Ravinder Nath
July 5, 2009

Syllabus: Physics of Radiation Therapy for Residents 2009-2010 Using 2007 ASTRO Guidelines

Time of Meeting: Thursdays from 7:30 – 8:30 AM
Room: WWW 201

Primary Text: *Physics of Radiation Therapy*, 3rd ed., Faiz M. Khan. Lippincott Williams & Wilkins, Philadelphia, 2003.

New Resident Orientation (4 hours)

Overview of planning process from simulation to treatment (1 hour) **Kim**
General operation of simulation devices (30 minutes) **Kim**
Overview of linear accelerator (linac) systems and operation (30 minutes) **Chen**
Treatment immobilization, localization, and verification (30 minutes) **Kim**
Basic monitor unit (MU) calculations for emergency patients (45 minutes) **Chen**
Radiation safety (45 minutes) **Bohan**

Lectures

1. Atomic and Nuclear Structure (2 Lectures) Guo

Learning Objectives
The resident should learn:
1. the structure of the atom, including types of nucleons, relation between atomic number and atomic mass, and electron orbits and binding energy; be able to relate energy to wavelength and rest mass; and understand and describe an energy spectrum (with respect to isotopes and/or linacs).
2. 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)
- Wave and quantum models of radiation
- Energy and wavelength, energy spectrum

B. Radioactivity and decay

- Decay processes (of commonly used isotopes for imaging/therapy)
- Probability and decay constant
- Activity, half-life, mean life
- Radioactive series

2. Production of Photons and Electrons (2 Lectures) Guo

Learning Objectives
The resident should learn:
1. the means by which X-rays are produced in a linac, in diagnostic X-ray units, and orthovoltage units.
2. production of bremsstrahlung-produced X-rays and characteristic X-rays.
3. the major components of a linac and their function.
4. about teletherapy machines (i.e., Gamma Knife) using radioactive materials.

A. Basic physics of X-ray beam production

- Bremsstrahlung production of X-rays
- Characteristic radiation
- Diagnostic X-ray tube design
- X-ray energy spectrum

B. Generation of beams

- X-ray energy spectra and filtration
- Gamma-radiation teletherapy sources (60Co)
- Linac production of X-rays and electrons

3. Treatment Machines, Generators and Simulators; (2 Lectures) Carlson

Learning Objectives

The resident should learn:

1. the mechanics and delivery of radiation with respect to wave guides, magnetron vs. klystron for production systems.
2. the production and delivery of electrons by the electron gun, buncher, and scattering foil vs. scanning.
3. the production and delivery of photons, including the target and flattening filter.
4. the benefits and limitations of multileaf collimators (MLCs) and cerrobend shielding and hand-blocking of photons.
5. the purpose and use of monitor chambers.
6. the production and collimation of superficial photons.
7. alternative to conventional linacs (i.e., X-Band).
8. the production of low-energy X-rays for imaging.
9. the differences in film and other imaging modalities for simulation.
10. generation of a digitally reconstructed radiograph (DRR).

A. Linacs

- 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
- MLCs
- Other collimation systems (radiosurgery)
- Radiation and light fields (including field size definition)
- Cobalt units (Gamma Knife)
- X-Band systems (CyberKnife, Mobetron)
- Therapeutic X-ray (<300 kVp)

Simulators

- Mechanical and radiographic operation
- Fluoroscopy, flat panel detectors, and intensifiers
- Computed tomography (CT) simulation machinery
- CT simulation operation
- Simulators with CT capability

4. Radiation Interactions (3 Lectures) Carlson

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. the definitions of key terms, such as attenuation, scatter, beam geometry, linear and mass attenuation coefficients, energy transfer, energy absorption, and 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. the definitions of key terms, such as linear energy transfer, specific ionization, mass stopping power, and range, and how these terms relate to energy deposition by particulate radiation.

