RAJASTHAN PUBLIC SERVICE COMMISSION, AJMER

SYLLABUS FOR SCREENING TEST FOR THE POST OF ASSISTANT PROFESSOR (Broad Speciality) RADIOLOGICAL PHYSICS (MEDICAL EDUCATION DEPARTMENT)

Unit: I BASIC RADIATION PHYSICS

Nuclear Physics

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.

Particle Accelerators

Particle accelerators for industrial, medical and research applications - The Resonant transformer - Cascade generator - Van De Graff Generator - Cyclotron – Betatron - Synchro-Cyclotron- Linear Accelerator - Klystron and magnetron - Travelling and Standing Wave Acceleration - Microtron - Electron Synchrotron - Proton synchrotron. Details of accelerator facilities in India.

X-ray Generators

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 – Ray proof and shock proof tubes - Insulation and cooling of X-ray tubes - Mobile and dental units - Faults in X-ray tubes – Limitations on loading.

Unit: II Interaction of Radiation with Matter

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 – Bremmstrahlung - 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 reactions.

Unit: III RADIOLOGICAL MATHEMATICS, RADIATION QUANTITIES AND UNITS

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.

Radiation Quantities and Units

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 - Kerma - 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: IV Dosimetry & Standardization of X and Gamma Rays

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 theory, Mathematical expression describing Bragg-Gray principle and its derivation. Burlin and Spencer Attix Cavity theories. Transient Charged Particle Equilibrium (TCPE). IAEA Protocol TRS-277: TRS-398. Calorimetric standards – Calibration 60Co 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: Parallel plate, cylindrical and spherical ion chambers, Two voltage method for continuous and pulsed beams, Polarity correction. Measurement of DW for high-energy photon beams from Linear accelerators: Beam quality, beam quality index, beam quality correction coefficient, Cross calibration. Measurement of DW for high energy Electron beams from linear accelerators: Beam quality, beam quality index, beam quality correction coefficient, 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 ^{192}Ir and ^{60}Co sources - Standardization of ^{125}I and beta sources.

Unit: V

Radiation Sources

Radiation sources - Natural and artificial radioactive sources - Large scale production of isotopes - Reactor produced isotopes - Cyclotron produced isotopes - Fission products - industrial uses –Telecobalt and Brachy Caesium sources – Gold seeds - Tantalum wire - ^{125}I Sources - Beta ray applicators - Thermal and fast neutron sources - Preparation of tracers and labeled compounds - Preparation of radio colloids.

Neutron Standards & Dosimetry

Neutron classification, neutron sources, Neutron standards - primary standards, secondary standards, Neutron yield and fluence rate measurements, precision long counter, Activation method. Neutron spectrometry, threshold detectors, scintillation detectors & multispheres, Neutron dosimetry, Neutron survey meters, calibration, neutron field around medical accelerators.

Standardization of Radionuclides

Methods of measurement of radioactivity - Defined solid angle and 4p counting - Beta gamma coincidence counting - Standardization of beta emitters and electron capture nuclides with proportional, GM and scintillation counters - Ionization chamber methods.

Radiation Chemistry and Chemical Dosimetry

Definitions of free radicals and G-value-Kinetics of radiation chemical transformations - LET and dose - rate effects - Radiation Chemistry of water and aqueous solutions.

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 and industrial irradiators.

Unit: VI Radiation detection, measurement and nuclear electronics

Principles of radiation detection and general properties of detectors : Principles of radiation detection, modes of detector operation, Pulse height spectra, Counting curves and plateaus, Energy resolution, Detector efficiency, Dead time, detector window. Gas filled radiation detectors: Various regions of operation of gas filled detectors – Ionization chambers, Proportional counters and GM counters - basic detection mechanism, types of radiation detected, mode of operation, different variants of detectors. Types of instruments which uses gas filled detectors – radiation dosimeters, survey meters, contamination monitors - Cylindrical, plane parallel, spherical and welltype ionization chambers, Extrapolation chamber. Scintillation (organic/inorganic) and semiconductor detectors: Advantages of scintillation detectors, properties of ideal scintillatior, basic electronic blocks in scintillation detector setup. Radiation detection mechanism of organic and in-organic scintillators, types of scintillators for various applications. Radiation detection by TLD. Photon detection devices - PMT, Photo diodes. Principles of detection mechanism in semiconductor detectors and its application for gamma and alpha spectrometry, Diode and MOSFET dosimeters. Neutron detectors: Neutron detection by activation, Nuclear track detectors, Radiographic and radiochromic films, Radiation field analyser (RFA).

