

*Outcome of the CMPI Workshop on Harmonization of Syllabus for
Medical Physics Held during 22nd to 23rd June 2012 at CMC, Vellore*

LIST OF PARTICIPANTS

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PROPOSED TITLES FOR THE PAPERS

I year

PAPER I - RADIATION PHYSICS

PAPER II - MATHEMATICAL PHYSICS

PAPER III - RADIATION DETECTION AND INSTRUMENTATION

PAPER IV - ANATOMY, PHYSIOLOGY AND RADIATION BIOLOGY

PAPER V – APPLIED ELECTRONICS

PAPER VI – SOLID STATE PHYSICS

II year

PAPER V- RADIATION DOSIMETRY AND STANDADIZATION

PAPER VI - PHYSICS OF MEDICAL IMAGING

PAPER VII - PHYSICS OF RADIATION ONCOLOGY

PAPER VIII - RADIOLOGICAL SAFETY AND PROTECTION

DRAFT SYLLABUS

PAPER I: RADIATION PHYSICS

UNIT I: NUCLEAR PHYSICS

10 hours

Radioactivity - General properties of alpha, beta and gamma rays - Laws of radioactivity - Laws of successive transformations - Natural radioactive series - Radioactive equilibrium - Alpha ray spectra - Beta ray spectra - Theory of beta decay - Gamma emission - Electron capture - Internal conversion - Nuclear isomerism - Artificial radioactivity - Nuclear cross sections - Elementary ideas of fission and reactors - Fusion.

UNIT II: X-RAY GENERATORS

15 hours

Discovery - Production - Properties of X-rays - Characteristics and continuous spectra - Design of hot cathode X-ray tube - Basic requirements of medical diagnostic, therapeutic and industrial radiographic tubes - Rotating anode tubes - Hooded anode tubes - Industrial X-ray tubes - X-ray tubes for crystallography - Rating of tubes - Safety devices in X-ray tubes - Rayproof and shockproof tubes - Insulation and cooling of X-ray tubes - Mobile and dental units - Faults in X-ray tubes - Limitations on loading.

Electric Accessories for X-ray tubes - Filament and high voltage transformers - High voltage circuits - Half-wave and full-wave rectifiers - Condenser discharge apparatus - Three phase apparatus - Voltage doubling circuits - Current and voltage stabilisers - Automatic exposure control - Automatic Brightness Control- Measuring instruments - Measurement of kV and mA - timers - Control Panels - Complete X-ray circuit - Image intensifiers and closed circuit TV systems - Modern Trends

UNIT III: INTERACTION OF RADIATION WITH MATTER

20 hours

Interaction of electromagnetic radiation with matter Exponential attenuation - Thomson scattering - Photoelectric and Compton process and energy absorption - Pair production - Attenuation and mass energy absorption coefficients - Relative importance of various processes.

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

Passage of heavy charged particles through matter - Energy loss by collision - Range energy relation - Bragg curve - Specific ionization - Stopping Power - Bethe Bloch Formula. Interaction of neutrons with matter - scattering - capture - Neutron induced nuclear reaction.

SUGGESTION :

- 1. To include Particle Accelerators under the heading "Radiation Generators" –
Dr.Sowmy**

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PAPER II – MATHEMATICAL PHYSICS

UNIT 1: PROBABILITY, STATISTICS AND ERRORS

15 hours

Probability - addition and multiplication laws of probability, conditional probability, population, variates, collection, tabulation and graphical representation of data.

Basic ideas of statistical distributions frequency distributions, averages or measures of central tendency, arithmetic mean, properties of arithmetic mean, median, mode, geometric mean, harmonic mean, dispersion, standard deviation, root mean square deviation, standard error and variance, moments, skewness and kurtosis.

Application to radiation detection - uncertainty calculations, error propagation, time distribution between background and sample, minimum detectable limit.

Binomial distribution, Poisson distribution, Gaussian distribution, exponential distribution - additive property of normal variates, confidence limits, Bivariate distribution, Correlation and Regression, Chi-Square distribution, t-distribution, F-distribution.

UNIT 2: COUNTING AND MEDICAL STATISTICS

10 hours

Statistics of nuclear counting - Application of Poisson's statistics - Goodness-of-fit tests - Lexie's divergence coefficients Pearson's chi-square test and its extension - Random fluctuations Evaluation of equipment performance - Signal-to-noise ratio - Selection of operating voltage - Preset of rate meters and recorders - Efficiency and sensitivity of radiation detectors - Statistical aspects of gamma ray and beta ray counting - Special considerations in gas counting and counting with proportional counters - Statistical accuracy in double isotope technique.

Sampling and sampling distributions - confidence intervals. Clinical study designs and clinical trials. Hypothesis testing and errors. Regression analysis.

UNIT 3: NUMERICAL METHODS

30 hours

Why numerical methods, accuracy and errors on calculations - round-off error, evaluation of formulae. Iteration for Solving $x = g(x)$, Initial Approximation and Convergence Criteria. Interpolations: Finite differences- Forward –Backward- Central differences-Newton-Gregory forward, backward interpolation Formulae for equal intervals-Missing terms-Lagrange's interpolation formula for unequal intervals-Inverse interpolations.

Curve fitting - Principle of least squares - Discrete Fourier Transform - Fast Fourier Transform - Applications – Random waveforms and noise.

