

**ASTRO/AAPM Jointly Recommended Core Curriculum
Proposed by the ASTRO Ad-hoc Committee on
Physics Curriculum for Radiation Oncology Residents
Approved by the AAPM Medical Physics Education of Physicians
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<i>Subject Matter</i>	<i>Relative Instructional Units/Weight per Subject</i>
Atomic and Nuclear Structure (including decay and Radioactivity)	3
Production of X-rays, photons and electrons	2
Radiation Interactions	3
Treatment Machines and Generators; Simulators (incl. CT)	3
Radiation Beam Quality and Dose	2
Radiation Measurement and Calibration	4*
Photons and x-rays (incl. concepts, isodoses, MU, heterogeneities, field shaping, compensation, field matching, etc.)	7*
Electrons (incl. concepts, isodoses, MU, heterogeneities, field shaping, field matching, etc.)	3*
External Beam Quality Assurance	2*
Radiation Protection and Shielding	2
Imaging for Radiation Oncology	4
3DCRT including ICRU concepts and beam related biology	3*
Assessment of Patient Setup and Treatment (incl. EPID, Immobilization, etc.)	2*
IMRT	2*
Special Procedures (incl. Radiosurgery, TBI, etc.)	3*

Brachytherapy (incl. Intracavitary, Interstitial, HDR, etc.)	7*
Hyperthermia	1
Particle Therapy	1
Total Instructional Units/Weights	54

***Indicates Subject Matter that should be Complemented During a Physics Rotation.**

Format As Follows

#. Subject (# of lectures)

Learning Objectives

- A. Unique lecture for subject
 - Main topic(s) within lecture
 - Subtopic within given
-

1. Atomic and Nuclear Structure (3 Lectures)

Learning Objectives

The resident should:

- 1) *learn the structure of the atom, including types of nucleons, relation between atomic number and atomic mass, and electron orbits and binding energy.*
- 2) *be able to relate energy to wavelength and rest mass, and understand and describe an energy spectrum*
- 3) *learn about radioactivity, including decay processes, probability, half life, parent-daughter relationships, equilibrium, and nuclear activation*

- A. The atom
 - Protons, Neutrons, Electrons (charge, rest mass)
 - Atomic Number and Atomic Mass
 - Orbital electron shells (binding energy, transitions)
- B. Wave and quantum models of radiation
 - Energy and wavelength, energy spectrum
- C. Radioactivity and decay
 - Decay processes
 - Probability and decay constant
 - Activity, half life, mean life
 - Radioactive series
 - Parent-daughter relationships and equilibrium
 - Nuclear reactions, bombardment, and reactors

2. Production of photons and electrons (2 Lectures)

Learning Objectives

The resident should learn:

- 1) *the concepts of beam production, including acceleration of electrons in diagnostic X-Ray tubes, Bremsstrahlung, X-Ray tube design, and characteristic radiation.*
- 2) *about the general design of a linear accelerator, including major components and their functions, steering, flattening filtration, and beam hardening.*

- A. Physics concepts of beam production
 - Concept of Bremsstrahlung
 - X-Ray tube design
 - Energy spectrum
 - Characteristic radiation
- B. Generation of Beams

- Filters
- Gamma- radiation teletherapy sources (Co-60, Cs-137)
- Linear accelerator production

3. Radiation Interactions (3 Lectures)

Learning Objectives

The resident should learn

- 1) *the physical description, random nature, and energy dependence of the five scatter and absorption interactions that x-ray photons undergo with individual atoms (coherent scatter, photoelectric effect, Compton effect, pair production, and photonuclear disintegration).*
- 2) *definitions of the key terms such as attenuation, scatter, beam geometry, linear and mass attenuation coefficients, energy transfer, energy absorption, half-value layer, and how these terms relate to radiation scatter and absorption through the exponential attenuation equation;*
- 3) *the physical description and energy dependence of the elastic and inelastic collision processes in matter for directly and indirectly ionizing particulate radiation*
- 4) *definitions of key terms such as linear energy transfer, specific ionization, mass stopping power, range, and how these terms relate to energy deposition by particulate radiation.*

A. Interactions of x and γ rays with matter

- Scatter vs absorption
- Coherent scatter
- Photoelectric effect
- Compton effect
- Pair production
- Photonuclear disintegration

