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Therapy Physics Review: Part 1

Basic Physics Examination and Study Guide

Bhudatt Paliwal, Ph.D.

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Preface

Practice examinations are very useful tools to prepare for board certification examinations. *Therapy Physics Review: Part 1* is specifically designed to provide a realistic simulation of a written board examination for residents, dosimetrists, and therapists in radiation therapy. In this volume, the focus is on some of the basic concepts implicit in the application of physics to radiation oncology.

The review material is categorized to emphasize some of the major important subtopics. This approach allows the reviewer, if so inclined, to go directly to a specific topic to detect and correct deficiencies in his or her understanding of the material.

Therapy Physics Review is not intended to be a complete encyclopedia of all terms and concepts. However, it represents an attempt to cover most of the major terms and concepts. To help the reviewers further enrich their knowledge, references are provided to easily accessible textbooks in the field.

In the last decade, there have been some changes in terminology, procedures, and scientific units used to quantify measured parameters. I attempt to introduce the new terminology, procedures, and scientific units while keeping some of the popular nonscientific terminology, procedures, and scientific units.

Many individuals have contributed to the compilation of this material. Special acknowledgments are extended to the following individuals for their significant contributions. Ms Judy Smith and Michele Paliwal prepared the original manuscript from my illegible handwriting. The assisting staff of Medical Physics Publishing included Elizabeth Seaman and June Johnson. The principle reviewers who made many extremely helpful corrects were Dr. John Cameron, Siyong Kim, Scott Murphy, Brian Waugh, and Timothy Zhu.

Bhudatt Paliwal
Compiler

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* These textbooks are *The Physics of Radiology, 4th Edition*, Harold E. Johns & John Cunningham, Charles C. Thomas, Publisher, 1983, and *The Physics of Radiation Therapy, 2nd Edition*, Faiz Khan, Williams & Wilkins, 1994.

Table of Contents

Radiation Quantities and Units

1. Which of the following is not a unit of energy:

   A. Heat unit
   B. MeV
   C. Watt
   D. Joule

2. If the muscle tissue is exposed to 50 roentgens of x-rays, this would produce an approximate dose of:

   A. 50 rad
   B. 50 Gy
   C. 50 sievert
   D. 50 becquerel

3. A gray is equal to:

   A. 10 roentgen
   B. 100 rad
   C. 1000 rad
   D. 1 Ci

4. 1 curie is equal to:

   A. 106 becquerel
   B. 103 becquerel
   C. 3.7×10^{10} becquerel
   D. 37 becquerel

5. Exposure is defined for ionization produced in:

   A. Water
   B. Tissue
   C. Air
   D. Fat

6. If a charge of 10 coulomb passes through a meter in 2 seconds, the current is:

   A. 20 amps
   B. 5 amps
   C. 10 amps
   D. 8 amps

7. In the following, match the quantity with the corresponding unit:

A. Rad
B. Ci
C. Roentgens
D. MeV

a. Electron beam energy
b. Exposure
c. Absorbed dose
d. Radioactivity

8. Which of the following is not a unit of energy:

A. Rad
B. cGy
C. Volt
D. Joules

9. One roentgen corresponds to a charge of:

A. 3.7×10^{10} disintegrations/sec
B. 2.58×10^{-4} coulomb/kg
C. 0.03 esu of electrostatic charge
D. 1 electron volt

10. Which of the following is not an SI unit:

A. Kilogram
B. Meter
C. Ci
D. Second

11. Match the following units with the quantity.

A. Hz
B. Amp
C. Angstrom
D. Coulomb
E. kV

a. Wavelength
b. Frequency
c. Charge
d. Current
e. Tube potential

12. A monitor unit in a linac usually represents an absorbed dose of:

A. 1 Gy
B. 0.01 Gy
C. 100 Gy
D. 0.1 Gy

13. A picocurie is equal to:

A. 0.1 Ci
B. 0.001 Ci
C. 10^{-6} Ci
D. 10^{-9} Ci
E. 10^{-12} Ci

14. Nanocoulomb is equal to:

A. 10^{-3} coulomb
B. 10^{-6} coulomb
C. 10^{-9} coulomb
D. 10^{-12} coulomb

Structure of Matter

15. Match the charge with the particle:

A.	Electron	a.	+1
B.	Positron	b.	-1
C.	Proton	c.	0 (neutral)
D.	Neutron		
E.	Photon		

16. Isobars are nuclides that have the same:

A. Number of protons
B. Atomic number
C. Mass number
D. Number of neutrons

17. Which of the following nuclear transitions produces only photon radiation:

A. Isomeric
B. Electron capture
C. Isobaric
D. Isotopic

18. Which of these transitions produces electrons:

A. Isobaric
B. Auger
D. Internal conversion
E. All of the above

19. What determines the binding energy of an electron:

A. The physical density of the material
B. The shell (K, L, etc.) location of the electrons and the atomic number of the element
C. The thickness of the material
D. The speed of the electron in the orbit

20. Match the following symbols with their corresponding parameters:

A.	Na	a.	Planck's constant
B.	A	b.	Mass number
C.	Z	c.	Atomic number
D.	h	d.	Avogadro's number

21. The mass of an electron at rest is:

A. 1.02 MeV
B. 0.511 MeV
C. 9.81 MeV
D. 5.11 MeV

22. One atomic mass unit is the same as:

A. 1.66×10^{-27} Kg
B. 1/12 the mass of a $^{12}C_6$ nucleus
C. 931 MeV
D. All of the above

23. The number of atoms in one gram is equal to:

A. The atomic weight divided by the atomic mass
B. Avogadro's number divided by atomic weight of the atom
C. Avogadro's number divided by the density of the material
D. The atomic weight divided by Avogadro's number

24. The binding energy of the nucleus is the:

A. Force of repulsion between the electrons of the atoms
B. Force of attraction between the protons and electrons of the atom
C. Energy needed to keep the nuclear particles together
D. Force of attraction between atoms

25. The mass of an electron is:

A. The same as that of a proton
B. Half of the proton's mass
C. The same as that of a neutron
D. Much smaller than the mass of a neutron

26. Which of the following does not ionize directly:

A. Positron
B. Neutron
C. Alpha particle
D. Electron
E. Proton

27. Approximately how heavy is a neutron compared to an electron:

A. 10 : 1
B. 100 : 1
C. 1000 : 1
D. 2000 : 1

28. The atomic mass number (A) is equal to the:

A. Number of neutrons
B. Number of electrons and protons
C. Number of neutrons, electrons and protons
D. Mass of electrons minus their binding energies
E. Number of nucleons (protons and neutrons)

29. The energy equivalent of an atomic mass unit is approximately:

A. 1 keV
B. 10 keV
C. 100 MeV
D. 1000 MeV

30. The binding energy of an electron is:

A. Highest for the most external shell
B. Highest for the inner most shell
C. Highest for a free electron
D. Highest for the fastest moving electron

