

EEE 491 - Biomedical Engineering

X-Ray Imaging



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MCQ Questions

1. Q Which type of x-rays are most commonly used in diagnostic imaging?

- (a) Characteristic x-rays
- (b) Gamma rays
- (c) Bremsstrahlung x-rays
- (d) Alpha particles

1. A (c)

2. Q What causes Bremsstrahlung x-rays to be emitted during x-ray production?

- (a) The slowing of a projectile electron by the nuclear field of a target atom nucleus
- (b) The absorption of gamma rays by the target element
- (c) The emission of alpha particles by the target element
- (d) The reflection of beta particles off the target element

2. A (a)

3. Q What is the function of the operating console in X-ray production?

- (a) To control the number of electrons in the anode
- (b) To convert kinetic energy into heat energy
- (c) To control the quantity and quality of the X-ray beam
- (d) To produce Bremsstrahlung X-rays

3. A (c)

4. Q What is the difference between radiation quantity and radiation quality?

- (a) Radiation quantity refers to penetrability of X-ray beam, and radiation quality refers to the intensity of the X-ray beam
- (b) Radiation quantity refers to the intensity of the X-ray beam, and radiation quality refers to the number of X-rays
- (c) Radiation quantity refers to number of X-rays or intensity of X-ray beam, and radiation quality refers to penetrability of X-ray beam
- (d) Radiation quantity refers to the penetrability of the X-ray beam, and radiation quality refers to the quality of the X-ray beam

4. A (c)

5. Q What is half-value layer (HVL)?

- (a) A measure of the intensity of the X-ray beam
- (b) A measure of the penetrability of the X-ray beam
- (c) A measure of the distance the X-rays travel through the tissue
- (d) A measure of voltage of the anode

5. A (b)

6. Q What does kVp determine in x-ray imaging?

- (a) The radiation quantity
- (b) The intensity of x-ray beam
- (c) The radiation quality
- (d) The anode heat

6. A (c)

7. Q How is kVp adjusted in an x-ray machine?

- Ⓐ By changing the anode heat
- Ⓑ By changing the half-value layer
- Ⓒ By increasing the current to the x-ray tube
- Ⓓ By selecting autotransformer connections with a knob, button, or touch screen

7. A (d)

8. Q What is thermionic emission?

- Ⓐ The release of electrons from a heated filament
- Ⓑ The measurement of the penetrability of an x-ray beam
- Ⓒ The process of increasing voltage to a chosen kilovolt peak
- Ⓓ The emission of characteristic x-rays when an outer-shell electron fills an inner-shell void

8. A (a)

9. Q How is the number of electrons emitted by a filament controlled?

- Ⓐ By the half-value layer (HVL) of the x-ray beam
- Ⓑ By the kVp of the x-ray beam
- Ⓒ By the filament current
- Ⓓ None of the above

9. A (c)

10. Q A K-shell electron is removed from a tungsten atom and is replaced by an L-shell electron. What is the energy of the characteristic x-ray that is emitted? given that the K-shell electrons have binding energies of 69 keV, and L-shell electrons are bound by 12 keV

- (a) $9.12 \times 10^{-15} \text{ J}$
- (b) $9.12 \times 10^{-19} \text{ J}$
- (c) $4.56 \times 10^{-15} \text{ J}$
- (d) $4.56 \times 10^{-19} \text{ J}$

$$KE = 69 - 12 = 57 \text{ KeV}$$

$$\therefore KE = 57 \text{ KeV} \times 1.6 \times 10^{-16} \text{ J/KeV} = 9.12 \times 10^{-15} \text{ J}$$

10. A (a)

11. Q In the previous question, calculate the velocity of the electron.

- (a) $1.4 \times 10^8 \text{ m/s}$
- (b) $0.4 \times 10^8 \text{ m/s}$
- (c) $1.4 \times 10^7 \text{ m/s}$
- (d) $0.4 \times 10^7 \text{ m/s}$

$$\therefore KE = \frac{1}{2}mv^2$$

$$\therefore v = \sqrt{\frac{2 \times 9.12 \times 10^{-15}}{9.109 \times 10^{-31}}} = 1.4 \times 10^8 \text{ m/s}$$

11. A (a)

12. Q What is the purpose of the Automatic Exposure Control (AEC) device in radiography?

- Ⓐ To control the voltage and current of the x-ray tube
- Ⓑ To measure the temperature of the filament in the x-ray tube
- Ⓒ To measure the quantity of radiation that reaches the image receptor
- Ⓓ To adjust the focus of the x-ray beam

12. A (c)

13. Q What are the two internal structures of an X-ray tube?

- Ⓐ Support structure
- Ⓑ Anode and cathode
- Ⓒ Glass and metal enclosure
- Ⓓ protective housing

13. A (b)

14. Q Which of the following is not a type of X-ray tube support system?

- Ⓐ Ceiling support
- Ⓑ Floor support
- Ⓒ Table support
- Ⓓ C-arm support

14. A (c)

15. Q Which of the following is not part of the external structure of an X-ray tube?

- (a) Support structure
- (b) Protective housing
- (c) Glass enclosure
- (d) Anode and cathode

15. A (d)

16. Q Which of the following interactions of X-rays with matter involves the release of a loosely bound electron from the outer shell of an atom?