B. Attenuation of Photon Beams

- Attenuation, energy transfer, and energy absorption
- Exponential attenuation equation
- Attenuation coefficients
- Half-value layer
- Beam geometry

C. Interactions of particulate radiation

- Directly and indirectly ionizing particles
- Elastic and inelastic collisions with orbital electrons and the nucleus
- Linear energy transfer, specific ionization, mass stopping power, range
- Interactions of electrons
- Interactions of heavy charged particles
- Interactions of neutrons

4. Treatment Machines and Generators; Simulators (3 Lectures)

Learning Objectives

The resident should learn about:

- 1) *the mechanics and delivery of radiation with respect to wave guides, magnetron v. klystron for production*
- 2) *the production and delivery of electrons by the electron gun, buncher, and scattering foil v. scanning*
- 3) *the use in photon and electron delivery*
- 4) *benefits and limitations of MLC collimators and cerrobend and hand-block*
- 5) *the production and collimation of superficial photons*

- 6) *the production of low energy x-rays for imaging*
- 7) *the differences in film and other imaging modalities for simulation*
- 8) *the DRR (digitally reconstructed radiograph) production and use*

A. Linear accelerators

- Operational theory of wave guides
- Bending magnet systems
- Photon beam Delivery
- Electron beam delivery
- Beam energy
- Monitor chamber

B. Linac Collimation systems and other Teletherapy

- Primary and secondary collimators
- Multileaf collimators
- Other collimation systems
- Radiation and light fields (including field size definition)
- Cobalt units
- Therapeutic x-ray (<300 kVp)

C. Simulators

- Mechanical and Radiographic Operation
- Fluoroscopy and Intensifiers
- CT Simulation Machinery
- CT Simulation Operation

5. Radiation Beam Quality And Dose (2 Lectures)

Learning Objectives

The resident should learn

1) the physical characteristics of monoenergetic and heteroenergetic photon and particle beams, the terms such as energy spectrum, effective energy, filtration, geometry, and homogeneity that are used to describe such beams;

2) definitions and units for kerma, exposure, absorbed dose, dose equivalent, and RBE dose, the conditions under which each quantity applies, and the physical basis for measuring or computing each quantity.

A. Monoenergetic and Heteroenergetic bremsstrahlung beams

- Energy spectra for bremsstrahlung beams
- Effects of electron energy, filtration, beam geometry
- Homogeneity coefficient
- Effective energy
- Clinical indices for megavoltage beams (e.g., PDD at reference depth)

B. Dose quantities and units

- kerma
- Exposure
- Absorbed dose
- Dose equivalent
- RBE dose
- Calculation of absorbed dose from exposure

Bragg-Gray cavity theory

6. Radiation Measurement and Calibration (4 Lectures)

Learning Objectives

The resident should learn:

- 1) *the units and definitions associated with radiation absorbed dose.*
- 2) *the relationship between Kerma, exposure, and absorbed dose.*
- 3) *how absorbed dose can be determined from exposure, and the historical development of this approach.*
- 4) *Bragg-Gray cavity theory and its importance in radiation dosimetry.*
- 5) *stopping power ratios, and the effective point of measurement for radiation dosimetry.*
- 6) *how photon and electron beams are calibrated, the dose calibration parameters, and the calibration protocols for performing linac calibrations.*
- 7) *how to determine exposure and dose from radioactive sources.*
- 8) *the various methods by which to measure absorbed dose. These should include calorimetry, chemical dosimetry, solid state detectors, and film dosimetry.*

A. Dose and Relationships

- Radiation Absorbed Dose – definition and units
- Relationship between Kerma, Exposure, and Absorbed Dose
- Bragg-Gray Cavity Theory – Stopping Powers

B. Ionization Chambers

- Cylindrical
- Parallel-Plate
- Effective Points of Measurement

C. Calibration of Megavoltage Beams

- Photon beams
- Electron beams
- Dose calibration parameters
- TG-21 & TG-51

D. Other Methods of Measuring Absorbed Dose

1. Calorimetry
2. Chemical Dosimetry
3. Solid State Detectors
 - TLDS
 - Diode detectors
 - FET detectors
 - Diamond detectors
4. Film Dosimetry
 - XV2 film
 - EDR2 film
 - Radiochromic film

