Faculty of Science

Syllabi

For

M.Sc. Medical Physics

(Session 2018-19)
Introduction
Medical Physics is an established clinical specialty with wide ranging application in Radiotherapy planning and treatment. It can be defined as embracing all applications of radioactive sources in the treatment of cancerous and non-cancerous disease. The student of Medical Physics also gains knowledge about different equipments used in Radiotherapy planning and treatment and their quality assurances. There is ample scope of research in area of medical physics. The students will also be imparted to training and teach. Therefore, medical Physics syllabus has been prepared in such a way that it will make the student a good clinical physicist, researcher and a teacher after qualifying this course. As this is a specialized branch of medicine and is multidisciplinary in nature, it requires skilled/trained manpower.

Aims and Objectives
The postgraduate training program is aimed at developing skilled technical manpower in Medical Physics. They should be able to demonstrate high standards of professional skills, competence/leadership qualities.

Duration of Course
Total Duration= 3 years (2 Academic Years + 1 year internship)
M.Sc. Medical Physics shall be of three years duration which includes one year internship programme in the final year of the course. Students shall undergo one year internship in the Radiotherapy Department of PGIMER (Chandigarh) or any other hospital as per AERB regulations. The dissertation on project work after its completion shall be submitted in the final year of the course.

No. of Seats
General seats = 10
NRI = 02
Total seats/year = 12

Admission Criteria:
Eligibility/Qualification
Admission to M Sc. Course in Medical Physics will be B.Sc. (Regular course) first class with Physics as core subject (studied for three years) and Mathematics as one of the subjects (studied for minimum two years) from a recognized university. The candidates who studied B.Sc. through correspondence and open university stream are not eligible.

Admission
Admission shall be made on the basis of PU-CET (P.G.). The entrance test paper will be the same as that for the admission to M.Sc. (H.S.) in Physics. While deciding the final merit of the entrance test, a weightage shall be given to the B.Sc. marks obtained by the candidate, as per university rules.

Syllabus
The broad outlines of the course are annexed and have been prepared keeping in view the guidelines/ requirements of AERB, BARC, Mumbai.

Teaching and Training
The Centre for Medical Physics, Panjab University, Chandigarh and the Department of Radiotherapy, PGIMER shall impart the teaching and training to the students jointly.
**First year** of the teaching/training will be mainly in the Panjab University in the Centre for Medical Physics.

**Second year** of the teaching and the clinical training shall be mainly in the Department of Radiotherapy, PGIMER, Chandigarh.

**Third year** of Internship Training (Duration one year) in Department of Radiotherapy, PGIMER, Chandigarh or any other hospital as per AERB regulation only.

After successful completion of one year Compulsory training the candidate becomes eligible to appear for Radiological safety Officer (RSO) qualifying examination conducted by AERB in coordination with RP&AD, BARC, Mumbai.

**Dissertation**
Every student shall be allotted a project under a supervisor (Medical Physicist) in the first month of the third year.

**Assessment and Evaluation**
In addition to regular internal assessment, theory and practical examinations will be held at the end of each semester.

**Award of M.Sc. Degree**
The candidates shall have to obtain a minimum of 50% marks in aggregate in theory and 50% marks in aggregate in practicals after each academic session, failing which, the candidate shall be reverted back and shall be awarded M.Sc. degree in Medical Physics after fulfilling the conditions. The Panjab University, Chandigarh shall award the final degree.
# FIRST YEAR

## First Semester

<table>
<thead>
<tr>
<th>Section</th>
<th>Marks</th>
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<tbody>
<tr>
<td>Theory</td>
<td>400</td>
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<tr>
<td>Practicals</td>
<td>200</td>
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<tr>
<td><strong>Total Marks</strong></td>
<td>600</td>
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**A. Theory Papers**

1. Cytology and Fundamental Anatomy of Human Body  100 Marks
2. Radiation Detection and Measurements  100 Marks
3. Radiation Physics  100 Marks
4. Radiation Biology  100 Marks

**Total = 400 Marks**

**B. Practicals**

1. Cytology and Fundamental Anatomy of Human Body  50 Marks
2. Radiation Detection and Measurements  50 Marks
3. Radiation Physics  50 Marks
4. Radiation Biology  50 Marks

**Total = 200 Marks**

## Second Semester

<table>
<thead>
<tr>
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</tbody>
</table>

**A. Theory Papers**

1. Basic Physiology and Cancer Biology  100 Marks
2. Analog and Digital Electronics  100 Marks
3. Applied Mathematics, Biostatistics and Computer Applications  100 Marks
4. Bio-Medical Applications of Radioisotopes  100 Marks

**Total = 400 Marks**

**B. Practicals**

1. Basic Physiology and Cancer Biology  50 Marks
2. Analog and Digital Electronics  50 Marks
3. Applied Mathematics, Biostatistics and Computer Applications  50 Marks
4. Bio-Medical Applications of Radioisotopes  50 Marks

**Total = 200 Marks**
SECOND YEAR

Third Semester

Theory = 400 Marks (4 Papers of 100 marks each)
Practicals = 200 Marks (4 Practicals of 50 marks each)
Total Marks = 600 Marks

A. Theory Papers
1. Radiotherapy Equipments and Quality Assurances 100 Marks
2. Medical Imaging equipments and Quality Assurances 100 Marks
3. Basics of Radiation Dosimetry 100 Marks
4. Teletherapy Treatment Planning 100 Marks
Total = 400 Marks

B. Practicals
1. Radiotherapy Equipments and Quality Assurances 50 Marks
2. Medical Imaging equipments and Quality Assurances 50 Marks
3. Basics of Radiation Dosimetry 50 Marks
4. Teletherapy Treatment Planning 50 Marks
Total = 200 Marks

Fourth Semester

Theory = 400 Marks (4 Papers of 100 marks each)
Practicals = 200 Marks (4 Practicals of 50 marks each)
Total Marks = 600 Marks

A. Theory Papers
1. Brachytherapy Treatment Planning and Radiobiological Models 100 Marks
2. Clinical Dosimetry and Standardization 100 Marks
3. Principles of Radiation Protection and Radiation Safety 100 Marks
4. Recent advances in Radiotherapy and Special Techniques 100 Marks
Total = 400 Marks

B. Practicals
1. Brachytherapy Treatment Planning and Radiobiological Models 50 Marks
2. Clinical Dosimetry and Standardization 50 Marks
3. Principles of Radiation Protection and Radiation Safety 50 Marks
4. Recent advances in Radiotherapy and Special Techniques 50 Marks
Total = 200 Marks

THIRD YEAR

Internship, Dissertation & Viva 300 marks
INTRODUCTORY CYTOLOGY
Cell Physiology and Biochemistry - Structures of the cell - Types of cells and tissues, their structures and functions - organic constituents of cells - carbohydrates, fats, proteins and nucleic acids - functions of mitochondria, ribosome, Golgi bodies and lysosomes - cell metabolism - DNA as a concepts of Gene and Gene actions - Mitotic and Meiotic cell divisions - semi-conservative DNA Synthesis, genetic variation crossing over, mutation, chromosome segregation- hereditary and its mechanisms.
DNA structure, Replication and Repair, RNA synthesis and Translation

MICROSCOPIC ANATOMY
Basic tissue: Epithelial tissue-electron microscopic structure and various structural modifications.
Connective tissue: Blood and its formed elements, loose connective tissue, extracellular components, fixed cellular elements.
Muscle: Structural and molecular organization of muscle and mechanism of muscle contraction.
Nervous tissue: Neurons, neuroglial cells and nerve fibre. Mechanism of myelination and synapsee

GROSS ANATOMY
AXIAL Skeleton: Skull - Cranium, face, air sinuses, Vertebral column: regions, movements and vertebrae characteristics; Sternum, Ribs
Anatomy and Imaging: Anatomical planes, diagnostic imaging techniques.
Back: Component parts (bones, muscles, vertebral canal, spinal nerves, dermatomes), regional anatomy (vertebrae, joints, ligaments, musculature), back surface anatomy.
Thorax: Component parts (thoracic wall, thoracic aperture, diaphragm, mediastinum, pleural cavities, thorax surface anatomy.
Head and Neck: Component parts (skull, cervical vertebrae, hyoid bone, soft palate and muscles in the head and neck.
Abdomen: Component parts (wall, abdominal cavity, inferior thoracic aperture, diaphragm, pelvic inlet, surface anatomy, defining surface projection, Liver, kidney and spleen position, gallbladder, pancreas.
Pelvis: component parts (Pelvic inlet, pelvic walls, pelvic outlet, pelvic floor, pelvic cavity and perineum).
Lower and Upper limb: Component parts (bones and joints, muscles)

PRACTICALS
1. To identify different parts of a human skeleton
2. To identify types of epithelial tissue: (squamous, stratified, pseudostratified) systems using light microscope.
3. To visualise microanatomical view of musculoskeletal system using light microscope.
4. To visualise microanatomical view of Respiratory system (Larynx, pharynx, trachea, principal bronchi, lungs) systems using light microscope.
5. To visualise microanatomical view of Digestive system (esophagus, stomach, small and large intestine, rectum)
7. To visualise microanatomical view of Reproductive system of male: Testes, Ductes deferens, Seminal vesicle, prostrate using light microscope.
8. To visualise microanatomical view of Reproductive system of female: Ovary, fallopian tube, uterus using light microscope.
10. To make block and cut section of the embedded tissue with the help of microtome and finally make a slide. To stain the sectioned tissue and prepare a permanent slide after H/E staining.
11. To determine TLC, red blood cell counts using hemocytometer
12. To study DLC in blood smear.
14. Estimation of activities of enzymes viz alkaline phoshatase, acid phophatase, SGOT and SGPT

Books for references:
1. Wolfgang Kuehnel, Color Atlas of Cytology, Histology, and Microscopic Anatomy
2. Guyton and Hall. Textbook of Medical Physiology
4. Tortora and Derrickson, Principles of Anatomy and Physiology
5. Bloom and Fawcett, Concise Histology
6. B.D. Chaurasia. Human Anatomy
7. Openstax College. Anatomy and Physiology
8. Frederic H. Martini, Michael J. Timmons, Robert B. Tallitsch, Human Anatomy
9. Susannah Longenbaker, Mader's Understanding Human Anatomy & Physiology
10. Kent M. Van De Graaff, R. Ward Rhees, Schaums Outline of Human Anatomy and Physiology
FIRST YEAR - FIRST SEMESTER

Paper – II

RADIATION DETECTION & MEASUREMENTS (45 Lectures)

Basics of Solid State Physics:


Charge carriers in semiconductors: Electrons and holes, Effective mass, Intrinsic Material, Extrinsic Material, Fermi levels

Drift of carriers in electric and magnetic fields: Conductivity and mobility, Drift and resistance, effects of temperature and doping on mobility, high fields effects, Hall effect.

