21. (1) Diffracted beams must be able to overlap to produce an interference pattern. ∴ 'L' needs to be large.

Also $\Delta y = \frac{\lambda L}{d}$

ie $\Delta y \propto L$. ∴ to see a pattern & to measure a fringe separation, the L needs to be relatively large.

(2) $\Delta y \propto \frac{1}{d}$.

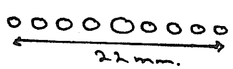
∴ To observe a 'fringe' d needs to be small.

Also, if 'd' is small the coherent beams will diffract more & ∴ will overlap over a bigger area ∴ more observable.

(3) $\Delta y \propto L$ ∴ if the screen is moved closer the fringe separation will be smaller ∴ harder to measure

(4)

(a)



The distance measured is 22mm.

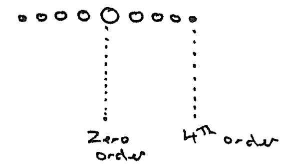
This 22mm encompasses 8 fringe separations, Δy.

$\therefore 22 = 8\Delta y$

$\therefore \Delta y = {}^{22}/_{8} = \underline{2.75\text{mm}}$

* Note: it is more accurate to measure the whole pattern and divide, by 8 in this case, than to measure one Δy value.

(b)



OPD for 4th order is 4λ.

22. Use the ruler on the photo to measure the distance between a large number of reinforcement - say 5 or 10.

Distance between 6 reinforcements is about 10 mm.

$\therefore \Delta y = {}^{10}/_{5} = 2\text{mm}.$

(remember, 6 reinforcements encompass 5 fringe separations.

1. $E = \frac{hc}{\lambda} = \frac{6.63\times10^{-34}\times 3\times10^{8}}{5.9\times10^{-7}}$

$\therefore \underline{E = 3.2\times10^{-19}\text{J}}.$

2. $E = \frac{hc}{\lambda} = \frac{6.63\times10^{-34}\times3.0\times10^{8}}{0.91\times10^{-7}}$

$= \underline{2.2\times10^{-18}\text{J}}.$

3. $\vec{p} = \frac{E}{c} = \frac{13.6\times1.6\times10^{-19}}{3\times10^{8}}$

$= \underline{7.2\times10^{-27}\text{sN}}.$

4. $p = \frac{h}{\lambda}$ ∴ $\lambda = \frac{h}{p}$

$\therefore \lambda = \frac{6.63\times10^{-34}}{2.3\times10^{-21}} = \underline{2.9\times10^{-13}\text{m}}$

$c = f\lambda$ ∴ $f = c/\lambda$

$\therefore f = \frac{3.0\times10^{8}}{2.9\times10^{-13}}$

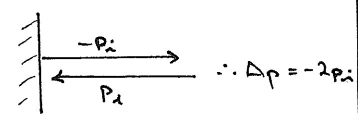
$\underline{f = 1.03\times10^{21}\text{ Hz}}.$

$E_\lambda = hf = 6.63\times10^{-34}\times1.03\times10^{21}$

$\underline{E_\lambda = 6.9\times10^{-13}\text{J} = 4.3\text{MeV}}$

5. $p = \frac{h}{\lambda} = \frac{6.63\times10^{-34}}{0.45\times10^{-7}}$

$= \underline{1.47\times10^{-26}\text{sN}}.$



$\therefore \Delta p = -2p_i$

$\therefore \Delta p = -2p_i$

$= 2.94\times10^{-26}\text{sN}$

away from the wall.

6. Red ←→ violet

$\lambda = 750\text{nm}$ $\lambda = 400\text{nm}$

Red $p = \frac{h}{\lambda} = \frac{6.63\times10^{-34}}{7.5\times10^{-7}}$

$\underline{p = 8.8\times10^{-28}\text{sN}}.$

Violet $p = \frac{h}{\lambda} = \frac{6.63\times10^{-34}}{4.0\times10^{-7}}$

$\underline{p = 1.66\times10^{-27}\text{sN}}.$

7. (1) $c = f\lambda$ ∴ $\lambda = \frac{c}{f}$

$\lambda = \frac{3.0\times10^{8}}{7.0\times10^{14}} = \underline{4.3\times10^{-7}\text{m}}$

(2) $p = \frac{h}{\lambda} = \frac{6.63\times10^{-34}}{4.3\times10^{-7}}$

$\underline{p = 1.54\times10^{-27}\text{sN}}.$

(3) $p_i = p_f$ ∴ $p_f = p_e$

$\therefore p_e = 1.54\times10^{-27} = mv$

$\therefore v = \frac{1.54\times10^{-27}}{9.11\times10^{-31}}$

$\underline{v = 1.7\times10^{3}\text{ ms}^{-1}}.$

8. Intensity is proportional to the number of photons passing through a given area.

ie Higher intensity means more photons.