Simultaneous linear equations: Gauss elimination method - Jordan's modification. - Inverse of a matrix by Gauss - Jordan Method - Roots of nonlinear equations: Newton-Raphson method - Iterative rule -Termination criteria.

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.

Monte Carlo: Random variables, discrete random variables, continuous random variables, probability density function, discrete probability density function, continuous probability distributions, cumulative distribution function, accuracy and precision, law of large number, central limit theorem, random numbers and their generation, tests for randomness, inversion random sampling technique including worked examples, integration of simple 1-D integrals including worked examples.

UNIT 4: COMPUTATIONAL TOOLS & TECHNIQUES

5 hours

Computational packages: Overview of programming in C++, MATLAB/ Mathematics, and STATISTICA in data analysis and graphics.

SUGGESTION:

- 1. To include Concept of Treatment Planning in Radiation Oncology, Computerized treatment planning system, Hardwares and softwares used and Development of Algorithms used in Treatment Planning System—Dr.Sowmy**

PAPER III – RADIATION DETECTION AND INSTRUMENTATION

UNIT I: MEDICAL ELECTRONICS

10 hours

Semiconductor diodes - JFET – MOSFET – Integrated Circuits - Operational amplifiers(OPAM) and their characteristics - Differential Amplifier - Operational amplifier systems – OPAM Applications -Addition, subtraction, Integration and Differentiation – Active amplifiers - Pulse Amplifiers - Decoders and Encoders - Microprocessors and associated peripherals - Power supplies - Regulated power supplies using IC's - DC-DC converter and RF power supplies – Switching mode power supplies – AC regulators.

UNIT II: PRINCIPLES OF RADIATION DETECTION

20 hours

Principles of Radiation Detection and measurement – Basic Principles of radiation detection – Gas filled detectors – ionization chambers – Theory and design – construction of condenser type chambers and thimble chambers – Gas multiplication – proportional and GM counters – Characteristics of organic and inorganic counters – Dead time and recovery time – scintillation detectors – Semiconductor detectors – Chemical systems – Radiographic and Radiochromic films –Thermoluminescent Dosimeters (TLD) – Optically stimulated Luminescence dosimeters (OSLD) – Radiophotoluminescent dosimeters – Neutron Detectors – Nuclear track emulsions for fast neutrons – Solid State Nuclear track (SSNTD) detectors – Calorimeters – New Developments.

UNIT III: RADIATION MEASURING & MONITORING INSTRUMENTS 25 hours

Dosimeters based on condenser chambers - Pocket chambers - Dosimeters based on current measurement - Different types of electrometers - MOSFET, Vibrating condenser and Varactor bridge types - Secondary standard therapy level dosimeters - Farmer Dosimeters – Radiation field analyser (RFA) - Radioisotope calibrator - Multipurpose dosimeter – Water phantom dosimetry systems - Brachytherapy dosimeters - Thermoluminescent dosimeter readers for medical applications - Calibration and maintenance of dosimeters.

Instruments for personnel monitoring - TLD badge readers - PM film densitometers – Glass dosimeter readers - Digital pocket dosimeters using solid state devices and GM counters - Teletector - Industrial gamma radiography survey meter - Gamma area (Zone) alarm monitors - Contamination monitors for alpha, beta and gamma radiation - Hand and Foot monitors - Laundry and Portal Monitors - Scintillation monitors for X and gamma radiations - Neutron Monitors, Tissue equivalent survey meters - Flux meter and dose equivalent monitors - Pocket neutron monitors - Teledose systems.

Instruments for counting and spectrometry - Portable counting systems for alpha and beta radiation - Gamma ray spectrometers - Multichannel Analyser - Liquid scintillation counting system - RIA counters – Whole body counters - Air Monitors for radioactive particulates and gases. Details of commercially available instruments and systems.

PAPER IV: ANATOMY, PHYSIOLOGY AND RADIATION BIOLOGY

UNIT 1: CELL BIOLOGY

5 Hours

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.

UNIT 2: ANATOMY, PHYSIOLOGY AND PATHOLOGY

10 Hours

Anatomy and physiology as applied to radio diagnosis and radiotherapy - Structure & function of organs and systems & their common diseases: Skin, Lymphatic system, Bone and muscle, Nervous, Endocrine, Cardiovascular, Respiratory, Digestive (Gastro-Intestinal), Urinary, Reproductive, Eye and ear.

Anatomy of human body, nomenclature & Surface anatomy, Radiographic Anatomy (including cross sectional anatomy – identification of different organs/ structures) on plain X-rays, CT scans and other available imaging modalities. Normal anatomy & deviation for abnormalities.

Tumour pathology and carcinogenesis, common pathological features of cancers and interpretation of clinical-pathology data

UNIT 3 : INTERACTIONS OF RADIATION WITH TISSUE

10 Hours

Survival curve - Shape of survival curves- mechanism of cell killing-DNA target, Bystander effect- mitotic and apoptotic death: autophagic cell death.

Action of radiation on living cells – Direct action, indirect action, radiolysis of water-Free radical interaction with bio molecules including DNA – Effect of oxygen and temperature: hyperthermia – radiation effects on cell: cell cycle- DNA strand breaks-chromosome aberrations and repair- Classification of radiation damage: Potentially lethal damage and sub lethal damage; recovery - Pathways for repair of radiation damage –dose and dose rate effect and fractionation. Other dose modifying agents: LET, RBE, radio sensitizers and radio protectors. Applications of above agents in radiotherapy.