7. Photons and x-rays (7 Lectures)

Learning Objectives

The resident should learn

- 1) *basic dosimetric concepts of photon beams*

- 2) *how these concepts are relate to calculation concepts*
- 3) *basic calculation parameters*
- 4) *how these parameters relate to one another and how to cross convert*
- 5) *parameters used for calculations and their dependencies for SSD and SAD setups*
- 6) *how beam modifiers affect beams and calculations*
- 7) *basic treatment planning arrangements and strategies*
- 8) *how beam shaping affects isodose maps*
- 9) *surface and exit dose characteristics*
- 10) *the effect and use of beam modifiers including bolus*
- 11) *heterogeneity corrections and affects on isodoses*
- 12) *beam matching techniques and understanding of peripheral dose*
- 13) *special considerations for pacemaker, pregnant patients*

A. External Beam Dosimetry Concepts (Part I)

1. Dosimetric Variables

- Inverse Square Law
- Backscatter factor
- Electron Buildup
- Percent Depth Dose
 - Mayneord F-factor
 - TAR Correction to F-factor
- Equivalent Squares

B. External Beam Dosimetry Concepts (Part II)

- Tissue-air Ratio
- Scatter-air Ratio
- Tissue-phantom Ratio
- Tissue-maximum Ratio

C. System of Dose Calculations

1. Monitor Unit Calculations

- a) Output Factor
- b) Field Size Correction Factors
- c) Collimator Scatter Factor and Phantom Scatter Factor
- d) Beam Modifier Factors
- e) Patient Attenuation Factors

2. Calculations in Practice

- a) SSD Technique
 1. SSD Treatment same as SSD of Calibration
 2. SSD Treatment Different from SSD of Calibration
 3. SSD Treatment and SAD Calibration
- b) SAD Technique
 1. SAD Treatment and SAD Calibration
 2. SAD Treatment and SSD Calibration
 3. SAD Rotational Treatment

D. Translation of Planning to Calculations

2. Beam Parameters
3. Beam Weighting

3. Arc rotation therapy
4. Irregular Fields
- E. Computerized Treatment Planning
 1. Isodose curves (beam characteristics)
 2. Surface Dose
 3. Parallel Opposed Beam Combination
 4. Wedge Isodose Curves
 - a) Wedge Angle and Hinge Angle
 - b) Wedge Factor
 5. Wedge Techniques
 - a) Wedge Pair
 - b) Open and Wedged Field Combination
 - c) Skin Compensation
 6. Beam Combination (3-,4-,6- field techniques)
- F. Surface Corrections & Heterogeneities
 1. Corrections for Surface Obliquities
 2. Corrections for Inhomogeneities
 - a) Linear (1-D) Attenuation Method
 - b) 2-D Methods
 - c) Volumetric Methods
 - d) Dose Perturbations at Interfaces
- G. Adjoining fields & Special Dosimetry Problems
 1. Two-Field Problem
 2. Three-Field Problem
 3. Craniospinal Gapping
 4. Pacemaker
 5. Gonadal Dose
 6. Pregnant Patient

8. Electron Beam (3 Lectures)

Learning Objectives

The resident should learn:

- 1) *the basic characteristics of electron beams for therapy, including components of a depth-dose curve as a function of energy, electron interactions, isodoses, oblique incidence, and electron dose measurement techniques.*
- 2) *the nature of treatment planning with electrons, including simple rules for selecting energy based on treatment depth and range, effect of field size, dose to skin and bolus, and effects of field shaping, especially for small fields.*
- 3) *about field matching with photons and other electron fields, internal shielding, backscatter, and the effects of inhomogeneities on electron isodoses.*

- A. Basic Characteristics
 - Depth-dose/Isodose characteristics
 - Electron interactions
 - CSDA and range
 - Dose versus depth

- Isodoses
 - Oblique incidence
 - AAPM TG-25
- B. Treatment Planning with Electrons**
1. Rules of Thumb
 2. Selection of energy, field size
 3. Electron Skin Dose
 4. Electron Bolus
 5. Electron Field Shaping
- C. Field Matching and other considerations**
1. Electron-electron Gapping
 2. Electron-photon Gapping
 3. Electron Backscatter
 4. Inhomogeneities
 5. Internal shielding

