MEDICAL PHYSICS

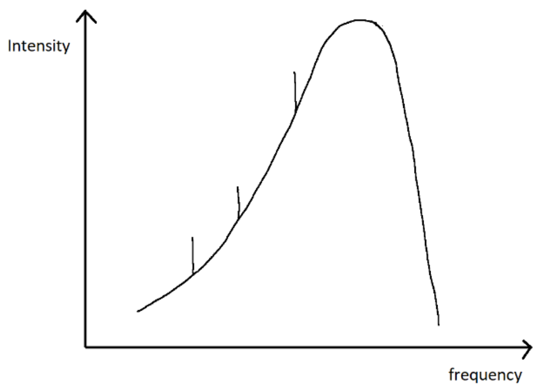
5-1 The physics of diagnostic X-rays

1. (a) (i) Heating of the filament wire produces electrons for acceleration

(ii) The anode attracts the emitted electrons which cause X-ray emission from the anode material when they impact. It is therefore the X-ray source.

(b) the focal spot on the anode is the area of the anode from which the X-rays are emitted. It needs to be as small as possible so that the image is as sharp as possible.

2. (a)



(b) (i) The photons have a maximum energy because the potential and hence the potential difference the electrons are accelerated through is constant and the potential difference determines the maximum energy

$$hf_{max} = eV$$

corresponding to complete conversion of the work done on the electron to accelerate it and give it kinetic energy which is then converted into the photon's energy.

(ii) The electrons in the beam knock out electrons in the tungsten/copper atoms from the inner shells. When the vacancies created are filled, an X-ray photon of a specific energy and hence wavelength is emitted. Therefore at those particular wavelengths the X-ray photons are very intense.

3. (a) As electrons are negatively charged, the anode must be positively charged with respect to the electrons in order to attract and accelerate them so that they will impact on the electrode and X-rays will be emitted.

(b) (i) p.d. = 70 kV, $e = 1.6 \times 10^{-19}$ C, $h = 6.63 \times 10^{-34}$ Js

Max k.e. = $eV = 1.6 \times 10^{-19} \times 70 \times 10^{3} = 1.12 \times 10^{-14}$ J

(ii) $hf_{max} = eV$ so $f_{max} = \frac{eV}{h} = \frac{1.12 \times 10^{-14}}{6.63 \times 10^{-34}} = 1.689.... \times 10^{19}\ s^{-1} = 1.7 \times 10^{19}$ Hz to 2 sf

$C = f\lambda$ therefore $\lambda_{min} = \frac{c}{f_{max}} = \frac{3.00 \times 10^{8}}{1.7 \times 10^{19}} = 1.775... \times 10^{-11} = 1.8 \times 10^{-11}$ m to 2 sf

4. (a) p.d. = 50 kV = 50 x 10^3 V, current = 0.05 A

Power P = IV = 0.05 x 50 x 10^3 = 2500 W

(b) (i) efficiency = 1% or 1/100th (W = Js^{-1})

Energy converted to X-rays per second = $\frac{2500}{100}$ = 25 W or Js^{-1}

(ii) Heat generated at the anode = the rest of the energy

= 2500 – 25

= 2475 W or Js^{-1}

(ii) n_{core} = 1.60, $n_{cladding}$ = 1.50

Therefore the critical angle i_c is given by $\sin i_c = \frac{1.50}{1.60} = 0.9375$

$$I_c = 69.635... = 69.6° \text{ to 3 sf}$$

Assuming the external medium is air so n = 1.00

$$\sin i_{max} = \frac{1.60}{1.00} \times \sin(90 - 69.6)$$

$$\sin i_{max} = 1.60 \times \sin 20.4°$$

$$= 0.5577 \qquad \text{(0.5568 keeping calculator values)}$$

$$i_{max} = 33.897... \qquad (33.833...)$$

$$= 33.9° \text{ to 3 sf} \qquad (33.8°)$$