Rajasthan Public Service commission, Ajmer

Syllabus for Screening Test for the post of Senior Demonstrator – RADIOLOGICAL PHYSICS (MEDICAL & HEALTH DEPARTMENT)

BASIC RADIATION PHYSICS

1. Basic Nuclear Properties

Nuclear size, shape, mass – Charge distribution – Spin and parity – Binding energy – Semi empirical mass formula – Nuclear stability – Mass parabola

Nature of nuclear forces – Ground state of deuteron – Magnetic dipole moment of deuteron – Proton-neutron scattering at low energies – Scattering length, phase shift – Properties of nuclear forces – Spin dependence – Charge symmetry – Charge independence – Repulsion at short distances – Exchange forces – Meson theory

2. Radioactive Decays

Alpha emission – Geiger – Nuttal law – Gamow theory – Neutrino hypothesis – Fermi theory of beta-decay – Selection rules – Nonconservation of parity – Gamma emission – Selection rules – Transition probability – Internal conversion – Nuclear isomerism

3. Nuclear Reactions

Q-values and kinematics of nuclear cross sections – Energy and angular dependence – Reciprocity theorem – Breit-Wigner formula – Compound nucleus – Resonance theory – Optical model-Shell model – Liquid drop model – Collective model

4. Interactions of radiation with matter

Mechanism of Interaction of Ionizing Radiation: Ionization and absorption of energy – Photon Beam Description - Photon Beam Attenuation – Attenuation Coefficient and mass energy attenuation coefficients – Half value layer-Narrow and broad beams-Mass, electronic and atomic attenuation coefficients-Energy transfer and energy absorption-Interactions of Photons with Matter – Coherent Scattering – Photoelectric absorption – Compton Effect-Klein –Nishina coefficients – Pair Production – Total attenuation coefficient-– Relative Importance of Various Types of Interaction

Interaction of heavy charged particles with matter. Energy loss per ion pair, primary and secondary ionization- dependence of collision energy loss on physical and chemical state of the absorber- Cerenkov radiation- electron absorption- Bremsstrahlung-range energy relation- Passage of heavy charged particles through matter-loss of collision-Brag curve-specific ionization-stopping power and restricted stopping power-Beth Bloch formula. Interaction of neutron with matter- scattering- capture-neutron induced nuclear reaction.Neutron sources, properties, energy classification, elastic and inelastic scattering, nuclear reaction, neutron activation, radio isotope production.

5. Radiation quantities and Units

Quantities to describe a radiation beam- particle flux and fluence- Photon flux and fluence- cross section- linear and mass absorption coefficient-stopping power and LET. Activity – Curie – Becquerel. Exposure and its measurements – Roentgen, Radiation absorbed Dose – Gray – Kerma- kerma rate constant- Electronic equilibrium- relationship between kerma, exposure and absorbed dose–Relative biological effectiveness-radiation weighting factors.

Equivalent dose-effective dose- tissue weighting factors-ambient and directional equivalent dose and their relevance in dosimetry, tissue equivalence, dose commitment and collective dose.

RADIATION DOSIMETRY

1.Radiation detection and Measurement

Principles of measurements of radiation and radioactivity.Gas filled Ionization chamber,proportional counters,GM counters,Scintillation detectors,semiconductor detectors,BF_3 counters for neutron detection. TLD dosimetry: process and properties,glow curves and dose response,photon energy dependence,fading,physical form of TLD materials,residual TL and annealing for reuse,repeated read out of TLD's.TL instrumentation,ultrathin TLD's,graphite /boron carbide mixed TLD'S glow curve analysis.

2.Ionization Dosimetry

Theoritical aspects of ionization dosimetry-Bragg-Gray theory-Models and equations-practical aspects of ionization dosimetry-characteristics of ionization chambers-polarity effect-stability and collection efficiency-principles of low current measurements. Measurement of absorbed dose: calculation of absorbed dose from exposure-Bragg-gray cavity theory-.Other methods of measuring absorbed dose: calorimetry- Chemical dosimetry-solid state methods; -Silicon diodes-Radiographic film-Radiocromic film.

3.Low and medium energy dosimetry and high energy Dosimetry

In phantom measurements –reference conditions-comparison with ICRU equations-in air measurements-comparison of two methods-Exposure and kerma calibrations(in air)-K-curves-D-curves-concept of CPE and TE-Determination of in water absorbed dose-Graphite dosimetric calibration. Historical developments-High energy photon dosimetry-CSDM,SAM models-cfactors-development of electron beam dosimetry-concept of cavity gas calibration factor for high energy dosimetry-development of new high energy dosimetry formalism-reference depth-Gradient correction-saturation correction-average stopping power ratio-comparison of electron and photon dosimetry-electron beam dose transfer formalism.