31. Ionization implies:

A. An excited state of the atom
B. The production of x-rays
C. The removal of an electron from the atom
D. A neutral state of the atom

32. A deuteron (^2H) is the nucleus of an isotope of hydrogen. Which of the following is true:

A. It has a mass number of 2
B. It has an atomic number of 2
C. It has a positive charge of 2
D. It has an energy of 2 MeV

33. In order for a photon to ionize an atom, its energy must be:

A. Greater than the binding energy of an electron in the atom
B. Less than the binding energy of an electron in the atom
C. Equal to the binding energy of an electron in the atom
D. None of the above

34. An atom is neutral if the number of its electrons is equal to its:

A. Number of protons
B. Number of nucleons
C. Atomic weight
D. None of the above

Radioactivity

35. When a radionuclide decays, radiation is emitted from the:

A. Outer orbital electrons of the atom
B. Innermost shell of the atom
C. The nucleus of the atom
D. All of the above

36. The half-life of a radionuclide is the time required to reduce:

A. The volume of the isotope into half
B. The number of radioactive atoms to half of their initial number
C. The activity to half of its initial value
D. B and C are true
E. A, B, C all are true

37. If the activity in a sample of a radionuclide is 100 mCi, how many half-lives would be required for it to decay to less than 2 mCi:

A. 3
B. 4
C. 5
D. 6

38. Samples of two radionuclides with different half-lives initially contain the same number of radioactive nuclei. The sample with the longer half-life will have:

A. A shorter biological half-life
B. A longer average life time
C. Produce a higher exposure rate
D. A higher activity

39. The disintegration constant lambda (λ) is equal to:

A. Physical half-life x 1.44
B. Biological half-life x .0693
C. Physical half-life x 0.693
D. 0.693/physical half-life

40. The dose delivered to an internal organ is a function of:

A. Organ uptake
B. Activity administered
C. Biological half-life
D. Physical half-life
E. All of the above

41. Specific activity of a radionuclide refers to:

    A. Number of disintegrations per second
    B. Number of grams per Ci
    C. Activity per unit mass
    D. Number of atoms per centimeter cube

42. If the specific activity in a sample decreases, its:

    A. Half-life decreases
    B. Physical life increases
    C. Activity per gram of the material decreases
    D. All of the above

43. The physical half-life of a radionuclide is:

    A. The same as the average life
    B. Less than the average life
    C. Directly proportional to the decay constant
    D. Reciprocal of biological half-life

44. After 5 half-lives, the fraction of initial activity is reduced to:

    A. One-fifth
    B. One-fifth to the power of 2
    C. Square root of 1/2
    D. 1/2 to the power of 5

X-Ray and Gamma Ray Interactions

45. The amount of attenuation of a photon beam by a material depends upon:

    A. Energy of the photon
    B. Linear attenuation coefficient of the material
    C. Thickness of the material
    D. All of the above

46. Monoenergetic photon beams interacting with tissue are attenuated:

    A. Linearly
    B. Exponentially
    C. Proportional to the density of tissue
    D. None of the above

47. Most often when a photon undergoes scattering:

    A. It gains energy
    B. Its energy remains unchanged
    C. Its energy decreases
    D. None of the above

48. In coherent scattering, the energy of the photon is:

    A. Increased
    B. Decreased
    C. Unchanged
    D. None of the above

49. Which coefficient is used to calculate energy absorbed:

    A. Attenuation
    B. Transfer
    C. Absorption
    D. Scatter

50. The photoelectric process is most significant in the energy range of:

    A. 1 keV to 100 keV
    B. 100 keV to 500 keV
    C. 500 keV to 1 MeV
    D. 1 MeV to 5 MeV

51. When a photon undergoes a Compton process:

    A. A photon of reduced energy is scattered
    B. It is completely absorbed
    C. Characteristic x-rays are produced
    D. Two Compton electrons are produced

52. The annihilation radiation produces:

A. 2 electrons
B. 1 electron and 1 positron
C. 2 photons of energy 0.511 MeV each
D. 1 photon of 1.02 MeV

53. A half value layer of a photon beam is:

A. The thickness required to reduce the beam to half of its initial intensity
B. Half of the number of photons in the beam
C. The photon beam is blocked into half
D. None of the above

54. The linear attenuation coefficient (μ) for monoenergetic photons is equal to:

A. HVL x 1.44
B. 0.693/HVL
C. HVL x 0.693
D. (HVL) to the power half

55. X-rays and gamma rays in their interaction with tissue:

A. Produce high speed electrons
B. Deposit energy
C. Undergo scattering
D. Produce ionization
E. All of the above

56. Photons transfer their energy directly to tissue by:

A. Scatter
B. The production of Cerenkov radiation
C. Absorption
D. Attenuation
E. Production of bremsstrahlung

57. The major type of interaction in megavoltage photon therapy is:

A. Photoelectric
B. Compton
C. Pair production
D. Triplet production

58. The photoelectric process of interaction is between the photons and:

A. The nucleus of the atom
B. The orbital electrons
C. Either of the above
D. None of the above

59. Pair production refers to:

A. Two orbital electrons are ejected from the atom
B. One electron and one positron is ejected from the atom
C. In the field of the nucleus, the energy of the interacting photon is converted into a positron and an electron
D. Any of the above

60. What is the threshold energy for pair production:

A. 0.511 MeV
B. 1.02 MeV
C. 1.533 MeV
D. 981 MeV

61. The probability that a photon interacts with a material is:

A. Dependent on its density
B. Proportional to the total attenuation coefficient
C. Inversely proportional to the number of protons in the atom
D. All of the above

62. Which of the following materials will be most effective in attenuating a high energy photon beam:

A. Air
B. Water
C. Lead
D. Copper

63. Pair production becomes significant (i.e., not accounted for in routine calculations) in tissue above:

A. 5 MeV
B. 10 MeV
C. 15 MeV
D. 20 MeV

64. The mass attenuation for photons in soft tissue:

A. Is maximum at 25 MeV
B. Increases continuously with energy
C. Decreases continuously with energy
D. Decreases to about 3 MeV, then increases

Charged Particle Interactions

65. Charged particles interact with body tissues by:

    A. Photoelectric process
    B. Triplet production
    C. Ionization and excitation
    D. All of the above

66. X-rays are more likely to be produced by interaction between:

    A. Alpha particles and nuclei
    B. Protons and nuclei
    C. Electrons and nuclei
    D. Neutrons and nuclei

67. The rate of kinetic energy loss per unit path length by a charged particle is called:

    A. Linear attenuation coefficient
    B. Stopping power
    C. Mass energy absorption coefficient
    D. All of the above

