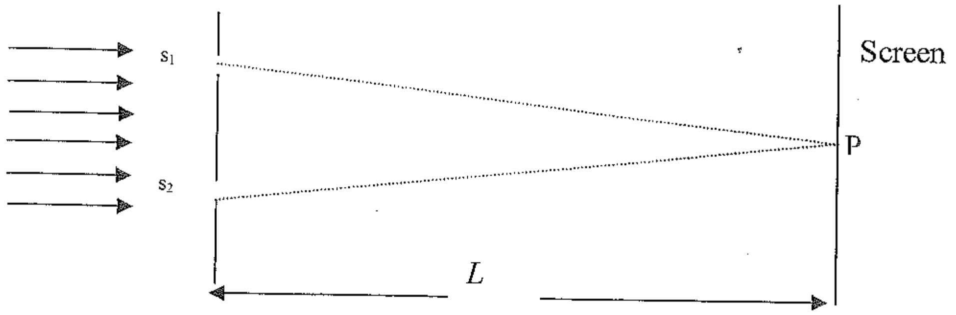
1. The interference pattern of two identical slits separated by a distance d =0.25 mm is observed on a screen at a distance L of 0.32 m from the plane of the slits. The slits are illuminated by monochromatic light of wavelength 589.3 nm travelling perpendicular to the plane of the slits. Bright bands are observed on each side of the central maximum P.



a. Calculate the distance between adjacent maxima of the interference pattern that would be observed at the screen

$\Delta y = \frac{\lambda L}{d} = \frac{589.3 \times 10^{-9} \times 0.32}{2.5 \times 10^{-4}} = 7.54 \times 10^{-4}$ m

[2 marks]

b. Point P is the same distance from both light sources. Comment on the intensity of light that occurs at point P and explain why this is so.

Central maxima (P) has the greatest intensity of light
Intensity of light decreases with distance, P is the bright fringe with minimum total distance from the light source.

[2 marks]

c. In a similar arrangement of apparatus, an experiment was conducted for which L = 1.0 m and d =0.10 cm, the bright fringes were 0.5 mm apart. What wavelength of light was being used?

$\Delta y = \frac{\lambda L}{d}$ $\quad \frac{d \Delta y}{L} = \lambda$ $\quad \frac{1 \times 10^{-3} \times 5 \times 10^{-4}}{1}$

$= 5 \times 10^{-7}$

$= 500$ nm

[2 marks]

d. The colours seen in the two slit interference pattern when white light is the source are sometimes mistaken for the spectra of visible light also referred to as the rainbow colours. Explain why this is not possible with a two slit interference pattern.

larger wavelengths of light diffract more than smaller ones. The maxima of the different wavelengths of light will therefore begin to overlap

[2 marks]

2. White light is incident on a diffraction grating with 300 lines per mm. A third order spectrum is observed to overlap a second order spectrum on a screen placed at a distance of 1.2 m from the grating. Given that the wavelength of a third order colour is 450 nm,

a. calculate the wavelength of the light for the second order that overlaps it.

300 lines/mm ∴ $d = 1/300000 = 3.33 \times 10^{-6}$

$m = 3$

$\lambda = 4.5 \times 10^{-7}$ $\lambda = \frac{d \sin\theta}{m}$

$\sin\theta = \frac{m\lambda}{d} = \frac{3 \times 4.5 \times 10^{-7}}{3.33 \times 10^{-6}}$ ∴ $\theta = 23.89°$ $\lambda = \frac{3.33 \times 10^{-6} \times \sin 23.89}{2}$

∴ $\lambda = 6.75 \times 10^{-7} = 675$ nm

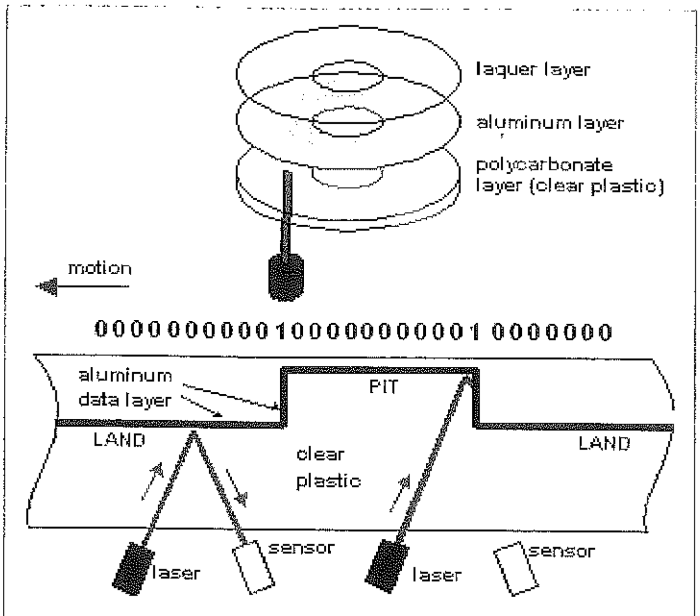
[2 marks]

b. determine the angle at which the two wavelengths of light overlap on the screen.

