Solutions

Each answer shows the steps, then the **result**.

2.1

- a heated **cathode** emits electrons (thermionic emission)
- a high p.d. accelerates them onto a metal **target**, where they decelerate and emit X-rays

2.2

- $\lambda_{\text{min}} = hc/(eV)$

2.3

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

2.4

- the **difference in brightness** between structures (e.g. bone vs soft tissue) caused by their different absorption of X-rays

3.1 B

- λ_{min} is set by the **accelerating p.d.**

3.2

- $\lambda_{\text{min}} = hc/(eV)$

$$\lambda_{\text{min}} = \frac{(6.63 \times 10^{-34}\ \text{J s})(3.0 \times 10^{8}\ \text{m s}^{-1})}{(1.6 \times 10^{-19}\ \text{C})(50\,000\ \text{V})} = \mathbf{2.5 \times 10^{-11}}\ \text{m}$$

3.3

- take many X-ray images of one **slice** from **different angles** and combine them into a 2D image of that slice
- repeat for many slices **along the body**
- stack the slices to build a **3D** image

3.4

(a) **bremsstrahlung** (braking radiation), where an electron is decelerated by a target nucleus

- **characteristic** X-ray emission, where an inner-shell electron is knocked out and an outer electron falls in to replace it
- bremsstrahlung gives the **continuous** spectrum; the characteristic process gives the sharp spikes on top of it

(b) the most energetic photon possible is produced when an electron gives up **all** of its kinetic energy in a single interaction

- no photon can carry more energy than that, and a maximum energy means a **minimum** wavelength

(c) $eV = hc/\lambda_{\text{min}}$

$$\lambda_{\text{min}} = \frac{(6.63 \times 10^{-34}\ \text{J s})(3.00 \times 10^{8}\ \text{m s}^{-1})}{(1.60 \times 10^{-19}\ \text{C})(5800\ \text{V})} = \mathbf{2.1 \times 10^{-10}}\ \text{m}$$

(d) $I/I_0 = e^{-\mu x}$ with $\mu x = 1.4 \times 2.8 = 3.92$

$$I/I_0 = e^{-3.92} = 0.0198$$

- the fraction **absorbed** is $1 - 0.0198$, i.e. 98%

(e) soft tissues have very similar attenuation coefficients, so they absorb almost equally and the image shows little contrast between them

- barium has a much higher atomic number and absorbs far more strongly, so an organ filled with it stands out sharply against the tissue around it