:

C01	Explain international and national standards governing radiation protection.	K1, K2
C02	Design and evaluate radiation shielding following NCRP 151 and IAEA 47 guidelines.	K3
C03	Plan medical and research facilities ensuring compliance with AERB codes.	K4

C04	Implement regulatory, monitoring, and security procedures for safe radiation use	K4, K5
C05	Prepare, manage, and respond effectively to radiation incidents and emergencies in healthcare and related industrial settings.	K2, K4, K5
K1 - Remember; K2 – Understand; K3 - Apply; K4 - Analyze; K5 – Evaluate		

MAPPING WITH PROGRAM OUTCOMES:

Map course outcomes **(CO)** for each course with program outcomes **(PO)** and program specific outcomes **(PSO)** in the 3-point scale of STRONG (3), MEDIUM (2) and LOW (1)**.**

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**
CO1	3	2	1	1	3	2	1	1	1	1
CO2	3	3	3	2	3	2	2	1	2	2
CO3	3	2	3	3	3	2	2	2	3	2
CO4	3	3	3	3	3	3	2	2	3	3
CO5	3	3	3	3	3	3	3	2	3	3

	PSO1	**PSO2**	**PSO3**	**PSO4**	**PSO5**	**PSO6**	**PSO7**	**PSO8**	**PSO9**	**PSO10**
CO1	3	3	2	1	2	1	1	1	1	1
CO2	3	3	3	2	3	2	3	2	2	2
CO3	3	3	3	3	3	2	3	2	3	3
CO4	3	3	3	3	3	3	3	2	3	3
CO5	3	3	3	3	3	3	3	2	3	3

Core 17: Radiation Hazard Evaluation and Waste Management	**II YEAR - IV SEMESTER**

Subject Code	**Subject Name**	**Category**	**L**	**T**	**P**	**Credits**	**Inst. Hours**	**Marks**
	Radiation Hazard Evaluation and Waste Management	Core	3	1	0	4	60	100

Pre-Requisites
Radiological Physics, Physics of Radiotherapy, Radiation Dosimetry and its related subjects
Learning Objectives
• Provide an in-depth understanding of the sources, evaluation, and control of radiation hazards in diagnostic, therapeutic, and nuclear medicine installations. • Impart comprehensive knowledge on the management, storage, and disposal of radioactive wastes in compliance with AERB, IAEA, and national regulations. • Introduce the principles and legal frameworks of radiation protection, transport, and emergency preparedness as per Waste Disposal Rules (1987) and relevant safety codes. • Develop skills in radiation hazard assessment, calibration, and implementation of quality assurance programs for safe clinical operations. • Enable learners to interpret and apply the principles of regulatory control, safety audit, and waste management practices in healthcare and research facilities.

UNITS	**Course Details**
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	Primary and secondary standards for radiation measurements – Calibration of dosimeters, contamination monitors, and survey meters – Reference radiation fields (Xray, gamma, neutron) and calibration geometry – Corrections for scattering, attenuation, and background – Traceability of calibration to national standards

(12 hrs)	(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.
TEXT BOOKS & REFERENCE BOOKS	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

Course Outcomes:

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

C01	Evaluate radiation hazards in medical and industrial installations and apply appropriate control measures for staff, patients, and the public	K1, K2
C02	Classify, treat, and dispose of radioactive wastes following Waste Disposal Rule 1987, AERB, and IAEA guidelines with emphasis on nuclear medicine practices.	K3
C03	Apply the principles of radiation transport regulations and safety standards for packaging, labeling, and secure handling of radioactive materials.	K4
C04	Implement and maintain calibration, traceability, and quality assurance procedures in radiation safety instrumentation and monitoring.	K4, K5
C05	Demonstrate competency in establishing institutional radiation protection programmes, including waste management, audits, and regulatory documentation.	K2, K4, K5
K1 - Remember; K2 – Understand; K3 - Apply; K4 - Analyze; K5 – Evaluate		

MAPPING WITH PROGRAM OUTCOMES:

Map course outcomes **(CO)** for each course with program outcomes **(PO)** and program specific outcomes **(PSO)** in the 3-point scale of STRONG (3), MEDIUM (2) and LOW (1)**.**