68. The rate of energy loss by a charged particle is:

    A. Proportional to the particle charge
    B. Proportional to the square of the particle charge
    C. Independent of the charge
    D. None of the above

69. Heavy particles lose most of their energy:

    A. Immediately as they enter the medium
    B. In the middle of their range
    C. Near the end of their range
    D. Equally throughout their range

70. The Bragg peak is not observed in electrons because of their:

    A. High speed
    B. Negative charge
    C. Small mass
    D. Short life span

71. Excitation produced by electron beams is of:

    A. Nucleus of the atom
    B. Neutrons of the atom
    C. Orbital electrons of the atom
    D. Protons of the atom

72. Which of the following particles will penetrate the deepest in tissue:

    A. 20 keV Auger electron
    B. 10 MeV alpha particle
    C. 20 keV proton
    D. 1 MeV positron
    E. 2 MeV beta particle

73. When an electron is ejected from an atom and leaves an ionization track, it is called:

    A. A characteristic electron
    B. An Auger electron
    C. A delta ray
    D. An electrostatic charge

74. In the production of bremsstrahlung, the electron:

    A. Ejects a cloud of electrons
    B. Slows down and loses some of its energy as an x-ray photon
    C. Produces a heavy particle
    D. Ejects an electron from the atom

Neutron Interactions

75. Neutrons are:

    A. Directly ionizing particles
    B. Indirectly ionizing particles
    C. Electromagnetic radiation
    D. Radiofrequency radiation

76. Most neutron interactions in soft tissue produce:

    A. Recoil protons
    B. High energy electrons
    C. Visible light
    D. Auger electrons

77. The most efficient absorber of neutrons is:

    A. Copper
    B. Aluminum
    C. Borated polyethylene
    D. Lead

78. When exposed to the same neutron beam, which of the following tissues receives a higher absorbed dose:

    A. Muscle
    B. Lung
    C. Fat
    D. Brain

79. Neutron dose estimates have a higher uncertainty because they:

    A. Are difficult to detect
    B. Lose significant energy in air
    C. Do not produce ionization
    D. Produce diverse secondary radiation

Production of X-Rays

80. The process of bremsstrahlung production is the result of collision between:

    A. Neutrons and a nucleus
    B. A high speed electron and the strong electric field near a nucleus
    C. A photon and a neutron
    D. A neutron and another neutron

81. The x-rays produced by 10 MeV electrons travel:

    A. Are mostly backscattered
    B. At about 30 degrees to the target
    C. At about 90 degrees to the target
    D. In same general direction as the electrons

82. The efficiency of x-ray production in radiation therapy machines is less than:

    A. 50%
    B. 10%
    C. 5%
    D. 1%

83. Characteristic x-rays are produced when:

    A. An electron is converted into a photon
    B. An ejected neutron gives away excess energy to become stable
    C. An electron from an outer shell makes a transition to an inner shell
    D. None of the above

84. Photons produced by an x-ray machine at 80 kVp:

    A. Are mostly monoenergetic
    B. Have about 90% of the same energy
    C. Have a distribution of energies
    D. Have about 50% of the maximum energy

85. The maximum energy of an x-ray photon from a 100 kVp unit is:

    A. 50 keV
    B. 10 keV
    C. 100 keV
    D. 1 keV

86. Hardening of x-ray beams refers to using filters to produce a beam of:

    A. Greater intensity
    B. Lower average energy photons
    C. Higher average energy photons
    D. None of the above

87. The average energy in keV of a diagnostic x-ray beam is about:

A. 50% of the maximum kVp
B. 33% of the maximum kVp
C. 25% of the maximum kVp
D. 20% of the maximum kVp

88. The output of an x-ray beam increases as:

A. The tube voltage increases
B. The tube current increases
C. The atomic number (Z) of the target increases
D. All of the above

89. X-ray tube targets are generally made of:

A. Low Z material such as Al
B. High Z material such as tungsten
C. An alloy of lead and copper
D. Complex organic compounds

90. Heel effect of a diagnostic x-ray beam:

A. Depends on the angle of the x-ray target
B. Produces a variation in intensity in the x-ray beam parallel to the cathode-anode axis
C. Results in a lower intensity at the anode end of the beam
D. All of the above

Ionization Chambers and Electrometers

91. A free-air ionization chamber is an instrument used to measure:

A. The charge of free electrons in a radiation beam
B. Ionization produced in a well specified volume of air according to the definition of roentgen
C. Charge particle equilibrium
D. Number of ionization tracks produced by electrons

92. Ionization chambers if not sealed require their readings to be corrected for temperature and pressure because:

A. Walls of the chamber expand and shrink with temperature
B. The collecting electrodes electrical conductivity changes
C. The volume of the air changes
D. Mass of the air in the chamber changes

93. Thimble chambers are used to calibrate radiation beams because:

A. These are sturdy
B. They have good spatial resolution
C. They do not significantly perturb the beams
D. All of the above

94. Thimble chamber walls:

A. Are made from high Z atomic number material
B. Need be very thick
C. Are air-equivalent
D. Are made of ferromagnetic material

95. Parallel-plate ionization chambers are primarily used to measure:

A. Ionization at deeper locations in a phantom
B. Surface dose
C. Scattered radiation dose
D. Interstitial dose

96. The most common wall material used for the outer wall of the ionization chamber is:

A. Aluminum
B. Cu
C. Graphite or nylon
D. Lead

97. Which of the following is not a desirable characteristic of an ionization chamber:

A. Energy independence
B. High signal to noise ratio
C. Change in sensitivity with the direction of the incident beam
D. Reproducibility

98. Calibration of an ionization chamber means it has been:

A. Exposed to radiation to stabilize
B. Compared against a national standard to establish a correction factor
C. Tested against leakage and electrical shorts
D. Made waterproof

99. An electrometer is an instrument used to measure:

A. Charge, current
B. Voltage, resistance
C. Capacitance
D. All of the above

Thermoluminescent Dosimetry

100. Thermoluminescence refers to emission of:

A. High intensity light from electron beams
B. High intensity light from photon beams
C. Light from certain materials when heated
D. Light from thermonuclear reaction

101. The light signal produced from thermoluminescence dosimetry is amplified by:

A. An electrometer
B. A densitometer
C. A photomultiplier tube
D. A calorimeter

102. The most commonly used thermoluminescence material used in radiation dosimetry is:

A. $Ca\ So_4$
B. $Ca\ F_2$
C. Li F
D. $Li_2\ B$

103. For megavoltage dosimetry, thermoluminescence dosimetry can provide accuracy of:

A. ± 20%
B. ± 10%
C. ± 3%
D. ± 1%

Film Dosimetry

104. A radiographic film consists of:

A. Acrylic coated with toner
B. Cellulose acetate coated with an emulsion containing silver bromide
C. Acrylic coated with cellulose acetate
D. Cellulose acetate coated with polystyrene