A. Interactions of X- and gamma-rays with matter

- Scatter vs. absorption of radiation
- 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 (i.e., protons)
- Interactions of neutrons

5. Radiation Beam Quality and Dose (2 Lectures) Ahmad

Learning Objectives
The resident should learn:
1. the physical characteristics of monoenergetic and polyenergetic photon and particle beams and terms, such as energy spectrum, effective energy, filtration, and homogeneity, that are used to describe such beam.
2. the definitions and units for kinetic energy released in medium (kerma), exposure, absorbed dose, dose equivalent, and relative to biologic effectiveness (RBE) dose; the conditions under which each quantity applies; and the physical basis for measuring or computing each quantity.
3. how absorbed dose can be determined from exposure, and the historical development of this approach.

A. Monoenergetic and polyenergetic bremsstrahlung beams
- Energy spectra for bremsstrahlung beams
- Effects of electron energy, filtration, beamgeometry
- Homogeneity coefficient
- Effective energy
- Clinical indices for megavoltage beams (e.g., percent depth dose [PDD] at reference depth)

B. Dose quantities and units
- Evolution of dose units
- Kerma
- Exposure
- Absorbed dose

Relationships of kerma, dose, and exposure
- Dose equivalent
- RBE dose
- Calculation of absorbed dose from exposure
- Bragg-Gray cavity theory

6. Radiation Measurement and Calibration (3 Lectures) Ahmad
Learning Objectives

The resident should learn:

1. Bragg-Gray cavity theory and its importance in radiation dosimetry.
2. stopping power ratios and the effective point of measurement for radiation dosimetry.
3. how photon and electron beams are calibrated, the dose calibration parameters, and the calibration protocols for performing linac calibrations.
4. how to determine exposure and dose from radioactive sources.
5. the various methods by which to measure absorbed dose. These should include calorimetry, chemical dosimetry, solid-state detectors, and film dosimetry.
6. devices used for clinical dosimetry (film, diodes, thermoluminescent dosimeters [TLDs], etc.).

A. Calculation of dose
- Calculation of absorbed dose from exposure: historical perspective (in light of AAPM task group report number 51 [TG51])

Bragg-Gray cavity theory: stopping powers, effective point of measurement

B. Dose output calibration
- Ionization chambers (cylindrical, parallel plate)
- Calibration of megavoltage beams

Photon beams

Electron beams

Dose calibration parameters

TG51 (theory and overview)
- Exposure from radioactive sources
- Other methods of measuring absorbed dose

- Calorimetry
- Chemical dosimetry (Fricke solution; Bis [N, N0-methylene-bisacrylamide], acrylamide, nitrogen,and gelatine [BANG] co-polymer gel dosimetry)

C. Clinical dosimetry

- Solid-state detectors

TLDs
Diode detectors
Field effect transistor (FET) detectors
Detector arrays (for IMRT/TomoTherapy verification)

- Film dosimetry (IMRT verification dosimetry)

XV2 film
EDR2 film
Radiochromic film
Processors in film dosimetry

7. Photons and X-ray Characteristics and Dosimetry (7 Lectures) Fan

Learning Objectives
The resident should learn:

1. basic dosimetric concepts of photon beams.
2. how these concepts relate to calculation concepts.
3. basic calculation parameters.
4. how these parameters relate to one another and how to cross convert.
5. how parameters depend on source-to-skin distance (SSD) and source-to-axis distance (SAD) setups.
6. how beam modifiers affect beams and calculations.
7. basic treatment planning arrangements and strategies.
8. how beam shaping affects isodose distributions.
9. surface and exit dose characteristics.
10. the effect and use of beam modifiers, including bolus.
11. interface dosimetry considerations.
12. heterogeneity corrections and effects on dose distributions.
13. beam-matching techniques and understanding of peripheral dose.
14. special considerations for pacemaker, pregnant patients.

