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Class 12 Physics – Chapter: Medical Imaging & Waves

Important MCQs & Short Questions

(Based on NCP SLOs: P-12-F-61 to P-12-F-65)

By MISBAH

SECTION A: Multiple Choice Questions (MCQs)

Q1. The piezoelectric effect refers to:

A) Generation of light by electric current
B) Generation of electric voltage when mechanical stress is applied to certain crystals
C) Generation of heat by ultrasound waves
D) Conversion of X-rays into electrical signals

Answer: B) Generation of electric voltage when mechanical stress is applied to certain crystals

Q2. Which material is commonly used in a piezoelectric transducer for ultrasound?

A) Silicon
B) Lead Zirconate Titanate (PZT)
C) Sodium Chloride
D) Copper oxide

Answer: B) Lead Zirconate Titanate (PZT)

Q3. The frequency range of ultrasound waves used in medical imaging is:

A) 20 Hz – 20 kHz
B) 1 MHz – 20 MHz
C) 100 Hz – 1 kHz
D) 20 kHz – 100 kHz

Answer: B) 1 MHz – 20 MHz

Q4. In a piezoelectric transducer, ultrasound waves are both generated AND detected by the same crystal because:

A) The crystal emits sound only
B) The piezoelectric effect is reversible
C) The crystal absorbs all radiation
D) Ultrasound reflects off air

Answer: B) The piezoelectric effect is reversible

Q5. X-rays are produced when:

A) Electrons are accelerated and strike a metal target
B) Protons collide with neutrons
C) Gamma rays hit a fluorescent screen
D) Ultrasound reflects off bone

Answer: A) Electrons are accelerated and strike a metal target

Q6. The minimum wavelength of X-rays produced depends on:

A) The material of the target only
B) The accelerating potential difference (P.d.)
C) The temperature of the cathode

D) The frequency of ultrasound

Answer: B) The accelerating potential difference (P.d.)

Q7. The formula for minimum wavelength of X-rays produced is:

A) $\lambda_{min} = hc / eV$

B) $\lambda_{min} = eV / hc$

C) $\lambda_{min} = mc^2 / h$

D) $\lambda_{min} = hf / c$

Answer: A) λ_min = hc / eV (where h = Planck's constant, c = speed of light, e = electron charge, V = accelerating P.d.)

Q8. The term 'contrast' in X-ray imaging refers to:

A) The brightness of the X-ray tube

B) The difference in image density between adjacent structures

C) The wavelength of X-rays used

D) The speed of X-ray photons

Answer: B) The difference in image density between adjacent structures

Q9. Which of the following body structures appears brightest (most opaque) on an X-ray image?

A) Muscle

B) Fat tissue

C) Bone

D) Air-filled lungs

Answer: C) Bone

Q10. Computed Tomography (CT) scanning is an improvement over conventional X-ray because it:

A) Uses lower radiation doses

B) Produces 3D cross-sectional images of the body

C) Uses sound waves instead of X-rays

D) Does not require any computer processing

Answer: B) Produces 3D cross-sectional images of the body

Q11. A-scan ultrasound displays information as:

A) A 2D image on screen

B) A series of pulses showing depth vs. amplitude

C) A colour-coded map of blood flow

D) A 3D reconstruction

Answer: B) A series of pulses showing depth vs. amplitude

Q12. The speed of ultrasound in soft tissue is approximately:

A) 330 m/s

B) 1500 m/s

C) 3000 m/s

D) 300 m/s

Answer: B) 1500 m/s

Q13. X-rays belong to which part of the electromagnetic spectrum?

A) Radio waves

B) Infrared radiation

C) High-frequency ionising radiation

D) Visible light

Answer: C) High-frequency ionising radiation

Q14. In CT scanning, the X-ray source rotates around the patient to:

A) Reduce radiation dose
B) Capture images from multiple angles for reconstruction
C) Increase image brightness
D) Avoid the use of contrast agents
Answer: B) Capture images from multiple angles for reconstruction

Q15. A contrast agent (e.g., barium) is used in X-ray imaging to:
A) Protect the patient from radiation
B) Enhance the visibility of soft tissue structures
C) Reduce the X-ray wavelength
D) Speed up X-ray production
Answer: B) Enhance the visibility of soft tissue structures

Q16. Which of the following is a non-ionising imaging technique?
A) CT scan
B) Conventional X-ray
C) Ultrasound scanning
D) Gamma-ray imaging
Answer: C) Ultrasound scanning

Q17. If the accelerating P.d. in an X-ray tube is doubled, the minimum wavelength of X-rays produced will:
A) Double
B) Remain the same
C) Halve
D) Become zero
Answer: C) Halve (since $\lambda_{min} = hc/eV$, doubling V halves λ_{min})

Q18. Piezoelectric transducers in medical ultrasound work on the principle of:
A) Electromagnetic induction
B) Photoelectric effect
C) Conversion between electrical energy and mechanical vibration
D) Nuclear magnetic resonance
Answer: C) Conversion between electrical energy and mechanical vibration