105. During the development of the film:

A. Silver is added to the film
B. Silver is removed from the film
C. Silver bromide affected by radiation is reduced to small crystals of silver
D. None of the above

106. During the of fixing of the developed film, the:

A. Unaffected granules of silver bromide are fixed in the film
B. Unaffected granules of silver bromide are removed from the film
C. Affected granules are removed
D. Affected granules are fixed

107. If I_o and I_t are incident and transmitted light intensities, respectively, the optical density is defined as:

A. I_o/I_t
B. $100 \times I_o/I_t$
C. $\text{Log}\,(I_o/I_t)$
D. $\text{Log}\,(I_o - I_t)$

108. The H-D curve for a type of film is a plot of:

A. Incident vs. transmitted light intensities
B. The optical density vs. exposure
C. Net light intensity vs. transmitted light intensity
D. Net light intensity vs. incident light intensity

109. Film dosimetry is extremely useful for:

A. Absolute dosimetry
B. Relative dosimetry
C. In-vivo dosimetry
D. Radiobiological dosimetry

110. With megavoltage film dosimetry, isodose curves can be measured to within:

A. ± 10%
B. ± 7%
C. ± 3%
D. ± 1%

111. Film badges for personnel dosimetry have a reliability of:

A. ± 50%
B. ± 30%
C. ± 10%
D. ± 1%

Radiochromic Film Dosimetry

112. Radiochromic films are best suited for measurements of:

   A. Low dose radiation (less than 1 millirad)
   B. High dose levels (10 Gy - 10^4 Gy)
   C. Temperature
   D. None of the above

113. Radiochromic film requires:

   A. Extensive processing
   B. Immediate processing
   C. No processing
   D. Low temperature storage

114. Measurements on a radiochromic film are made with:

   A. An electrometer
   B. Spectrometer or densitometer
   C. Magnetometer
   D. None of the above

115. The response of radiochromic films is:

   A. Independent of pressure
   B. Dependent on room temperature
   C. Dependent on room light intensity
   D. Independent of all of the above

116. The reproducibility of radiation measurements with radiochromic film is about:

   A. ± 1%
   B. ± 5%
   C. ± 7%
   D. ± 10%

117. For use in the clinical range of photon and electron therapy beams, the response of radiochromic film is:

   A. Independent of energy
   B. Slightly energy-dependent
   C. Very dependent
   D. None of the above
   E. ± 1%

Diode Radiation Detectors

118. A diode dosimeter is:

   A. An ionization chamber coated with silicon
   B. A vacuum tube
   C. A solid state device
   D. Baldwin Farmer chamber

119. In megavoltage therapy, diodes are well suited for:

   A. Absolute dosimetry
   B. Relative dosimetry
   C. Thermometry
   D. Imaging

120. In megavoltage therapy, typical use(s) of diodes is for:

   A. Patient dosimetry
   B. Beam scanning
   C. Quality assurance
   D. All of the above

121. Which of the following is best suited for calibration of a megavoltage beam:

   A. Diode detector
   B. Thermoluminescence dosimetry
   C. Film
   D. Ionization chamber

Superficial and Orthovoltage Machines

122. Superficial machines operate between:

A. 10-20 kV
B. 20-50 kV
C. 50-150 kV
D. 150-400 kV

123. The half value layer of a superficial beam is between:

A. 0-1 mm Al
B. 1-10 mm Al
C. 10-30 mm Al
D. 30-50 mm Al

124. Superficial machines are useful for treating tumors confined to:

A. 0-5 mm
B. 0-10 mm
C. 0-20 mm
D. 0-30 mm

125. Typical SSD for superficial units is:

A. 5-15 cm
B. 15-20 cm
C. 20-30 cm
D. 30-50 cm

126. Orthovoltage therapy is delivered with x-rays produced by potentials ranging from:

A. 50-100 kV
B. 100-150 kV
C. 150-500 kV
D. 500-660 kV

127. Orthovoltage beams have a half value layer in the range of:

A. 1-3 mm A1
B. 3-5 mm A1
C. 1-4 mm Cu
D. 1-2 mm W

128. In orthovoltage therapy, 90% of the dose occurs at an approximate depth of:

A. 0.5 cm
B. 1.0 cm
C. 2.0 cm
D. 5.0 cm

129. The greatest limitation of the orthovoltage beams for treating deeper tumors is:

A. Low dose rate
B. High skin dose
C. Poor penumbra
D. Unstable dose rate

130. The f-factor for soft tissue for an orthovoltage beam is typically:

A. About unity
B. About 3
C. About 10
D. None of the above

Cobalt Units

131. Cobalt-60 therapy machines produce photon beam energies of:

   A. 1-1.33 MeV
   B. 1.17 and 1.33 MeV
   C. 1.25 MeV
   D. 1.17 MeV

132. A cobalt-60 therapy source usually has a diameter of:

   A. 1-3 mm
   B. 3-5 mm
   C. 5-10 mm
   D. 10-20 mm

133. The output of a cobalt-60 therapy source decreases each month by about:

   A. 0.1%
   B. 1.0%
   C. 2.0%
   D. 5.0%

134. The penumbra at 80 cm SSD from a 2 cm diameter Cobalt-60 source collimated at 40 cm from the source is:

   A. 0.5 cm
   B. 1.0 cm
   C. 2.0 cm
   D. 4.0 cm

135. The half value thickness (HVT) for a cobalt-60 beam is:

   A. 10 mm A1
   B. 10 mm Cu
   C. 12 mm Pb
   D. 12 mm W

136. The transmission of a cobalt-60 beam through a 6 cm thick lead block is about:

   A. 25%
   B. 10%
   C. 7.5%
   D. 3.1%

137. Special collimation used to reduce the penumbra from a cobalt-60 unit is called:

   A. Cheater block
   B. Multileaf system
   C. Trimmers
   D. None of the above

Linear Accelerators

138. In order to accelerate electrons, linear accelerators use:

   A. Ultrasound waves
   B. Electromagnetic waves
   C. Ultraviolet rays
   D. Low energy rays

139. The frequency of electromagnetic waves typically used in linear accelerators to accelerate electrons is:

   A. 3 kHz
   B. 30 MHz
   C. 300 MHz
   D. 3000 MHz
   E. 3000 GHz

140. In a standing wave accelerator, the energy gained by an electron is approximately:

   A. 10 keV/cm
   B. 20 keV/cm
   C. 75 keV/cm
   D. 150 keV/cm

141. Which of the following is not an accelerator component:

   A. Waveguide
   B. Transducer
   C. Circulator
   D. Modulator
   E. Thyratron

142. The sources of accelerating power in a linear accelerator are:

   A. Thyratron and electron gun
   B. Klystron and magnetron
   C. Magnetron and electron gun
   D. Buncher and pre-buncher