9. 60 Watts = 60 joules/sec.

En of red photon $= \frac{hc}{\lambda}$

$\therefore E_\lambda = 2.8\times10^{-19}\text{ J}.$

∴ Number of photons = total energy ÷ energy of photon

$= \frac{60}{2.8\times10^{-19}} = 2.14\times10^{20}$ per sec.

9. (cont)

$\therefore 2.14\times10^{20}$ /sec.

$= 2.14\times10^{20}\times60\times60$ /hour

$= 7.7\times10^{23}$ /hour.

10. P.E effect is the ejection of electrons from a metal surface by light photons.

11. Minimum frequency photons that will eject photo-electrons from a metal surface.

. No! – different metals have different f_0 values.

12. Photo-electric equation

$K = hf - W$.

$\therefore K = \left(\frac{6.63\times10^{-34}\times3\times10^{8}}{3.81\times10^{-7}}\right) - W$

$[W = 2.1\times1.6\times10^{-19} = 3.36\times10^{-19}\text{ J}]$

$\therefore K = 1.86\times10^{-19}$ J.

$\therefore$ electrons will be ejected (ie K is positive)

13. (1) $W = hf_0$

$\therefore f_0 = \frac{W}{h} = \frac{2.32\times1.6\times10^{-19}}{6.63\times10^{-34}}$

$f_0 = 5.6\times10^{14}$ Hz.

(2)

$K = hf - W = \frac{hc}{\lambda} - W$

$K = 5.1\times10^{-19} - 3.7\times10^{-19}$

$\therefore K = 1.4\times10^{-19}$ J.

14. Maximum speed electrons will be produced by the highest energy photons ie violet ($\lambda = 400$ nm)

$\therefore K = \frac{hc}{\lambda} - W$

$= 4.97\times10^{-19} - 2.32\times1.6\times10^{-19}$

$= 1.26\times10^{-19}$ J

$\therefore 1.26\times10^{-19} = \frac{1}{2}mv^2$

$\therefore 1.26\times10^{-19} = \frac{1}{2}\times9.11\times10^{-31}v^2$

$\therefore v = 5.3\times10^{5}\text{ ms}^{-1}$.

15. (1) $W = hf_0 \quad \therefore f_0 = \frac{W}{h}$

$f_0 = \frac{4.2\times1.6\times10^{-19}}{6.63\times10^{-34}}$

$f_0 = 1.0\times10^{15}$ Hz

(2) $K = \frac{hc}{\lambda} - W$

$\therefore K = \frac{6.63\times10^{-34}\times3\times10^{8}}{0.9\times10^{-7}} - 4.2\times1.6\times10^{-19}$

$K = 1.54\times10^{-18}$ J.

(3) Some ejected electrons lose KE due to collisions with other atoms & electrons after they are released by the incoming photons.

(4) $E_n = \Delta V_s q$

$\therefore \Delta V_s = \frac{1.54\times10^{-18}}{1.6\times10^{-19}} = 9.6$ Volts

16. See text.

17. $W = 2.3$ eV

$\therefore W = 2.3\times1.6\times10^{-19}$

$= 3.68\times10^{-19}$ J.

E_n of photon $= \frac{hc}{\lambda}$

$\therefore E_n = \frac{6.63\times10^{-34}\times3\times10^{8}}{5.8\times10^{-7}}$

$= 3.43\times10^{-19}$ J.

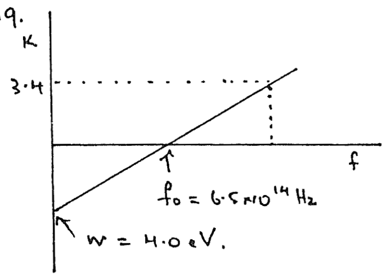
Thus the photon energy is not enough to overcome the work function $\therefore$ electrons will not be emitted.

18. (1) Intensity increase increases the number of photons, all still having the same energy; and if they are not energetic enough to overcome the work function at low intensity they still will not be at high intensity.

PE effect is a one photon – one electron interaction.

(2) The number of electrons emitted only $\therefore$ the photo-current.

19.



(2) Slope $= h = \frac{\text{rise}}{\text{run}}$

$\therefore h = \frac{[3.4\times1.6\times10^{-19}] - 0}{[12.2 - 6.5]\times10^{14}}$

$h = 9.5\times10^{-34}$ Js.

20 (1) See text

(2) • Density needs to be high to stop electrons

• High melting point – most electron energy lost as heat.

(3) Most of the electron energy is converted to heat by target collisions $\therefore$ target might melt if not cooled.

21 (1) see text

(2) See text.

22. (1) $K = \Delta Vq$

$K = 60{,}000\times1.6\times10^{-19}$

$K = 9.6\times10^{-15}$ J.

(2) $K = hf_{max}$.