Unit: VII

Radiation Protection Instruments

Instruments for personal monitoring, area monitoring, contamination monitoring, measurement of non-penetrating radiations - tritium, soft beta particles, Method of estimating activity present inside the body - whole body counter. Calibration of Radiation Protection Instruments : Fundamental concepts of instrument calibration, Basic requirements for calibration, Various parameters checked during calibration, Selection of radioactive sources and source strength for calibration check.

Quality Assurance

Goals, Role and responsibilities, RSO, QA of External beam units, Linear Accelerator, Proton beam therapy, Cyclotron, QA of HDR brachytherapy, sources, Accepting testing, Periodicity of QA, Multi Leaf Collimator(MLC) Micro MLC, CT Simulator, 4D Simulator, Intravascular Brachytherapy. Digital Subtraction Angiography (DSA).

Periodic Quality assurances of – Telecobalt unit - Linear accelerator – MLC – EPID – OBI– Treatment planning system – Stereotactic Radiosurgery – Stereotactic Radiotherapy –IMRT – patient specific QA of IMRT – QA of special procedures – Rapid Arc – Cyber knife – Tomotherapy.

Unit: VIII CLINICAL AND RADIATION BIOLOGY

Cell Biology

Structure of the cell - Types of cells and tissue, their structures and functions - DNA as concepts of gene and gene action - Mitotic and meiotic cell division.

Interaction of Radiation with Cells

Action of radiation on living cells - Radiolytic products of water and their interaction with biomolecule – Giant cell formation, cell death Recovery from radiation damage - Potentially lethal damage and sublethal damage recovery - Pathways for repair of radiation damage. Law of Bergonie and Tribondeau. Survival curve parameters - Model for radiation action - Target theory - Multihit, Multitarget – Repair misrepair hypothesis - Dual action hypothesis - Modification of radiation damage - LET, RBE, dose rate, dose fractionation - Oxygen and other chemical sensitizers - Anoxic, hypoxic, base analogs, folic acid, and energy metabolism inhibitors - Hyperthermic sensitization - Radio-protective agents.

Unit: IX Biological Effects of Radiation

Somatic effects of radiation - Physical factors influencing somatic effects - Dependence on dose, dose rate, type and energy of radiation, temperature, anoxia, - Acute radiation sickness - LD 50 dose -Effect of radiation on skin and blood forming organs, digestive tract - Sterility and cataract formation - Effects of chronic exposure to radiation - Induction of leukaemia - Radiation Carcinogenesis – Risk of carcinogenesis - Animal and human data - Shortening of life span - In-utero exposure – Genetic effects of radiation - Factors affecting frequency of radiation induced mutations - Dose-effect relationship - first generation effects - Effects due to mutation of recessive characteristics.

Unit: X Clinical Aspects of Medical Imaging & Radiation Oncology

Radiation Therapy, Surgery, Chemotherapy, Hormone Therapy, Immunotherapy & Radionuclide therapy, Benign and malignant disease, Methods of spread of malignant disease, Staging and grading systems, Treatment intent - Curative & Palliative, Acute & Late - Monitoring and common management of side effects - Information and communication. Professional aspects and role of medical physicists : General patient care.

Biological Basis of Radiotherapy

Physical and biological factors affecting cell survival, tumour re-growth and normal tissue response – Non - conventional fractionation scheme and their effect of re-oxygenation, repair, redistribution in the cell cycle - High LET radiation therapy.

Time Dose Fractionation

Time dose fractionation - Basis for dose fractionation in beam therapy - Concepts for Nominal Standard Dose (NSD), Roentgen equivalent therapy (RET) - Time dose fractionation (TDF) factors and cumulative radiation effects (CRE) - Gap correction, Linear and Linear Quadratic models.

Unit: XI MEDICAL IMAGING

Principles of X-ray Diagnosis & Conventional Imaging. Physical principle of diagnostic radiology : Interactions of X-rays with human body, differential transmission of x-ray beam, spatial image formation, visualization of spatial image, limitations of projection imaging technique Viz. superimposition of overlying structures and scatter, application of contrast media and projections at different angles to overcome superimposition of overlying structures Radiography techniques: Prime factors (kVp, mAs and SID/SFD), influence of prime factors on image quality, selection criteria of prime factors for different types of imaging, different type of projection and slices selected for imaging, objectives of radio-diagnosis, patient dose Vs image quality Filters: inherent and added filters, purpose of added filters, beryllium filter, filters used for shaping X-ray spectrum grids, air gap technique Intensifying screens: Function of intensifying screens, screen function evaluation parameters, emission spectra and screen film matching, conventional screens Vs rare earth screens Radiographic Film: Components of radiographic film, physical principle of image formation on film, double and single emulsion film, sensitometeric parameters of film (density, speed, latitude etc.) QA a test methods for performance evaluation of x-ray diagnostic equipment.