4. Dosimeters and survey meters

Dosimeters: Primary standard dosimeters, secondary standard dosimeters, Victoreen R meter, dosimeter based on current measurements, radio isotope calibrator, multi purpose dosimeters -water phantom dosimetry systems, Brach therapy dosimeters. Calibration and maintenance of dosimeters.

Instruments for personal monitoring, digital pocket dosimeters using solid state devices, and GM counters, teledetectors, portable survey meters, gamma area (zone) alaram monitors, contamination monitors for alpha, beta and gamma radiations, scintillation monitors for X ray and gamma radiation –neutron monitors- tissue equivalent survey meter-flux meters, dose equivalent monitors.

5. Standardization of electrons,x-ray and gamma rays beams

Determination of exposure and air kerma, conditions for the realization of exposure, ionization chamber for low, medium and high energy x-rays and gamma rays, determination of absorbed dose, Bragg Gray theory and its validity, Burlin's theory for measurement for radiation quantities,

PHYSICS OF DIAGNOSTIC RADIOLOGY

1. Physical Principles of X- ray Diagnosis

X-Ray production, properties, Characteristic spectrum and Bremmsrahlung spectrum, X-ray tubes- X-ray tube insert, Tube housing, filtration, and collimation. X-ray generator function and components. X-ray generator circuit designs. Timing the x-ray exposure in radiography. Factors affecting x-ray emission-Quality of x-ray beams-HVL and its measurement-measurement of energy. Power ratings and heat loading. X-ray exposure ratings charts

Historical x-ray tubes; Gas tube-coolidge tube. Moderrn x-ray tubes;Stationary x-ray tube-Rotating anode x-ray tube-Grid controlled x-ray tubes. Therapeutic and industrial radiographic tubes, X-ray tubes for mobile,dental, mammography,CT and DSA applications.

2. Screen – Film Radiography

Projection radiography – Basic geometric principles.The screen-film cassette. Characteristics of screens. Chracteristics of film. The screen-film system. Contrast and dose in radiography. Scattered radiation in projection Radiography-Grid.

Film processing: Film Exposure – Film processor-manual and automatic-dark room – Processor artifacts – Other considerations – Laser Cameras – Dry processing- Processor Quality assurance.

3. Mammography & Fluoroscopy

X-ray tube design. X-ray generator and photo timer system. Compression, scattered radiation and magnification. Screen – film cassettes and film Processing. Ancillary procedures. Radiation dosimetry. Regulatory requirements. Functionality – Fluoroscopy Imaging chain components – peripheral equipment – Fluoroscopy modes of operation – Automatic brightness Control – Image quality – Fluoroscopy suites- Radiation dose

4. Image Quality & Digital Radiography

Contrast - Spatial Resolution – Noise -Detective quantum efficiency –Contrast-detail curves- Received operating characteristic curves-

Computed Radiography – Charged Coupled Devices (CCDS)- Flat panel
detectors -Digital mammography-Digital verses analog processes- implementation- patient dose considerations – Hard copy verses soft copy display- Digital image Processing- contrast verses spatial resolution in digital imaging
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5. Industrial Radiography

Industrial application of radiation: Principles of industrial radiography with x and gamma ray, radiographic exposure devices, photographic film technique, radiographic contrast, definition and sensitivity, intensifying screens and penetrameters.

Principle and measurement of thickness and level in different applications, density and moisture, hydrogen in hydrocarbons, well logging, composition analysis. Principle of operation of consumer products using radiation sources fire detector, baggage inspection systems, static eliminators, luminous paints and gas mantles. Industrial radiation processing: gamma chambers, radiation sterilization, irradiation of food and medical product

PHYSICS OF RADIATION THERAPY

1.Overview of Clinical Radiation oncology

Cancer incidence/etiology. Overview of Radiotherapy(Tele ,Brachy,neutron,ptoton and high Z therapy) hyperthermia.

Review of pertinent radiobiology; Dose response curves,4R's,relationship of volume and time to radiation effects (TDF,alpha/beta ratio).side effects/complication.Tolerance doses for normal tissue and tumors.Role of clinical medical physicist.

