Faculty of Science

Syllabi

For

M.Sc. Medical Physics

(Session 2016-17)
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 = 08
NRI = 02
Total seats /year = 10

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>
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<th>Marks</th>
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<tbody>
<tr>
<td>Theory</td>
<td>400 (4 papers of 100 marks each)</td>
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<tr>
<td>Practical</td>
<td>200 (4 practicals of 50 marks each)</td>
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<td><strong>Total</strong></td>
<td><strong>600</strong></td>
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### A. Theory Papers

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<td>100</td>
</tr>
<tr>
<td>2. Applied Mathematics, Biostatistics and Computer Applications</td>
<td>100</td>
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<tr>
<td>3. Radiation Physics</td>
<td>100</td>
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<tr>
<td>4. Radiation Biology</td>
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### B. Practicals

<table>
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## Second Semester

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<td>2. Analog and Digital Electronics</td>
<td>100</td>
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<tr>
<td>3. Radiation Detection and Measurements</td>
<td>100</td>
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<td>4. Bio-Medical Applications of Radioisotopes</td>
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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
M.Sc. Medical Physics Syllabus
FIRST YEAR - FIRST SEMESTER

Paper – I
CYTOLOGY AND FUNDAMENTAL ANATOMY OF HUMAN BODY (45 Lectures)

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 synapse

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 Derricson, 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
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

Radioactive decay: Laws of radioactivity, types of radiation (α,β,γ, 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 γ 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, x), (n, γ) 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.


General Properties of Radiation Detectors: Simplified Detector Model, Modes of Detector Operation, Pulse Height Spectra, Counting Curves and Plateaus, Energy Resolution, Detection Efficiency, Dead Time
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 β and γ 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 β and γ 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. Penelope 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, Radio sensitzers 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 $^{13}$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
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), Parathyroid 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 Derricson, 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 organized 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
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.

Optical Properties : Absorption processes- Photoconductivity – Photoelectric effect – Photovoltaic effect–Photoluminescene, Thermoluminescence, Fluorescence, Radioluminesce, Phosphorescence
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, Ytrium orthosillicate detector.

Liquid scintillation counters: Composition of liquid scintillator (scintillation cocktail): primary solute, secondary, solute and organic solvent (toluene,1,4 dioxane, anthracene) and solubilizing 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
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 $^{131}\text{I}$ for diagnosis of hypo and hyper thyroidism, blood volume studies using RIHSA and Cr-51; Red cell survival studies using $^{51}\text{Cr}$; studies of iron metabolism, diagnostic test using Vitamin $^{12}\text{B}$ labeled with radio cobalt; circulation studies with $^{24}\text{Na}$, cardio vascular studies, tumour localization.

Preparation of tracers and labeled compounds, Preparation of radio colloids; Bone scanning, principle, agents for bone scanning, $^{99}\text{Mo}$, $^{99m}\text{Tc}$, 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 $^{99m}\text{Tc}$, Sulphur scans, pitfalls, clinical applications; Ga in Clinical Studies: Energy spectrum of $^{67}\text{Ga}$, optimization of parameters for $^{67}\text{Ga}$ 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.
$^{131}\text{I}$ therapy for treatment of hyperthyroidism, thyroid follicular carcinoma.

$^{125}\text{I}$ applications: Radio-immuno assays of T3, T4, TSH and other hormones, uptake by thyroid and treatment of thyroid disorders

$^{123}\text{I}$ applications

$^{99m}\text{Tc}$ applications in medical imaging of different organs and dynamic /function studies.

$^{201}\text{Tl}/^{82}\text{Rb}$ – myocardial uptake/perfusion imaging, $^{67}\text{Ga}$ for scintigraphy of tumors and infections,

$^{18}\text{FDG}$ in brain, heart and tumor imaging

Radionuclides in therapy- $^{88}\text{Sr}$, $^{186}\text{Re}$-HEDP, $^{153}\text{Sm}$-EDTMP, $^{177}\text{Lu}$.