A. External beam dosimetry concepts (Part I)

- Dosimetric variables from calibration

Inverse square law
Backscatter factor
Electron buildup
PDD
Mayneord F-factor
Definition of area (collimator, scatter, patient)
Equivalent squares

B. External beam dosimetry concepts (Part II)

- Primary vs. scatter

- Scatter-to-primary ratio
- Tissue–phantom ratio
- Tissue–maximum ratio (TMR)
- Converting PDD to TMR
- Dose normalization and prescription

C. System of dose calculations

- MU calculations

Calibration
Collimator scatter factor and phantom scatter factor
Field size correction factors
Beam modifier factors (wedges)
Patient attenuation factors
Output factor

- Calculations in practice

SAD technique
SAD treatment and SAD calibration
SAD treatment and SSD calibration
SAD rotational treatment
SSD technique
SSD treatment same as SSD of calibration
SSD treatment different from SSD of calibration
SSD treatment and SAD calibration
Calculation of maximum dose in parallel opposed field plans

D. Translation of computerized planning

- Beam models (i.e., convolution)
- Flatness and symmetry of beam profiles
- Isodoses
- Beam combination (2-, 3-, 4-, 6-field techniques)
- Beam weighting
- Irregular fields
- Bolus
- Arc rotation therapy

E. Computerized treatment planning (TP) strategies

- Surface and buildup dose
- Entrance and exit dose
- Penumbra
- Wedge isodose curves and techniques

Wedge angle and hinge angle
Wedge factor

- Wedge and compensator techniques

Wedge pair
Open and wedged field combination
Custom compensators
Different types of wedges (universal, dynamic, physical, segmentation)

F. Surface corrections and heterogeneity calculations

- Effects and corrections for surface obliquities

- Corrections and limitations for inhomogeneities
Simple one- (1D) and two-dimensional (2D) Methods
Convolution and superposition methods
Monte Carlo methods
Dose perturbations at interfaces

G. Adjoining fields and special dosimetry problems

- Two-field matching
- Three-field matching
- Craniospinal field matching
- Treatment considerations for pacemaker and defibrillators
- Gonadal dose, measurement and minimization
- Pregnant patient, considerations and dosimetry

8. Electron Beam Characteristics and Planning (2 Lectures) Deng

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, skin dose, 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, bolus, and field shaping (especially for small fields), 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 characteristics
- Electron interactions
- Continuous slowing down approximation (CSDA) and range
- Dose vs. depth
- Electron skin dose
- Isodoses
- Oblique incidence

B. Treatment planning with electrons

- Selection of energy, field size
- Bolus for surface buildup
- Bolus for depth–range compensation
- Field shaping
- Electron-electron matching
- Electron-photon matching
- Electron backscatter dosimetry
- Inhomogeneities
- Internal shielding
- External shielding (i.e, eye shields, bremmstrahlung production, energy and shielding material

thickness)

9. External Beam QA (2 Lectures) Deng

Learning Objectives
The resident should learn:
1. the goals of a departmental QA program, the staffing required to perform these QA activities, and the duties and responsibilities of the individuals associated with the QA 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 linac and in commissioning both a linac and a TP system.
4. what linac QA is required on a daily, monthly, and yearly basis and the acceptance tolerances associated with these tests.

A. Overview of QA in radiation therapy

- Goals, regulations
- Continuing quality improvement vs. QA
- Staffing

Roles, training, duties, and responsibilities of individuals
- Equipment specifications
- Error analysis and prevention

B. Linac and imaging QA

- Acceptance testing; linac
- Commissioning; linac
- Data required
- TP commissioning and QA
- Routine QA and test tolerance

Daily QA
Monthly QA
Yearly QA
- QA of imaging apparatus

Portal imagers
CT simulators
Conventional simulators
Processors

10. Informatics (1 Lecture) Deng

Learning Objectives
The resident should learn:
1. the various information systems and how they communicate with imaging, planning, and delivery systems.
2. methods of data transfer, storage, and security.

A. Informatics

DICOM
PACS

Network integration and integrity
Storage and archival
Information system (IS) maintenance
Physics and information technology (IT) staff roles

11. 3D-CRT, ICRU Concepts and Biology (2 Lectures) Chen

Learning Objectives
The resident should learn:
1. the intended goals and technologies needed for planning and delivering volumetric (3D-CRT) vs. nonvolumetric planning.
2. the concepts associated with 3D-CRT planning, including uniform vs. nonuniform tumor dose distributions, nonbiologic and biologic models for computing dose–volume metric.
3. the ICRU definitions and reporting recommendations for tumor-related volumes, such as gross tumor (GTV), clinical target (CTV), and planning target volumes(PTV).
4. the magnitudes, sources, and implications of day-to-day treatment variabilities.