UNIT 4 : BIOLOGICAL EFFECTS OF RADIATION

10 Hours

Somatic effects of radiation – deterministic effects and stochastic effects- effect of dose, dose rate, radiation type and energy - acute radiation syndrome: cerebro-vascular, gastrointestinal and hematopoietic and associated symptoms. Chronic radiation exposure effects- radiation carcinogenesis - genetic effects of radiation- mutation, chromosomal changes, multi factorial - Genetic effects on humans and genetic risk estimate.

UNIT 5 : TIME, DOSE AND FRACTIONATION IN RADIOTHERAPY 5 HOURS

Four R's of radiobiology- dose response relation for elate and early responding tissues, Fractionation size and overall treatment time: hyper fractionation, accelerated

treatment, hypo fractionation - Calculation of effective doses in radiotherapy using LQ models.

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PAPER V – APPLIED ELECTRONICS

Fabrication of IC and logic families

Fabrication of IC - Monolithic integrated circuit fabrication - IC pressure transducers - Monolithic RMS - Voltage measuring device - Monolithic voltage regulators - Integrated circuit multipliers - Integrated circuit logic - Schottky TTL - ECL - I^2L - P and NMOS Logic - CMOS Logic - Tristate logic circuits. Noise in electronics due to ionising radiation, radiation damage; radiation hardening techniques in manufacture and in application

Opto electronic devices

Light sources and Displays - Light emitting diodes - Surface emitting LED - Edge Emitting LED - Seven segment display - LDR - Diode lasers - Photo detectors - Basic parameters - Photo diodes - p-i-n Photo diode - Solar cells - Photo transistors - IR and UV detectors

Op-amp applications

Basic operational amplifier applications- Differential DC amplifier- instrumentation amplifier- integrators and differentiators – Analog computation- Active filters-comparators-sample and hold circuit- precision Ac/Dc converters- Logarithmic amplifiers- waveform generators- Regenerative comparator- voltage regulators. Instrumentation amplifier - V to I and I to V converter - Op-amp circuits using diodes - Sample and Hold circuits - Log and Antilog amplifiers - Multiplier and Divider - Electronic analog Computation - Schmitt Trigger - Astable, Monostable Multivibrator - Triangular wave generators - Sine wave generators - Rc Active filters

Electronic Devices

Thyristors- SCR & Triac- characteristics and ratings- power control using thyristors-power MOSFETs, IGBT- switch mode DC power supplies

Digital Electronics

Binary adders- Decoder & encoder- multiplexer & demultiplexer- JK flipflop- shift registers- Ripple counter- synchronous counter- A/D and D/A converters

Microprocessors & Micro Controllers

Introduction to microprocessors , architecture, families, examples of manufacturer specific features. Programming, input and output, timers and interrupts - interfacing memory & I/O devices- Memory address space and data organization- segment registers and memory segmentation generating a memory address- I/O address space- Addressing modes-

comparison of 8086 and 8088- Basic 8086/80888 configuration- Minimum mode- maximum mode.

Introduction to microcontrollers- comparison with microprocessors- study of microcontroller(MC 51 family)- Architecture, instruction set, addressing modes and its programming.

REFERENCES

1. YU-Cheng Liu & Glenn A Gibson , “Microprocessor system, Architecture programming & Design.
2. Bre, “The Intel Microprocessors –“ PHI
3. Douglas V Hall ,”Microprocessors & Interfacing” – TMH
4. Avtar Singh, “IBM PC/8088 assembly Language Programming”
5. Scott MacKeinz “The 8051 Microcontroller, 3/E” Prentice Hall Inc.

PAPER VI – SOLID STATE PHYSICS

Crystal Physics

Types of lattices - Miller indices - simple crystal structures - Crystal diffraction - Bragg's law - Reciprocal lattice (sc, bcc, fcc) - Laue equations - Structure factor - Atomic form factor - Types of crystal binding - Cohesive energy of ionic crystals - Madelung constant - Inert gas crystals - Vander Waal - Landon equation - Metal crystals - Hydrogen bonded crystals.

Lattice dynamics

Monoatomic lattices - Lattice with two atoms per primitive cell - First Brillouin zone - Group and phase velocities - Quantization of lattice vibrations - Phonon momentum - Inelastic scattering by phonons - Debye's theory of lattice heat capacity - Einstein's model and Debye's model of specific heat - thermal expansion - Thermal conductivity - Umklapp processes.

Theory of metals and semiconductors

Free electrons gas in three dimensions - Electronic heat capacity - Wiedmann-Franz law - Hall effect - Band theory of metals and semiconductors - Bloch theorem - Kronig-Penny model - Semiconductors - Intrinsic carrier concentration - Mobility - Impurity conductivity - Fermi surfaces and construction - Experimental methods in Fermi surface studies - de Haas Van Alphen effect.

Magnetism

Elementary ideas of dia, para and ferro magnetism - quantum theory of paramagnetism - Rare earth ion - Hund's rule - Quenching of orbital angular momentum - Adiabatic demagnetization - Quantum theory of ferromagnetism - Curie point - Exchange integral - Heisenberg's interpretation of Weiss field - ferromagnetic domains - Bloch Wall - Spin waves - Quantization - Magnons - thermal excitation of magnons - Curie temperature and susceptibility of ferrimagnets - Theory of antiferromagnetism - Neel temperature. M.Sc. Physics : Syllabus (CBCS) 24

Super conductivity

Experimental facts-occurrence - Effect of magnetic fields - Meissner effect - Entropy and heat capacity - Energy gap - Microwave and infrared properties - Type I and II superconductors - theoretical explanation - thermodynamics of super conducting transition - London equation - Coherence length - BCS Theory - single particle Tunneling - Josephson tunneling - DC and AC Josephson effects - High temperature super conductors - SQUIDS.

