

EEE 491 - Biomedical Engineering

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# X-Ray Imaging

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Taha Ahmed

## MCQ Questions

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**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)

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**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)

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**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)

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**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)

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**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)

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**6. Q** What does kVp determine in x-ray imaging? A) B) C) D)

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

**6. A** (c)

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**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** (b)

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**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)

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**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)

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**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)

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**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)  $0.4 \times 10^7 \text{ m/s}$

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

$$\therefore v = \sqrt{\frac{2 \times 9.12 \times 10^{-15}}{9.10910^{-31}}} = 1.4 \times 10^8 \text{ m/s}$$

**11. A** (a)

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**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)

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**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)

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**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)

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**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)

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**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)

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**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)

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**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)

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## 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.

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**19. Q** An x-ray photon with an incident energy of 200 keV undergoes Compton scattering with an outer-shell electron of an atom. If the scattered photon has an energy of 50 keV and the kinetic energy of the electron equals 3 keV, what is the binding energy of the electron?

- Ⓐ 1 keV
- Ⓑ 2 keV
- Ⓒ 3 keV
- Ⓓ 4 keV



rearranging the previous equation

$$E_b = (E_i/E_s) - E_{KE}$$

therefore

$$E_b = (200/50) - 3 = 1 \text{ keV}$$

**19. A** (a)

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## 2 Photoelectric Effect

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

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**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)

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**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)

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**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 ( $Z = 6.3, \rho = 910 \text{ kg/m}^3$ ) ?

- (a) 54.4: 1
- (b) 17.1: 1
- (c) 5.4:1
- (d) 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)

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### 3 Attenuation

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

where

$\alpha$  : Attenuation coefficient

$x$  : Path length

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**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)

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**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)

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**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)

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**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)

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**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)

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**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)

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**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)

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**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)

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**31. Q** A radiation worker is exposed to 2.3 mGy<sub>2</sub>/ 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 mGy<sub>2</sub>
- (b) 3.833 mGy<sub>2</sub>
- (c) 2.21 mGy<sub>2</sub>
- (d) 1.38 mGy<sub>2</sub>

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

**31. A** (d)

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**32. Q** A fluoroscope emits 42 mGy<sub>2</sub>/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<sub>a</sub>
- (b) 105 mGy<sub>a</sub>
- (c) 1.7 mGy<sub>a</sub>
- (d) 3.15 mGy<sub>a</sub>

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

**32. A** (a)

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**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<sub>a</sub>/mAs
- (b) 7.31 mGy<sub>a</sub>/mAs
- (c) 4.2 mGy<sub>a</sub>/mAs
- (d) 14.63 mGy<sub>a</sub>/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)

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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)

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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)

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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  $0.1\text{ mGy}_t$ , an exit dose of  $0.001\text{ mGy}_t$  ( $1\mu\text{Gy}_t$ ), and an average tissue dose of  $0.05\text{ mGy}_a$  ( $50\mu\text{Gy}_a$ ). 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)