Crystal structure: Crystalline state- Periodic structure, cubic Lattice, Planes and directions, the Diamond Lattice, Basic definitions- Lattice and basis-Lattice translational vector-Primitive cells and unit cells – Wigner –Seitz cell – Indexing of planes, directions and positions of atoms-crystal systems – Bravais lattices - Simple crystal structures (Hexagonal close packed structure, NaCl, CsCl, Diamond structure, Cubic ZnS structure), Growth of single-crystal Ingots

X-ray diffraction – Laue’s treatment-Braggs treatment – Laue’s method-Rotating crystal method-Powder method.


Colour centres – Types of colour centres, F-Centre, Generation of colour centres.

Gas filled detectors

Theory of ionization chamber, design consideration in an ionization chamber, operating voltage, theory and construction of condenser type of chambers and thimble chambers; gas multiplication, Proportional counters- design and characteristics. Geiger-Mueller counters – design consideration.

Ionization Chambers: The Ionization Process in Gases, Charge Migration and Collection, Design and Operation of DC ion Chambers, Radiation Dose Measurement with Ion Chambers, Applications of DC Ion Chambers, Pulse Mode Operation.

Proportional Counters: Gas Multiplication, Design Features of Proportional Counters, Counter performance, Variants of Counter Design.


Scintillation detectors


Gamma-Ray Spectrometers, Gamma-ray spectrum, photo peaks, Compton valley, edge and plateau, backscatter peak, escape peak, annihilation peak. Pulse height selector and resolution of energies, FWHM an energy calibration, geometric efficiency, intrinsic efficiency.

Bismuth Germanate detector, Barium Fluoride detector, Technetium orthosilicate detectors, Yttrium orthosilicate detector.


Liquid scintillation counters: Composition of liquid scintillator (scintillation cocktail): primary solute, secondary, solute and organic solvent (toluene,1,4 dioxane, anthracene) and solublizing agents for tissues, coincidence circuits and display. Quenching and quench correction methods: Internal standard method, external standard method and channel ratio.
Semiconductor Diode Detectors: Semiconductor Properties, Semiconductors as Radiation Detectors, Semiconductors junction and surface barrier detectors, HPGe and Si(Li) detectors, their response and characteristics.

Slow and fast Neutron Detection Methods: Nuclear reactions of interest for detection of slow and fast neutrons, Detectors based on activation.

Instruments for nuclear spectrometry:

**Pulse Processing:** Overview of Pulse Processing, Device Impedances, Coaxial Cables, Linear and Logic Pulses, Instrument Standards, Pulse-Processing Units.

**Pulse Shaping and Counting:** Preamplifiers, amplifiers, pulse height analyzers, Single-Channel Methods, MCA, high voltage supply, coincidence & anti coincidence circuits.

**Background and Detector Shielding:** Sources of background, Background In gamma-ray Spectra, Background in other detectors, Shielding materials, Active methods of background reduction.

**Thermo Luminescent Dosimeters:** Physics of TLD, characteristics TLD phosphors, glow curves, dose and energy response, sensitivity and application in-dosimetry and personnel monitoring devices.

**Miscellaneous Detector Types:** Track-Etch Detectors, use of photographic emulsions stripping film technique, dipping method, grain density counting and track counting, X-ray films, intensifying screens, fluoroscopy.

**PRACTICALS**

1. To prepare FBX dosimeter and check its linearity with different radiation exposures.
2. To estimate the radiation dose absorbed by different organs by using FBX dosimeter.
3. To determine the energy resolution of spectrometer and effect of scatter in source volume
4. To learn the mode of operation of a scintillation counter and its operating characteristics.
5. To identify unknown radionuclide on the basis of its principal energy by using scintillation counter
6. To determine the radiation response of thermo luminescent dosimeter (TLD)
7. To find out the spectrum of energies emitted by a radioisotope by using gamma ray – spectrometer.
8. Gamma ray spectrometry with a single channel analyzer.
9. Effect of EHT and gain on spectrometer using a mixture of two radionuclides.
10. Demonstration of liquid scintillation counter.
11. To determine the plateau of GM tube and find out the dead time/ resolving time of GM counter
12. To determine the efficiency of GM counter and find out the strength of the unknown radioactive source
13. To demonstrate how well type gamma ray spectrometer can be used as a whole body counters for small animals.
14. To demonstrate the retention of activity in organ of interest or whole body by using scintillation counter and whole body counter.

**Books for references:**

1. Price W.J. Nuclear Radiation Detection
2. Stepanor B.I., Theory of Luminescence
3. Glenn F Knoll, Radiation Detection & Measurement
4. William R. Leo, Techniques for Nuclear and Particle Physics Experiments
5. Gordon R. Gilmore, Practical Gamma-ray Spectrometry
7. Paul-Horowitz. Art of Electronics

Radioactive decay: Laws of radioactivity, types of radiation ($\alpha$, $\beta$, $\gamma$, X-ray, n), Decay processes; decay modes, Probability and decay constant. Radioactivity, decay equation, physical half life, mean life; Radioactive series- natural radioactive series & artificial radioactivity; beta particle spectrum; K-electron capture. General aspects of gamma decay, internal conversion, Metastable state and isomeric transition.

Nuclear reactions: Conservation Laws, reaction cross section, types of reactions, compound nucleus, nuclear fission, fission products, fissile materials, various types of reactors, Fusion and thermo nuclear reactions.

Interaction of $\gamma$ and X-rays with matter: Exponential attenuation, Photoelectric and Compton process, Pair production - Attenuation and mass energy absorption coefficients - Relative importance of various processes.

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


Interaction of neutrons with matter - Diffusion and slowing down of neutrons, Neutron capture, elastic scattering, energy transfer and logarithmic energy decrement, inelastic scattering, thermal neutrons, dependence on E and Z. ($n$, p), ($n$, $\alpha$), ($n$, $\gamma$) and other reactions, neutron activation.

Radiation Exposure and Dose - Units of radioactivity: Becquerel, Curie, specific activity, carrier free activity. Radiation dose, Roentgen unit of exposure, radiation sensitivity of biological materials, radiation absorbed dose (RAD, Gray), radiation weighting factor, Relative biological effectiveness (RBE), Quality factors, Roentgen Equivalent man (REM), Sievert, equivalent dose, effective dose, collective equivalent dose, total effective dose equivalent.


Radiation generators
X-ray generators: Physics of X-ray production - Inner-shell vacancy decay, Characteristic x-ray radiation, Auger effect, fluorescent yield. X-ray tube, Anode, Cathode filament, High voltage generation, voltage rectification, operating characteristics.
Particle accelerators: Motion of charged particles in electric field, magnetic field and E x B fields, Relativistic particles,

PRACTICALS
1. To measure Half Value Layer's of $\beta$ and $\gamma$ emitters and determine linear mass absorption coefficients.
2. To study the factors producing background counts.
3. To study self absorption using beta emitting radioisotopes.
4. To study the back scatter of beta particle.
5. To study the absorption of radiation by solvents and to determine the counting errors originating from sample geometry.
6. To study how to avoid certain errors in handling carrier free solutions.
7. To determine absorption coefficients of biological tissues with $\beta$ and $\gamma$ radioactive sources of different energies.
8. To study the change in activity of a sample consisting of two independently decaying radioisotopes.
9. To study the statistics of radioisotopic measurements and observe the effect of background on the counting statistics.
10. To determine the half lives of radioactive isotopes

Books for references:
1. Oliver R., Radiation Physics in Radiology.
2. E.B. Podgarsak,: Radiation Physics for Medical Physicists (Springer Verlag,1996)
7. Chesney, D.N. & Chesney,M.O, X-ray equipment for student radiographers
8. K.S. Krane, Introductory Nuclear Physics, Wiley India
9. C. J. Karzmark, Robert J. Morton, A Primer on Theory and Operation of Linear Accelerators in Radiation Therapy
11. Thomas S. Cury, James E. Dowdey, Christensen Physics of Diagnostic Radiology
12. Bushberg, The Essential Physics for Medical Imaging
13. Penelop Allisy Roberts and Jerry Williams, Farr's Physics for Medical Imaging
Radiation Chemistry: direct and indirect effects of radiations, radiation chemical yields and G-values, formation of free radicals, radiolysis of water, radiation effects on simple chemical systems, interactions of free radicals with several solutes. Direct versus indirect effects in aqueous solutions. Reactions in aqueous, organic and inorganic solutions.