Books for Study

1. C. Kittel, 1996, Introduction to Solid State Physics, 7th Edition, Wiley, New York.

2. M. Ali Omar, 1974, Elementary Solid State Physics-Principles and Applications, Addison-Wesley, London.
3. H.P. Myers, 1998, Introductory Solid State Physics, 2nd Edition, Viva Book, New Delhi.
4. S.O. Pillai, 1997, Solid State Physics, New Age International, New Delhi.

Books for Reference

1. N.W. Ashcroft and N.D. Mermin, Solid State Physics, Rhinehart and Winton, New York.
2. J.S. Blakemore, 1974, Solid State Physics, 2nd Edition, W.B. Saunder, Philadelphia.
3. A.J. Dekker, Solid State Physics, Macmillan India, New Delhi.
4. H.M. Rosenburg, 1993, The Solid State, 3rd Edition, Oxford University Press, Oxford.
5. S.O. Pillai, 1994, Problems and Solutions in Solid State Physics, New Age International, New Delhi.
6. S.L. Altmann, Band Theory of Metals, Pergamon, Oxford.
7. M.A. Wahab, 1999, Solid State Physics, Structure and Properties of Materials, Narosa, New Delhi.
8. J.M. Ziman, 1971, Principles of the Theory of Solids, Cambridge University Press, London.

SECOND YEAR

PAPER V : RADIATION DOSIMETRY AND STANDARDIZATION

UNIT I: RADIATION QUANTITIES AND UNITS

10 hours

Radiation quantities and units - Radiometry - Particle flux and fluence - Energy flux and fluence - Cross section - Linear and mass attenuation coefficients - Mass energy transfer and mass energy absorption coefficients - Stopping power - LET - Radiation chemical yield - W value - Dosimetry - Energy imparted - Absorbed dose - Radiation and tissue weighting factors, equivalent dose, effective dose, committed equivalent dose, committed effective dose - Concepts of collective dose - KERMA-CEMA - Exposure - Air kerma rate constant - Charged particle equilibrium (CPE) - Relationship between kerma, absorbed dose and exposure under CPE - Dose equivalent - Ambient and directional dose equivalents [(H*(d) and H'(d))] - individual dose equivalent penetrating Hp(d) - Individual dose equivalent superficial Hs(d).

UNIT II: RADIATION SOURCES

5 hours

Radiation Sources – Natural and artificial radioactive sources – Large scale production of isotopes – Reactor produced isotopes – Cyclotron produced isotopes – Fission products – Telecobalt and Brachytherapy sources- Caesium sources – Gold seeds – Tantalum wire – ¹²⁵I sources – Beta ray applicators – Thermal and fast neutron sources – Preparation of labelled compounds and radio colloids.

UNIT III: DOSIMETRY & STANDARDISATION OF X AND GAMMA RAYS BEAMS

25 hours

Standards – Primary and Secondary Standards, Traceability, Uncertainty in measurement. Charged particle Equilibrium (CPE), Free Air Ion Chamber (FAIC), Design of parallel plate FAIC, Measurement of Air Kerma/Exposure. Limitations of FAIC. Bragg-Gray cavity theory, Mathematical expression describing Bragg-Gray principle and its derivation. Burlin and Spencer Attix Cavity theories. Transient Charged Particle Equilibrium (TCPE), Concept of D_{gas}, Cavity ion chambers, Derivation of an expression for sensitivity of a cavity ion chamber. General Definition of calibration factor – N_x, N_K, N_{D,air}, N_{D,w}. IAEA TRS277: various steps to arrive at the expression for Dw starting from N_x. TRS398: N_{D,w,Q}, K_{Q,Q0}, K_Q, Derivation of an expression for K_{Q,Q0}, Calorimetric standards – Intercomparison of standards.

Measurement of Dw from Cobalt-60 teletherapy machines - Reference conditions for measurement, Type of ion chambers, Phantom, Waterproof sleeve, Derivation of an expression for Machine timing error, procedure for evaluation of Temperature and pressure correction. Thermometers and barometer. Measurement of temperature and pressure. Saturation correction - derivation of expression for charge collection efficiency of an ion chamber based on Mie theory - Parallel plate, cylindrical and spherical ion chambers, k_{sat} . Two voltage method for continuous and pulsed beams, polarity correction.

Measurement of Dw for high-energy photon beams from Linear Accelerators: Beam quality index, beam quality correction co-efficient, Cross calibration using intermediate beam quality. Quality Audit programmes in Reference and Non-Reference conditions.

Standardization of brachytherapy sources – Apparent activity – Reference Air Kerma Rate – Air Kerma strength Standards for HDR Ir-192 and Co-60 sources – standardization of I-125 and beta sources – IAEA TECDOC 1274 – room scatter correction.

Calibration of protection level instruments and monitors.

UNIT IV: NEUTRON STANDARDS AND DOSIMETRY

10 hours

Neutron Classification, Neutron Sources, Neutron standards – primary standards, secondary standards, Neutron yield and fluence rate measurements, Manganese sulphate bath system, precision long counter, Activation method. Neutron spectrometry, threshold detectors, scintillation detectors & multispheres, Neutron dosimetry, Neutron survey meters, calibration, neutron field around medical accelerators.

