EEE 491 - Biomedical Engineering

X-Ray Imaging

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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)

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) 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)

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

(a) By changing the anode heat

(b) By changing the half-value layer

(c) By increasing the current to the x-ray tube

(d) By selecting autotransformer connections with a knob, button, or touch screen

7. A (d)

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8. Q What is thermionic emission?

(a) The release of electrons from a heated filament

(b) The measurement of the penetrability of an x-ray beam

(c) The process of increasing voltage to a chosen kilovolt peak

(d) 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?

(a) By the half-value layer (HVL) of the x-ray beam

(b) By the kVp of the x-ray beam

(c) By the filament current

(d) 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) 9.12×10^{-15} J

(b) 9.12×10^{-19} J

(c) 4.56×10^{-15} J

(d) 4.56×10^{-19} 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) 1.4×10^{8} m/s

(b) 0.4×10^{8} m/s

(c) 1.4×10^{7} m/s

(d) 0.4×10^{7} m/s

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

$$\therefore v = \sqrt{\frac{2 \times 9.12 \times 10^{-18}}{9.109 \times 10^{-31}}} = 1.4 \times 10^{8} \text{ m/s}$$

11. A (a)

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

(a) To control the voltage and current of the x-ray tube

(b) To measure the temperature of the filament in the x-ray tube

(c) To measure the quantity of radiation that reaches the image receptor

(d) 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?

(a) Support structure

(b) Anode and cathode

(c) Glass and metal enclosure

(d) 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?

(a) Ceiling support

(b) Floor support

(c) Table support

(d) 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?

(a) Compton scattering increases

(b) Compton scattering decreases

(c) No effect on Compton scattering

18. A (c)

1 Compton (Incoherent) Scattering

$$E_i = E_s + E_b + E_{KE} \tag{1}$$

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)

(a) 17.96 keV

(b) 8.98 keV

(c) 4.49 keV

(d) 2.245 keV

rearranging the previous equation

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

therefore

$E_s = 30 - 0.04 - 12 = 17.96$ keV

19. A (a)

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2 Photoelectric Effect

$$E_i = E_b + E_{KE} \tag{2}$$

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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)

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

$= 32 \times 1.7 = 54.4 : 1$

$\boxed{22.\ A}$ (a)

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3 Attenuation

$$I = I_o \exp(-\alpha x) \tag{3}$$

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)

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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)

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)

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 mGy_2/ 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_2

(b) 3.833 mGy_2

(c) 2.21 mGy_2

(d) 1.38 mGy_2

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

31. A (d)

32. Q A fluoroscope emits 42 $\mathrm{mGy_2/min(4.2R/\ min)}$ at the tabletop for every milliampere 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 $\mathrm{mGy_a}$

(b) 105 $\mathrm{mGy_a}$

(c) 1.7 $\mathrm{mGy_a}$

(d) 3.15 $\mathrm{mGy_a}$

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

32. A (a)

33. Q An x-ray tube has an output intensity of 26 $\mathrm{mGy/mAs(2.6mR/mAs)}$ 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 $\mathrm{mGy_a/mAs}$

(b) 7.31 $\mathrm{mGy_a/mAs}$

(c) 4.2 $\mathrm{mGy_a/mAs}$

(d) 14.63 $\mathrm{mGy_a/mAs}$

From inverse square law

$$\frac{I_1}{I_2} = \frac{d_2^2}{d_1^2}$$

$$\begin{aligned} I_2 &= I_1 \frac{d_1^2}{d_2^2} \\ &= (26\ \mathrm{mGy_2/mAs}) \left(\frac{100\ \mathrm{cm}}{350\ \mathrm{cm}}\right)^2 \\ &= (26\ \mathrm{mGy_2/mAs})\,(0.082) \\ &= 2.1\ \mathrm{mGy_a/mAs} \end{aligned}$$

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 mGy_t, an exit dose of 0.001 mGy_t ($1\mu Gy_t$), and an average tissue dose of 0.05 mGy_a ($50\mu Gya_a$). What is the effective dose?

(a) 17.1μSv

(b) 23μSv

(c) 13.5μSv

(d) 5.5μSv

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\begin{aligned}
E &= \Sigma\,(D_i W) & &= 6.0 \text{ lung} \\
&= (50)(0.12) \text{ lung} & &+ 2.5 \text{ breast} \\
&+ (50)(0.05) \text{ breast} & &+ 2.5 \text{ esophagus} \\
&+ (50)(0.05) \text{ esophagus} & &+ 2.5 \text{ thyroid} \\
&+ (50)(0.05) \text{ thyroid} & &= 13.5\mu\text{Sv}
\end{aligned}
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All other tissues receive essentially zero dose.

37. A (c)