Interaction of radiation with living cells: Direct action, indirect action, radiolysis of water-Free radical interaction with bio molecules including DNA, radiation effects on cell: cell cycle- DNA strand breaks, energy metabolism, synthetic processes, chromosomes, chromosomal type aberrations and repair, chromatid type aberrations, sub chromatid aberrations, relation between aberration structure and the mitotic and meiotic cycles. Radiation effects on cell division.

Radiation Molecular Biology: radiation effects on proteins, nucleic acids, carbohydrates, lipids, polymerases, transferases, isomerases and anti-oxidative enzymes.

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- radio sensitivity protocol of different tissues in human.

Radiation and independent cell systems: Target theory, multitarget theory, target size, multihit theory, multitarget multihit theory.

Differential cell response: Criteria of radiosensitivity, factors affecting sensitivity, average interphase chromosomal volume, ploidy, nuclear factors, cytoplasmic factors, categories of mammalian cell sensitivity, Specific classifications of mammalian cell sensitivity.

Biological effects of radiation
Classification of radiation damage, Potentially lethal damage and sub lethal damage; recovery - Pathways for repair of radiation damage.


Modification of radiation injury - Physical modifications of radiation injury, relative biological effectiveness, linear energy transfer, dose rate effect, chronic irradiation, biological factors influencing radiation response, age, diet, genetic constitution, oxygen concentration, temperature etc.
Acute radiation effects: Lethality, acute radiation syndrome in mammals, effects of prenatal development, radiation effects on regeneration.
Dose and dose rate effect and fractionation. Other dose modifying agents: LET, RBE, Radiosensitizers and Radio protectors. Applications of above agents in radiotherapy.
Radiation Effects on Major Organ Systems
Effects of radiation on skin and blood forming organs (Spleen, bone marrow, Lymphoid tissue, thymus) and blood constituents, vascular system, digestive system, respiratory system, urinary system, nervous system, endocrine system, immune system reproductive system, embryo Sterility.

Applications of Radionuclides in Biology
Concept of uptake of radionuclides in the organ of interest, effective half life/ biological half life in specific organs and whole body. $^{51}$Cr labeling with red blood cells: applications in blood volume measurement, spleen uptake, red cell survival studies, red cell volume and proteins turn over. Theoretical aspects of tracer techniques and basic requirements for radiotracer investigations. $^{59}$Fe absorption studies, Techniques for studying absorption of labeled substance, $^{59}$Fe turn over studies, plasma iron clearance
$^{58}$Co/$^{57}$Co: Applications in schilling’s test of vitamin B12 absorption, double tracer technique and whole body counting
$^{60}$Co: in cancer treatment, gamma knife
$^{32}$P applications in polycythemia vera and leukemia
$^{14}$C applications in urea breath test, Radiorespirometry, in vitro uptake and turnover studies using $^{14}$C glucose, $^{14}$C amino acids and fatty acids.
$^{45}$Ca, $^{65}$Zn and $^{3}$H metabolic studies and other biomedical applications.

PRACTICALS
List of experiments is same as mentioned in Paper IV (Second semester). Students are expected to perform at least 6 experiments in each semester. The experiments performed in first semester cannot be repeated in second Semester.

1. To determine the turnover of $^{14}$C glucose in liver slices using radiorespirometric technique.
2. To demonstrate that tritium labeled thiamidine is incorporated in DNA
3. To study in vivo incorporation of $^{14}$C uracil in RNA.
4. To determine the in-vitro uptake of $^{14}$C labeled amino acids in the given organ slices.
5. To study the bio-kinetics of $^{45}$Ca in understanding its metabolism in bone when administered in an animal.
6. To study the effects of ionizing radiations on the activities of enzymes
7. Use of gamma ray scintillation counter for measuring in vivo thyroid uptakes following administration of carrier-free $^{131}$I.
8. To study the influence of carrier on in- vivo uptake carrier free $^{131}$I by the thyroid.
9. To find out the bio-distribution of a given radionuclide in a given animal.
10. To label the red blood cells using $^{51}$Cr and to determine the efficiency of labeling.
11. To find out the average life span of red blood cells by using $^{51}$Cr radionuclide
12. To determine the blood volume of a given animal using $^{51}$Cr labeled red blood cells.
13. To measure the blood volume of a given animal using $^{99}$Tc labeled red blood cells.
14. To prove that spleen is the storehouse of worn out red blood cells by using $^{51}$Cr labeled red blood cells.
15. To find out the target / non target ratio of $^{99m}$Tc labeled pharmaceuticals.
16. To determine the biological half life of $^{99m}$Tc $O_4^-$ and labeled pharmaceuticals.
Books for references:
1. Alison P Casserette, Radiation Biology
2. Uma Devi, Handbook of Radiation Biology
3. Erij J Hall, Radiobiology for the Radiologist
4. Gordon Steel, Radiobiology
5. Michael Joiner, Albert van der Kogel, Basic Clinical Radiobiology
6. Gopal B. Saha, Fundamentals of Nuclear Pharmacy
7. Gopal B. Saha, Physics and Radiobiology of Nuclear Medicine
FIRST YEAR - SECOND SEMESTER

Paper – I
BASIC PHYSIOLOGY AND CANCER BIOLOGY (45 Lectures)

HUMAN PHYSIOLOGY
Respiratory system: General physiological functions of respiratory system, Nose and nasal cavities – functions, respiratory vocal, Tracheal, Bronchi, lungs: lobes, lobules, pleura.
Common terms relating to diseases and conditions of the system.
The Circulatory System - Blood vessels arteries, veins, capillaries, sinusoids, structure and functions. Heart Position, structure and functions.
Circulation of blood Pulmonary, systemic, portal, main blood vessels, their origins and distribution.
Diseases of blood vessels and conditions of the system.
Methods of recording ECG.
The lymphatic system - parts of the lymphatic system. Lymph channels: capillaries, vessels, ducts. Lymph nodes. Lymphatic tissues tonsils, adenoids, intestinal nodules. Spleen. Diseases and conditions of the system.
The digestive systems - Elementary tract structure: Position, structure and functions of Mouth, Pharynx, Salivary glands, Esophagus, Stomach, Liver, Gallbladder, Small intestine, Large intestine.
Digestion and absorption, Metabolism of carbohydrates. Proteins and fats. Diseases and conditions of the digestive systems.
The Urinary System - Parts of urinary systems. Kidneys, Ureters, Urinary bladder, Urethra.
Formation and composition of urine. Diseases and conditions of the system.
The reproductive system - Female reproductive system: Position, structures and functions of External genitalia, Perineum, Internal organs, Vagina, Uterus, Fallopian tubes, Ovaries.
Menstrual cycle: stages, hormone control, ovulation.
Breasts (mammary glands); Changes: puberty, in pregnancy, during lactation.
Male reproductive system: Scrotum, testis, epididymus, Spermatogenesis, Spermatic cords, seminal vesicles, ejaculatory ducts, Prostate glands, Urethra and penis, Functions of male reproductive system. Puberty, Disease of female and male reproductive systems.
Endocrine system:
Endocrine glands, Pituitary and hypothalamus, Thyroid glands, Thyroid hormone production and hormonal control, Adrenal (Supra renal gland), Parathyroids glands, Pancreas, Pineal gland. Secretion of hormones, their function & control. diseases produced by excess or deficiency of the hormones.
The organs of sense:
Hearing and the ear: external, middle and inner ear.
Physiology of hearing and diseases of ear.
Sight and the eye: Sclera, cornea, choroids, ciliary body, iris, lens, retina, optic nerves.
Physiology of sight and disease of the eye.
Sense of the smell: olfactory nerves- origins, distribution. Physiology of the smell.
Sense of taste - organs, physiology of the taste. Common disease of the system.
The nervous systems:
Neurons, Central nervous system: neurons, neuralgia, meninges.
Ventricles of the brain, C.S.F.
BRAIN, SPINAL CORD: structures, functions peripheral nervous system.
Spinal and cranial nerves, Automatic nervous system, Sympathetic and para sympathetic.
Common disease of the system.
Hypothermia, wound healing, primary and secondary disease of the skin.
BIOLOGY OF CANCER
Classification, nomenclature and definition of neoplasm: Transformed cells and cell lines, cancer cells differentiation, alterations in cancer cell behavior, diminished contact inhibition and defects in cell to cell metastasis.
Cancer Invasion and Metastasis: Stages of metastasis (Invasion, local extension, discontinuous extension), transport of cancer cells to distant sites

PRACTICALS
1. Demonstration of micronucleus assay.
2. To perform DNA fragmentation assay.
3. To perform COMET assay for DNA damage.
4. To study apoptosis using TUNEL assay.
5. To estimate proteins in serum and tissues.
6. To study chromosomal aberrations.
7. To study the cell proliferation using MTT assay.
8. To study muscular activity using actophotometer.
9. To study locomotor functions by rotarod.
10. To study learning and memory process using moris water maze and plus maze

Books for references:

1. Wolfgang Kuehnel, Color Atlas of Cytology, Histology, and Microscopic Anatomy
2. Guyton and Hall, Textbook of Medical Physiology
4. Tortora and Derrickson, Principles of Anatomy and Physiology
5. Bloom and Fawcett, Concise Histology
6. Kumar Abbas Aster, Robbins Basic Pathology
7. Openstax College, Anatomy and Physiology
8. Susannah Longenbaker, Mader's Understanding Human Anatomy & Physiology
9. Kent M. Van De Graaff, R. Ward Rhees, Schaums Outline of Human Anatomy and Physiology
Semiconductor devices - pn-junction, forward and reversed bias, Rectification circuits, power supplies, Monolithic voltage regulators and filters, Voltage multipliers, clippers. PNP and NPN junction transistors, transistor current components, CB, CE and CC configurations. Biasing of transistors, Transistor switching action, Small signal equation and equivalent circuits for transistors, Field effect transistor (FET), MOFET. Special devices- UJT, SCR, Diac-Triac, Opto-isolator, Zener diode, Schottky diode, Tunnel diode, Solar cells, photodiode, p-i-n diode; phototransistor, LED and Semiconductor LASER. LCD and LED based displays. Opto electronic devices, Optical fibre communication

Transducers - Properties and the principle of transducers, Resistive transducer, thermoresistors, Inductive transducers, Thermoelectric, Piezoelectric, Magnetostrictive, Hall effect type, Electromechanical, Accelerometer, Photoelectric, Ionization, Electrochemical their biomedical applications. Charge coupled devices and its applications in imaging.

