

ABR Radiation Oncology Study Guide:

Radiologic Physics for Radiation Oncology

■ This exam tests your knowledge of the principles of physics underlying the practice of radiation oncology. Included are questions on:

- basic physics
- instruments and measurements
- dosimetry
- radioactivity (radionuclides and physics of therapeutically employed radionuclides)
- protection and safety

Categories for Radiologic Physics for Radiation Oncology

■ Atomic and Nuclear Structure

- Bohr model of the atom
 - Coulombic force and electron binding energy
 - Electron orbits (energy levels)
 - Electron transitions—absorption and emission of energy
 - Characteristic radiation and the Auger effect
- Nuclear structure
 - Nucleons —protons and neutrons
 - Nuclear force
 - $E = mc^2$ and nuclear binding energy
- Factors affecting nuclear stability
 - Neutron-to-proton ratio
 - Average binding energy per nucleon
 - Pairing of similar nucleons in the nucleus
- Nuclear nomenclature
 - The four isos (isotopes, isotones, isobars, isomers)
 - Shorthand representation of isotopes

■ Radioactive Decay

- Modes of radioactive decay
 - Beta (β)
 - β^- (negative beta, negatron)
 - β^+ (positive beta, positron)
 - Electron capture
 - Alpha (α)
- Other decay processes
 - Gamma rays
 - Internal conversion
- Decay schemes
 - Construction and interpretation
 - Examples for each decay mode

- Mathematics of radioactive decay
 - Units (SI Units)
 - Exponential decay equation
 - Half-life
 - Decay constant
 - Mean life, average life, and effective half life
 - Simple dose calculation for implants
 - Radioactive equilibrium
 - Secular equilibrium
 - Radium needles
 - ⁹⁰Sr applicators
 - Transient equilibrium
 - Nuclear medicine generators
 - Counting statistics
- Naturally occurring radioisotopes
- Manmade radioisotopes
 - Fission
 - Nuclear bombardment
- Decay schemes and properties for therapeutic isotopes

■ Properties and Production of Particulate and Electromagnetic Radiation

- Particulate radiation
 - Mass, charge
 - Relativistic energy equation
- Electromagnetic radiation
 - Wave-particle duality
 - Wave equations
 - Electromagnetic spectrum
- Production of radiation
 - Principles
 - Radioactive decay
 - X-ray tube
- Linear accelerators
 - Operational theory of wave guides
 - Standing wave guides
 - Traveling wave guides
 - Bending magnet systems
 - Flattening filters
 - Electron scattering foils
 - Electron cones
 - Targets
 - Factors affecting
 - Beam energy
 - Entrance dose
 - Depth of maximum dose
 - Beam uniformity
 - Dose rate
 - Monitor chamber
 - Collimation systems

- Primary and secondary collimators
 - Coupled and independent jaws (including virtual wedges)
 - Multileaf collimators
 - Other collimation systems (e.g., stereotactic systems)
 - Radiation and light fields (including field size definition)
 - Mechanical and operational features
- Cyclotron
- Microtron
- Cobalt units
- Therapeutic x-ray (<300 kVp)

■ Interactions of Electromagnetic Radiation with Matter

- Coherent scatter
- Photoelectric effect
- Compton effect
- Pair production
- Photonuclear disintegration
- Relative probabilities of interactions in human tissues
 - Energy dependence
 - Atomic number dependence
 - Electron density dependence

■ Interactions of Particulate Radiation with Matter

- Formalism
 - W value
 - Specific ionization
 - Linear energy transfer
 - Range
 - Stopping power
- Types of interactions
 - Heavy vs light particles
 - Charged vs uncharged particles
 - Elastic collisions
 - Inelastic collisions
- Heavy charged particles
 - Inelastic collisions with electrons
 - Depth dose characteristics (Bragg peak)
- Light charged particles
 - Elastic and inelastic collisions with electrons
 - Inelastic collisions with nuclei
- Neutrons

- Elastic collisions with hydrogen nuclei
- Depth dose characteristics vs charged particles and photons
- Biological implications of particle therapy

■ Quantification and Measurement of Dose (including SI units)

- Exposure (air kerma)
- Absorbed dose (kerma)
- Dose equivalent
- RBE dose
- Calculation of absorbed dose from exposure (e.g., f factor)
- Bragg-Gray cavity theory
- Gas-filled detectors
 - Principles of operation
 - Uses
- Ion chambers
 - Types
 - Exposure measurement
 - As a Bragg-Gray cavity
 - Correction factors (e.g., temperature and pressure)
 - Calibration of photon and electron beams (e.g., TG 21 and TG 25)
- Thermoluminescent dosimetry
- Calorimetry
- Film
- Chemical dosimetry
- Solid state diodes
- Scintillation detectors
- Measurement techniques

■ Characteristics of Photon Beams

- Mathematics of exponential attenuation
 - Half-value thickness
 - Attenuation coefficients (linear, mass, partial, total)
 - Narrow beam vs broad beam geometry
 - Monoenergetic vs heteroenergetic
 - Parallel vs diverging beams
- Beam quality for heteroenergetic beams
 - Energy distribution of accelerated electron beam