$\therefore f_{max} = K/h = \frac{9.6\times10^{-15}}{6.63\times10^{-34}}$

$\therefore f_{max} = 1.45\times10^{19}$ Hz.

(3) $p = \frac{E_n}{c} = \frac{9.6\times10^{-15}}{3\times10^{8}}$

$p = 3.2\times10^{-23}$ sN.

23. (1) $\Delta V q = \frac{1}{2}mv^2$

$\therefore v = \sqrt{\frac{2\Delta V q}{m}}$

$\therefore v = \sqrt{\frac{2 \times 50{,}000 \times 1.6 \times 10^{-19}}{9.11 \times 10^{-31}}}$

$v = 1.3 \times 10^{8}\ ms^{-1}$

(2) $\text{Power} = \frac{E_n}{\text{time}}$

$P = \frac{10^{15} \times 8 \times 10^{-15}}{1} \times \frac{98}{100}$

$P = 7.84$ watts.

(3) Increase the current in the filament ∴ more electrons emitted ∴ more target hits ∴ more X-ray photons.

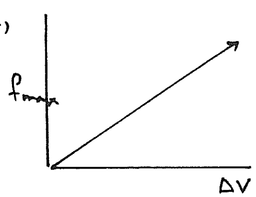
24. (1) Energy of electron $= \Delta V q \equiv \Delta V e$.

Now if all the electron's energy is transferred as a photon then

$\Delta V e = h f_{max}$.

$\therefore f_{max} = \frac{\Delta V e}{h}$.

(2)



Straight line as $f_{max} \propto \Delta V$

(3) Slope $= e/h$.

25. (1) 'Hard' X-rays are X-rays with high penetrating power & hence high photon energies and frequencies.

(2) Hard X-rays are produced in X-ray tubes by high accelerating voltages ie 100,000 V

(3) The degree of absorption of X-rays by body tissue is called the attenuation of the X rays.

1. (1) $\lambda = \frac{h}{mv} = \frac{6.63 \times 10^{-34}}{60 \times 20}$

$\lambda = 5.5 \times 10^{-37}$ m.

(2) $\lambda = \frac{h}{mv} = \frac{6.63 \times 10^{-34}}{1.675 \times 10^{-27} \times 1 \times 10^{6}}$

$\lambda = 3.9 \times 10^{-13}$ m

(3) $6.0\ eV = 9.6 \times 10^{-19}$ J.

$\therefore K = \frac{1}{2}mv^2 = 9.6 \times 10^{-19}$

$\therefore v = \sqrt{\frac{9.6 \times 10^{-19} \times 2}{9.11 \times 10^{-31}}}$

$v = 1.45 \times 10^{6}\ ms^{-1}$

$\therefore \lambda = \frac{h}{mv} = \frac{6.63 \times 10^{-34}}{9.11 \times 10^{-31} \times 1.45 \times 10^{6}}$

$\lambda = 5.0 \times 10^{-10}$ m.

2. (1) $a = \frac{\Delta v}{\Delta t}$

$\therefore a = \frac{17.1 \times 10^{6}}{1 \times 10^{-6}}$

$a = 1.71 \times 10^{13}\ ms^{-2}$

$\therefore F = ma$

$= 9.11 \times 10^{-31} \times 1.71 \times 10^{13}$

$F = 1.56 \times 10^{-17}$ N

(2) $\lambda_1 = \frac{h}{mv_1}$

$\lambda_2 = \frac{h}{mv_2}$

$\lambda_1 = 3.8 \times 10^{-11}$ m

$\lambda_2 = 3.8 \times 10^{-10}$ m

$\therefore \Delta\lambda = 3.42 \times 10^{-10}$ m

ie $\lambda_{deBroglie}$ increases as it slows down.

3. (1) $K = \Delta V q$

$K = 20{,}000 \times 1.6 \times 10^{-19}$

$K = 3.2 \times 10^{-15}$ J.

(2) $\lambda = \frac{h}{mv}$

$\lambda = \frac{6.63 \times 10^{-34}}{9.11 \times 10^{-31} \times v}$

$\left[v = \sqrt{\frac{2E_k}{m}} \right]$

$v = 8.4 \times 10^{7}\ ms^{-1}$

$\therefore \lambda = 8.7 \times 10^{-12}$ m

(3) $\lambda = \frac{h}{mv}$

$\therefore \lambda \propto \frac{1}{v}$

∴ as electrons accelerate v increases ∴ λ decreases.

4. (1) You do! However, as your $\lambda_{deBroglie}$ is very small your diffraction is difficult to detect.

(2) In a diffraction grating the slit width is smaller than in a 2-slit setup. The 'd' value is closer to the wavelength of light ∴ light diffracts more.

(3) Electrons have a similar wavelength to the crystal spacings ∴ they show 'good' diffraction.