143. A magnetron in a 4 - 6 MV linear accelerator typically operates at a peak power of:

   A. 0.5 MW
   B. 1.0 MW
   C. 2.0 MW
   D. 2.5 MW
   E. 3.0 MW

144. Typical Klystron used in high energy linear accelerators (10-25 MeV) operates at a peak power of:

A. 1.0 MW
B. 2.0 MW
C. 3.0 MW
D. 5.0 MW
E. 10.0 MW

145. In a linear accelerator, the flattening filter is used to:

A. Flatten the front end of the accelerator head
B. Make the beam intensity uniform
C. Produce electron beams
D. Filter the neutrons from the beam

146. The flattening filter typically is made of:

A. Low Z material
B. Lead or tungsten
C. Inert materials
D. Zinc or copper

147. Which of the following does not accelerate electrons:

A. Microtron
B. Betatron
C. Cyclotron
D. X-ray tube
E. Van de Graaf generator

Acceptance Testing, Calibration, and Commissioning

148. Acceptance testing of a radiation therapy machine relates to:

A. Developing a better design of its components
B. Comparing the specifications in the purchase order to the measured performance of the machine
C. Adjusting the electrical and mechanical parameters of the machine
D. Measuring the performance of subsystems

149. The commissioning of a therapy machine requires:

A. Measuring equipment
B. Acquisition of clinical data
C. Calibration of all the physical and radiation parameters
D. All of the above

150. Calibration of a machine primarily deals with:

A. Radiation beam parameters
B. Mechanical parameters
C. Digital displays
D. Laser equipment
E. All of the above

151. A good standard of practice requires that a treatment machine should undergo a complete calibration at least:

A. Before any treatment
B. Daily
C. Weekly
D. Monthly
E. Annually

152. A consistency check of radiation beams should be performed at least:

A. Daily
B. Weekly
C. Monthly
D. Annually

Radiation Quantities and Units

1. C.
In radiation therapy the energy of photons and electrons is expressed in MeV. However, heat units and joules are also units of energy. Watt, instead, is a unit of power or the rate of energy transfer in joules/second.

Johns and Cunningham, 4th Edition, pages 8-9

2. A.
A roentgen can be approximated by one rad in soft tissue. For accurate conversion, the quantity f factor, also called roentgen to rad conversion factor, must be used. Its value is dependent upon the beam energy and the composition of the medium.

Khan, 2nd Edition, pages 136-137

3. B.
Gray is the SI unit of absorbed dose and is equal to 1 joule/kg. This is 100 times greater than the rad, the old unit of absorbed dose.

Johns and Cunningham, 4th Edition, page 10

4. C.
The curie (Ci) is a unit of radioactivity defined as 3.7×10^{10} becquerel (Bq).

Johns and Cunningham, 4th Edition, page 10

5. C.
Exposure is a measure of ionization produced in air. It is measured in coulombs/kg of air or the older unit roentgens (R). $1 \text{ R} = 2.58 \times 10^{-4}$ C/Kg air.

Khan, 2nd Edition, pages 94-95

6. B.
Current is defined as the flow of charge per unit time. Hence, 10 coulomb in 2 seconds represents $10/2 = 5$ amps.

Johns and Cunningham, 4th Edition, pages 7-8

7. A. c.
B. d.
C. b.
D. a.

8. C.
A volt is not a unit of energy. It expresses difference in potential and is not to be confused with keV and MeV, etc., which represent the energy of ionizing radiation.

9. B.
A roentgen is the unit of exposure and is defined as 2.58 x 10^{-4} coulomb/Kg of air.

Johns and Cunningham, 4th Edition, page 10

10. C.
Ci was originally defined to quantify the activity of 1 gm of radium. It is not an SI unit.

Johns and Cunningham, 4th Edition, page 10

11. A. b.
B. d.
C. a.
D. c.
E. e.

12. B.
0.01 Gy is equal to one cGy or 1 rad.

13. E.
A picocurie is one trillionth part of one curie of radioactivity.

14. C.
A nanocoulomb is one billionth part of one coulomb charge.

Structure of Matter

15. A. b.
B. a.
C. a.
D. c.
E. c.

Positrons and protons both carry a unit of positive charge. Electrons are negatively charged. Neutrons are neutral particles in the nucleus of an atom. Photons are quanta of electromagnetic energy and do not have any charge.

Khan, 2nd Edition, pages 1-2

16. C.
On the basis of different proportions of neutrons and protons in the nuclei, atoms have been classified into different categories. Isobars have the same number of nucleons but different numbers of protons. The mass number for the atoms is the same if the number of nucleons is the same.

Khan, 2nd Edition, pages 1-2

17. A.
Isomeric transitions produce gamma, e.g., Tc-99m goes to Tc-99 with the emission of a 140 keV gamma. Electron capture and isobaric transitions do not produce photons directly. These are followed by additional transitions which in turn produce photons.

Khan, 2nd Edition, pages 22-28

18. E.
All of the transitions listed produce electrons.

Khan, 2nd Edition, pages 22-28

19. B.
The binding energy of an electron relates to the energy required to maintain an electron in its shell. It depends on the magnitude of coulomb force of attraction between the nucleus and the orbital electrons.

Khan, 2nd Edition, page 5

20. A. d.
B. b.
C. c.
D. a.

21. B.
The rest mass of an electron is 9.1×10^{-31} kg. Using the relationship $E = mc^2$, where c is the velocity of light (3×10^8 meters/second), E can be calculated to be 0.511 MeV.

Khan, 2nd Edition, page 4

22. D.
Each of the Options A, B and C represents the atomic mass unit in different units.

23. B.
According to Avogadro's Law, every gram atomic weight of a substance contains the same number of atoms. The quantity of Avogadro's number (Na) has a value of 6.0288×10^{23} and represents atoms per atomic weight (A). Thus, numbers of atoms per gram = Na/A.

Khan, 2nd Edition, page 3

24. C.
The mass of an atom is not exactly equal to the sum of the masses of constituent particles. When the nucleus is formed, a certain mass is converted into energy which acts as a "glue" to keep the nucleons together. This energy is called binding energy.

Khan, 2nd Edition, page 3

25. D.
The mass of a nucleon is almost 2,000 time more than that of an electron.

26. B.
A neutron is not a charged particle and cannot ionize directly.

27. D.
Neutrons and protons are about 2,000 times heavier than electrons.

28. E.
For example, an isotope of lithium with 4 neutrons and 3 protons would have an atomic mass number of 7.

29. D.
The conversion of 1 atomic mass unit. 1.66×10^{-29} Kg in energy ($E = mc^2$, where m is mass in Kg, c is the speed of light 3×10^8 meter/second) gives E (MeV) = 931 MeV.

