Medical Imaging Questions – OCR A Level Physics

Praneel Physics

1. State what is meant by an X-ray. **(P)**

Working and Answer:

An X-ray is a high-frequency electromagnetic wave used in medical imaging.

2. What is meant by attenuation of X-rays? **(P)**

Working and Answer:

It is the reduction in intensity of X-ray radiation as it passes through matter.

3. Give one use of ultrasound in medical imaging. **(P)**

Working and Answer:

To produce images of soft tissues such as in prenatal scanning.

4. State what is meant by the acoustic impedance of a material. **(P)**

Working and Answer:

It is the product of the density and speed of sound in the material.

5. Explain why a gel is used in ultrasound imaging. **(PP)**

Working and Answer:

To eliminate air gaps and reduce reflection due to impedance mismatch between the transducer and skin.

6. Describe the role of computed tomography (CT) in medical imaging. **(PP)**

Working and Answer:

It combines multiple X-ray images taken from different angles to produce cross-sectional images.

7. Define half-value thickness in X-ray attenuation. **(PP)**

Working and Answer:

The thickness of material required to reduce the X-ray intensity to half its original value.

8. Write the equation for X-ray attenuation. **(PP)**

Working and Answer:

$$I = I_0 e^{-\mu x}$$

where μ is the attenuation coefficient, x is thickness.

9. An X-ray beam with an initial intensity of $200\,\mathrm{W/m^2}$ passes through 5 cm of tissue with $\mu = 0.15\,\mathrm{cm^{-1}}$. Calculate the transmitted intensity. **(PPP)**

Working and Answer:

$$I = 200 \times e^{-0.15\times 5} = 200 \times e^{-0.75} \approx 94.3\,\mathrm{W/m^2}$$

10. Calculate the half-value thickness of a material with attenuation coefficient $\mu = 0.12\,\text{cm}^{-1}$. **(PPP)**

Working and Answer:

$$x_{1/2} = \frac{\ln 2}{\mu} = \frac{0.693}{0.12} \approx 5.78\,\text{cm}$$

11. Ultrasound of frequency 5 MHz is used. If the speed of sound in tissue is $1.5 \times 10^3\,\text{m/s}$, calculate the wavelength. **(PPP)**

Working and Answer:

$$\lambda = \frac{v}{f} = \frac{1.5 \times 10^3}{5 \times 10^6} = 3.0 \times 10^{-4}\,\text{m}$$

12. A boundary between two tissues has impedances $Z_1 = 1.6 \times 10^6$ and $Z_2 = 1.8 \times 10^6\,\mathrm{kg\,m^{-2}s^{-1}}$. Calculate the intensity reflection coefficient. **(PPP)**

Working and Answer:

$$R = \left(\frac{Z_2 - Z_1}{Z_2 + Z_1}\right)^2 = \left(\frac{0.2 \times 10^6}{3.4 \times 10^6}\right)^2 \approx 0.0035$$

13. Explain how MRI creates an image of internal body structures. **(PPPP)**

Working and Answer:

It uses the magnetic properties of hydrogen nuclei. A strong magnetic field aligns spins, radiofrequency pulses disturb this, and the emitted signals are detected and used to form an image.

14. Describe how an image is formed using A-scan ultrasound. **(PPPP)**

Working and Answer:

Single-direction pulses are reflected by boundaries; the time delay gives distance, and amplitude reflects the nature of the boundary.

15. Calculate the distance to a boundary if an ultrasound pulse returns after $40\,\mu$s. Speed of sound $= 1.5 \times 10^3\,$m/s. **(PPPP)**

Working and Answer:

$$d = \frac{vt}{2} = \frac{1.5 \times 10^3 \times 40 \times 10^{-6}}{2} = 0.03\,\text{m}$$

16. A CT scanner completes one rotation in 0.4 s and captures 1000 images per rotation. What is the imaging rate? **(PPPP)**

Working and Answer:

$$\text{Rate} = \frac{1000}{0.4} = 2500\,\text{images/s}$$

17. Calculate the energy of an X-ray photon with frequency 5.0×10^{18} Hz. **(PPPPP)**

Working and Answer:

$$E = hf = 6.63 \times 10^{-34} \times 5.0 \times 10^{18} = 3.32 \times 10^{-15}\,\text{J}$$

18. A patient receives a dose of 1.5 mGy over 0.02 m^2. Calculate the total energy absorbed. **(PPPPP)**

Working and Answer:

$$\text{Energy} = \text{Dose} \times \text{Mass} \Rightarrow D = 1.5 \times 10^{-3}\ \text{J/kg}$$

Assuming 1 kg of tissue: $E = 1.5 \times 10^{-3}\ \text{J}$

19. An X-ray beam loses 70% of its intensity through a body. What is the ratio I/I_0? **(PPPPP)**

Working and Answer:

$$I/I_0 = 0.30$$

20. Calculate the impedance of a tissue with density $1000\,\mathrm{kg/m^3}$ and sound speed $1500\,\mathrm{m/s}$. **(PPPPP)**

Working and Answer:

$$Z = \rho c = 1000 \times 1500 = 1.5 \times 10^6\,\mathrm{kg\,m^{-2}s^{-1}}$$