2. Clinical Radiation Generators

Kilo Voltage Units-Grenz ray therapy-contact therapy, superficial therapy, orthovoltage therapy – Megavoltage therapy – Resonant Transformer, Cascade generator, Vande Graff Generator – Linear Accelerator; magnetron, klystron, x-ray beam, electron beam, beam collimation ,Gantry – Betatron – Microtron - cyclotron - Machines using radio nuclides – Co-60 unit – Heavy Particle Beams –neutrons-protons and heavy ions-Negative pions.

3. Dose Distribution, Scatter Analysis & Treatment Planning

Phantoms- Depth dose distribution-Percentage Depth Dose – Tissue air Ratio – Scatter Air Ratio – Integral Dose. Dosimetric calculations-Dose calculation parameters – Practical Applications - Other Practical methods of calculating depth dose distribution.

a). Isodose Distributions: Isodose chart – Measurement of Isodose curves –Parameters of isodose curves- Wedge Filters – combination of radiation fields- Isocentric techniques- Wedged Field Techniques - Tumor Dose Specification for External Photon Beams.

b) Patient Data, Corrections, and Setup: Acquisition of Patient Data -Treatment Simulation – Treatment Verification – Corrections for contour Irregularities – Corrections for Tissue (body) Inhomogenities – Absorbed Dose within an Inhomogenity – Tissue Compensation –Patient positioning.

c) Field Shaping, Skin Dose, and Field Separation: Field Blocks – Field Shaping – Skin dose- Separation of Adjacent Fields.

4. Electron Beam Therapy & Brachytherapy

Electron interactions- Energy Specification and Measurement – Determination of Abosrbed Dose – Characteristics of Clinical electron beams- Treatment Planning – Field Shaping – electron Arc Therapy – Total Skin Irradiation-Treatment planning algorithms. Radioactive Sources – Radium and radium substitutes, Cesium – 137, Cobalt – 60, Iridium – 192, Iodine – 125-Gold 198-Iodine 125-Palladium-103 sources. - Calibration of Brachytherapy Sources – Checking of source integrity and uniformity- Specification of Source Strength – Exposure Rate Calibration – Calculation of Dose Distributions – Systems of implant Dosimetry - The Paterson-Parker System – The Quimby System – The Memorial System – The Paris System – Computer System – Use of Computers in Brachy therapy Dosimetry – Implantation Techniques – Dose Specification: Cancer of the Cervix – Milligram hours- Manchester system- ICRU system- Afterloading Techniques, Manual After loading - Remote Afterloading Units– Beta ray applicators .

RADIATION BIOLOGY

1 . Action of Radiation on Living Cells

Elements of cell biology – effects of ionizing radiation at molecules and cellular levels – secondary effects - Target theory - single hit and multi hit target theory - other theories of cell inactivation - concepts of micro dosimetry - direct and indirect action - radicals and molecular products -cellular effects of radiations – Bacterial

and Mammalian cell survival – application in cancer therapy, food preservation, radiation sterilization etc – Radio sensitivity at different phases of the cell cycle – inactivations - division delay - DNA. damage - depression of macromolecular synthesis - giant cells - chromosomal damage- point mutations- survival parameters- invitro and invivo experiments on mammalian ceil systems - RBE - response - modifiers- LET; oxygen, cell stage – Physical chemical and Biological factors influencing the effect of radiation - recovery mechanism radio protective and radio sensitizing chemicals- radiometric substances - chemical mutagenesis - effects of UV, microwave and other non - ionizing radiations – Physics and biological factors affecting cell survival, tumor regrowth the normal tissue tolerance, repair redistribution in the cell cycle – basis for dose fractionation in beam therapy.

2 . Somatic effects of Radiation :

Bergonis - Tribondeau law – radio sensitivity protocol of different tissues in human:LD50/30 - effect of radiation on skin - blood forming organs, lenses of-eyes, blood constituents, embryo, digestive tract, endocrine glands, gonads, dependence of effect on dose, dose rate, type and energy of radiation syndrome - effects of chronic exposure to radiation – radiation Carcinogenesis - shortening of life span risk estimates. Late effects, radiation indused carsinogenisis Stochastic and deterministic effect. Effects on embryonic and fetal development

3. Radiobiological basis of Radiotherapy:

Benign and malignant tumours, Tissue tolerance dose and tomour lethal dose,fraction, palliative and curative therapy.Tumor growth kinetics -rational of fractionation - problem of hypoxic compartment and quiescent cells - radiobiology of malignant neoplasm - solution of hypoxic cell sensitizers, hyperthermia, recourse to high LET radiation - combination of chemotherapy and Radiotherapy – chronoradio biology and its applications to get better cure - problem of tumor regression – Application of Various models in clinical Radiotherapy – Practical considerations.