UNIT V: STANDARDIZATION OF RADIONUCLIDES

10 hours

Methods of measurement of radioactivity – Defined solid angle and 4π counting – Beta gamma coincidence counting – standardization of Beta emitters and electron capture nuclides with proportional, GM and Scintillation counters – standardization of gamma emitters with scintillation spectrometers – Ionization chamber methods – Extrapolation chamber – Routine sample measurements – Liquid counter – Windowless counting of liquid samples – scintillation counting methods of alpha, beta and gamma emitter – Re-entrant ionization chamber methods – methods using (n, γ) and (n,p) reactions – Determination of yield of neutron sources – Space integration methods – Solid state detectors.

UNIT VI:

RADIATION CHEMISTRY AND CHEMICAL DOSIMETRY

15 hours

Definition of free radicals and G-value – Kinetics of radiation chemical transformations – LET and dose-rate effects – Radiation Chemistry of water and aqueous solutions, peroxy radicals, pH effects – Radiation chemistry of gases and reactions of dosimetry interest – Radiation polymerization, effects of radiation on polymers and their

applications in dosimetry – Formation of free radicals in solids and their applications in dosimetry — Dosimetry principles – Definitions of optical density, molar absorption coefficient, Beer-Lambert's law, Spectrophotometry – Dose calculations – Laboratory techniques – Reagents and procedures – Requirements for an ideal chemical dosimeter – Fricke dosimeter – FBX dosimeter – Free radical dosimeter – Ceric sulphate dosimeter – Other high and low level dosimeters – Applications of chemical dosimeters in Radiotherapy.

PAPER VI: PHYSICS OF MEDICAL IMAGING

UNIT 1: PRODUCTION OF X-RAYS

10 hrs

Discovery and properties of x-rays –Production of x-rays –X-ray spectrum, Bremsstrahlung Spectrum, Characteristic spectrum – X-ray tube design, Cathode, space charge effect, anode, focal spot size, line focus principle, anode angle, anode heel effect, tube insert and vacuum, tube cooling- Types of x-ray tubes, gas tubes, Coolidge tube, stationary and rotating anode X ray tubes, grid controlled x-ray tube- off focal radiation

X ray generators- transformers- Transformer construction- Autotransformer-High tension transformer- Rectifiers- Filament control and kV control circuits- Single & three phase generator –high and medium frequency generator- Complete X-ray circuit- exposure timers- automatic exposure control- xray tube ratings & heat loading- Quality and quantity of x-rays.

UNIT II: SCREEN & FILM RADIOGRAPHY

10 hrs

Primary radiological image- contrast agents- Grids, grid ratio, types of grid, oscillating grid, air gap techniques- cassettes- intensifying screen, Characteristics of screens, absorption efficiency and conversion efficiency - structure of x-ray film, types of films, manual processing - film handling and storage, characteristics of x-ray film, film processing, influence of temperature and time, replenisher, dark room, Automatic film processor- Image quality, contrast resolution, noise, geometric factors, optimal quality image, artefact, beam limiting devices, filtration. Quality assurance in film processor, Laser Cameras – wet and dry processing

UNIT III: DIGITAL RADIOGRAPHY

10 hrs

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

assessment Modality worklist, DICOM, Data compression, radiological information system, data encryption, firewalls, storage requirements, disaster recovery and security. Computer Networks: basic principle, local area network, large network and network linking, telecommunication network. PACS and Teleradiology: digital images to network for image and data transfer-storage, PACS-security and reliability; quality control.

UNIT IV: MAMMOGRAPHY AND FLUOROSCOPY

10 hrs

Mammography: mammographic X-ray tube design, x-ray generator and AEC. Compression paddle, grid, collimation, filtration and HVL- Magnification-Screen film cassettes and film Processing- Digital Mammography- Radiation dosimetry- quality Assurance.

Fluoroscopy: conventional fluoroscopy, dark room adaptation, image intensifiers, closed circuit TV systems, flat panel detectors. Modern trends in interventional Radiology-Bi-plane imaging, rotational angiography, cardiac imaging, real time imaging characteristics – filtration, continuous and pulsed fluoroscopy, high dose rate fluoroscopy, spot imaging, Digital Subtraction acquisition technique, road mapping, image magnification, last image hold, automatic exposure control, automatic brightness control, brightness gain- image quality- Radiation dose management: dose area product (DAP) meters, peak skin dose, cumulative dose and dosimetric techniques in interventional radiology. Dose management for pediatric and pregnant patients in interventional imaging, Diagnostic Reference levels and guidelines.

UNIT V: COMPUTED TOMOGRAPHY

10 hrs

Computed tomography scanning principle- CT number, image display- CT equipment, system design, Gantry geometry, x ray tubes, filters and collimation, Detector array – Generation of CT- Modes of CT acquisition, Axial acquisition, Helical acquisition, Cone beam acquisition, Cardiac CT, CT angiography, CT perfusion- CT image reconstruction, back projection, Filtered back projection, Fourier reconstruction, cone beam reconstruction, Iterative reconstruction, postprocessing tools, volume rendering, SSD, MPR, MIP- Image quality, Spatial resolution, Noise and factors influencing them, Quality assurance - Image artefacts, Radiation dose management: factors affecting patient dose CTDI, CTDIvol, dose length product (DLP), multiple scan average dose (MSAD) .

