inkPhysics

ANSWER BOOK

X-rays and CT scanning

Medical physics · Year 13

AQA 3.10.5 · CIE 24.2 · OCR A 6.5.1

12 questions · 34 marks

NAVY EDITION

SECTION A · Warm-up

A1 Electrons are released from a heated cathode by thermionic emission and accelerated through a large pd towards a metal target. When they decelerate rapidly in the target, part of their kinetic energy is radiated as X-ray photons; most of the rest becomes heat in the target. [3]

A2 $E_{max} = eV = 1.60 \times 10^{-19} \times 65\,000 = 1.04 \times 10^{-14}$ J. No photon can carry more energy than one electron brought across the tube. [2]

A3 $I = I_0e^{(-\mu x)}$, where I_0 is the incident intensity, I the intensity after passing through thickness x of material, and μ the attenuation coefficient of that material. [2]

SECTION B · Standard

B1 $E_{max} = eV = 1.60 \times 10^{-14}$ J, and $\lambda_{min} = hc/E_{max} = (6.63 \times 10^{-34} \times 3.00 \times 10^{8})/(1.60 \times 10^{-14}) = 1.24 \times 10^{-11}$ m $\approx 1.2 \times 10^{-11}$ m. [3]

B2 $I/I_0 = e^{-\mu x} = e^{-0.21} \times 4.0 = 0.43$, about 43%. [3]

B3 Raising the voltage raises the maximum photon energy, making the beam more penetrating (harder). Raising the current increases the number of electrons per second, so more photons are produced and the beam is more intense, with the photon energies unchanged. [2]

B4 $e^{-\mu x} = 0.5$ gives $x = \ln 2/\mu = 0.693/0.60 = 1.2$ cm. [3]

B5 Contrast comes from differences in attenuation coefficient. Bone's μ is much larger than soft tissue's, so bone transmits far less intensity and throws a sharp shadow. Neighbouring soft tissues have similar μ and transmit almost equally, so they are nearly indistinguishable. A contrast medium such as a barium compound is a strong absorber swallowed into the organ, painting its outline into the image. [3]

SECTION C · Stretch

C1 $e^{-\mu x} = 0.1$ gives $x = \ln 10/\mu = 2.303/0.35 = 6.6$ cm. [3]

C2 The X-ray tube and detectors rotate around the patient, measuring attenuation along very many directions through one slice. A computer reconstructs the map of attenuation coefficient across the slice that is consistent with all the measurements, giving a cross-sectional image; stacked slices give three dimensions. Advantage: structures are not superimposed, and soft tissues can be distinguished. Disadvantage: many exposures give a much larger radiation dose than a single film. [4]

C3 $E_{max} = eV = 1.60 \times 10^{-19} \times 120\,000 = 1.92 \times 10^{-14}$ J. Electrons per second = $I/e = 2.0 \times 10^{-3}/1.60 \times 10^{-19} = 1.25 \times 10^{16}$ s^{-1}. [3]

C4 It becomes heat in the target: only around one per cent of the electron energy is radiated as X-rays. The anode is made of tungsten, whose very high melting point tolerates the heating, and it is rotated so that the electron beam spreads its heating over a ring of material rather than boring into one spot. [3]