Op-amp applications - Basic operational amplifier applications- Differential DC amplifier- instrumentation amplifier- integrators and differentiators – Analog computation- Active filters. Comparators, Regenerative comparator, Square, triangular and sine waveform generators, sample and hold circuit, precision AC/DC converters, voltage regulators. Instrumentation amplifier, voltage to current and current to voltage converter, Sample and Hold circuits, Log and Antilog amplifiers. 555 timer based circuits - Astable, Monostable Multivibrator. RC Active filters


Digital logic families: RTL, DTL, TTL, ECL, CMOS, MOS, Tri-state logic - switching and propagation delay, fan out and fan in, TTL-CMOS and CMOS-TTL interfaces. Noise in electronics due to ionising radiation, radiation damage; radiation hardening techniques in manufacture and in application

Microprocessors & Micro Controllers
Microprocessor, Buffer registers, Bus organised computers, SAP-I, Microprocessor (µP) 8085 Architecture, memory interfacing, interfacing I/O devices. Assembly language programming: Instruction classification, addressing modes, timing diagram, Data transfer, Logic and Branch operations- Programming examples. Introduction to microcontrollers- comparison with microprocessors- study of microcontroller (MC 51 family) - Architecture, instruction set, addressing modes and its programming.
PRACTICALS
1. To measure AC voltage signal and its frequency using an oscilloscope and to study NPN & PNP transistor and characteristic of multivibrator.
2. To use an Oscilloscope as a display for studying the half wave rectifier and to set up LC filter circuit, L and C filter circuits and study the waveform obtained on the oscilloscope. Find the ripple factor in each case.
3. Two stage RC coupled amplifier - frequency response.
5. Characteristics of a regulated power pack.
6. OPAMP circuits - Inverting and non inverting amplifiers.
7. Integrator and differentiator circuit using OPAMP.
8. To demonstrate ECG in normal and treated animals.
9. To demonstrate electrical impedances in biological tissues.

Books for references:
2. Curry, T.S. Dowdey and J.E. Murry, R.C, Christensen’s introduction to the Physics of diagnostic radiology (Philadelphia, Lea & Febiger)
5. Ben Streetman, Sanjay Banerjee, Solid State Electronic Devices
7. R.S. Gaonkar Microprocessor Architecture, Programming and Applications with 8085
8. Robert Boylestad Louis Nashelsky, Electronic Devices and Circuit Theory
9. Boylestad, Introductory Circuit Analysis
FIRST YEAR - SECOND SEMESTER

Paper – III

APPLIED MATHEMATICS, BIOSTATISTICS AND COMPUTER APPLICATIONS

(45 Lectures)

VECTOR CALCULUS AND MATRICES

SPECIAL MATHEMATICAL FUNCTIONS
Definition and general properties (without proof) Dirac delta function, Gamma function, Beta function.
Bessel functions of first and second kind, Legendre functions, Associated Legendre functions and Laguerre functions - Generating function, recurrence, orthogonality and special properties and its applications.

FOURIER AND LAPLACE TRANSFORMS
Fourier series – Harmonic analysis, Fitting of data with Fourier Series.
Fourier transform- Properties – transforms of simple functions and derivatives- Convolution theorem. Applications of Fourier Transform in Medical imaging.

BASICS OF DIGITAL SIGNAL PROCESSING
Classification of signals, Sampling of analog signals, Sampling theorem (without proof), Aliasing, Quantization, Frequency range of natural signals.
Classification of Discrete-Time (DT) systems, Analysis of Discrete-Time Linear Time-Invariant (LTI) systems, DT systems described by difference equations, Cross-correlation, Auto-correlation and Convolution of sequences of DT signals.
Frequency analysis of Discrete-Time signals. Fourier series for Discrete-time periodic signals and power density spectrum, Fourier transform of Discrete-time A periodic signals and energy density spectrum. Discrete Fourier Transform (DFT) and applications in image processing.

MONTE CARLO METHODS: Random variables, random variables – discrete & continuous, probability density function – discrete & continuous, cumulative distribution function, accuracy and precision, law of large number, central limit theorem.
Random numbers and their generation, tests for randomness, inversion random sampling technique including worked examples, integration of simple multidimensional integrals including worked examples.
Simulations using Monte Carlo methods: Geometrical simulations, absorption of gamma rays in matter. Brief account of electron-gamma shower (EGS), MCNP and GEANT simulation codes.

PROBABILITY, STATISTICS AND ERRORS
Fundamentals of Probability - addition and multiplication laws of probability, conditional probability, population, variates, collection, tabulation and graphical representation of data.
Basic ideas of statistical distributions frequency distributions, Measures of central tendency, arithmetic mean, median, mode, geometric mean, harmonic mean. Measures of dispersion, standard deviation, root mean square deviation, standard error and variance.
Moments, skewness and kurtosis.
Binomial distribution, Poisson distribution, Gaussian distribution, Multinomial distribution, Hypergeometric distribution, exponential distribution - additive property of normal variates, confidence limits, Bivariate distribution.

Sampling and sampling distributions, Sample distribution of sample mean and sample proportions. Significance tests, Tests of hypothesis for the parameters of normal distribution including testing for population proportions. Confidence intervals for the parameters of normal distribution.

Chi-Square distribution, t-distribution, F-distribution.

Correlation analysis, Regression analysis, Partial and multiple.
Categorical data: measurements scales, tests of associations, Chi-square test, Yate's correction.

PRACTICALS


Computational packages: MATLAB, and SPSS in data analysis and graphics.
MATLAB: Introduction to MATLAB environment, Constants, Variables and Expression, Matrices, Polynomials, I/O statements, MATLAB graphics, Data handling with Structures, Arrays with large dataset, Matrix operations in 3D and 4D datasets, Programming, Image processing toolbox – Coding, scanning and recognition, optimization toolbox, wavelet toolbox


Curve fitting - Principle of least squares.
Taylor series, approximating the derivation, numerical differentiation formulas. Introduction to numerical quadrature, Trapezoidal rule, Simpson's 2/3 rule, Simpson's Three-Eighth rule. Picard's method, Taylor’s method, Euler's method, the modified Euler’s method, Runge-Kutta method.

Books for references:
1. Sabine Landau and Brian S. Everitt, A Handbook of Statistical Analyses using SPSS
2. E. Balaguruswami, Object Oriented Programming by C++
3. S.S. Sastry, Introductory Methods of Numerical Analysis
4. Tao Pang, An Introduction to Computational Physics
Nuclear Medicine:
Physics of Nuclear Medicine: Radioisotopes in medical diagnosis; scintillation counters, properties of radioisotopes; units of dosage, specific activity; effective half-life; diagnostic use of radioisotope in vivo and in vitro procedures

Use of $^{131}$I for diagnosis of hypo and hyper thyroidism, blood volume studies using RIHSA and Cr-51; Red cell survival studies using $^{51}$Cr; studies of iron metabolism, diagnostic test using Vitamin $^{12}$B labeled with radio cobalt; circulation studies with $^{24}$Na, cardiovascular studies, tumour localization.

Preparation of tracers and labeled compounds; Preparation of radio colloids; Bone scanning, principle, agents for bone scanning, $^{99}$Mo, $^{99m}$Tc, indications for bone scanning, various agents for one scanning, interpretation, pitfalls in bone scanning, limitations, radiopharmaceuticals used for brain scanning, technique with technetium per technetate, the normal clinical applications, radiopharmaceuticals in liver scanning comparison, technique with $^{99m}$Tc, Sulphur scans, pitfalls, clinical applications; Ga in Clinical Studies: Energy spectrum of $^{67}$Ga, optimization of parameters for $^{67}$Ga scanning, clinical applications.

Therapeutic applications in Nuclear Medicine: Choice of radio nuclides and choice of radiopharmaceuticals, Radio immunotherapy, Pre and post imaging, patient preparation and hospital practice.

Bio-medical applications
Thyroid radioactive uptake measurements: Tracer dose, use of carrier, standard and phantom, shielding and collimation, factors affecting thyroid radioactive iodine uptake, PBI-131, thyroid stimulation test, thyroid clearance rate thyroid suppression test, perchlorate discharge test, uptake of radiolabel T3 by red cells, T3 charcoal test.

$^{131}$I therapy for treatment of hyperthyroidism, thyroid follicular carcinoma.
$^{125}$I applications: Radio-immuno assays of T3, T4, TSH and other hormones, uptake by thyroid and treatment of thyroid disorders
$^{123}$I applications
$^{99m}$Tc applications in medical imaging of different organs and dynamic/function studies.
$^{201}$Tl/$^{82}$Rb – myocardial uptake/perfusion imaging, $^{67}$Ga for scintigraphy of tumors and infections, $^{18}$FDG in brain, heart and tumor imaging
Radionuclides in therapy- $^{89}$Sr, $^{186}$Re-HEDP, $^{153}$Sm-EDTMP, $^{177}$Lu.