A. 3D-CRT concepts, volumetric (3D-CRT) vs. nonvolumetric

- Technology and methods for planning (volumebased planning)
- Building patient models (image reconstruction and segmentation)
- Virtual simulation
- Implications of treatment variabilities

Systematic and random setup variability, patient breathing
ICRU Report 62 (Supplement to ICRU Report 50)
Contouring variability

B. Volumetric beam placement

- DRR generation
- Beam's eye view (BEV), dose–volume histogram (DVH)
- Noncoplanar beams
- Planning tools

Biologic implications of uniform vs. nonuniform dose delivery
Nonbiologic and biologic dose–volume metrics (DVHs, tumor control probabilities [TCPs], normal tissue complication probabilities [NTCPs])
Margins (PTVs, planning organ at risk volumes [PRVs])

Treatment planning methods

- Beam selection
- 4D imaging and planning
- Dose reporting
- Volumetric vs. point prescriptions

12. Assessment of Patient Setup and Verification (1 Lecture) Chen

Learning Objectives
The resident should learn:
1. the principles and devices currently associated with patient positioning and immobilization.
2. imaging methods applied in the treatment position for localization of the target and critical structures before treatment.
3. use of in-room measurements for post-treatment adjustments.
4. the use of these resultant images and localization data for potentially modifying the initial treatment plan through an adaptive planning strategy.

A. Positioning and immobilization methods and devices

- Table coordinates, lasers, distance indicators
- Positioning options (calibrated frames, optical and video guidance, etc.)
- Breathing maintenance
- Immobilization methods (thermoplastic masks, bite blocks, etc.)

Treatment verification
- Image based
Radiographic
Cone-beam CT
Megavoltage CT (MVCT)
Internal markers (e.g., implanted fiducials)
- Non–image based
Ultrasound
Video imaging
Electromagnetic sources
On-line correction of setup errors
- Dosimetry based
Diodes
TLDs
Metal oxide semiconductor FET (MOFSET)
- Adaptive planning concepts

13. IMRT (3 Lectures) Chen

Learning Objectives
The resident should learn:
1. the details of the different delivery systems, including advantages, differences, and limitations.
2. the differences for simulation and positioning compared with conventional therapy.
3. the principles of forward and inverse planning and optimization algorithms.
4. the issues with inverse planning.
5. systematic and patient-specific QA.

A. IMRT delivery systems

- Segmental (SMLC) and dynamic MLCs (DMLC)
- Serial tomotherapy (MIMiC)
- Helical tomotherapy
- Robotic linac
- Compensators

B. Dose prescription and inverse planning

- Discuss concept of PRVs- Forward and inverse planning components
- Key components of planning system (optimization)
- Planning evaluation

Isodoses, DVH
Deliverability
Hot spots

C. IMRT QA

- Commissioning of planning and delivery
- Systematic QA
- Patient-specific QA tools and metrics

Chambers, film, EPID, Monte Carlo calculations

- Delivery QA

Record/verify
Machine treatment delivery records

14. Special Procedures (3 Lectures) Bond

Learning Objectives
The resident should learn:
1. the basis of stereotactic radiation therapy (SRT) delivery and dosimetry.
2. SRT, extracranial treatments, including immobilization and localization systems.
3. dosimetry of small-field irradiation, including stereotactic radiosurgery (SRS) cones and micro/mini MLCs.
4. TBI techniques and large-field dosimetry.
5. Logistics and dosimetric considerations for total skin electron therapy (TSET) and electron arc (e-arc).