Q19. The depth of a structure detected by ultrasound is calculated using:
A) $d = v \times t$
B) $d = v \times t / 2$
C) $d = f / v$
D) $d = \lambda \times f$
Answer: B) $d = v \times t / 2$ (time for pulse to travel to and return from structure)

Q20. Which of the following limits the resolution of an ultrasound image?
A) The colour of the transducer
B) The wavelength of the ultrasound used
C) The voltage applied to the X-ray tube
D) The mass of the patient
Answer: B) The wavelength of the ultrasound used

SECTION B: Short Questions & Answers

Q1. What is the piezoelectric effect? (SLO P-12-F-61)

The piezoelectric effect is the property of certain crystals (e.g., quartz, PZT) to generate an electric voltage when mechanical stress (compression or tension) is applied to them, and conversely to vibrate mechanically when an alternating electric field is applied. This makes them useful as both emitters and detectors of ultrasound.

Q2. How is a piezoelectric transducer used to generate ultrasound waves?

An alternating electric voltage at ultrasonic frequency is applied across the piezoelectric crystal. This causes the crystal to vibrate mechanically at the same frequency, generating ultrasound waves. When ultrasound echoes return, they make the crystal vibrate again, producing a detectable voltage – so the same transducer acts as both sender and receiver.

Q3. How does ultrasound help obtain diagnostic information about internal body structures? (SLO P-12-F-62)

Ultrasound pulses are transmitted into the body. At every boundary between tissues of different acoustic impedance (e.g., muscle-bone), part of the pulse is reflected as an echo. The time taken for echoes to return is used to calculate the depth of structures ($d = vt/2$). These echoes are processed to build up a 2D image (B-scan) showing internal organs, tissues, and abnormalities.

Q4. State two advantages of ultrasound over X-rays for medical imaging.

1) Ultrasound is non-ionising so it does not damage DNA or cells, making it safe for repeated use and in pregnancy.

2) Ultrasound can distinguish between soft-tissue structures (e.g., liver, kidney) that appear similar on X-rays, and can also show movement (e.g., a beating heart) in real time.

Q5. How are X-rays produced in an X-ray tube? (SLO P-12-F-63)

In an X-ray tube, electrons are emitted from a heated cathode (thermionic emission) and accelerated through a high potential difference toward a metal anode (target, often tungsten). When the fast-moving electrons decelerate rapidly upon hitting the target, they lose kinetic energy which is emitted as X-rays (Bremsstrahlung radiation). Some electrons also knock inner-shell electrons out of target atoms, producing characteristic X-rays.

Q6. Derive the expression for the minimum wavelength of X-rays produced. (SLO P-12-F-63)

The maximum kinetic energy gained by an electron accelerated through P.d. V is:

$KE = eV$

At minimum wavelength, all this energy converts to one X-ray photon:

$eV = hf_{max} = hc / \lambda_{min}$

Therefore: $\lambda_{min} = hc / eV$

(where $h = 6.63 \times 10^{-34}$ J·s, $c = 3 \times 10^{8}$ m/s, $e = 1.6 \times 10^{-19}$ C)

Q7. What is meant by contrast in X-ray imaging? (SLO P-12-F-64)

Contrast in X-ray imaging is the difference in darkness (optical density) between adjacent regions of an image. High contrast means structures stand out clearly from their surroundings. Bone has high contrast against soft tissue because it absorbs X-rays much more strongly. Contrast can be artificially enhanced using contrast agents such as barium (for GI tract) or iodine-based dyes (for blood vessels).

Q8. Why is bone visible on an X-ray image while soft tissue is not clearly visible?

Bone contains calcium, which has a high atomic number and therefore a high X-ray absorption coefficient. Bone absorbs most of the incident X-rays, allowing few to reach the film/detector, creating a bright (white) area. Soft tissue has a lower density and lower atomic number, so it absorbs fewer X-rays and appears darker (greyer) on the image, giving poor contrast between different soft tissues.

Q9. How does Computed Tomography (CT) scanning work? (SLO P-12-F-65)

In CT scanning, an X-ray tube and an array of detectors rotate around the patient, taking hundreds of X-ray images from different angles in a thin cross-sectional 'slice'. A computer processes these using back-projection algorithms to reconstruct a detailed 2D cross-sectional image (tomogram) of that slice. Multiple slices can be stacked to build a 3D image of internal structures, providing far greater detail than a conventional X-ray.

Q10. State two advantages of CT scanning over conventional X-ray imaging.

1) CT provides detailed cross-sectional (3D) images of soft tissues, blood vessels, and organs, whereas conventional X-rays produce only a 2D shadow image with poor soft-tissue contrast.

2) CT can detect small differences in density between different soft tissues (e.g., tumours vs. normal tissue) that would be invisible on a plain X-ray.