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 Radioisototope 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 $^{99}$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:
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 (Lectures 40)

RADIOThERAPY EQUIPMEnTScs

Radiation sources (10 Lectures)

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 (15 Lectures)

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 checks flatness, symmetry, Field size definition, penumbra

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

Treatment Planning Systems

Proton and neutron Beam and heavy charge particle accelerating machine: Production of high energy particle with cascade, Van-de-Graff generators, Cyclotrons, Betatron, Proton Synchrotrons
**Brachytherapy Equipment (15 Lectures)**

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

**Paper – II**

**Medical Imaging Equipments and Quality Assurances (Total lectures 40)**

**Medical Imaging Equipments**

**X-Ray Technology: (12 Lectures)**

Production of a pattern on radiograph, latent image, developing, fixing, X-ray films, construction characteristics, optical density, contrast, gamma, speed and latitude, screen films, non-screen films, single coated films. Fluorescence, Intensifying screens, construction and action, types of screens, intensification factor, rare earth screens, screen unsharpness, fluoroscopic screens, use of lead screens, artificial contrast and contrast media. Scattered radiation, grid, types of grid, grid ratio, grid factor, Potter-Bucky diaphragms, unsharpness in radiographs. Exposure timer, hand timer, synchronous timer, electronic timer, mAS timer, photo timer, ionization chamber timer, timer testing. Image intensifier and CCTV, Tomography. Interlocking and safety devices.

**Computer Tomography: (5 Lectures)**

Principles of Computer Tomography, Basic principles of data accumulation, storage, image reconstruction and display, CT numbers, different generations of CT machines, reasons for higher contrast and resolution, various scan configurations, modern developments like Cone Beam CT, Spiral CT, 3D reconstruction; Characteristics at X-ray tubes in CT units, Detectors and detector configurations in various generations, Mathematics of image reconstruction and display, algorithms for imaging reconstruction, back projection, interactive methods, analytical methods; Characteristics of image display systems, image quality, quantum mottle, Resolution – Spatial and contrast resolution, Artifacts – Motion artifacts – Streak Artifacts – Beam-hardening Artifacts – Ring Artifacts;

**Ultrasound: (5 Lectures)**

techniques and principles of Colour Doppler, Pulse Doppler, Duplex Scanner, Real time measurements. Various types of Probes, Oscillating Transducer, Rotating Wheel Transducer, Linear Array etc. Thermography, basic principles, scanning techniques, radiation dose to patients.

**Nuclear Magnetic Resonance and MRI: (5 Lectures)**

Angular momentum of the nucleus, electro angular momentum, orbital angular momentum, Magnetism and the Magnetic Dipole, Moment, MDM in a magnetic field, MDM for Rotating Charges, Angular Momentum and Precession, Larmor Frequency, Energy States for Nuclear Spin Systems. NMR parameters, Magnetization Vector, RF Field, the rotating coordinate system, Free induction decay, T1 and T2 relaxation, Mechanisms for relaxation, spin-Echo Techniques, Use of Fourier Transforms. Instrumentation, Magnets, Resistive Coil Air Core Magnets, Superconducting Magnets, RF Coils, Study of NMR spectrum and schematic arrangement for a nonimaging NMR System. Principles of MRI, Gradient Coils, Slice Selection, Phase Encoding, Frequency Encoding; The Spin Echo Imaging Sequence, Image Reconstruction; Multi Slice Imaging; Multi Echo Imaging, Contrast Enhancement, T1 and T2 Weighted Images, Signal to Noise Ratio; Safety Considerations, Recent Developments, Functional MRI.

**Nuclear Medicine: (8 Lectures)**

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

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

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

Preparation of tracers and labeled compounds, Preparation of radio colloids; Bone scanning, principle, agents for bone scanning, Mo$^{99}$, Tc$^{99m}$, 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 67Ga optimization of parameters for 67Ga scanning, Clinical applications

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: (5 Lectures)**

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 PET/CT studies (respiratory and cardiac gating)


**Practicals:**
1. Q. A. testing of a diagnostic X-ray unit.
4. Measurement of KVP, mAs, Timer of an X-ray Unit.
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 machine.
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.
13. QA of an ultrasound machine.
14. QA of an MRI machine.
Paper – III

Basics of Radiation Dosimetry (Lectures 40)

Radiation Beam Quality and Dose (5 Lectures)
Monoenergetic and Heteroenergetic bremsstrahlung beams: Energy spectra for bremsstrahlung beams; Effects of electron energy, filtration, beam geometry; Homogeneity coefficient; Effective energy; Clinical indices for megavoltage beams (e.g., PDD at reference depth).

Radiation quantities and units (2 Lectures): Kerma; Exposure; Absorbed dose; Dose equivalent; RBE dose; Calculation of absorbed dose from Bragg-Gray cavity theory.

Radiation Sources both Natural and Artificial (2 Lectures): Generation through Reactors and Cyclotrons.