30. B.
The magnitude of coulomb forces is highest near the inner most shell.

Khan, 2nd Edition

31. C.
The ionization process involves a transfer of charge. It is often done by stripping an electron from an atom.

32. A.
In the formula $^{A}_{Z}X$, A represents the mass number and Z represents the atomic number for the element X.

33. A.
Ionization requires stripping an electron from an atom. The photon must transfer the necessary binding energy to the atom to remove an electron from its shell. Hence, the energy of the photon has to be greater than the binding energy of the electron to be removed.

34. A.
The number of negative and positive charges must be equal.

Radioactivity

35. C.
Radioactive isotopes are unstable because the nucleus is in an excess energy state. The nucleus achieves stability by redistributing energy between the nucleons. In this process, any of the nucleons can escape the nucleus and lower its energy state.

Khan, 2nd Edition, page 12

36. D.
Volume of a substance can change with temperature and pressure. The radioactivity quantifies the number of radioactive atoms, hence B and C are true.

Khan, 2nd Edition, pages 12-17

37. D.
For the activity to decrease to less than 2 mCi from 100 mCi, set-up the equation $1/50 = (1/2)^n$. Solving for n would give n = 5.8. Or you may count how many times you have to sequentially reduce the initial activity into half of the original, i.e., 100 mCi to 50 mCi to 25 mCi to 12.5 mCi, 6.25 mCi, 3.125 mCi, and 1.55 mCi.

Khan, 2nd Edition, page 14

38. B.
The activity is inversely related to half-life. The average life is 1.44 x $T_{1/2}$. The biological half-life is independent of the physical half-life.

39. D.
$T_{1/2}$ = natural log of 2 divided by lambda, λ, where λ is the disintegration constant, natural log of 2 = 0.693.

Khan, 2nd Edition, page 14

40. E.
In the calculation of dose, all of the four parameters A-D are needed to calculate the total dose.

41. C.
The term specific activity refers to the radioactivity per unit mass of substance, i.e., Bq/kg or Ci/g.

Khan, 2nd Edition, page 16

42. C.
The higher the specific activity of a sample, the higher is its activity for a unit mass.

43. B.
Half-life = 0.693/decay constant
Average half-life = 1.44 x half-life

44. D.
The activity of a source sample after n half-lives is given by $(1/2)^n$.

X-Ray and Gamma Ray Interactions

45. D.
The mathematical relationship for attenuation is $I = I_0 e^{-\mu x}$ where I_0 and I are the incident and transmitted intensities, respectively. μ is the linear attenuation coefficient and x is the thickness of the material. μ depends on the energy of the photons.

Khan, 2nd Edition, page 73

46. B.
See previous answer.

47. C.
When a photon is scattered by the Compton interaction, part of its energy is given to the electron and the scattered photon has reduced energy.

Khan, 2nd Edition, page 77

48. C.
Coherent scattering involves an interaction of the photon with the whole atom and its energy is essentially unchanged.

Khan, 2nd Edition, page 79

49. C.
The energy absorption coefficient is defined as the product of energy transfer coefficient and (1-g) where g is the fraction of the energy of secondary charged particles that is lost to bremsstrahlung in the material.

50. A.
Photoelectric process is most significant between 1-50 keV. It is still significant between 50-100 keV for high Z materials.

Khan, 2nd Edition, page 80

51. A.
In the Compton process the photon transfers some of its energy to a loosely bound electron and is scattered. The angle of scatter depends on the energy loss.

Khan, 2nd Edition, pages 81-83

52. C.
Annihilation radiation is produced when a positron combines with an electron. This process produces two photons of 0.511 MeV, each traveling in opposite directions.

Khan, 2nd Edition, page 87

53. A.
The half value layer (HVL) is the thickness of an absorber required to attenuate the intensity of the beam to half its original value.

Khan, 2nd Edition, page 74

54. B.
HVL = (ln 2)/attenuation coefficient
= 0.693/attenuation coefficient

55. E.
In photon and gamma ray interactions with the atoms of a material electrons from the atoms are ejected producing ionization. Transfer of energy takes place, some of which is absorbed and some are scattered.

Khan, 2nd Edition, pages 71-72

56. C.
The transfer of energy implies giving energy to the atom (or to any of its components). All energy transferred by a photon is not always absorbed by tissue. Energy transferred to tissue implies actually absorbed by it.

57. B.
The major mode of x and gamma ray interaction in the megavoltage radiation therapy energy range of 1-20 MeV is the Compton process.

58. B.
The photoelectric effect is a phenomenon in which a photon interacts with an electron and ejects it. All the energy of the photon is transferred to the electron.

59. C.
If the energy of the photon is greater than 1.02 MeV, it interacts with the electromagnetic field of the nucleus and gives up all its energy in the creation of a negative and positive electron. Since the rest mass energy of electron is 0.511 MeV, it takes a threshold energy of 1.02 MeV for pair production. The excess energy of the photon is shared by the two particles.

Khan, 2nd Edition, page 86

60. B.
See answer to 59, above.

61. B.
The total attenuation coefficient represents the sum of the cross section of all possible interactions and thus determines the interaction probability.

62. C.
Lead has the highest Z and the highest attenuation coefficient between 3 MeV and 30 MeV and therefore is the better attenuation of a high energy photon beam.

Khan, 2nd Edition, Figures 5-12

63. B.
The minimum energy threshold for pair production is 1.02 MeV. It, however, begins to be significant above 10 MeV.

Johns and Cunningham, 4th Edition, page 162

64. C.
Contrary to high Z materials like lead which have a K-edge, the mass attenuation coefficient in soft tissue is similar to that in water which decreases continuously with energy.

Johns and Cunningham, 4th Edition, Figure 5-5, page 147.

Charged Particle Interactions

65. C.
The charged particle interactions or collisions are mediated by coulomb forces between the electric field of the traveling particle and the electric field of orbital electrons and the nuclei of an atom of the material. The collisions between particles and electrons results in ionization and excitation. The interaction between the electrons and atomic nuclei produces Bremsstrahlung (x-rays).

Khan, 2nd Edition, page 90

66. C.
See above.

Khan, 2nd Edition, page 90

67. B.
The rate of kinetic energy loss per unit path of the particle, dE/dx, is called stopping power (S). S/r is called the mass stopping power, where r is the density of material. When the "restricted" stopping power (when implies energy locally absorbed) is used then it is called the linear energy transfer or LET.

Khan, 2nd Edition, pages 90 and 349.

68. B.
The rate of energy loss for a charged particle is proportional to the square of the particle change and inversely proportional to the square of its velocity.

Khan, 2nd Edition, page 90

69. C.
Heavy particles lose energy sharply at the end of their range. This peaking of dose near the end of the particle range is called the Bragg peak.