UNIT VI: NUCLEAR IMAGING

15 hrs

Review of Radioactivity and nuclear transformation-Production of Radioisotopes, cyclotron, Medical cyclotron, cyclotron produced radionuclides, Radiopharmaceuticals- radionuclide generators- Gamma camera – Scintillation detector, Pulse height analyser, Pulse height spectrum- image display, Types of collimators-single photon emission computed tomography SPECT- Positron emission tomography(PET) principle, Positron emitters, coincidence detection-PET/CT scanner, data acquisition, attenuation correction, image display-Radiation dose -recent developments. -Performance-Design factors determining performance- Effects of scatter and attenuation on projection images-Protocols followed for

Quality Assurance / Quality control of imaging instruments. In-vitro techniques: RIA / IRMA
Techniques and its principles

UNIT VII : ULTRA SOUND IMAGING

5 hrs

Basics of ultrasound, propagation of sound, interaction of ultrasound with matter- Ultrasound transducer, piezoelectric material, transducer design, transducer array- Beam properties- near field-far field-side lobes-spatial resolution. Image data acquisition- data acquisition systems, ADC-receiver, Echo display modes, scan converter. Image data acquisition, pulse echo acquisition- ultrasound image display, amplitude mode, Motion mode, brightness mode- Doppler ultrasound, Ultrasound image quality- image artifacts- Bioeffects of ultrasound

UNIT VIII: MAGNETIC RESONANCE IMAGING (MRI)

10 hrs

Basics physics of MRI, magnetism, nuclear characteristics, hydrogen characteristics, magnetization vector, precession, radiofrequency and resonance, MRI signal, flip angle- Relaxation time, T1 relaxation time, T2 relaxation time, Comparison of T1 and T2- MR signal localization, gradient field, slice selection, phase encoding gradient, frequency encoding gradient, composite signal, K-space- MR imaging sequences, spin echo sequence, T1 weighted image, T2 weighted image, spin density weighted image, inversion recovery, gradient recalled echo – specialized MR sequences, MR angiography, perfusion imaging, diffusion imaging, functional imaging, MR spectroscopic imaging – MR instrument and bio safety, Image quality and artifacts

UNIT IX: IMAGE QUALITY AND QUALITY ASSURANCE

10 hours

Digital versus analog processes, analog to digital conversion; reconstruction techniques: image fusion and registration, gray scale processing, frequency processing, sampling and quantisation, aliasing, Nyquist limit, window and level, Digital image Processing - contrast versus spatial resolution in digital imaging. Display characteristics and viewing conditions for monitors (CRT, LCD and other display systems).

Image Quality parameters: Sources of un-sharpness, reduction of un-sharpness, factors influencing radiographic contrast, resolution (spatial, contrast and temporal), factors influencing resolution, evaluation of resolution (Point spread function (PSF), Line spread function (LSF), Edge spread function (ESF), Modulation transfer function (MTF), full width at half maximum (FWHM), Noise: quantum mottle, electronic noise and other sources of noise; Detective quantum efficiency (DQE); SNR, contrast to noise ratio (CNR).

QA of conventional diagnostic x-ray equipment: purpose of QA, QA Protocols, QA Test methods for performance evaluation of diagnostic equipments - Collimator congruence test; accuracy of kVp; HVL, accuracy of mAs; consistency of output; accuracy of mA; Focal Spot size evaluation, radiation safety survey conventional and interventional radiographic systems, phantom test in digital radiography. QA in CT. Other related quality assurance as per the guidelines of the AERB as part of the regulation. QA in mammography using phantoms. Performance testing and quality assurance in ultrasound and MRI using accredited phantoms,

PAPER VII: PHYSICS OF RADIATION ONCOLOGY

UNIT I: BEAM THERAPY

60 Hours

Description of low kV therapy x-ray units - spectral distribution of kV x-rays and effect of filtration - thoraeus filter - output calibration procedure. Construction and working of telecobalt units - source design - beam collimation and penumbra - trimmers and breast cones. Design and working of medical electron linear accelerators - beam collimation - asymmetric collimator - multileaf collimator - dose monitoring - electron contamination. Output calibration of ^{60}Co gamma rays, high energy x-rays and electron beams using IAEA TRS 398, AAPM TG 51 and other dosimetry protocols. Relative merits and demerits of kV x-rays, gamma rays, MV x-rays and electron beams. Radiotherapy simulator and its applications. CT and virtual simulations.

Central axis dosimetry parameters - Tissue air ratio (TAR) Back scatter/ Peak scatter factor (BSF/PSF) - Percentage depth doses (PDD) - Tissue phantom ratio (TPR) - Tissue maximum ratio (TMR) - Collimator, phantom and total scatter factors. Relation between TAR and PDD and its applications - Relation between TMR and PDD and its applications. SAR, SMR, Off axis ratio and Field factor. Build-up region and surface dose. Tissue equivalent phantoms. Radiation field analyzer (RFA). Description and measurement of isodose curves/charts. Dosimetry data resources.

Beam modifying and shaping devices - wedge filters - universal, motorized and dynamic wedges- shielding blocks and compensators.

Treatment planning in teletherapy – target volume definition and dose prescription criteria- ICRU 50 and 62 - SSD and SAD set ups - two and three dimensional localization techniques - contouring - simulation of treatment techniques - field arrangements - single, parallel opposed and multiple fields - corrections for tissue inhomogeneity, contour shapes and beam obliquity - integral dose. Arc/ rotation therapy and Clarkson technique for irregular fields - mantle and inverted Y fields. Conventional and conformal radiotherapy. Treatment time and Monitor unit calculations.