9. External Beam Quality Assurance (2 Lectures)

Learning Objectives

The resident should learn:

- 1) the goals of a departmental quality assurance program, the staffing required to perform these quality assurance activities, and the duties and responsibilities of the individuals associated with the quality assurance program.*
- 2) what is entailed in making equipment selections in radiation therapy and the content of equipment specification.*
- 3) what is involved in acceptance testing of a linear accelerator and in commissioning both a linear accelerator and a treatment planning system.*
- 4) what linear accelerator quality assurance is required on a daily, monthly, and yearly basis and the acceptance tolerances associated with these tests.*

- A. Overview of Quality Assurance in Radiation Therapy**
- Goals
 - JCAHO
 - ACR
 - AAPM TG-40
 - Staffing
 - Roles, training, duties & responsibilities of individuals
 - Equipment Selection and Specifications
- B. Linac QA**
1. Acceptance Testing – Linac
 2. Commissioning – Linac
 - Data Required
 - Computer Commissioning
 3. Routine Quality Assurance and Tolerances
 - Daily QA
 - Monthly QA
 - Yearly QA

10. Radiation Protection and Shielding (2 Lectures)

Learning Objectives

The resident should learn

- 1) the general concept of shielding, including ALARA and Federal Regulations.*
- 2) the units of personnel exposure, sources of radiation (man made and natural), and means of calculating and measuring exposure for compliance with regulations.*
- 3) components of a safety program, including NRC definitions and the role of a radiation safety committee.*

A. Radiation Safety

1. Concepts and Units
 - Radiation Protection Standards
 - Quality Factors
 - Definitions for Radiation Protection
 - Dose Equivalent
 - Effective Dose Equivalent
2. Types of Radiation Exposure
 - Natural Background Radiation
 - Man-Made Radiation
 - NCRP #91 Recommendations on Exposure Limits
3. Protection Regulations
 - a) NRC Definitions
 1. Medical Event
 2. Authorized User
 - b) NRC Administrative Requirements
 1. Radiation Safety Program
 2. Radiation Safety Officer
 3. Radiation Safety Committee
 - c) NRC Regulatory Requirements
 - d) Personnel Monitoring

B. Radiation Shielding

1. Treatment Room Design
 - a) Controlled/Uncontrolled Areas
 - b) Types of Barriers
 - c) Factors in Shielding Calculations
 1. Workload (W)
 2. Use factor (U)
 3. Occupancy factor (T)
 4. Distance
2. Shielding Calculations
 - a) Primary Radiation Barrier
 - b) Scatter Radiation Barrier
 - c) Leakage Radiation Barrier
 - d) Neutron Shielding for High Energy Photon and Electron Beams
3. Sealed Source Storage

4. Protection Equipment and Surveys
 - a) Operating Principles of Gas-filled Detectors
 - b) Operating Characteristics
 - c) Radiation Monitoring Equipment
 1. Ionization chamber (Cutie Pie)
 2. Geiger-Mueller Counters
 3. Neutron Detectors

11. Imaging for Radiation Oncology (4 Lectures)

Learning Objectives

The resident should learn:

- 1) the physical principles associated with good diagnostic imaging techniques*
- 2) the rationale behind taking port films, how port films are used in the clinic, and the response characteristics of common films used in the radiation therapy department.*
- 3) the types of portal imaging devices that are available in radiation therapy, the operating characteristics of these various devices, and the clinical application of this technology in daily practice.*
- 4) the physical principles of ultrasound, its utility and limitations as an imaging device, and its application to diagnosis and patient positioning.*
- 5) the physical principles behind CT, MR, and PET scanning, how these modalities are applied to treatment planning, and their limitations.*
- 6) the advantages of one imaging modality over another for various disease and body sites.*
- 7) image fusion, its advantage in treatment planning, the difficulties and limitations associated with image fusion, and how image fusion can be accomplished.*

A. Routine Imaging

- Diagnostic Imaging Physical principles
- Port Films
- XV-2 film, EDR-2 film characteristics
- Processors

B. Other Imaging

1. Electronic Portal Imaging
 - Overview of electronic portal imaging devices
 - Types of portal imaging devices
 - Clinical applications of EPID technology in daily practice
2. Ultrasound
 - Physical principles
 - Utility in diagnosis and patient positioning