Khan, 2nd Edition, page 91

70. C.
Because of their relatively small mass, electrons have a high velocity until their last few interactions. Heavy particles move much slower for a considerable distance at the end of their path. This slow motion permits many more interactions and more dense ionizations resulting in the Bragg peak.

71. C.
If the energy transferred to an orbital electron is not sufficient to eject it (i.e., it is not higher than its binding energy), it is temporarily displaced from its stable position. The energy could also be transferred to an excited state of a molecule. This effect is called excitation.

Khan, 2nd Edition, page 91

72. E.
Electrons and beta particles penetrate about one cm per two MeV where as alpha particles penetrate a few microns/MeV.

73. C.
Occasionally, an electron stripped from an atom acquires sufficient energy to make its own track of ionization. Such electrons are called secondary electrons or delta rays.

Khan, 2nd Edition, page 91

74. B.
An electron in the strong electromagnetic field of the nucleus decelerates rapidly. Part of its kinetic energy is converted into an x-ray photon called bremsstrahlung.

Khan, 2nd Edition, page 90

Neutron Interactions

75. B.
Like x-rays and gamma rays, neutrons are indirectly ionizing.

Khan, 2nd Edition, page 91

76. A.
Neutrons interact basically by two processes; 1) recoil protons from hydrogen and recoiling heavy nuclei from other elements, and 2) nuclear disintegration.

Khan, 2nd Edition, page 91

77. C.
The most efficient absorber of neutrons is a hydrogenous material such as paraffin wax or polyethylene. Adding borax, which contains boron also improves absorption.

Khan, 2nd Edition, page 91

78. C.
Because of the higher hydrogen content, fat would receive about a 20% higher dose.

Khan, 2nd Edition, page 91

79. D.
Nuclear disintegration produced by neutrons results in the emission of heavy charged particles, neutrons and gamma rays which gives rise to about 30% of the dose. This makes neutron dosimetry difficult.

Production of X-Rays

80. B.
The electron, while passing near a nucleus, may be deflected from its path by the action of coulomb forces and lose energy as bremsstrahlung. The electromagnetic field abruptly slows down the electron and thus, it loses its kinetic energy.

Khan, 2nd Edition, page 39

81. D.
As the energy of electrons increases, the direction of x-ray bremsstrahlung becomes increasingly forward. This is why high energy linear accelerators use transmission targets and field flattening filters.

Khan, 2nd Edition, page 39

82. D.
Most of the energy in diagnostic x-ray machines are converted into heat. Only about 1% results in x-ray production.

Khan, 2nd Edition, page 41

83. C.
When a fast electron ejects an inner orbital electron, a vacancy is created. An electron from an outer orbit falls into this vacancy and in the process gives up energy in the form of a characteristic x-ray. The energy of the photon is the difference in binding energy of the two shells, which is characteristic of the target element.

Khan, 2nd Edition, page 41

84. C.
X-ray photons produced by x-ray machines are heterogeneous in energy. The energy of the incoming electrons are lost as they enter the target. Photons of lower average energy are produced as they penetrate further in the target.

Khan, 2nd Edition, page 41

85. C.
The maximum energy in kilo-electron-volts (keV) is numerically equal to the applied kilovolt peak (kVp). However, the intensity of these photons is practically zero.

86. C.
Filters in the x-ray beams selectively absorb the low energy photons. This increases the relative abundance of high energy photons in the beam which is called beam hardening.

Khan, 2nd Edition, page 43

87. B.
The rule of thumb is that average x-ray energy in keV is approximately one-third of the maximum kVp.

Khan, 2nd Edition, page 43

88. D.
Increase in each of the parameters causes an increase in x-ray production.

89. B.
The efficiency of x-ray production is higher for the high Z materials.

Khan, 2nd Edition, page 32

90. D.

Ionization Chambers and Electrometers

91. B.
The free-air chamber, also called a standard ionization chamber, is employed for the measurement of the roentgen according to its definition. It is built to make ionization measurements in a well defined volume with charged particle equilibrium conditions.

Khan, 2nd Edition, page 96

92. D.
In an ionization chamber open to the atmosphere, the density of air in the collecting volume changes with a change in temperature or pressure, hence the mass of air changes. This effect must be taken into account to precisely quantify the ionization produced per unit mass of air and thus assess exposure.

Khan, 2nd Edition, page 116

93. D.
Free ionization chambers are not practical for use in a clinical environment. Small and sturdy ionization chambers have good spatial resolution and do not perturb the radiation beams.

Khan, 2nd Edition, page 97

94. C.
The walls are made of air-equivalent low Z materials, thick enough to provide charge particle equilibrium in the air cavity.

Khan, 2nd Edition, page 98

95. B.
Parallel-plate chambers, with one of the plates made very thin, are extremely useful for measuring doses at shallow depths, such as the skin dose.

Khan, 2nd Edition, page 112

96. C.
Low atomic number material such as graphite plastics or nylons are better suited to provide desirable wall characteristics for ionization chambers.

Khan, 2nd Edition, page 99

97. C.
A good ionization chamber should not have directional dependence.

Khan, 2nd Edition, page 101

98. B.
By comparing the response of the chamber in a known radiation beam against a nationally traceable standard, a correction factor is established. This process is called calibration. The correction factor is called the calibration factor.

Khan, 2nd Edition, page 100

99. A.
An electrometer is basically a charge and current measuring device. Many special purpose electrometers have been designed to measure charge and current and display the measurement as R or R per min.

Khan, 2nd Edition, page 111

Thermoluminescent Dosimetry

100. C.
Some substances when exposed to ionizing radiation store some of the energy as trapped charges in their crystal lattice. When exposed to heat, they are released from their traps and return to their original energy level and release this energy as light. The process is called thermoluminescence.

Khan, 2nd Edition, page 167

101. C.
The emitted light from thermoluminescence dosimetry is measured by a photomultiplier tube which converts it into an electrical signal.

Khan, 2nd Edition, page 167

102. C.
Lithium fluoride (Li F) has been the most studied and extensively used material for radiation dosimetry due to its excellent dosimetric properties.

Khan, 2nd Edition, pages 169-172

103. C.
Careful handling and calibration process can provide up to ± 3% accuracy.

Film Dosimetry

104. B.
The exposed crystals of silver bromide when exposed to ionizing radiation or visible light records the latent image.

Khan, 2nd Edition, page 172

105. C.
The developing process reduces the silver bromide crystals to silver.

Khan, 2nd Edition, page 172

106. B.
The metallic silver, which is not affected by the fixer, causes darkening of the film.

Khan, 2nd Edition, page 172

107. C.

Khan, 2nd Edition, page 172

108. B.
The H-D curve is a plot of net optical intensity as a function of radiation exposure or dose. It is also called the sensitometric curve.