A. SRT Delivery and positioning

- Stereotactic systems

Linac based
Gamma Knife
Robotic linac
Extracranial

- Positioning and immobilization

Frames
Extracranial SRT (ESRT)
Frameless

B. SRS dose prescription and planning, QA

- Prescriptions
- Dosimetry

Outputs
Profiles
- TP commissioning
- Delivery options
Arc therapy
MLC based
- QA

C. Other special procedures

- Photon TBI
Simulation
Patient setup (lateral, AP/AP, multifield: advantages and disadvantages)
Dosimetry
Selection of energy, field size, distance, dose-rate considerations
MU calculations
- TSET
- Electron arc

15. Brachytherapy (5 Lectures) Bond

Learning Objectives
The resident should learn:
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 milligram-hours of radium, and National Institute of Standards and Technology (NIST) standards for calibration.
3. the application of HDR vs. low dose-rate (LDR) in terms of alpha/beta ratios, fractionation, and dose equivalence.
4. specification and differences of linear and point sources.
5. implant systems and related dosimetry.
6. implantation techniques for surface and interstitial implants regarding the sources used and how they are optimized, especially for prostate and breast treatments.
7. dose calculations for temporary vs. permanent implants.
8. uterine cervix applicators: Fletcher-Suit applicators (tandem and ovoids), HDR applicators (tandem and ovoids/ring), vaginal cylinders, and TP systems for each applicator system.
9. cervix dosimetry conventions: milligram-hours, Manchester system, bladder and rectum dose, and the ICRU system (points A, B, and P).
10. radiation detectors used for calibration and patient safety during implantations.
11. implant-loading specifics of dose rates, delivery devices, safety concerns, emergency procedures, and shielding for both patients and personnel.
12. discuss NRC and state regulations regarding use, storage,and shipping of sources.
13. QA and safety program development.

A. Radioactive sources (general information) and calibration

- Radium; disadvantages of radium, effect of source casing
- Cesium 137
- Cobalt 60
- Iridium 192
- Gold 198
- Iodine 125
- Cesium 131
- Palladium 103
- Specification of source strength
- Linear sources
- Seeds
- Exposure rate calibration

B. Calculations of dose distributions

- Biologic considerations of dose, dose rate, and fractionation
- Calculation of dose from a point source (AAPM Task group report number 43 [TG43])
- Calculation of dose from a line source

C. Implantation techniques

- Remote and manual
- Surface molds/plaques- Interstitial therapy

Prostate brachytherapy
HDR vs. LDR treatments
Planning techniques
Uniform vs. peripheral
Breast brachytherapy
Single-catheter vs. multiple-catheter planning

Gynecologic implants
- General information (advantages/disadvantages)
- Remote afterloading units
- HDR vs. LDR

Intracavitary therapy
Uterine cervix
Milligram-hours
Manchester system
Bladder and rectum dose
ICRU system
Absorbed dose at reference points
Interstitial therapy

D. Systems of implant dosimetry

- Historic (Paterson-Parker)
- Computerized TP process and calculations
- Units, decay
- Applicators
- Limitations
- Imaging

E. QA and safety

- QA

Placement verification
Treatment planning accuracy
Applicator integrity

- Safety

Detectors
Regulatory requirements
Surveys
Inventory and wipe tests
Shipping and receiving
Source handling

16. Radiopharmaceutical Physics and Dosimetry (1 Double Lecture) Bond

Learning Objectives
The resident should learn:

1. methods of radiopharmaceutical production.
2. clinical treatments using internally administered radioisotopes.
3. internal dosimetry.
4. safety and regulations.

A. Radiopharmaceutical Physics

Methods of production and clinical treatments

- Reactor-produced isotopes
- Cyclotron-based production
- Radiochemistry basics
- Clinical treatments using internally administered radioisotopes

Iodine treatment for thyroid
Radioimmunotherapy
Emerging treatments
Internal dosimetry and safety

- Dosimetry systems
- Compartmental models
- Medical Internal Radiation Dose (MIRD) Committee method
- Dose estimates for embryo/fetus and breast-feeding infant
- Radiation safety Equipment

Survey meters, sodium iodide (NaI) probes,well counters, radionuclide calibrators
Instrument quality controls and checks
Safety procedures
Radiation protection, including internal protection, spill response, and decontamination, inpatient and outpatient therapy precautions, written directive, medical event, radioactive package receipt, and area surveys/removable contamination wipe tests
Regulations

17. Particle Therapy (1 Lecture) Chu

Learning Objectives
The resident should learn:
1. basic physics and safety of neutron and proton beams.
2. configurations of proton and neutron delivery systems.
3. treatment planning considerations for particle therapy.