C. Image Based Treatment Planning

1. CT scans
 - Physical principles
 - Hounsfield Units, CT numbers, inhomogeneity corrections based on CT scan images
2. MRI Scanning
 - Physical principles
 - T1, T2, TE, TR imaging characteristics
 - Advantages & limitations of MRI images for diagnosis and computerized treatment planning

D. PET Imaging

1. Physical principles

2. Utility for Radiation Therapy
3. Image Fusion
 - a) Advantages
 - b) Challenges
 - c) Techniques
 - d) Limitations

12. 3DCRT including ICRU concepts and beam related biology (3 Lectures)

Learning Objectives

The resident should learn

1. *the concepts, goals, and technologies needed for planning and delivering 3DCRT compared to conventional RT,*
2. *concepts and definitions associated with 3DCRT planning including optimization strategies, uniform vs nonuniform tumor dose distributions, non-biological and biological models for computing dose-volume metrics, beam shaping techniques, and magnitudes, sources, and implications of day-to-day treatment variabilities*
3. *ICRU definitions and reporting recommendations for tumor related volumes such as GTV, CTV, and PTV.*

A. 3DCRT concepts and goals vs traditional RT, comparison to protons

- Technology and methods for planning
- Multiple volume images (CT, MR, PET, MRSI, etc)
- Image processing (registration, segmentation)
- Virtual simulation
- DRRs
- Multiple beams (>4)
- Non-coplanar beams

B. Optimization methods

- Biological implications of uniform vs non-uniform dose delivery
- Non-biological and biological dose-volume metrics (DVHs, TCPs, NTCPs)
- Margins

C. Implications of treatment variabilities (systematic and random setup variabilities, patient breathing)

- ICRU 50 Prescribing, Recording and Reporting
- ICRU Report 62: (Supplement to ICRU Report 50)

13. Assessment of Patient Setup and Verification (2 Lectures)

Learning Objectives

The resident should learn the principles of and devices for

1. *patient immobilization and positioning,*
2. *imaging methods for monitoring patient geometry in the treatment position and how such images can be used for correcting patient alignment and modifying the initial treatment plan via an adaptive planning strategy*

A. Immobilization devices and methods

- Table Positions, lasers, distance indicators
- Immobilization methods
- Positioning methods (calibrated frames, optical and video guidance, etc)

B. In-the-room intra-treatment imaging (cont'd)

- Cone-beam
- Ultrasound
- Internal markers (eg, implanted seeds)
- On-line correction of setup errors
- Adaptive planning concepts

14. IMRT (2 Lectures)

Learning Objectives

The resident should learn:

- 1) *details on the different delivery system including advantages, differences and limitations*
- 2) *the differences for simulation and positioning compared with conventional therapy*
- 3) *principles of inverse planning and optimization algorithms*
- 4) *systematic and patient specific quality assurance*

A. IMRT Delivery Systems

1. Segmental MLC (SMLC) and Dynamic MLC (DMLC)
2. Serial Tomotherapy (MIMiC)
3. Helical Tomotherapy
4. Robotic Linac
5. Simulation and immobilization/repositioning

B. Dose prescription & inverse planning

1. Treatment calculations
2. IMRT quality assurance

15. Special Procedures (3 Lectures)

Learning Objectives

The resident should learn:

- 1) *the basis of stereotaxic frame systems*
- 2) *the frame placement, imaging and treatment logistics*
- 3) *differences in the SRS systems and accuracy requirements*
- 4) *dosimetry of small field irradiation*
- 5) *TBI techniques and large field dosimetry*
- 6) *Logistics and dosimetric considerations for TSET and e-arc*

A. Stereotactic Radiosurgery

1. SRS Delivery Systems
2. Linac based
3. Gamma Knife
4. Robotic Linac
5. Simulation and immobilization/repositioning

B. SRS Dose prescription & treatment planning

1. Treatment calculations
2. SRS quality assurance

C. Other Special Procedures

1. Photon Total Body Irradiation

- Patient Set-up
- Dosimetry
- Selection of energy, field size, distance
- MU calculations
- 2. TSET
- 3. Electron Arc

