1. A piezo-electric crystal:

   ☐ conducts current in one direction only

   ☐ only emits light

   ☐ stores charge like a battery

   ☐ changes shape with a p.d., and makes an e.m.f. when squeezed

2. X-rays are produced when fast electrons:

   ☐ are heated gently

   ☐ hit a metal target and slow down sharply

   ☐ travel through glass

   ☐ pass through a magnet

3. A PET tracer is:

   ☐ an ultrasound gel spread on the skin

   ☐ a strong magnet placed near the organ

   ☐ a positron (β^+) emitter taken up by active tissue

   ☐ an X-ray source swallowed by the patient

4. An echo returns after 2.0×10^{-4} s; the speed of sound is 1500 $\dfrac{\text{m}}{\text{s}}$. How deep is the boundary?

   _____ m

5. Most of the electrons' kinetic energy in an X-ray tube becomes heat, not X-rays.

   ☐ True ☐ False

6. Why is a tracer's half-life chosen as a compromise? Select **all** that apply.

   ☐ long enough that it has not decayed before reaching the tissue

   ☐ long enough to stay in the body for later scans

   ☐ short enough that the patient's dose after the scan is small

   ☐ short enough that the activity is high during the scan

   Tick every correct option.

7. An ultrasound pulse returns 60 μs after transmission, with a speed of sound of 1500 $\dfrac{\text{m}}{\text{s}}$. How deep is the boundary, in cm?

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8. The minimum X-ray wavelength from a tube at accelerating voltage V is:

   ☐ $hceV$

   ☐ $\dfrac{eV}{hc}$

   ☐ $\dfrac{h}{eV}$

   ☐ $\dfrac{hc}{eV}$

9. When the emitted positron meets an electron, they:

   ☐ form a stable atom

   ☐ do nothing

   ☐ bounce off each other

   ☐ annihilate into two photons

10. A higher ultrasound frequency has which effects? Select **all** that apply.

    ☐ stronger attenuation, so less penetration

    ☐ better resolution

    ☐ a larger reflection at every boundary

    ☐ a shorter wavelength

    Tick every correct option.

1. **changes shape with a p.d., and makes an e.m.f. when squeezed**

   Both effects let one crystal send ultrasound (apply p.d.) and detect it (read the e.m.f.).

2. **hit a metal target and slow down sharply**

   The sudden deceleration on the target gives out X-ray photons (Bremsstrahlung).

3. **a positron (β^+) emitter taken up by active tissue**

   It is a β^+ emitter on a molecule (like glucose) that active tissue absorbs more of.

4. **0.15 m**

   $d = \dfrac{ct}{2} = \dfrac{1500 \times 2.0 \times 10^{-4}}{2} = 0.15$ m (the pulse travels there and back).

5. **True**

   Only a small fraction becomes X-rays – which is why the target must be cooled.

6. **long enough that it has not decayed before reaching the tissue; short enough that the patient's dose after the scan is small; short enough that the activity is high during the scan**

   Fluorine-18 has 110 minutes; oxygen-15 has only 2 and must be made on the spot. Leaving activity in the patient afterwards is the thing to avoid, not to aim for.

7. **4.5**

   $d = \dfrac{ct}{2} = 4.5$ cm. Halve it: the pulse travelled there AND back. Forgetting the 2 gives 9.0 cm.

8. $\dfrac{hc}{eV}$

   From $hf_{\max} = eV$ and $c = f\lambda$: $\lambda_{\min} = \dfrac{hc}{eV}$.

9. **annihilate into two photons**

   Matter and antimatter annihilate: their mass turns into two photons.

10. **stronger attenuation, so less penetration; better resolution; a shorter wavelength**

    Reflection is set by the impedance mismatch, not the frequency. The frequency choice is a resolution-against-penetration compromise, so a deep organ is scanned at a lower frequency.

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