Radiation protection
Principles of radiation protection – Quantities used in radiation protection, Justification of practice, optimization of protection and Individual dose and risk limits, regulatory aspects of radiological safety, Control of internal and external hazards.
Radioactive waste disposal - decontamination of labs, clothes, hands, glassware, gloves, metals, plastics, paints and bricks, decontamination of person, decontamination of room Radiosotopic waste, general principles, liquid and solid waste, disposal of solid, liquid and gaseous effluents/waste, decaying storage transfer to authorized personal, management of sealed and unsealed sources.
Transport of radioactive material - storage and transport of waste, transport index.
Introduction to designing of radiation laboratory: Classification of radiation labs, design of areas for radioisotope laboratories, criteria for grading laboratories using unsealed radioisotopes
PRACTICALS

List of experiments is same as mentioned in Paper II (First semester). Students are expected to perform at least 6 experiments in each semester. The experiments performed in first semester cannot be repeated in second Semester.

1. To determine the turnover of $^{14}$C glucose in liver slices using radiorespirometric technique.
2. To demonstrate that tritium labeled thiamidine is incorporated in DNA
3. To study in vivo incorporation of $^{14}$C uracil in RNA.
4. To determine the in-vitro uptake of $^{14}$C labeled amino acids in the given organ slices.
5. To study the bio-kinetics of $^{45}$Ca in understanding its metabolism in bone when administered in an animal.
6. To study the effects of ionizing radiations on the activities of enzymes
7. Use of gamma ray scintillation counter for measuring in vivo thyroid uptakes following administration of carrier-free $^{131}$I.
8. To study the influence of carrier on in-vivo uptake carrier free $^{131}$I by the thyroid.
9. To find out the bio-distribution of a given radionuclide in a given animal.
10. To label the red blood cells using $^{51}$Cr and to determine the efficiency of labeling.
11. To find out the average life span of red blood cells by using $^{51}$Cr radionuclide
12. To determine the blood volume of a given animal using $^{51}$Cr labeled red blood cells.
13. To measure the blood volume of a given animal using $^{99m}$Tc labeled red blood cells.
14. To prove that spleen is the storehouse of worn out red blood cells by using $^{51}$Cr labeled red blood cells.
15. To find out the target / non target ratio of $^{99m}$Tc labeled pharmaceuticals.
16. To determine the biological half life of $^{99m}$Tc O$_4$ and labeled pharmaceuticals.

Books for references:

8. Herman Cember. Introduction to Health Physics
9. Shapiro J. Radiation Protection
10. Mckenzie. Radiation protection in Radiotherapy
SECOND YEAR - THIRD SEMESTER

Paper – I
RADIOTherapy EQUIPMENTS AND QUALITY ASSURANCES (45 lectures)

RADIOTherapy EQUIPMENTS

Radiation sources
Natural and artificial Radioactive Sources: large scale production of isotopes, reactor produced isotopes, cyclotron produced isotopes, fission products, containers for sources, self shielding, gamma ray sources for medical and industrial uses, telegamma sources, radium needles, tubes and plaques, cobalt needles and gold seeds, tantalum wire, beta ray applicators, thermal and fast neutron sources;

Use of radium, Co-60, Ir-192, Cs-137, Au-198, Iodine-125, Palladium-103 for surface, interstitial and intracavitary applications; radium implants, treatment with Sr-90, P-32 and other beta applicators.

Teletherapy Equipment
Orthovoltage X rays, Therapeutic x-ray (<300 kVp) construction and working, High Energy gamma rays, Cs Teletherapy.
Cobalt Teletherapy Machine – principle constructions and working of Cobalt 60 Teletherapy.
Linear Accelerator: High Energy X rays and Electron production, Variable Energy; Working principle and construction; Operational theory of wave guides, Bending magnet systems, Photon beam Delivery, Electron beam delivery, Beam energy, Monitor chamber, Linac collimation systems - Primary and secondary collimators, Multi leaf collimators, Other collimation systems, Different Quality assurance parameter checks, isocentre check, flatness, symmetry, Field size definition, penumbra/construction & working of gamma knife & cyber knife machine.

Simulators: Mechanical and Radiographic Operation, Fluoroscopy and Intensifiers, CT, Simulation Machinery, CT Simulation Operation, CT simulator & simulator CT machines.

Treatment Planning Systems.
Proton and neutron Beam and heavy charge particle accelerating machine.

Brachytherapy Equipment
Radium needle, tubes, Preloaded and after loading Manual Cs needle/tubes LDR and Iridium 192 wires LDR Brachytherapy system, source uniformity and integrity, Remote after loading LDR machine – Construction and working principles

Construction and working principles of single miniature HDR source, Construction and working principles of PDR and quality assurance tests, dwell position accuracy, auto radiograph, shutter time error, timer linearity.

Temporary Implant sources – eye applicator Permanent Implant sources, Endovascular Brachytherapy in cardiology.
PRACTICALS

1. Source Strength verification of a micro-Selectron HDR Brachytherapy Machine using a well type ionization chamber.
2. Time linearity and end time error measurement of a micro-Selectron HDR Machine
3. To verify the Mechanical and Dosimetrical isocentre of collimator rotation of a Teletherapy unit using a therapy localization film.
4. To verify the Mechanical and Dosimetrical isocentre of collimator rotation of a Teletherapy unit using a therapy localization film.
5. To find the congruency of radiation and optical field of a Teletherapy machine and penumbra width using a film scanner.
6. Quality Assurances of a Cobalt-60 Teletherapy unit
7. Quality Assurance and commissioning a conventional Simulator
9. Mechanical and Dosimetry verification of isocentre of a Linear Accelerator
10. Quality Assurances of a Linear Accelerator unit
SECOND YEAR - THIRD SEMESTER

Paper – II
MEDICAL IMAGING EQUIPMENTS AND QUALITY ASSURANCES (45 lectures)

Diagnostic Radiology:


Fluorescence, intensifying screens, construction and function of intensifying screens types of screens, function evaluation parameters, intensification factor, emission spectra and screen film matching, conventional screens a Vs rare-earth screens , unsharpness, fluoroscopic screens, use of lead screens.
Scattered radiation and their control - grid, types of grid, grid ratio, grid factor, Potter- Bucky grid , diaphragms and collimators..

Digital Radiography- Analog and digital representation of data-- Computed Radiography-phosphors in imaging plate, phosphor reader, image quality Charge coupled device – digital radiography systems, indirect and direct flat panel systems, phosphor materials, Image quality

Mammography - X-ray tube design, films and screens for mammography compression devices, grid, collimation, filtration and HVL, scatter, magnification in mammography. Digital Mammography.
Fluoroscopy- Image intensifier-input screen, output screen, characteristic of Image intensifier performance, CCTV system, flat panel detectors, fluoroscopy modes of operation

Computer Tomography:
Principles of Computer Tomography-Basic principles of tomographic acquisition and reconstruction. EMI scanner and different generations of CT machines modern developments - Spiral CT, Multi detector arrays CT, Cone Beam CT-Detector pitch and collimator pitch, CT number and Hounsfield unit. Characteristics of - X-ray tubes in CT units, Detectors and detector configurations in various generations. Tomographic reconstruction-rays and views, pre-processing of data, algorithms for imaging reconstruction-back projection, filtered back projection methods, analytical methods. Image display-windowing and levelling, multiplaner reconstruction, 3D image display. Image quality- Spatial Resolution and contrast resolution, factors affecting spatial resolution and contrast resolution. Artifacts – Motion Artifacts, Streak Artifacts, Beam- hardening Artifacts, Ring Artifacts. Radiation dose management: factors affecting patient dose, CTDI, CTDIvol, dose length product (DLP), multiple scan average dose (MSAD).
Ultrasound:

Nuclear Magnetic Resonance and MRI:


Instrumentation-permanent Magnets, Resistive Coil Air Core Magnets, Superconducting Magnets, RF Coils, gradient coils Magnetic field Gradients- Slice Selection, Phase Encoding, Frequency Encoding. K space data acquisition and image reconstruction, 2D data acquisition, 2D Multiplaner acquisition, Multislice data acquisition. spin Echo Imaging, fast spin echo imaging Inversion recovery acquisition Contrast Enhancement, T1 and T2 Weighted Imaging. Spatial resolution and contrast sensitivity, Signal to Noise Ratio and Artifacts, Safety Considerations, MRI safety consideration.

Nuclear Medicine:
Rectilinear Scanners and Gamma Cameras: Single head scanners, design criteria, resolution, sensitivity measurements, linearity, Multiple Window spatial resolution, Uniformity, Energy resolution, choice of collimators, Dual head scanners; Gamma cameras: Anger type camera, Single and Dual Head Camera, resolution sensitivity measurements, collimators, comparison between Gamma cameras and scanners, quality control in instrumentation

Display Systems: Criteria for evaluation of radioisotope imaging systems in terms of concentration ratios, Radioisotope systems comparison between black and white and color displays, observers visual response curves and determination of detection contracts, ROC curves

Dynamic Studies using Radioisotopes: Saturation; analysis; dynamic methods, activation analysis, models of body compartments, deconvolution techniques, the occupancy principle etc
**PET and PET/CT:**
Basic principles- detectors and image processing, procedures in PET and PETCT, source of radioisotopes from cyclotron and its basic concept, Co registration in PETCT for image fusion, Gating in PETCT studies (respiratory and cardiac gating)
Radiopharmaceuticals: Radioisotope generators, method of preparation, purity, quality and stability of radiopharmaceuticals, quality control in preparation of radiopharmaceuticals

**Practicals:**
1. Q. A. testing of a diagnostic X-ray unit.
4. Measurement of KVp, mAs, Timer of an X-ray Unit and find the total filtration of an x-ray beam.
5. To find the total filtration of an x-ray beam
6. To find the effective focal spot size of the x-ray tube.
7. To check the perpendicularity of x-ray beam to image receptor and the alignment of the centre of radiation field and the centre of image receptor in the plane.
8. Q. A. testing of CT Simulator.
9. To perform Quality Control of Planar Gamma Camera, Flood field for Scintigraphy.
10. To demonstrate the Quality Control of SPECT System.
11. To study iso-response curves of different collimators of a Gamma Camera.
12. Dark room practicals e.g. preparation of Developer and Fixer and X-ray film development, fixation and washing.
14. QA of an MRI machine.
15. To find the effective focal spot size of the x-ray tube.
Description of Ionizing Radiation
Consequences of the random nature of ionizing radiation: Stochastic and Non-stochastic quantities; Simple description of radiation fields by Non-stochastic quantities: Fluence and its definitions, Flux density (or Fluence Rate), Energy flux density (Energy fluence Rate), Differential distribution of flux density as a function of energy and angle of incidence.