4. Genetic effects of Radiations:

Threshold and linear dose - effect relationship - factors affecting frequency of radiation induced mutations recessive and dominant mutations - gene controlled hereditary diseases human data on animals and lower species - doubling dose and its influence of genetic equilibrium.

PHYSICS OF NUCLEAR MEDICINE

1. Production of Radiomuclides and Radio-Pharmaceuticals:

Radioactivity and nuclear transformation: Radionuclide decay terms and relationships-Activity-decay constant-Physical half life- Decay equation.Nuclear tranformation-Alpha decay-Beta decay-Electron capture-Isomeric transition.

Methods of Radiomuclide production-Reactor produced-accelerator produced--General considerations. Production of short lived radionuclides, using a generator-Principle and description.

Radiophraceuticals: Design and development considerations-Quality copntrol-Technetium-99m Labelled radiopharmaceuticals- Radioiodine labeled radiopharmaceuticals -Compounds labellled with other radionuclides-Radiopharmaceuticals for PET-Therapeutic uses of pharmaceuticals-Mis admininistration of Radiopharmaceuticals-In –vitro kit procedures-RIA kit

2. **Radiation Dose, Detectors and Standardization**

Radiation dose calculations-general considerations-S-factor-Radiation doses in imaging process. Detector characteristics-Types of detectors- Gas filled detectors Ion chambers-

Geiger –Proportional copunters-Muller counters– Scintillation detectors – Semi conductor detectors-single and multi channel anlysers. Pulse height spectroscopy.In Vitro radiation detection-Well type NaI (TL) Scintillation detectors-Liquid scintillation detectors-Thyroid uptake probes.Counting statistics, application of poisson's statistics, goodness fit tests, Lexide's divergence coefficients, Pearson's chi-square test and students test

Methods of measurements of radioactivity, defined solid angle and 4π β-γ coincidence counting, standardization for beta emitters and electron capture nuclides with proportional, GM and scintillation counters, standardization of gamma emitters with scintillation spectrometers, routine sample measurements, re-entrant ionization chamber methods, using (n,γ) and (n,p) reactions.

3. **Nuclear Imaging- Scintilation Camera**

Planar Nuclear imaging – The Anger Scintillation Camera-design and principle–collimators-Detector-Position Determining circuits-Display-Imaging with scintillation camera-principles of image formation-Performance-Design factors determining performance- Effects of scatter and attenuation on projection images-Whole body

scanning and SPECT-Computers in Nuclear Imaging. Operation Characteristics: spatial resolution-Sensitivity-Uniformity and high count rate performance

ADVANCED MEDICAL IMAGING PHYSICS

1. Computers in Medical Imaging

Storage and transfer of data in computers-number systems-decimal and binary form-transfer of data in digital form. Analog data and conversion between analog and digital form. Components and operation of computers-main memory-computer program and CPU—input /output bus and expansion slots-mass storage devices-keyboard and printing devices. Performance of Computer systems. Computer Software – Storage, Processing and display of digital Images.

2. Computed Tomography

Basic Principles – Geometry and historical development –different generations- Detectors and Detector arrays – xenon detectors-solid state detectors—Multi detector arrays– Details of acquisition –Single and Multiple array scanners- Tomographic Reconstruction –sinogram-Data processing-interpolation-simple back projection reconstruction-Filtered back projection-Bone kernals and soft tissue kernels-CT number –CT fluoroscopy- Digital image display – windowing and leveling- Multiplanar reconstruction-3D image display-stack mode viewing-Radiation dose –dose measurement-Dose in helical and CT fluoroscopy-Image Quality – Factors affecting image quality-Artifacts.

3. Ultra Sound

Characteristics of sound-propagation of sound- wavelength, frequency and speed-Pressure, intensity and dB scale. Interactions of Ultra sound with matter – acoustic impedence- reflection-refraction-scattering-attenuation. Transducers – Piezoelectric materials-resonance transducers-damping block-matching layer-Multi frequency transducers-transducer arrays. Beam properties- near field-far field-side lobes-spatial resolution. Image data acquisition-data acquisition systems-ADC-receiver-Echo display modes-scan converter. Image display and storage-Early B mode scanners- mechanical scanning-electronic scanning and real time display- Image storage. Biometric measurements-contrast agents-harmonic imaging-3D imaging. Image Quality and artifacts – Doppler Ultra sound –doppler frequency shift-continuous and pulsed Doppler-Duplex scanning-doppler spectral interpretation-Color flow imaging-power Doppler. Performance and Quality assurance – Acoustic power and Bio effects