Clinical electron beams - energy specification - electron energy selection for patient treatment - depth dose characteristics (Ds, Dx, R100, R90, R50, R etc.) - beam flatness and symmetry - penumbra - isodose plots - monitor unit calculations - output factor formalisms - effect of air gap on beam dosimetry - effective SSD.

Particulate beam therapy

10 Hours

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

Quality assurance in radiation therapy - precision and accuracy in clinical dosimetry - quality assurance protocols for telecobalt, medical linear accelerator and radiotherapy simulators - IEC requirements - acceptance, commissioning and quality control of telecobalt, medical linear accelerator and radiotherapy simulators. Portal and in-vivo dosimetry. Electronic portal imaging devices.

UNIT II: BRACHYTHERAPY

15 Hours

Definition and classification of brachytherapy techniques - surface mould, intracavitary, interstitial And intraluminal techniques. Requirement for brachytherapy sources – Description of radium and radium substitutes - ^{137}Cs , ^{60}Co , ^{192}Ir , ^{125}I and other commonly used brachytherapy sources. Dose rate considerations and classification of brachytherapy techniques - Low dose rate (LDR), high dose rate (HDR) and pulsed dose rate (PDR). Paterson Parker and Manchester Dosage systems. ICRU 38 and 58 protocols. Specification and calibration of brachytherapy sources - RAKR and AKS - IAEA TECDOC 1274 and ICRU 72 recommendations. Point and line source dosimetry formalisms - Sievert Integral - AAPM TG-43/43U1 and other dosimetry formalisms.

Afterloading techniques - Advantages and disadvantages of manual and remote afterloading techniques. AAPM and IEC requirements for remote afterloading brachytherapy equipment. Acceptance, commissioning and quality assurance of remote after loading brachytherapy equipment. ISO requirements and QA of brachytherapy sources. Integrated brachytherapy unit. Brachytherapy treatment planning - CT/MR based brachytherapy planning - forward and inverse planning - DICOM image import / export from OT - Record & verification. Brachytherapy treatment for Prostate cancer. Ocular brachytherapy using photon and beta

sources. Intravascular brachytherapy - classification - sources - dosimetry procedures - AAPM TG 60 protocol. Electronic brachytherapy (Axxent, Mammosite, etc.).

UNIT III: COMPUTERS IN TREATMENT PLANNING

10 Hours

Scope of computers in radiation treatment planning - Review of algorithms used for treatment planning computations - Pencil beam, double pencil beam, Clarkson method, convolution superposition, lung interface algorithm, fast Fourier transform, Inverse planning algorithm, Monte Carlo based algorithms. Treatment planning calculations for photon beam, electron beam, and brachytherapy - Factors to be incorporated in computational algorithms. Plan optimization - direct aperture optimization - beamlet optimization - simulated annealing - dose volume histograms - Indices used for plan comparisons - Hardware and software requirements - beam & source library generation. Networking, DICOM and PACS. Acceptance, commissioning and quality assurance of radiotherapy treatment planning systems using IAEA TRS 430 and other protocols.

UNIT IV: SPECIAL AND ADVANCED TECHNIQUES OF RADIOTHERAPY **15 Hours**

Special techniques in radiation therapy - Total body irradiation (TBI) - large field dosimetry - total Skin electron therapy (TSET) - electron arc treatment and dosimetry – intraoperative radiotherapy.

Stereotactic radiosurgery/radiotherapy (SRS/SRT) - cone and mMLC based X-Knife - Gamma Knife - immobilization devices for SRS/SRT - dosimetry and planning procedures - Evaluation of SRS/SRT treatment plans - QA protocols and procedures for X- and Gamma Knife units - Patient specific QA. Physical, planning, clinical aspects and quality assurance of stereotactic body radiotherapy (SBRT) and Cyber Knife based therapy.

Intensity modulated radiation therapy (IMRT) - principles - MLC based IMRT - step and shoot and sliding window techniques - Compensator based IMRT - planning process – inverse treatment planning - immobilization for IMRT - dose verification phantoms, dosimeters, protocols and procedures - machine and patient specific QA. Intensity Modulated Arc Therapy (IMAT e.g. Rapid Arc). Image Guided Radiotherapy (IGRT) - concept, imaging modality, kV cone beam CT (kVCT), MV cone beam CT (MVCT), image registration, plan adaptation, QA protocol and procedures - special phantom, 4DCT. Tomotherapy - principle - commissioning - imaging - planning and dosimetry - delivery - plan adaptation - QA protocol and procedures.