Radiation Beam Quality and Dose:
Monoenergetic and Heteroenergetic bremsstrahlung beams: Energy spectra for bremsstrahlung beams.

Radiation quantities and units:
Kerma; Exposure; Absorbed dose; Dose equivalent; RBE dose; Calculation of absorbed dose from Bragg-Gray cavity theory, Charge Particle Equilibrium and other cavity theories

Radiation Sources both Natural and Artificial: Generation through Reactors and Cyclotrons,

Principles of Radiation Detection:

Radiation Measuring & Monitoring Instruments:


**Practicals**

1. Study of Linearity and reproducibility of a pocket dosimeter.
2. Study of Linearity and reproducibility of a survey meter.
4. Radiation dose measurement with a thimble ionization chamber.
5. Calibration of a film dosimetry system for dose measurement.
6. Demonstration of Radiation dose profile and PDD curve measurement using RFA.
SECOND YEAR – THIRD SEMESTER

Paper – IV
TELEThERAPY TREATMENT PLANNING (45 Lectures)

Photons and x-rays Teletherapy:
External Beam Dosimetry Concepts (Part I) - Dosimetric Variables, Inverse Square Law, Backscatter factor, Electron Buildup, Percent Depth Dose, Mayneord F factor, TAR Correction to F factor, Equivalent Squares

External Beam Dosimetry Concepts (Part II) - Tissue air Ratio - Scatter air Ratio - Tissue phantom Ratio - Tissue maximum Ratio

System of Dose Calculations - Monitor Unit Calculations, Output Factor, Field Size Correction Factors, Collimator Scatter Factor and Phantom Scatter Factor, Beam Modifier Factors, Patient Attenuation Factors.

Calculations in Practice: SSD Technique - SSD Treatment same as SSD of Calibration, SSD Treatment Different from SSD of Calibration, SSD Treatment and SAD Calibration, SAD Technique - SAD Treatment and SAD Calibration, SAD Treatment and SSD Calibration, SAD Rotational Treatment.

Translation of Planning to Calculations - Beam Parameters, Beam Weighting, Arc rotation therapy, Irregular Fields

Simulation of patients on conventional and CT Simulator. Mould Room Procedures, Making of casts, compensators and shields

Computerized Treatment Planning: Isodose curves (beam characteristics), Surface Dose, Parallel Opposed Beam Combination, Wedge Isodose Curves, Wedge Angle and Hinge Angle, Wedge Factor, Wedge Techniques, Wedge Pair, Open and Wedged Field Combination, Skin Compensation, Beam Combination (3-,4-,6- field techniques)

Surface Corrections & Heterogeneities: Corrections for Surface Obliquities, Corrections for Inhomogeneities, Linear (1-D) Attenuation Method, 2-D Methods, Volumetric Methods, Dose Perturbations at Interfaces

Adjoining fields & Special Dosimetry Problems: Two-Field Problem, Three-Field Problem, Craniospinal Gapping, Pacemaker, Gonadal Dose, Pregnant Patient

Clinical aspects of treatment planning: Define Conventional and different types of Conformal techniques. Steps in conventional and conformal radiation planning, Beam modification and beam shaping in radiotherapy. Radiation techniques used for treatment of various sites of malignancies.

Electron Beam and Planning of Medical Radiation Installations:
Electron Beam Teletherapy:
Basic Characteristics: Depth-dose/Isodose characteristics, Electron interactions, CSDA and range, Dose versus depth, Isodoses, Oblique incidence, AAPM TG-25 – energy specification – electron energy selection for patient treatment – depth dose characteristics (D_s, D_x, R_{100}, R_{90}, R_{50}, R_p etc)
beam flatness and symmetry – penumbra – isodose plots – monitors unit calculations – output factor formalisms – effect of air gap on beam dosimetry – effective SSD.


Field Matching and other considerations: Electron-electron Gapping, Electron photon Gapping, Electron Backscatter, Inhomogeneities, Internal shielding

Particulate beam therapy – Relative merits of electron, neutron, x-ray and gamma ray beams – Neutron capture therapy – Heavy ion therapy.

**Practicals**

1. Dosimetry verification of computerized treatment planning of a single and parallel opposing photon field and comparison with manual planning.
2. Dosimetry verification of computerized treatment planning of an oblique three fields technique (SAD) and comparison with manual planning.
3. Dosimetry verification of computerized treatment planning of an oblique three fields technique (SSD) and comparison with manual planning.
4. Dosimetry verification of computerized treatment planning of a four fields (SAD) box technique and comparison with manual treatment planning.
5. Dosimetry verification of computerized treatment planning of a four fields (SSD) box technique and comparison with manual planning.
6. Computerized treatment planning and dosimetry of rotation therapy.
7. Measurement of entrance and exit doses and evaluation in SSD and SAD technique AP-PA field in case of CaCx.
Clinical aspects of Brachytherapy:
Definition, advantages and limitations as well as different methods of brachytherapy. Indications for various types of brachytherapy.

Treatment Planning of Brachytherapy
Calibration of Brachytherapy Sources: Specification of source strength, Radium Substitutes and Radioactive Isotopes Currently Used in Brachytherapy, Linear Sources, Seeds, Exposure Rate Calibration using well chamber.

Calculation of dose distributions: Biological consideration of dose, dose rate, and fractionation; calculation of dose from a point source and line source using sievert Integrals; calculation of absorbed dose distribution in water around sealed sources with AAPM TG 43 algorithm protocol, point source, line, unfiltered and filtered; optimization of dose distribution.

Systems of Implant Dosimetry: Paterson-Parker, Quimby, Memorial, Paris, Computer

Implantation Techniques: Surface Molds/Plaques, Interstitial Therapy, Intracavitary Therapy - Uterine Cervix, Milligram-Hours, Manchester System, Bladder and Rectum Dose, ICRU System, Absorbed Dose at Reference Points

Brachytherapy Treatment Planning:

Radiobiological Models

1. Time Dose and fractionation model
Radiobiology, therapeutic ratio, RBE, cell survival curves and fractionation, Time Dose Model, NSD, CRE, TDF, Modified TDF Model; Use of bio-effect models, limitations of NSD, TDF and CRE Models, LQ Model,

2. Biodose Model
Concept of BED, BED for fractionated and continuous irradiation, calculation of $\alpha/\beta$ values for tumor, calculation of fraction size for alternate schedules. Normal Tissue Complication Probability and Tumor Control Probability,

3. Altered fractionation regimes
Various fractionation schedules: Conventional fractionation and Altered fractionation; hyper fractionation; Accelerated hyper fractionation - CHART schedule, concomitant boost, split course schedule; hypo fractionation and their rationale.
4. NTCP and TCP for Treatment Planning and Radiobiology of Particle beam therapy

Tissue Dose–Response Classification – $\gamma_{50}$ and TD$_{50}$, Concepts of “Serial” and “Parallel” Tissue Dose–Response - Local vs. Global Organ Injuries and concepts of functional sub units; NTCP Models - Generalized Equivalent Uniform Dose Equation, Basic Mathematical Features of Common NTCP Functions - parallel function model and Lyman Kutcher Burman model, Tumor Control Probability- $\gamma_{50}$ and TCD$_{50}$, Optimization of Radiotherapy using Biological Parameters: Radiobiological Models - Poisson Model, Logistic model, Probit model LKB model and Uncomplicated Tumor control modeling; Biological Optimization using Sub-volume-Based Radiobiological Models, Drawbacks to Treatment Planning Based on Dose–Volume Limit, Uncertainties in NTCP Models, Incorporating Fractionation Sensitivity.

Practicals:
1. QA for High dose rate brachytherapy machine.
2. Calibration of Ir-192 high intensity source.
4. Brachytherapy dosimetry for single and double plane implants.
5. In-vivo dosimetry in Brachytherapy procedure.
6. Auto-radiograph of different intracavitary and interstitial applicators
7. X-Ray based ICRT Brachytherapy Planning.
8. Source position verification in HDR brachytherapy.
9. Autoradiograph of different intracavitary and interstitial applicators.
10. TPS QA in Brachytherapy.
11. Radiation survey of Brachytherapy HDR unit.
SECOND YEAR – FOURTH SEMESTER

Paper – II

CLINICAL DOSIMETRY AND STANDARDIZATION (45 Lectures)

Radiation Measurement and Calibration
Dose and Relationships: Radiation Absorbed Dose - definition and units; Relationship between Kerma, Exposure, and Absorbed Dose; Bragg-Gray Cavity Theory; Spencer Attix Stopping Powers and Spencer Attix Cavity Theory; Burlin Cavity Theory of large and intermediate size cavity ionization Chamber.