16. Brachytherapy (7 Lectures)

Learning Objectives

The resident should learn about:

- 1) *characteristics of the individual sources: Half-life, photon energy, half-value layer shielding, exposure rate constant and typical clinical use.*
- 2) *Source strength units: Activity, Apparent activity, Air Kerma Strength, Exposure rate, Equivalent of mg hours of radium, and NIST Standards for calibration*
- 3) *high dose rate v. low dose rate on terms of alpha/beta ratios, fractionation, dose equivalence*
- 4) *Specification of linear and point sources*
- 5) *Implant dosimetry for Planar implants vs. volume implant, including Patterson-Parker, Quimby, Memorial, Paris, and Computational optimizations and calculations*
- 6) *Implantation techniques for surface and interstitial implants, the sources used, and how they are optimized*
- 7) *Uterine Cervix applicators: Fletcher-Suit applicators (tandem and ovoids), High dose rate applicators (tandem and ovoids/ring), and Vaginal cylinders, and the treatment planning systems for each applicator*
- 8) *Cervix dosimetry conventions: Milligram-Hours, Manchester System, Bladder and Rectum Dose, and the ICRU System (points A and point B)*
- 9) *Radiation detectors used for calibration and patient safety*
- 10) *Remote Afterloading Units, including dose rates and devices for delivery, safety concerns and emergency procedures, and shielding for patient and personnel*
- 11) *Discuss NRC and state regulations regarding use, storage and shipping of sources.*

A. Radioactive Sources (General Information)

- Radium
- Cesium-137
- Cobalt-60
- Iridium-192
- Gold-198
- Iodine-125
- Palladium-103

B. Calibration of Brachytherapy Sources

- Specification of Source Strength
- Radium Substitutes and Radioactive Isotopes Currently Used in Brachytherapy
- Linear Sources
- Seeds
- Exposure Rate Calibration

C. Calculations of Dose Distributions

- Biological considerations of dose, dose rate, and fractionation
- Calculation of dose from a point source

- Calculation of dose from a line source
- D. Systems of Implant Dosimetry**
 - Paterson-Parker
 - Quimby
 - Memorial
 - Paris
 - Computer
- E. Implantation Techniques**
 - Surface Molds/Plaques
 - Interstitial Therapy
 - Intracavitary Therapy
 - Uterine Cervix
 - Milligram-Hours
 - Manchester System
 - Bladder and Rectum Dose
 - ICRU System
 - Absorbed Dose at Reference Points
- F. Gynecological Implants**
 - General Information (advantages/disadvantages)
 - Remote Afterloading Units
 - HDR vs. LDR
- G. Radiation Protection for Brachytherapy**
 - Detectors
 - Regulatory Requirements
 - Surveys
 - Inventory and Wipe Tests
 - Shipping and Receiving

17. Hyperthermia

Learning Objectives

The resident should learn:

- 1) *basic physics of Hyperthermia and how this applies clinically*
- 2) *hyperthermia systems*
- 3) *thermometry*

A. Physics Aspects of Hyperthermia

- The bio-heat equation and simplified solutions.
- Specific Absorption Rate (SAR).
- Thermal aspects of blood flow/perfusion
- Basic physics of ultrasound
- Important technical considerations with microwaves and ultrasound devices

B. Elements of Clinical Hyperthermia Physics

- External superficial electromagnetic hyperthermia applicators.
- Interstitial electromagnetic hyperthermia applicators.
- Electromagnetic applicators for regional hyperthermia.
- Thermometry performance criteria, tests, and artifacts.

C. Ultrasound hyperthermia systems

18. Particle Therapy

Learning Objectives

The resident should learn:

- 1) *basic physics of neutron and proton beams*
- 2) *configurations of proton and neutron delivery systems*
- 3) *treatment planning considerations for particle therapy*

A. Protons

- Proton Beam Energy Deposition
- Equipment for Proton Beam Therapy
- Clinical Beam Dosimetry
- Clinical Proton Beam Therapy
- Treatment Planning
- Treatment Delivery
- Clinical Applications

B. Neutrons

- Fast Neutron Production
- Basic Interactions
- Accelerator Requirements
- Clinical Beam Dosimetry
- Treatment Planning
- Treatment Delivery
- Clinical Applications
- Boron Neutron Capture