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	3	2	1	1	3	2	1	1	1	1
CO2	3	3	3	2	3	2	2	1	2	2
CO3	3	2	3	3	3	2	2	2	3	2
CO4	3	3	3	3	3	3	2	2	3	3
CO5	3	3	3	3	3	3	3	2	3	3

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8	PSO9	PSO10
CO1	3	3	2	1	2	1	1	1	1	1
CO2	3	3	3	2	3	2	3	2	2	2
CO3	3	3	3	3	3	2	3	2	3	3
CO4	3	3	3	3	3	3	3	2	3	3
CO5	3	3	3	3	3	3	3	2	3	3

Elective IV: Dosimetric Audit and Clinical Trials in Medical Physics	**II YEAR - IV SEMESTER**

Subject Code	**Subject Name**	**Category**	**L**	**T**	**P**	**Credits**	**Inst. Hours**	**Marks**
	Dosimetric Audit and Clinical Trials in Medical Physics	Elective	2	1	0	3	45	100

Pre-Requisites
Radiological Physics, Physics of Radiotherapy, Radiation Dosimetry and its related subjects
Learning 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.

UNITS	Course Details
UNIT I: Principles and Framework of Audit (9 Hours: 6 Lecture +	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–Characteristicsofaneffectiveaudit: independence, documentation, and reproducibility –Roles of medical physicists within audit teams–International guidelines (IAEA,WHO,EURATOM) shaping

3 Tutorial)	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 m 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 (asperAAPMTG-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 SBRTaudits. • **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, team work, 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 dash boards, AI-based compliance tracking, and integrated safety analytics. **Tutorial Exercises:** • Evaluate compliance gaps using an example AERB audit check list. • Design a performance-indicator matrix for a hospital's radiation-safety program.

TEXT BOOKS & REFERENCE BOOKS	**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.

Course Outcomes:

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

C01	Differentiate between clinical, dosimetric, and safety audits, and apply appropriate frameworks in medical physics practice	K1, K2
C02	Design and conduct dosimetric audits at various levels (I–V) following AAPM TG113 and IAEA guidance	K3
C03	Implement audit methodologies and analyze findings to ensure quality and patient safety in radiotherapy and imaging.	K4
C04	Integrate safety governance, leadership, and human factor principles into institutional quality management systems.	K4, K5
C05	Demonstrate competence in meeting regulatory compliance requirements and contributing to continuous institutional quality improvement.	K2, K4, K5
K1 - Remember; K2 – Understand; K3 - Apply; K4 - Analyze; K5 – Evaluate		

MAPPING WITH PROGRAM OUTCOMES:

Map course outcomes **(CO)** for each course with program outcomes **(PO)** and program specific outcomes **(PSO)** in the 3-point scale of STRONG (3), MEDIUM (2) and LOW (1)**.**

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**
CO1	3	2	1	1	3	2	1	1	1	1
CO2	3	3	3	2	3	2	2	1	2	2
CO3	3	2	3	3	3	2	2	2	3	2
CO4	3	3	3	3	3	3	2	2	3	3
CO5	3	3	3	3	3	3	3	2	3	3

	PSO1	**PSO2**	**PSO3**	**PSO4**	**PSO5**	**PSO6**	**PSO7**	**PSO8**	**PSO9**	**PSO10**
CO1	3	3	2	1	2	1	1	1	1	1
CO2	3	3	3	2	3	2	3	2	2	2
CO3	3	3	3	3	3	2	3	2	3	3
CO4	3	3	3	3	3	3	3	2	3	3
CO5	3	3	3	3	3	3	3	2	3	3

Elective IV: Monte Carlo Techniques in Dosimetry	**II YEAR - IV SEMESTER**

Subject Code	**Subject Name**	**Category**	**L**	**T**	**P**	**Credits**	**Inst. Hours**	**Marks**
	Monte Carlo Techniques in Dosimetry	Elective	2	1	0	3	45	100

Pre-Requisites
Radiation Dosimetry
Learning Objectives
• 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.

UNITS	**Course Details**
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 miniproject proposal for clinical QA validation using Monte Carlo simulations.
TEXT BOOKS & REFERENCE BOOKS	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.