Ionization Chambers: Well type, Cylindrical, Parallel-Plate, Effective Points of Measurement.

Factors affecting in dose measurement: Correction Factors, Calibration of Kilo-voltage Beam.

Dose measurement in air using a thimble ionization chamber and determination of \( N_{gas} \) calibration factor.

Calibration of Megavoltage Beams: \( N_{dav} \) and \( N_{dw} \) based Calibration of Photon beams and Electron beams; Dose calibration parameters; TRS 277 and TRS 398 for calibration of Photon and Electron Beam; TG-21 & TG-51 for calibration of Photon and Electron Beam.

Other Methods of Measuring Absorbed Dose: Calorimetry; Chemical Dosimetry; Solid State Detectors; TLDs; Diode detectors; FET detectors; Diamond detectors; Film Dosimetry - XV2 film, EDR2 film, Radio chromic film.


Practicals
1. To find the Reproducibility and Linearity of a radiation dosimeter
2. Output calibration of 6 MV/15 MV photon beam in water at an ambient environmental conditions using IAEA TRS-398 protocol.
3. To find the shutter time error of a cobalt-60 Teletherapy unit and find the output in water phantom using TRS 398 protocol
4. To find the \( N_{dav} \) Co-60 calibration factor of a dosimeter using cross calibration method.
5. To find the \( N_i \) and \( N_{dav} \) from \( N_{dav} \) calibration factor using TRS 277.
6. To find the output of electron beam using both TRS 398 and TG51 protocols.
9. To find the Reproducibility and Linearity of a radiation Pocket dosimeter.
Acute and Chronic effects of Whole Body Irradiation
Knowledge of various acute radiation syndromes and chronic effects of whole body irradiation.

Principles of Radiation Protection

Evaluation of radiation hazards in medical diagnostic therapeutic installations – Radiation monitoring procedures – Protective measures to reduce radiation exposure to staff and patients – radiation hazards in brachytherapy departments and teletherapy departments and radioisotope laboratories – Particle accelerators protective equipment – handling of patients – waste disposal facilities – radiation safety during source transfer operations special safety features in accelerators, reactors.

Radioactive decontamination and waste disposal
Radioisotopic waste disposal of solid, liquid and gaseous effluents/waste, decaying storage transfer to authorized personal, management of sealed sources, quality management program, misadministration of radiopharmaceuticals, release of patients administered with radiopharmaceuticals.


Disposal of radioactive wastes – General methods of disposal – Management of radioactive waste in medical, industrial, agriculture and research establishments.

Regulatory Aspects & Licensing
The Atomic Energy Act, Rules issued under the Act, Surveillance procedures issued under the Rules, Notifications issued under RPR, 1971 and 2004 AERB Safety Directive, Safety code for Radiotherapy, Radiodiagnosis and NM facility, Duties of Medical physicist/ Technologists/Radiopharmacists/RSO, Regulatory clearance-Approval of Radiotherapy, Radiodiagnosis and NM Lab, Physician & RSO, Regulatory consent, authorization - for disposal of radioactive waste and safe transport of Radioactive materials. Ethics, Registration of radiopharmaceuticals and their use. Historical background of legislation in the atomic energy field, need for control of radiation exposure at national and international levels, national control through acts with supporting regulation at central and state levels international control through specialized agencies, third party
liability and insurance in the atomic energy field; ICRU and ICRP Recommendations on Dose Limits, Protection Regulations, Basic Framework of Radiation Protection, Radiation Safety Program, Radiation Safety Officer and duties of Radiation Safety Officer, Radiation Safety Committee, Personnel Monitoring, Responsibilities for Implementation of Basic Safety Standards Requirements

Planning & Design of Radiation generating Equipment Installation
Design and safety aspects of planning a Nuclear medicine department, radiotherapy department, cyclotron facility and PET centre. Planning of medical radiation installation, both therapeutic and diagnostic, which includes construction of room for cobalt, linear accelerator, high dose rate brachytherapy machine, simulator and CT simulator.

General considerations, design of diagnostic, telegamma, accelerator installations, brachytherapy facilities and medical radioisotope laboratories; Step one: - Design dose in occupied areas (annual dose and weekly dose), Step two - Calculation of the radiation field (air kerma) in the occupied area without shielding. Step three - Attenuation by shielding barriers Teletherapy Installation: Workload, Use factor, Occupancy factor, Distance, Calculation of the primary transmission factor, Calculation of the scatter barrier transmission factor, Calculation of the leakage barrier transmission factor, Determination of barrier thickness, Consideration of neutron production in a high energy linac, Door of a linac room, Other considerations under AERB radiation safety protocol. Shielding thickness calculation under AERB radiation safety code and federal code of regulation 10 CFR20 in uptake room, imaging room, PET tomography from ambient radiation level and cyclotron.

Potential Exposure and Emergency Plans:
Potential exposure and safety assessment, Mitigation of consequences: emergency plans - Lost source, Stuck source, Contamination, Off-site accidents, Patient accidental exposure. Radiation emergencies, preparedness and record keeping, Large scale spillage, leakage of radioactivity substance to environment, accidental inhalation, death of a patient with radioactivity etc.

Transportation of radioactive substances:
Historical background, classification of radioactive materials, general packing requirements, transport documents, labeling and marking of packages, transport of large radioactive sources and fissile material, exemptions from regulations.

Principles of Monitoring and Protection

Personnel Monitoring Devices
Principle construction and use of different radiation protection monitors – Film badge, TLD badge and pocket dosimeter.

Radiation Survey of the Department
Principle and construction of radiation survey meter and gamma zone monitors

Safety in Industrial, Agriculture and Research uses of Radiation
Use of ionizing radiation in irradiator, industrial radiography, nucelonic gauging, well logging and research such as medical research, industrial research and agriculture research.
Duties and responsibilities of Radiation Safety Officer (RSO)

Legislation
Physical protection of sources – Safety and security of sources during storage, use, transport and disposal – security provisions; administrative and technical – security threat and graded approach in security provision.


Practicals

1. Radiation Survey of Linear Accelerator to find the adequacy of shielding on safety point of view.
2. Radiation Survey of Cobalt-60 Teletherapy unit to find the adequacy of shielding on safety point of view.
4. Room lay out planning of a Linear Accelerator of dual photon energies of 6 MV and 15 MV.
5. Room Lay Out planning of a Cobalt-60 Teletherapy unit
6. Room Lay out planning and radiation survey of a HDR Brachytherapy unit
7. Room Lay out planning and radiation survey of a Conventional Simulator
8. Room Lay Out planning and radiation survey of a CT Simulator unit.
9. To find HVT and TVT of a radiation beam.
SECOND YEAR - FOURTH SEMESTER

Paper – IV

RECENT ADVANCES IN RADIOTHERAPY AND SPECIAL TECHNIQUES

(45 Lectures)

Imaging for Radiation Oncology:
Routine Imaging: Diagnostic Imaging Physical principles, Port Films, XV- film, EDR-2 film characteristics, Processors.

Other Imaging:
Electronic Portal Imaging: Overview of electronic portal imaging devices, Types of portal imaging devices, Clinical applications of EPID technology in daily practice,
Ultrasound: Physical principles, Utility in diagnosis and patient positioning.

Image Based Treatment Planning:
CT scans: Physical principles, Hounsfield Units, CT numbers, Inhomogeneity corrections based on CT scan images
MRI Scanning: Physical principles, T1, T2, TE, TR imaging characteristics, Advantages & limitations of MRI images for diagnosis and computerized treatment planning
PET Imaging: Physical principles, Utility for Radiation Therapy, Image Fusion, Advantages, Challenges, Techniques, Limitations

3DCRT including ICRU concepts and beam related biology
3DCRT concepts and goals vs traditional RT, comparison to protons, Technology and methods for planning, Acceptance testing of multileaf collimators, Commissioning of multileaf collimators, Quality assurance programme for multileaf collimators, Multiple volume images (CT, MR, PET, MRSI, etc), Image processing (registration, segmentation), Virtual simulation, DRRs, Multiple beams (>4), Non-coplanar beams

Optimization methods:
Biological implications of uniform vs non-uniform dose delivery, Non-biological and biological dose-volume metrics (DVHs, TCPs, NTCPs), Margins
Implications of treatment variabilities (systematic and random setup variabilities, patient breathing), ICRU 50 Prescribing, Recording and Reporting; ICRU Report 62: (Supplement to ICRU Report 50); Algorithms of treatment planning system: General overview of various dose calculation and inverse planning optimization algorithms for photon and electrons.

Assessment of Patient Setup and Verification:
Immobilization devices and methods: Table Positions, lasers, distance indicators, Immobilization methods, and Positioning methods (calibrated frames, optical and video guidance, etc)
In-the-room intra-treatment imaging (cont’d): Cone-beam CT, Ultrasound, Internal markers (e.g. implanted seeds), On-line correction of setup errors, Adaptive planning concepts,

IMRT
IMRT Delivery Systems: Commissioning of intensity modulated radiotherapy Systems, Quality assurance for intensity modulated radiotherapy Systems, Dose verification for intensity modulated radiotherapy, treatment plans Segmental MLC (SMLC) and Dynamic MLC (DMLC), Serial
Tomotherapy (MIMiC), Helical Tomotherapy, Robotic Linac, Simulation and immobilization/repositioning
Dose prescription & inverse planning: Treatment calculations, IMRT quality assurance

**General**

**Special Procedures**
Stereotactic Radiosurgery: SRS Delivery Systems, Linac based, Gamma Knife, Robotic Linac, Simulation and immobilization/repositioning, SRS Dose prescription & treatment planning, Treatment calculations, SRS quality assurance

Image Guided Radiotherapy (IGRT) & 4D Gated Image Guided Radiotherapy: Cone beam computed tomography (MV CT and KV CT), Computed tomography Primatom, Tomotherapy, B – Mode Acquisition and Targeting (BAT) system, Cyber Knife, Tomotherapy, Respiratory Gated Radiotherapy and Dynamic Adaptive Radiotherapy.
Electronic brachytherapy

**Particle Therapy:**
Protons: Proton Beam Energy Deposition, Equipment for Proton Beam Therapy, Clinical Beam Dosimetry, Clinical Proton Beam Therapy, Treatment Planning, Treatment Delivery, Clinical Applications. Radiotherapy with beams of $^{12}$C ions. comparison of $^{12}$C beam with proton beam.