Unit: XII Modern Techniques in Diagnostic Radiology

Xero-radiography, mammography, Interventional radiology, digital radiography (CR and DR systems), digital subtraction techniques, Conventional tomography (principle only), orthopan tomography (OPG), Computed Tomography (CT), QA of CT equipment.

Magnetic Resonance Imaging (MRI) Magnetic Resonance image - proton density, relaxation time T1 & T2 images - Image characteristics -MRI system components - Magnets, Magnetic fields, Gradients, Magnetic field shielding, Radio Frequency systems, computer functions - Imaging process – Image artifacts – MRI safety. Ultrasound Imaging. Interaction of sound waves with body tissues, production of ultrasound - transducers – acoustic coupling - image formation - modes of image display - colour Doppler.

Unit: XIII Nuclear Medicine & Internal Dosimetry

Physics of Nuclear Medicine

Introduction to Nuclear Medicine, Unsealed Sources, Production of Radionuclide used in Nuclear Medicine; Reactor based Radionuclides, Accelerator based Radionuclides, Photonuclear activation, Equations for Radionuclide Production, Radionuclide Generators and their operation principles. Various usages of Radiopharmaceuticals. In-vivo Non-imaging procedures; Thyroid Uptake Measurements, Renogram, Life Span of RBC, Blood Volume studies, Life Span of RBC etc. General concept of Radionuclide Imaging and Historical developments. Radionuclide Imaging: Other techniques and Instruments; The Rectilinear Scanner and its operational principle, Basic Principles and Design of the Anger Camera /Scintillation Camera.

Physics of PET and Cyclotron:

Principles of PET, PET Instrumentations, Annihilation Coincidence Detection, PET Detector ad Scanner Design, Data Acquisition for PET, Data corrections and Quantitative Aspect of PET, Working of Medical Cyclotron, Radioisotopes Produced and their characteristics. Planning and Shielding Calculations during the installation of SPECT, PET/CT and Medical Cyclotron.

Unit: XIV EXTERNAL BEAM THERAPY

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- electron contamination. Output calibration of 60Co 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 filed analyzer (RFA). Description and measurement of isodose curves/charts. Dosimetry data resources. Beam modifying and shaping devices - wedge filters - universal, motorized and dynamic wedgesshielding 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 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

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

Unit: XV Brachytherapy

Definition and classification of brachytherapy techniques - surface mould, intracavitary, interstitial and intraluminal techniques. Requirement for brachytherapy sources - Description of radium and radium substitutes - 137Cs, 60Co, 192Ir, 125I and other commonly used brachytherapy sources. Dose rate considerations and classification 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/AKS and Absorbed Dose to Water calibration - IAEA TECDOC 1274 and ICRU 72 recommendations – Point and line source dosimetry formalisms - Sievert Integral. CT/MR based brachytherapy planning - GEC ESTRO recommendations - forward and inverse planning – DICOM image import /export .

Computers in Treatment Planning

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 - DICOM and PACS. Acceptance, commissioning and quality assurance of radiotherapy treatment planning systems using IAEA TRS 430 and other protocols.

Unit: XVI Advanced Techniques of Radiotherapy

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. inverse treatment planning - immobilization for IMRT - dose verification phantoms, dosimeters, protocols and procedures - machine and patient specific QA. Concept of Intensity Modulated Arc Therapy (IMAT e.g. Rapid Arc), Image Guided Radiotherapy (IGRT), and Volumetrically Modulated Arc Therapy (VMAT) - Imaging modality, kV cone beam CT (kVCT), MV cone beam CT (MVCT), image registration, plan adaptation.

Unit: XVII RADIATION SAFETY

Radiation Protection Standards. 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.

Principles of Monitoring and Protection

Evaluation of external radiation hazards - Effects of distance, time and shielding – Shielding calculations - 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 – disaster monitoring.

Safety in the Medical Uses of Radiation

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 .

Unit: XVIII REGULATORY ASPECTS OF MEDICAL RADIATION FACILITIES

Radioactive Waste Disposal

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. Disposal of radioactive wastes - General methods of disposal.

Transport of Radioisotopes

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.

Legislation

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

Radiation Emergencies and their Medical Management

Radiation accidents and emergencies in the use of radiation sources and equipment in industry and medicine - Radiographic cameras and teletherapy units - Loading and unloading of sources - Loss of radiation sources and their tracing - Typical accident cases.

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Pattern of Question Papers:

1. Objective Type Paper
2. Maximum Marks : 180
3. Number of Questions : 180
4. Duration of Paper : Three Hours
5. All Questions carry equal marks
6. There will be Negative Marking

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