- (a) Coherent scattering
- (b) Compton scattering
- (c) Photoelectric effect
- (d) Pair production

16. A (b)

17. Q As the energy of X-rays increases, what happens to the amount of Compton scattering relative to photoelectric effect?

- (a) Compton scattering decreases relative to photoelectric effect increases
- (b) Compton scattering increases relative to photoelectric effect decreases
- (c) Compton scattering and photoelectric effect remain constant
- (d) None of the above

17. A (b)

18. Q In Compton scattering , what happens when the atomic number of absorber increases?

- Ⓐ Compton scattering increases
- Ⓑ Compton scattering decreases
- Ⓒ No effect on Compton scattering

18. A (c)

1 Compton (Incoherent) Scattering

$$E_i = E_s + E_b + E_{KE} \quad (1)$$

where

E_i : energy of the incident x-ray

E_s : energy of the scattered x-ray

E_b : electron binding energy

E_{KE} : kinetic energy of the electron.

19. Q A 30-keV x-ray ionizes an atom of barium by ejecting an O-shell electron with 12 keV of kinetic energy. What is the energy of the scattered x-ray? (the binding energy of an O-shell electron of barium is 0.04 keV)

- Ⓐ 17.96 keV
- Ⓑ 8.98 keV
- Ⓒ 4.49 keV
- Ⓓ 2.245 keV

rearranging the previous equation

$$E_s = E_i - E_b - E_{KE}$$

therefore

$$E_s = 30 - 0.04 - 12 = 17.96 \text{ keV}$$

19. A (a)

2 Photoelectric Effect

$$E_i = E_b + E_{KE} \quad (2)$$

20. Q When does the photoelectric effect become less likely to occur relative to Compton scattering?

- (a) When x-ray energy is equal to electron binding energy
- (b) When x-ray energy is much higher than electron binding energy
- (c) When x-ray energy is much lower than electron binding energy
- (d) None of the above

20. A (b)

21. Q How does the photoelectric effect change with increasing atomic number of the absorber?

- (a) Increases linearly
- (b) Increases proportionately with the cube of the atomic number
- (c) Decreases linearly
- (d) Decreases proportionately with the cube of the atomic number

21. A (b)

22. Q Assume that all x -ray interactions during mammography are photoelectric. What is the differential absorption of x -rays in microcalcifications ($Z = 20, \rho = 1550 \text{ kg/m}^3$) relative to fatty tissue ($Z = 6.3, \rho = 910 \text{ kg/m}^3$) ?

- Ⓐ 54.4: 1
- Ⓑ 17.1: 1
- Ⓒ 5.4:1
- Ⓓ 3.1:1

Differential absorption due to atomic number:

$$\left(\frac{20}{6.3}\right)^3 = \frac{8000}{250} = 32 : 1$$

Differential absorption due to mass density

$$= \frac{1550}{910} = 1.7 : 1$$

Total differential absorption

$$= 32 \times 1.7 = 54.4 : 1$$

22. A (a)

3 Attenuation

$$I = I_o \exp(-\alpha x) \quad (3)$$

where

α : Attenuation coefficient

x : Path length

23. Q What is the definition of attenuation in X-ray imaging?

- (a) The increase in number of x-rays remaining in an X-ray beam
- (b) The reduction in number of x-rays remaining in an X-ray beam after penetration through a given thickness of tissue
- (c) The scattering of X-rays after penetration through a given thickness of tissue
- (d) The absorption of X-rays after penetration through a given thickness of tissue

23. A (b)

24. Q Which of the following is the combined effect of both absorption and scattering of X-rays?

- (a) Transmission
- (b) Reflection
- (c) Refraction
- (d) Attenuation

24. A (d)

25. Q Which unit is used to measure the quantity of radioactive material?

- (a) Air Kerma (Gya)
- (b) Sievert (Sv)
- (c) Absorbed Dose (Gyt)
- (d) Becquerel (Bq)

25. A (d)

26. Q Which unit is used to measure the kinetic energy transferred from photons to electrons during ionization and excitation?