SUGGESTION :

- 1. To include a topic on Proton and Hadron therapy --- Dr. D.Deshpande**

PAPER VIII: RADIOLOGICAL SAFETY AND PROTECTION

UNIT I: RADIATION PROTECTION STANDARDS

10 Hours

Radiation dose to individuals from natural radioactivity in the environment and man-made sources. Basic concepts of radiation protection standards - Historical background - International Commission on Radiological Protection and its recommendations – The system of Radiological Protection – Justification of Practice, Optimisation of Protection and individual dose limits – Radiation and tissue weighting factors, equivalent dose, effective dose, committed equivalent dose, committed effective dose – Concepts of collective dose- Potential exposures, dose and dose constraints – System of protection for intervention - Categories of exposures – Occupational, Public and Medical Exposures - Permissible levels for neutron flux - Factors governing internal exposure - Radionuclide concentrations in air and water - ALI, DAC and contamination levels

UNIT II: PRINCIPLES OF MONITORING AND PROTECTION

5 Hours

Evaluation of external radiation hazards - Effects of distance, time and shielding – Personnel and area monitoring - Internal radiation hazards – Radio toxicity of different radionuclides and the classification of laboratories – Control of contamination – Bioassay and air monitoring – chemical protection – Radiation accidents

UNIT III SAFETY IN THE MEDICAL USES OF RADIATION

20 Hours

Planning of medical radiation installations – General considerations – Design of diagnostic, deep therapy, telegamma and accelerator installations, brachytherapy facilities and medical radioisotope laboratories.

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, Use of ionising radiation in medical research

UNIT IV: RADIOACTIVE WASTE DISPOSAL

5 Hours

Radioactive wastes – sources of radioactive wastes - Classification of waste – Treatment techniques for solid, liquid and gaseous effluents – Permissible limits for disposal of waste - Sampling techniques for air, water and solids – Geological, hydrological and meteorological parameters – Ecological considerations.

Disposal of radioactive wastes - General methods of disposal - Management of radioactive waste in medical and research establishments.

UNIT V: TRANSPORT OF RADIOISOTOPES

5 Hours

Transportation of radioactive substances - Historical background - General packing requirements - Transport documents - Labeling and marking of packages - Regulations

applicable for different modes of transport - Transport by post - Transport emergencies - Special requirements for transport of large radioactive sources and fissile materials - Exemptions from regulations – Shipment approval – Shipment under exclusive use – Transport under special arrangement – Consignor's and carrier's responsibilities

UNIT VI: LEGISLATION

5 Hours

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 - National legislation – Regulatory framework – Atomic Energy Act – Atomic Energy (Radiation Protection) Rules – Applicable Safety Codes, Standards, Guides and Manuals – Regulatory Control – Licensing, Inspection and Enforcement – Responsibilities of Employers, Licensees, Radiological Safety Officers and Radiation Workers – National inventories of radiation sources – Import, Export procedures

UNIT VII: RADIATION EMERGENCIES AND THEIR MEDICAL MANAGEMENT

5 Hours

Radiation accidents and emergencies in the use of radiation sources and equipment in and medicine and teletherapy units - Loading and unloading of sources - Loss of radiation sources and their tracing - Typical accident cases. Radiation injuries, their treatment and medical management - case histories.

PRACTICALS

Radiation therapy

1. Production and attenuation of bremsstrahlung.
2. Range of beta particles
3. Study of voltage and current characteristics of an ion-chamber
4. Calibration of survey instruments and pocket dosimeters
5. Construction and calibration of a G.M. monitor
6. Determination of plateau and resolving time of a G.M. counter
7. Output measurement of a gamma chamber using Fricke dosimeter
8. Calibration and use of chemical dosimeter
9. Calibration of a TLD personnel monitoring badge and dose evaluation
10. Dose output measurement of photon (^{60}Co gamma rays and high energy x-rays) beams used in radiotherapy treatment
11. Dose output measurement of electron beams used in radiotherapy treatment
12. Determination of percentage depth dose of photon and electron beams.
13. Integrity check for brachytherapy sources
14. AKS/ RAKR measurement of an HDR brachytherapy source using well type and cylindrical ionisation chambers.
15. In-phantom dosimetry of a brachytherapy source.
16. Radiation protection survey of teletherapy installations
17. Determination of half-value thickness (HVT) and linear attenuation coefficient(μ)
18. Verification of inverse square law

19. Preparation and indexing for transport package for a radioactive source.
20. Determination of the half-life of a given radioactive source which is having a short half life .
21. Wedge and tray factor determination
22. Determination of wedge factor and verification using Treatment planning system.
23. Dosimetric verification of 4 fields to evaluate the plan and verify it in phantom.
24. Contamination check of teletherapy machine
25. Contamination check of brachytherapy source.
26. Autoradiography test for brachy therapy source in remote afterloader unit.
27. Calibration check of a therapy level dosimeter against calibrated ion chamber
28. Dosimetry verification of computerized treatment planning of a four fields (SAD) box technique and comparison with manual planning.
29. Dosimetry verification of computerized treatment planning of a four fields (SSD) box technique and comparison with manual planning

Radio Diagnosis

1. Congruence of Radiation and optical field and beam.
2. Determination of focal spot size of X-ray tube.
3. Accuracy of KVp
4. Linearity testing of the timer.
5. Consistency of mA loading.
6. Consistency of Radiation output.
7. Evaluation of total filtration of the tube.
8. Table top exposure rate measurement in fluoroscopy.
9. CTDI dosimetry
10. QA in CT

Nuclear Medicine

1. Statistics of radioactive counting
2. Calibration of Gamma ray spectrometer [NaI(Tl), HPGe] and identification of unknown sources using multichannel analyser.
3. Preparation and standardization of unsealed sources
4. Study and calibration of thyroid uptake measurement.
5. Measurement of beta activity
6. Survey of a radioisotope laboratory and study of surface and air contamination.

7. Study of the nuclear counting statistics using a G.M. counter and given radioactive source
8. QA for Gamma camera
9. Radiation Protection in I-131 therapy and patient preparation and patient monitoring.
10. Measurement of activity of I-131 and Tc-99m using isotope calibrator

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