Principles of Radiation Detection: (11 Lectures)

Radiation Measuring & Monitoring Instruments: (20 Lectures)


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**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.

**Paper – IV**

**Teletherapy Treatment Planning (40 Lectures)**

**Photons and x-rays Teletherapy: (20 Lectures)**

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:** (20 Lectures)

**Electron Beam Teletherapy:**


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 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
SECOND YEAR - FOURTH SEMESTER

Paper – I

Brachytherapy Treatment Planning and Radiobiological Models (40 Lectures)

Clinical aspects of Brachytherapy (2 lecture): Definition, advantages and limitations as well as different methods of brachytherapy. Indications for various types of brachytherapy.

Treatment Planning of Brachytherapy (10 Lectures)

Brachytherapy, advantages, disadvantages & methods:

Brachytherapy Sources: Radium, Cesium-137, Cobalt-60, Iridium-192, Gold-198, Iodine-125, Palladium-103 and others.

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 Gynecological Implants: General Information (advantages/disadvantages), Remote Afterloading Units, LDR, MDR, HDR, PDR, HDR vs. LDR

Brachytherapy Treatment Planning: (10 Lectures)


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

Paper – II

Clinical Dosimetry and Standardization (Total 40 Lectures)

Radiation Measurement and Calibration (40 Lectures)

Dose and Relationships: Radiation Absorbed Dose - definition and units; Relationship between Kerma, Exposure, and Absorbed Dose; Bragg-Gray Cavity Theory; Stopping Powers.

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

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

Calibration of Megavoltage Beams: \( N_{\text{dair}} \) and \( N_{\text{dw}} \) 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. Quality assurance in radiation therapy – precision and accuracy in clinical dosimetry – quality assurance protocols for Deep X-ray Therapy machine, Telecobalt, medical linear accelerator of all types and radiotherapy simulators both conventional and CT-Simulator, High dose rate remote control afterloading machines – IEC requirements – acceptance, commissioning and quality control of telecobalt, medical linear accelerator and radiotherapy simulators. Portal and in-vivo dosimetry. Electronic portal imaging devices.
Practicals

1. To find the Reproducibility and Linearity of a radiation dosimeter
2. Energy measurement of photon and electron beam of linear accelerator using TRS 398
3. Energy measurement of photon and electron beam of linear accelerator using TG 51
4. Output calibration of 6 MV/15 MV photon beam in water at an ambient environmental conditions using IAEA TRS-398 protocol.
5. To find the shutter time error of a cobalt-60 Teletherapy unit and find the output in water phantom using TRS 398 protocol
6. To find the $N_{dw,Co60}$ calibration factor of a dosimeter using cross calibration method
7. To find the $N_x$ and $N_{dair}$ from $N_{dw}$ calibration factor using TRS 277
8. To find the output of electron beam using both TRS 398 and TG51 protocols

Paper – III

Principles of Radiation Protection and Radiation Safety (40 Lectures)

Acute and Chronic effects of Whole Body Irradiation (2 Lectures)

Knowledge of various acute radiation syndromes and chronic effects of whole body irradiation.

Principles of Radiation Protection (6 Lectures)


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 (3 Lectures)

Radiation decontamination of labs, clothes, hands, glassware, gloves, metals, plastics, paints and bricks. 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 (5 Lectures)


Planning & Design of Radiation generating Equipment Installation (7 Lectures)

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: (3 Lectures)**

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: (3 Lectures)**

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 (3 Lectures)**


**Personnel Monitoring Devices (2 Lectures)**

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

**Radiation Survey of the Department (1 Lectures)**

Principle and construction of radiation survey meter and gamma zone monitors

**Safety in Industrial, Agriculture and Research uses of Radiation (2 Lectures)**

Use of ionizing radiation in irradiator, industrial radiography, nucleonic gauging, well logging and research such as medical research, industrial research and agriculture research.

**Duties and responsibilities of Radiation Safety Officer (RSO) Legislation (3 Lectures)**

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.
Paper – IV

Recent Advances in Radiotherapy and Special Techniques (40 Lectures)

Imaging for Radiation Oncology: (20 Lectures)

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 (5 Lectures)**

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 (15 Lectures)**

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, CyberKnife, 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


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.
THIRD YEAR SYLLABUS

Internship:

The student will undergo internship for one year at the Department of Radiotherapy, Regional Cancer Center, Postgraduate Institute of Medical Education & Research, Chandigarh.

Dissertation:

The student will also do a project and write dissertation and submit to the University one month before completion of internship.