- (a) Air Kerma (Gya)
- (b) Sievert (Sv)
- (c) Absorbed Dose (Gyt)
- (d) Becquerel (Bq)

26. A (a)

27. Q Which unit is used to measure the quantity of radiation received by radiation workers and populations?

- (a) Air Kerma (Gya)
- (b) Sievert (Sv)
- (c) Absorbed Dose (Gyt)
- (d) Becquerel (Bq)

27. A (b)

28. Q What is the relationship between dose and duration of radiation exposure?

- (a) They are inversely related
- (b) They are directly related
- (c) There is no relationship
- (d) It depends on the type of radiation

28. A (b)

29. Q How does radiation exposure change as distance from the radiation source increases?

- (a) It remains the same
- (b) It increases linearly
- (c) It decreases linearly
- (d) It decreases rapidly by inverse square law

29. A (d)

30. Q What type of material is commonly used for shielding in diagnostic radiology?

- (a) Concrete
- (b) Wood
- (c) Lead
- (d) Steel

30. A (c)

31. Q A radiation worker is exposed to 2.3 mGy₂/ hr (230mR/hr) from a radiation source. If the worker remains in that position for 36 minutes, what will be the total occupational exposure?

- (a) 82.8 mGy₂
- (b) 3.833 mGy₂
- (c) 2.21 mGy₂
- (d) 1.38 mGy₂

$$\text{Occupational exposure} = 2.3 \text{ mGy}_2/\text{hr} \frac{36 \text{ min}}{60 \text{ min/hr}} = 1.38 \text{ mGy}_2$$

31. A (d)

32. Q A fluoroscope emits 42 mGy₂/min(4.2R/ min) at the tabletop for every milliamperere of operation. What is the patient exposure in a barium enema examination that is conducted at 1.8 mA and requires 2.5 minutes of fluoroscopic x-ray exposure time?

- (a) 189 mGy_a
- (b) 105 mGy_a
- (c) 1.7 mGy_a
- (d) 3.15 mGy_a

$$\text{Patient radiation exposure} = \left(\frac{42 \text{ mGy}_a}{\text{mAmin}} \right) (1.8 \text{ mA})(2.5 \text{ min}) = 189 \text{ mGy}_a$$

32. A (a)

33. Q An x-ray tube has an output intensity of 26 mGy/mAs(2.6mR/mAs) at 100 – cm source-to-image receptor distance (SID) when operated at 70kVp. What would be the radiation exposure 350 cm from the target?

- (a) 2.1 mGy_a/mAs
- (b) 7.31 mGy_a/mAs
- (c) 4.2 mGy_a/mAs
- (d) 14.63 mGy_a/mAs

From inverse square law

$$\begin{aligned} \frac{I_1}{I_2} &= \frac{d_2^2}{d_1^2} \\ I_2 &= I_1 \frac{d_1^2}{d_2^2} \\ &= (26 \text{ mGy}_2/\text{mAs}) \left(\frac{100 \text{ cm}}{350 \text{ cm}} \right)^2 \\ &= (26 \text{ mGy}_2/\text{mAs}) (0.082) \\ &= 2.1 \text{ mGy}_a/\text{mAs} \end{aligned}$$

33. A (a)

34. Q What is the effective dose?

- (a) The radiation dose to a single organ
- (b) The equivalent dose to the whole body
- (c) The dose at which radiation sickness occurs
- (d) The dose at which acute radiation syndrome occurs

34. A (b)

35. Q Why is effective dose important in medical imaging?

- (a) It helps determine the power of the radiation
- (b) It helps determine the dose required for imaging to be effective
- (c) It helps determine the overall risk of radiation exposure to the body
- (d) It helps determine the effectiveness of radiation shielding

35. A (c)

36. Q How is the effective dose calculated?

- (a) By measuring the dose to a single organ
- (b) By taking an average of the doses to all organs and tissues
- (c) By multiplying the radiation dose by the exposure time
- (d) By calculating the attenuation of the radiation by shielding

36. A (b)

37. Q

The following table tells the weighting factors for various tissues

Tissue	Tissue Weighting Factor (W_t)
Gonad	0.20
Active bone marrow	0.12
Colon	0.12
Lung	0.12
Stomach	0.12
Bladder	0.05
Breast	0.05
Esophagus	0.05
Liver	0.05
Thyroid	0.05
Bone surface	0.01
Skin	0.01

A PA chest radiograph results in an entrance skin dose of 0.1 mGy_t , an exit dose of 0.001 mGy_t ($1\mu\text{Gy}_t$), and an average tissue dose of 0.05 mGy_a ($50\mu\text{Gy}_a$). What is the effective dose?

- (a) $17.1\mu\text{Sv}$
- (b) $23\mu\text{Sv}$
- (c) $13.5\mu\text{Sv}$
- (d) $5.5\mu\text{Sv}$

$E = \Sigma (D_i W)$
 $= (50)(0.12)\text{ lung}$
 $+ (50)(0.05)\text{ breast}$
 $+ (50)(0.05)\text{ esophagus}$
 $+ (50)(0.05)\text{ thyroid}$

$= 6.0\text{ lung}$
 $+ 2.5\text{ breast}$
 $+ 2.5\text{ esophagus}$
 $+ 2.5\text{ thyroid}$
 $= 13.5\mu\text{Sv}$

All other tissues receive essentially zero dose.

37. A (c)