**Heavy ion therapy.**

Other Special Procedures
Photon Total Body Irradiation: Patient Set-up, Dosimetry, Selection of energy, field size, distance, MU calculations.
Total Skin Electron beam Therapy, Electron Arc.

**Practicals**
1. Brachytherapy dosimetry for single and double plane implants.
2. Patient specific QA for IMRT verification using EDR2 film
3. Intracavitary planning of carcinoma of cervix and dose prescription using treatment planning system
4. Dosimetry of Interstitial brachytherapy implants using treatment planning system
5. Calibration of Portal imaging system
6. Patient specific QA for IMRT verification using 2D array ion Chamber matrix
7. IMRT planning using treatment planning system.
8. CT simulation planning and execution of patient treatment.
9. Online and off line correction for patient setup using OBI
Additional Clinical Practicals to be carried out in the 2nd year of M.Sc. Medical Physics Course.

1. Production and attenuation of bremsstrahlung.
2. Range of beta particles by Feather analysis.
5. Study of voltage and current characteristics of an ion-chamber.
6. Calibration of survey instruments and pocket dosimeters.
8. Calibration of a therapy level dosimeter.
15. Evaluation of characteristics of radiographic image.
16. Dose output measurement of photon (Co-60, Gamma Rays and high energy X-rays) beams used in radiotherapy treatment.
17. Dose output measurement of electron beams used in radiotherapy treatment.
19. Measurement of Dosimetric parameters (Beam Profile, Depth Dose Profile, TMR etc) using a Radiation Field Analyser (RFA).
20. Measurement of head scatter factors and phantom scatter factors using a Radiation Field Analyser (RFA).
21. Integrity check and calibration of low activity brachytherapy sources.
22. AKS/RAKR measurement of an HDR brachytherapy source using well type and cylindrical ionization chambers.
23. In-phantom dosimetry in brachytherapy.
24. Familiarisation with treatment planning procedure using a computerized radiotherapy treatment planning system.
25. Survey of a radioisotope laboratory and study of surface and air contamination.
27. Absorption and backscattering of gamma rays – Determination of HVT.
28. Measurement of Computed Tomography Dose Index (CTDI) of a CT unit.
30. Radiation protection survey of diagnostic radiology (X-ray/CT/Mammography etc) & simulator installations.
THIRD YEAR SYLLABUS

Part – I: Core Components

1. Radiotherapy Equipment (treatment and imaging) and QA
   Specifications, operation and use of telecobalt unit and its accessories such as wedges, breast cone, trays (if available), medical LINAC and its accessories (MLC, EPID, Electron applicators, etc), radiotherapy simulator and its accessories; remote after-loading brachytherapy equipment and its accessories (connectors, guide tubes, applicators, needles, etc), and radiotherapy treatment planning system (RTPS), Familiarization with networking and Record and Verify systems (if available).
   Purchase document preparation, tendering and selection of equipments; Acceptance testing, commissioning measurements and Quality assurance (QA) of radiotherapy treatment and imaging equipments, maintenance of QA records.

2. Beam Calibration and Dosimetry
   Dosimeters, phantoms and protocols (e.g. IAEA TRS 398/TG-51) for reference dosimetry; output measurements in reference conditions of telecobalt gamma ray beams, high energy x-ray and electron beams from medical LINACs; Familiarization with radiation field analyser (RFA); Measurements of relative dosimetry parameters and factors such as PDD, TPR, TMR, Scatter factors, Wedge factor, Tray transmission factor, electron applicator output factor; Measurement of beam profiles and evaluation of flatness, symmetry and beam penumbra. Uncertainty analysis and testing the authenticity of measured data; Verification of measured data by alternate techniques such as film dosimetry; Quality assurance and up-keeping of dosimetry systems.

3. External Beam Treatment Planning
   Customization and creation of beam library in the RTPS; Capabilities and limitations of the RTPS, Forward and inverse planning - algorithms; Definition and localization of PTV, CTV, ITV, Organ at risks (OARs), Time and monitor unit calculations for simple treatments, time dose fractionation and gap correction; Steps of treatment planning and treatment planning procedures – patient data acquisition, contouring, immobilization, mould preparation; optimization and evaluation – DVH/ TCP/ NTCP; Planning of common treatment cases; Execution of treatment plans and supervision. Practice with conventional planning, 3D CRT, SRS/SRT, IMRT/IGRT; Acceptance testing and quality assurance of RTPS.

4. Brachytherapy Dosimetry and Treatment Planning
   Dosimeters for source strength measurements, source strength measurement methods and protocols; dosimetry formalisms, measurement of dosimetry parameters, Definition of reference points of dose calculation, applicator placements, image acquisition, planning procedures, optimization, evaluation; Brachytherapy treatment protocols and recommendations; Practice of planning with clinical cases of intracavitary, intraluminal and interstitial brachytherapy. Execution and supervision of brachytherapy treatments.

5. In-Vivo Dosimetry and Patient Dose Verification
   Objectives of patient in-vivo dosimetry and dose verification; Understanding the use of different dosimeters in such measurements e.g. ionization chambers, TLD, diodes, MOSFET, films; Selection criteria for the dosimeter; In-vivo dosimetry measurements in gamma rays, x-rays and electron beams; Familiarization with national/ international protocols/ procedures of in-vivo dosimetry and patient dose verification.
6. Radiation Protection and Safety
Familiarization with regulatory requirements - safety codes and guides; Responsibilities and duties of a Medical Physicist and radiological safety officer (RSO) in radiotherapy; Working out room layout and shielding calculations for external beam, brachytherapy and simulator (Physical/CT) installations; Submission of safety status report to AERB – ASR, Unusual occurrences, source loss etc. Maintenance of records – QA, calibration certificates of equipments, source inventory, personnel dose records, protection survey

Radiation safety requirements for radiotherapy equipments; Radiation protection survey of equipment and installations; Analysis of survey data and assessing the safety status of equipment and installations; Familiarization with national regulation pertaining to procurement, use and decommissioning of radiotherapy equipment and sources; Safety of radioactive sources; Experience in handling emergency situations. Safety requirements for occupational, medical and public exposures; Understanding the methods for minimizing the dose to critical sites of the patients. Orientation for RSO certification examination.

Part – II: Auxiliary Components

1. Clinical Orientation
Surface and cross sectional anatomy with reference to radiotherapy, identify key anatomical features on x-ray/ CT images, role of radiotherapy in cancer treatment, benign and malignant tumours, primary and secondary tumours, metastasis and routes of metastases, tumour stage and grading, common cancer sites, identification of abnormal size of organs due to primary tumours and metastases on radiological images, identification of organs at risk surrounding the tumours, palliative and curative therapy, time dose fractionation, accuracy requirement in radiotherapy, tissue tolerances, therapeutic gain, clinical targets, anatomical and physiological changes due to radiotherapy treatment, Patient related clinical experiences. Familiarisation with different professionals/ departments involved directly or indirectly with radiation treatment of cancer.

2. Professional Skill Development and Career Planning
Ethics in medical use of ionizing radiation; Development of research and teaching skills; Planning research and development on a given topic related to development of dosimetry methods, development of dosimeters, development of QA tools and methods, development of treatment devices and accessories, etc. Training to work as effective educator and mentor in radiation oncology physics.
Suggested Books for 2\textsuperscript{nd} & 3\textsuperscript{rd} year Reference:

**Radiation Physics & Radiation Generators:**
1. R.D. Evans, Atomic Nucleus
2. Preston M.A. Physics of Nucleus
3. Lapp R.E. Nuclear Radiation Physics
4. Segre E. Experimental Nuclear Physics
5. Slack L. Radiations from Radioactive Atoms
6. Oliver R. Radiation Physics in Radiology

**Radiological Mathematics:**
3. Croxton. Elementary Statistics

**Radiation Dosimetry and Standardization:**
1. Joseph Magill and Jean Galy. Radioactivity Radionuclides Radiation, European Commission Joint Research Centre, Institute of Transuranium Elements, P.O. Box 2340, 76125 Karlsruhe, Germany.
2. IAEA TRS 374, Calibration of Dosimeters used in Radiation Therapy.

**Radiation Detectors and Instrumentation:**
2. Stepanor B.I. Theory of Luminescence
4. Albert Paul Malvino. Electronics Principles
5. Robert L. Boylestad. Electronics Devices and Circuit Theory
6. Paul – Horowitz. Art of Electronics
7. Greiner R.A. Semiconductor Devices & Application
Clinical and Radiation Biology:
1. Meschan. Normal Radiation Anatomy

Medical Imaging:
Radiation Therapy

Radiation Safety
1. Herman Camber. Introduction to Health Physics
3. AERB Radiation Protection Rules 2004
4. ICRP 1990 Recommendations
5. ICRP 2007 Recommendations
6. IAEA Basic Safety Standards 115, 1997
7. Shapiro J. Radiation Protection
8. Mckenzie. Radiation Protection in Radiotherapy

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