A. Particle Therapy

Cyclotrons and synchrotrons
Protons
- Proton beam energy deposition; RBE
- Equipment for proton beam therapy
- Clinical proton beam dosimetry
Range modulation
Spot-scanning vs. passive scattering
Beam penumbra
- Clinical proton beam therapy
Treatment planning
Neutrons- Fast vs. slow neutron production
- Boron neutron capture
Accelerator requirements
Clinical beam dosimetry; basic PDD curves for neutron beams
Safety and shielding for protons and neutrons

18. Imaging for Radiation Oncology (3 Lectures) Chu

Learning Objectives
The resident should learn:
1. the principles and factors influencing radiograph in the megavoltage (MV) and kilovoltage (kV) ranges.
2. commonly used in-room imaging equipment technology and its use.
3. imaging technology and related physical principles for treatment planning (CT, positron emission tomography [PET], and magnetic resonance imaging [MRI]).
4. nuclear medicine imaging applied to radiation oncology.
5. image registration methods typically used to aid in treatment planning.
6. QA procedures to aid in successful integration of imaging within radiation oncology.

A. Radiography fundamentals

- Diagnostic imaging physical principles
Physical principles
Impact on quality
Systems
- Port film imaging
Film types and cassettes
- Electronic portal imaging
Overview of electronic portal imaging devices
Types of portal imaging devices

Clinical applications of electronic portal imaging device [EPID] technology in daily practice kV flat panel detectors
Room mounted systems
Gantry mounted systems

B. CT and PET

- CT
Principles of image formation (Hounsfield numbers, CT numbers, etc.)
Systems (large bore, small bore, single/multidetector,
conebeam, and field of view [FOV])
Factors influencing image artifacts
Image quality
Dose
- PET
Principles of image formation
Detection
Reconstruction (brief)
Quantitative use of PET (standardized uptake value [SUV])
Artifacts

C. MRI and ultrasound

- MRI scanning
Physical principles of image formation
Signal generation
Sources of contrast
Artifacts
Longitudinal relaxation time (T1), transverse relaxation time (T2), time to echo (TE), time of repetition (TR), imaging characteristics
Advantages and limitations of MRI
- Ultrasound
Physical principles of image formation
Systems (endorectal, volumetric, planar)
Utility in diagnosis and patient positioning
Artifacts and image distortion

Use of imaging in treatment planning
- Image registration
- Contrast agents
- Image fusion
Advantages
- Challenges
- Techniques
- Limitations (deformable body)
Use of Hybrid systems (including single-photon emission CT [SPECT])
- QA
Image transfer process
Imager QA

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July 5, 2009

19. Radiation Protection and Shielding (1 Double Lecture) Bohan

Learning Objectives
The resident should learn:
1. the general concept of shielding, including ‘‘as low as reasonably achievable’’ (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 and Shielding

Radiation Safety
- Concepts and units

Radiation protection standards
Quality factors
Definitions for radiation protection
Dose equivalent
Effective dose equivalent
- Types of radiation exposure

Natural background radiation
Man-made radiation
National Council on Radiation Protection and Measurements (NCRP) #91
Recommendations
on Exposure Limits
- Protection regulations

NRC definitions
Medical event
Authorized user
NRC administrative requirements
Radiation safety program
Radiation safety officer
Radiation safety committee
NRC regulatory requirements (including security)
Personnel monitoring
Radiation shielding
- Treatment room design

Controlled/uncontrolled areas
Types of barriers
Factors in shielding calculations
Workload (W)
Use factor (U)
Occupancy factor (T)
Distance
- Shielding calculations (including IMRT)

Primary radiation barrier

Scatter radiation barrier
Leakage radiation barrier
Neutron shielding for high-energy photon and electron beams
- Sealed source storage
- Protection equipment and surveys

Operating principles of gas-filled detectors
Operating characteristics of radiation monitoring equipment
Ionization chambers (Cutie Pie)
Geiger–Mueller counters
Neutron detectors
- Shielding requirements for conventional simulators, CT simulators
- High dose-rate (HDR) unit shielding (linac vault vs. dedicated bunker)
- Special procedure shielding (total body irradiation [TBI])