[3 marks]

$\frac{m\lambda}{d} = \frac{m\lambda}{d}$ $\frac{m\lambda}{d} = \frac{m\lambda}{d}$

5. The diagram Reading CD's and CD ROMS provided shows the surface of a CD with binary code (000100100) for the pattern of a series of bumps.



Reading CDs and CD-ROMs

173.5 nm

a) What is occurring where the binary code 1 is assigned?

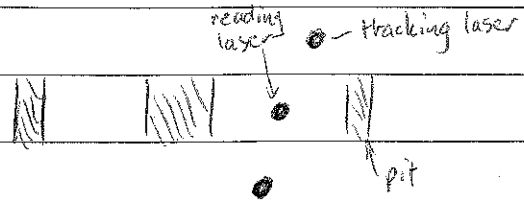
change from pit to land. [1 mark]

b) Explain how a laser light wavelength = 694 nm is used to read the binary code 1and binary code 0. Add quantitative information onto the diagram.

The height of the pit is 173.5nm, which is 1/4 the wavelength of the laser used.
When the laser hits the boundary between the land + pit there is a path difference between them.
The p.d. is twice the height of the pit
ie $2 \times \frac{1}{4}\lambda = \frac{\lambda}{2}$
As the p.d. is $\lambda/2$ destructive interference occurs and the reading at the sensor will change.

[3 marks]

c) Describe with a diagram how a laser detects it is off track when reading the CD.



The laser beam is split via a diffraction grating.
The central beam reads the bumps / pits
The two side beams travel between the path of bumps / pits.
If either records a change in intensity due to being off course the laser is redirected to its proper position

[4 marks]

6. In a laboratory experiment, Ultra Violet light with a photon energy E of 4.6 eV is incident on a metal with a known work function W of 1.8 eV.

a. Calculate the threshold frequency f_o for this metal.

$W = hf_o$

$f_o = \frac{W}{h}$

$= \frac{1.8 \times 1.6 \times 10^{-19}}{6.63 \times 10^{-34}}$

$= 4.34 \times 10^{14}$

[2 marks]

b. Determine the stopping voltage V_s for the photoelectrons released from the metal.

~~K = hf ...~~

$K_{max} = V_s q$

$K = 4.6 - 1.8 \text{ eV}$

$= 2.8 \text{ eV}$

$\frac{2.8 \times 1.6 \times 10^{-19}}{1.6 \times 10^{-19}} = V_s$

$V_s = 2.8$

[2 marks]

c. Calculate the frequency f of the incident light.

$E = hf$

$f = \frac{E}{h} = \frac{4.6 \times 1.6 \times 10^{-19}}{6.63 \times 10^{-34}}$

$f = 1.11 \times 10^{15}$ hz

[2 marks]

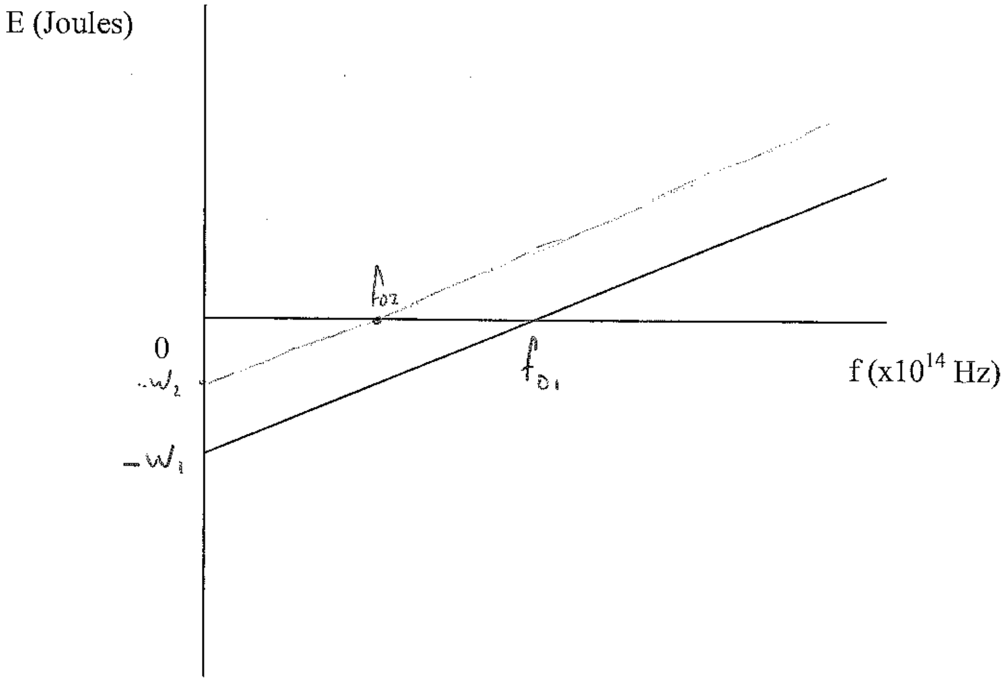
d. A range of photon energies were used to plot a graph for energy against frequency for the metal and a line of best fit was drawn as shown.

