MEDICAL PHYSICS

5-2 X-rays and matter

1. (a) The half-value thickness (HVT) of a substance is the thickness required to reduce the intensity of the X-rays to 50%.

(b) (i) HVT = 15 mm for 50 keV X-rays.

$x_{1/2} = \frac{\ln 2}{\mu}$ therefore $\mu = \frac{\ln 2}{x_{1/2}} = \frac{\ln 2}{15 \times 10^{-3}}$

= 46.2....

= 46 m^{-1}

(ii) $I = I_0 e^{-\mu x}$ therefore $\frac{I}{I_0} = e^{-\mu x}$

$\frac{I}{I_0} = e^{-(4.6 \times 10 \times 10^{-3})} = e^{-0.46}$

= 0.63

Therefore 63% of the intensity remains and the reduction is 37%

2. 80 keV, $I_0 = 1.4 \times 10^{-2}$ Wm^{-2}, x = 0.50 mm = 5.0×10^{-4} m, μ = 690 m^{-1}

(a) (i) $I = I_0 e^{-\mu x} = 1.4 \times 10^{-2} \times e^{-(690 \times 5.0 \times 10^{-4})}$

$= 1.4 \times 10^{-2} \times e^{-0.345}$

= 9.9×10^{-3} Wm^{-2}

(ii) therefore energy absorbed = $(1.4 \times 10^{-2} - 9.9 \times 10^{-3})$ Wm^{-2}

= 4.1×10^{-3} Wm^{-2}

Area of the sheet = 0.10 x 0.10 = 1.0×10^{-2} m^2

Therefore, energy absorbed per second by the sheet = 4.1×10^{-3} $Wm^{-2} \times 1.0 \times 10^{-2}$ m^2

= 4.1×10^{-5} W or Js^{-1}

(b) $\frac{I}{I_0} = e^{-0.46} = 0.25 = e^{-(690 \times x)}$

-690x = ln(0.25)

$x = \frac{\ln 0.25}{-690}$

= 2.0×10^{-3} m or 2 mm

3. $\mu_m = 0.012$ m^2kg^{-1}, ρ = 2700 kgm^{-3}

(a) The mass attenuation coefficient is defined by the equation

$\mu_m = \frac{\mu}{\rho}$ where μ is the attenuation coefficient and ρ is the density of the material

(b) $\mu = \rho\mu_m$ $= 2700\ kgm^{-3} \times 0.012\ m^2kg^{-1}$

$= 32.4\ m^{-1}$

$$x_{1/2} = \frac{\ln 2}{\mu} = \frac{\ln 2}{32.4}$$

$= 0.0213....$

$= 0.021$ m to 2 sf or 21 mm

4. (a) (i) A metal filter is placed in the path of the X-ray beam in order to remove photons with an energy of less than about 30 keV which are absorbed by soft tissue as well as bone.

(ii) A suitable metal for such a filter would be copper, tin or lead.

(b) X-ray photons with an energy greater than about 100 keV are not used for X-ray imaging because all tissue types absorb them fairly equally so there would be no contrast between different types of tissue.