Course Outcomes:

After completing this course, students will be able to –

C01	Explain the theoretical foundations and statistical basis of Monte Carlo simulations in radiation dosimetry.	K1, K2
C02	Design and execute Monte Carlo simulations for photon, electron, and neutron transport.	K3

C03	Apply simulation tools to solve complex dosimetric problems in radiotherapy, diagnostic imaging, and radiation protection.	K4
C04	Assess and minimize uncertainties in simulation results through proper statistical and physical validation	K4, K5
C05	Integrate Monte Carlo–based methods into clinical quality-assurance and research protocols with awareness of regulatory standards.	K2, K4, K5
K1 - Remember; K2 – Understand; K3 - Apply; K4 - Analyze; K5 – Evaluate		

MAPPING WITH PROGRAM OUTCOMES:

Map course outcomes **(CO)** for each course with program outcomes **(PO)** and program specific outcomes **(PSO)** in the 3-point scale of STRONG (3), MEDIUM (2) and LOW (1)**.**

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**
CO1	3	2	1	1	3	2	1	1	1	1
CO2	3	3	3	2	3	2	2	1	2	2
CO3	3	2	3	3	3	2	2	2	3	2
CO4	3	3	3	3	3	3	2	2	3	3
CO5	3	3	3	3	3	3	3	2	3	3

	PSO1	**PSO2**	**PSO3**	**PSO4**	**PSO5**	**PSO6**	**PSO7**	**PSO8**	**PSO9**	**PSO10**
CO1	3	3	2	1	2	1	1	1	1	1
CO2	3	3	3	2	3	2	3	2	2	2
CO3	3	3	3	3	3	2	3	2	3	3
CO4	3	3	3	3	3	3	3	2	3	3
CO5	3	3	3	3	3	3	3	2	3	3

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 (last3–5years).
- 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 Frame work 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.
- Effectiveuse of Power Point, LaTeX-Beamer, or Google Slides.
- Voice modulation, pace, posture, and audience interaction techniques.
- Time management for 15–20 minute seminars with QCA.

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 view points.
- 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 (UniformWeightage–20%each)

Component	Description	Weightage
Topic Selection C Relevance	Novelty, scientific depth, And the suitability of chosen topic	20%
Technical Content C Understanding	Quality of review, depth of comprehension, Interpretation of data	20%
Presentation Structure C Slide Design	Logical flow, visual quality, And clarity of information	20%
Critical Analysis C Discussion	Insightfulness, comparative assessment, Originality of viewpoints	20%
Delivery C Interaction	Confidence, timing, clarity, QCA 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 resentations that effectively communicate research objectives, methodologies, and findings.
- Critically analyze 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, SpringerNature.
2. Davis, M. (2024). *Scientific Papers and Presentations*, 4th Edition, Academic Press.
3. Reynolds,G.(2023).*Presentation Zen: Simple Ideason Presentation Designand Delivery*,4thEdition,NewRiders.
4. O'Hair,D.,Stewart,R.,CRubenstein,H.(2023).*A Pocket Guide to Public Speaking*,8th Edition,Bedford/St.Martin's.
5. Alley,M.CAdair,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 (1Week)

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 (1Week)

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 work flow 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. International Atomic Energy Agency (IAEA). *Human Health Series No. 25: Postgraduate Medical Physics Training Curriculum*. IAEA, Vienna, Austria, 2013.
2. Atomic Energy Regulatory Board (AERB). *Safety Code No. AERB/RF-MED/SC-1: Medical Diagnostic X-ray Equipment and Installations*. AERB, Mumbai, India.
3. International Atomic Energy Agency (IAEA). *Training Course Series No. 37: Clinical Training of Medical Physicists Specializing in Radiation Oncology*. IAEA, Vienna, Austria, 2010.
4. World Health Organization (WHO). *Quality Assurance in Diagnostic Radiology Services*. WHO, Geneva, Switzerland.
5. American Association of Physicists in Medicine (AAPM). *AAPM Report No. 249: Essentials and Guidelines for Clinical Medical Physics Residency Training*. AAPM, Alexandria, VA, USA, 2022.

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.

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):

i. 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.

ii. 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.

iii. 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

THIRD YEAR

Residency Credits (32)

MEDICAL PHYSICS RESIDENCY PROGRAM

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.

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.

All Residents are shall be entitled to receive a monthly stipend throughout the duration of the residency of Rs.15000/- per month as per consumer price index 2025. The remuneration should be revised as per consumer price index on every year. 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

a) 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.

b) 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.

<u>Assessment Plan:</u>

- 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 mark sheet 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.

********* BEST WISHES *********