Khan, 2nd Edition, page 172

109. B.
The response of a film to radiation is dependent on several factors such as changes in processing conditions, interfilm emulsion variations and other artifacts. It is therefore only practical for relative dosimetry.

Khan, 2nd Edition, page 173

110. C.

Khan, 2nd Edition, page 173

111. C.

Khan, 2nd Edition, page 173

Radiochromic Film Dosimetry

112. B.
Radiochromic films are very well suited for the 10 Gy-104 Gy levels of radiation dose.

See reference at the end of section.

113. C.
The radiochromic film emulsion changes color when exposed to radiation without any processing.

114. B.
Radiation response signal in a radiochromic film is typically measured using a spectrometer or densitometer.

115. B.
The coloring in a radiochromic film is dependent on room temperature. Best result is obtained if exposure and measurements are performed at the same temperature. Room temperature of 20-30 °C is acceptable.

116. B.
In the range of 2-200 Gy, the radiochromic films have a reproducibility of ± 5% at a 95% confidence level.

117. B.
Energy dependence is about ± 5%.

Suggested reading

1. Photon energy dependence of the sensitivity of radiochromic film and comparison with silver halide film and LiF TLDs used for brachytherapy dosimetry, Muench P J, Meigooni A S, Nath R, Med Phys. 18(4), 769 - 775, 1994

Diode Radiation Detectors

118. C.
A diode is typically a device with two electrodes which allows current to only flow in one direction. The diode dosimeter is a solid state device which generates a current when exposed to radiation.

119. B.
The relative signal produced by the diodes in a radiation beam can be calibrated to provide excellent relative dosimetry information.

120. D.

121. D.

Superficial and Orthovoltage Machines

122. C.
Superficial x-ray units operate between 50-150 kV and 1-6 mm aluminum are added to harden the beam.

Khan, 2nd Edition, page 47

123. B.
The half value layer for superficial beams is usually between 1-8 mm Al.

Khan, 2nd Edition, page 47

124. A.
The percent depth dose at 5 mm from a superficial x-ray beam is about 90%. Beyond this depth, the dose falls off very rapidly and is not adequate for treatment because it will result in excessive skin dose.

Khan, 2nd Edition, page 47

125. B.
Superficial treatments are delivered with the help of applicators or cones providing SSD in the range of 15-20 cm.

Khan, 2nd Edition, page 47

126. C.
Most orthovoltage is operated between 200-300 kV and 10-20 mA.

Khan, 2nd Edition, page 47

127. C.
Using various filters, a half value layer of 1-4 mm Cu is achieved in orthovoltage beams.

Khan, 2nd Edition, page 47

128. C.
Beyond 2 cm, the depth dose from an orthovoltage falls off very rapidly. It is not practical to use these beams beyond 2-3 cm.

Khan, 2nd Edition, page 47

129. B.
Beyond 2-3 cm, the dose rate falls off rapidly resulting in an excessive high skin dose if a therapeutic dose is to be delivered to a deep tumor.

Khan, 2nd Edition, page 47

130. A.

See Khan, 2nd Edition, pages 136-137

Cobalt Units

131. B.
The Cobalt-60 source produces two photons per disintegration of energies 1.17 and 1.33 MeV. The average of these two is 1.25 MeV.

Khan, 2nd Edition, page 62

132. D.
The typical diameter of a cobalt source is 1-2 cm in diameter. A smaller diameter source does not have enough output to produce a practical therapeutic dose rate at 80 cm SSD.

Khan, 2nd Edition, page 63

133. B.
The Cobalt-60 source has a half life of 5.26 years which undergoes a reduction in dose rate of about one per cent per month.

Khan, 2nd Edition, page 62

134. C.
When an x-ray source is collimated by collimators at half the distance of the SSD, the penumbra at the SSD is the same as the diameter of the source.

Khan, 2nd Edition, page 65

135. C.
About 12 mm of lead reduces the cobalt dose rate to half its initial value.

136. D.
6 cm represents 5 HVLs. This will reduce the incident cobalt beam intensity by $(1/2)^5 = 1/32$ which is about 3.1%.

137. C.
Specially constructed heavy metal bars used to better define the beam near the patient are called trimmers.

Khan, 2nd Edition, page 65

Linear Accelerators

138. B.
In linear accelerators, high frequency electromagnetic waves are used to accelerate and provide energy to electrons.

Khan, 2nd Edition, page 51

139. D.
The typical frequency of 3000 MHz in S band is found to be optimum for accelerating electrons in a gantry-mounted accelerator structure.

Khan, 2nd Edition, page 51

140. D.
In standing wave accelerators, up to 150 keV/cm of energy transfer is possible. Instead, a traveling wave accelerator can only transfer up to approximately 75 keV/cm.

Johns and Cunningham, 4th Edition, page 11

141. B.
Transducers are used in producing ultrasound beams. Waveguides and circulators are used for microwave power, the modulator includes the pulse-forming network and the thyratron is a switch tube.

Khan, 2nd Edition, page 51

142. B.
Pulsed microwave power is produced by Klystron and magnetrons. High-energy accelerators run better with Klystron.

Khan, 2nd Edition, page 52

143. C.
Typically, linacs of 6 MV or less operate using magnetron of 2 MW peak power output.

Khan, 2nd Edition, page 54

144. D .
High energy linacs in the 10-25 MeV energy range are designed to operate with Klystron of 5 MW peak power.

145. B.
The x-ray beam from a target in the accelerator is very non-uniform. It has a bell shape profile. The flattening filter is used to produce a uniformly flat beam.

Khan, 2nd Edition, pages 155-56

146. B.
The flattening filter is usually made of lead, although tungsten, uranium, steel, aluminum or a combination has also been suggested to produce superior beams.

Khan, 2nd Edition, page 56

147. C.
Cyclotron is used for accelerating high energy protons for proton beam therapy.

Khan, 2nd Edition, page 60

Acceptance Testing, Calibration, and Commissioning

148. B.
The process of acceptance testing requires measurements of machine parameters and comparing the measured values to those specified in the purchase order.

149. D.
The commissioning process requires measurement of all the mechanical and radiation data necessary to treat patients using the machine in question. It includes parameters such as beam profiles, percent depth dose, field size and cone factors, etc.

150. E.
The term calibration usually means measuring a parameter and comparing it with a national standard. It has come to mean measuring and adjusting all parameters that have significant impact on the dose delivered to the patient.

151. E.
Most federal and professional standards require an annual complete calibration.

152. B.
Most federal and professional standards require at least a weekly check of output consistency. Some institutions perform it daily.

Suggested reading:

AAPM code of practice for radiotherapy accelerators: Report of AAPM Radiation Therapy Task Group No. 45, Nath R, Biggs P J , Bova F J, Ling C C, Purdy, J A, Van de Geijn J, Weinhous M S, Med Phys. 21 (7), 1093 -1121, July 1994