4. Magnetic Resonance Imaging (MRI):

Magnetization properties – Generation and detection of MR signal-free induction decay –T1 and T2 relaxation. Pulse sequences – Spin EcoT1 weighting-spin density weighting-T2 weighting. Inversion Recovery – Gradient recalled Eco – Signal from flow – Perfusion and diffusion contrast-Magnetization transfer contrast

Localization of the MR Signal –magnetic field gradients-slice select gradient-frequency encode gradient-phase encode gradient. K- Space data acquisition and Image reconstruction –2D data acquisition- 3D Fourier transform image acquisition – Image Characteristics – Angiography and Magnetization transfer contrast – Artifacts – Instrumentation-magnet-ancillary bequipment-quality control – Safety and Bio effects.

5. Computer Networks, Pacs and Teleradiology

Computer Networks-basic principle-local area network-large network and network linking- Long distance telecommunication links—network security. PACS and Teleradiology acquisition of digital images-network for image and data transfer-storage of images-display of images-advantage and disadvantage of PACS-security and reliability-quality control.

RADIATION SAFETY AND REGULATIONS

1. Radiation Hazard Evaluation and Control and Emergency Preparedness

Hazard evaluation by calculation, methods of calculation,time distance shielding, area monitoring, personal monitoring.Detection and measurement of contamination on work surface,person and samples, methods of decontamination, evaluation of radiation hazards in medical diagnostic and therapy installations,protective measure to reduce radiation exposure to staff and patients, radiation hazards in brachytherapy, departments and teletherapy departments, radioisotope laboratories and particles accelerator facilities, protective equipments, handling of patients,radiation safety during source transfer operation, special safety consideration for accelerator installations.

2. Transport of Radioactive Material

Examples of radioactive shipments for medical and industrial, research applications of radioactive sources and in connection with nuclear fuel cycle. Special form radioactive materials and non-special form radioactive materials, Al and A2 values and basis of derivation of these values, low specific activity materials and surface contaminated objects. Design and test requirements of special form radioactive material, industrial package Type IP-1,IP-2 and IP-3 Type A packaging and Type B(U)/(M) packing, transport under exclusive use and special arrangements, expected packages and fissile exception, exempt radioactive material, approval requirements for radioactive materials, packaging and shipments, requirements for preparation, forwarding, storage and transport of packages, and marking and labeling requirements, limits on Non-fixed contamination and radiation level and temperature outside packages, transport documents, emergency response requirements.

3. Planning of Radiation Installation

Of various types for different applications (X-ray diagnostic, deep therapy, telegamma ad accelerator installations, brachytherapy facilities, nuclear medicine facilities, etc.) effects of scattering, albedo, sky shine, noxious gas production, designing a shielded container for storage/transport of radioactive materials (e.g. gamma chamber, radiographic exposure device, nucleonic gauge, neutron source container etc). Emergency preparedness, emergency handling, graded approach, site emergency.

4. Radiation Protection Standards and Regulations

Need for protection, philosophy of radiation protection, basic radiation protection criteria, External and internal exposure, additive risk model and multiplicative risk model. Risk coefficients. Dose to the foetus. Dose limits for occupational exposure, for public and special exposure situations. ICRP and AERB recommendations. Basic safety standards. Source, practices, types of exposures, interventions. Atomic energy act, Radiation protection Rules, Notifications, Transport regulations, Waste disposal rules, Food irradiation rules, licensing, approval of devices, installations, sites and packages containing radioactive material. Source of radioactive waste and classification of waste, treatment techniques for solid, liquid and gaseous effluents, permissible limits for disposal of waste, sampling techniques for air,water and solids, ecological consideration, general methods of disposal, management of radioactive waste in medical and research institutions.

5. Radiation Shielding

Shielding calculation for gamma radiation, choice of material, Primary and secondary radiation, source geometry, discrete sources, point, kemel method, introduction to Monte

Carlo method, Beta shielding, Bremsstrahlung. Neutron shielding, scattering and absorption, activation of the shielding material, heat effects. Optimization of shielding, gamma, electron, neutron irradiation facilities. Transport and storage of containers for high activity sources. Shielding requirements for medical and research facilities including accelerator installations

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Pattern of Question Papers:

1. Objective Type Paper
2. Maximum Marks : 100
3. Number of Questions : 100
4. Duration of Paper : Two Hours
5. All Questions carry equal marks
6. There will be Negative Marking

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