- Filtration
- Geometry
- Effective energy
- Energy spectra

■ Dosimetry of Photon Beams in a Homogeneous Water Phantom

- Dose distributions
 - Central axis percent depth dose
 - Isodose curves
 - Factors affecting dose distributions and penumbra
 - Beam energy or quality (including patient dose from neutrons)
 - Source size
 - SSD and SAD
 - Mayneord F factor
 - Inverse square law
 - Field size and shape
 - Equivalent square
 - Scatter effects
 - Flattening filters
 - Depth
 - Surface dose
 - Other
 - Dose distributions for multiple unshaped beams
 - Open beams
 - Wedged beams
 - Tissue-air ratio and backscatter factor
 - Tissue-maximum ratio
 - Tissue-phantom ratio
 - Relationships between PDD, TAR, TMR, TPR
 - Point dose and treatment time calculation methods for single unshaped fields
 - Machine output factors (e.g., absolute and relative output, head scatter, patient scatter factors)
 - Equivalent squares
 - SSD vs SAD setups
 - Beam modifier factors (e.g., wedge and tray factors)
 - Dose calculation at the isocenter of a rotating beam
 - Point dose and treatment time calculations for single shaped fields
 - Separation and recombination of primary and scatter radiation (e.g., Clarkson techniques)
 - Off-axis factors
 - Dose under blocks
 - Equivalent squares for shaped fields
 - Isodose distributions for multiple fields, including arc therapy
 - Measurement of photon dose distributions

■ Dosimetry of Photon Beams in a Patient

- Dose specification (eg, ICRU 50)
- Corrections for patient contour
 - Effective SSD method
 - TAR ratio method
 - Isodose shift method
- Corrections for tissue inhomogeneities
 - TAR ratio method
 - Power law method
 - Isodose shift method

- Equivalent TAR
- Dose within and around an inhomogeneity
- Matching of adjacent fields
- Using multiple wedged fields
- Parallel opposed beams
 - Point of maximum dose
 - Uniformity, dependence upon
 - Energy
 - Separation
 - SSD
- Entrance dose and exit dose, including beam modifying devices
- Isodose distributions for multiple beams, including mixed modality and arc therapy
- Compensation
 - Missing tissue
 - Dose compensation
 - Bolus
- Off-axis factors
- Practical/simple calculation of dose
- Practical/simple 2D treatment planning
- 3D conformal treatment planning 3D conformal treatment planning *Advanced Treatment Planning for EBRT, Letter G*)
- Dose delivery accuracy and precision

■ Dosimetry of Electron Beams

- Dose distributions
 - Central axis percent depth dose
 - Isodose curves
- Factors affecting dose distributions
 - Beam quality
 - Beam spreading systems
 - SSD and SDD
 - Effective SSD techniques
 - Inverse square
 - Field size and shape
 - X-ray contamination
 - Depth
 - Surface dose
 - Inhomogeneities (e.g., CET)
 - Other
- Energy specification
 - Most probable energy
 - Mean energy

- Energy at depth
 - Ranges (extrapolated, practical, R50)
- Choice of energy and field size
- Air gaps and oblique incidence
- Tissue inhomogeneities
- Bolus, absorbers, and spoilers
- Matching adjacent fields
- Point dose and treatment time calculations
- Field shaping techniques
- Electron arc
- Total skin electron therapy

■ Brachytherapy

- Historical review—role of radium
- Calculation of dose from a point source
- Calculation of dose from a line source
- Physical and dosimetric properties of commercial sealed sources and applicators
- Implant instrumentation and techniques
 - Low dose rate
 - High dose rate (including PDR)
 - Biological considerations of dose, dose rate, and fractionation
- Calibration and specification of sources
- Disseminated (unsealed sources)
- Acceptance testing and quality assurance
- Dose specification, implantation dosimetry, and dosimetry systems
 - Patterson-Parker
 - Quimby
 - Paris
 - Other
- Dose specification and dosimetry systems of intracavitary implants

■ Advanced Treatment Planning for EBRT

- Plane radiography and fluoroscopy for simulation
- Portal imaging

- Film-based
 - Electronic
- Imaging for radiation therapy planning
 - CT
 - MRI
 - Ultrasound
 - Isotope imaging
- Image processing
 - Image enhancement
 - 2D and 3D visualization of volumetric data (DRRs, volume rendering)
 - Image registration
- Virtual simulation (including BEV techniques)
- Treatment planning systems
- 3D conformal treatment planning
 - Plan evaluation (DVH, NTCP, TCP, etc)
 - Dose optimization techniques
 - Noncoplanar beams
 - IMRT
- Radiosurgery
- Patient setup and alignment

■ Quality Assurance

- Equipment-related
 - Regulations and recommendations
 - Measurement techniques
- Patient related
 - Misadministration
 - External beam
 - Brachytherapy
- Brachytherapy source inventory

■ Radiation Protection and Safety

- Principles, biological effect models, personnel dose limits, rules, regulations
- Structural shielding design for external beam therapy
 - Primary barriers
 - Secondary barriers
 - Machine shielding (beam stoppers and head shielding)
 - Neutrons
- Radiation protection for brachytherapy procedures
 - Source storage and transport containers
 - Patient room
 - Special considerations for high dose rate brachytherapy
 - Special procedures and source prep rooms
 - Release of patients treated with temporary implants

- Leak testing of sealed sources
- Routine radiation surveys
- Personnel monitoring
- Protection against nonionizing radiation
- Administrative requirements
 - Radiation Safety Officer
 - Radiation Safety Committee
- Safety instructions and safety precautions
 - Sealed-source brachytherapy
 - Radiopharmaceutical therapy

■ Quality Management Program

- Written directive
- Identification of patient
- Plan and delivery in accordance with written directive
- Unintended deviation
 - Recordable events
 - Misadministrations

■ Special Topics

- Hyperthermia
- Computers