i) Label the work function W and the threshold frequency f_o for the metal.

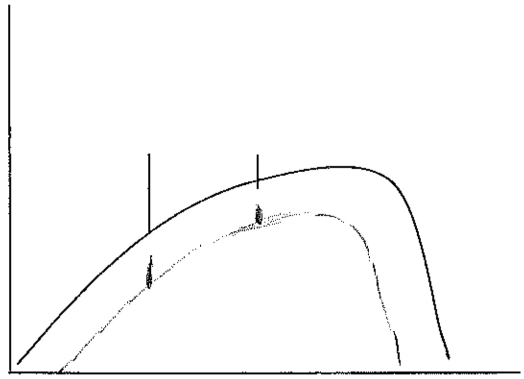
[2 marks]

ii) Sketch a line graph on the same axes for a metal with a smaller work function.

[2 marks]



7. Consider the typical intensity graphs for the X-rays emitted from an X-ray tube with accelerating potential of 70kV.



a. Explain the continuous range of frequencies and the sharp peaks in the spectrum of x-rays.

When electrons hit the anode they are decellerated by the electric field.
Each electron will be decelerated by a different amount and hence will have different amounts of energy.
As the ~~el~~ electrons have different amounts of energy the photons produced will have a range of frequencies ($E=hf$)

[4 marks]

b. The accelerating voltage was reduced with all other factors remaining constant. On the axes system shown above, sketch the graph that would result from the reduction.

[2 marks]

c. Determine the minimum accelerating voltage for an electron to produce an x-ray photon of wavelength 2.160 x10^{-11}.

$\lambda = 2.160 \times 10^{-11}$

$\Delta V = \frac{hc}{q\lambda} = \frac{6.63\times10^{-34}\times3\times10^{8}}{1.6\times10^{-19}\times2.16\times10^{-11}}$

$q\Delta V = hf$ $f = \frac{q\Delta V}{h}$ = ~~[illegible]~~

$f = c/\lambda$ $q\Delta V = \frac{hc}{\lambda}$ ~~$\lambda = \frac{hc}{q\Delta V}$~~ ~~$\frac{6.63\times10^{-34}\times3\times10^{8}}{1.6\times10^{-19}\times}$~~

[3 marks]

57 552 V

57.5 kV

8. It is proposed to send a beam of electrons travelling at a speed of 4.0×10^6 ms^{-1} through a crystal with the spacing between the atoms being $d = 3.0 \times 10^{-10}$ m.

a. Find the wavelength of the electrons.

$p = mv$

$mv = \frac{h}{\lambda}$

$\lambda = \frac{h}{mv} = \frac{6.63\times10^{-34}}{9.11\times10^{-31} \times 4\times10^{6}}$

$= 1.8 \times 10^{-10}$ m

[3 mark]

b. Determine the first order angle of diffraction for the electron beam.

$d \sin\theta = m\lambda$

$\theta = \sin^{-1}\left(\frac{m\lambda}{d}\right)$

$= 37.3^{\circ}$

[2 marks]

c. Explain why there is only one possible order for the beam of electrons and crystal arrangement described above.

if $m \geq 2$ then $\frac{m\lambda}{d} > 1$, ∴ impossible.

[2 marks]

d. Explain why electron microscopes achieve a much higher resolution than optical microscopes.

smaller wavelength ⇒ smaller resolution

[2 marks]