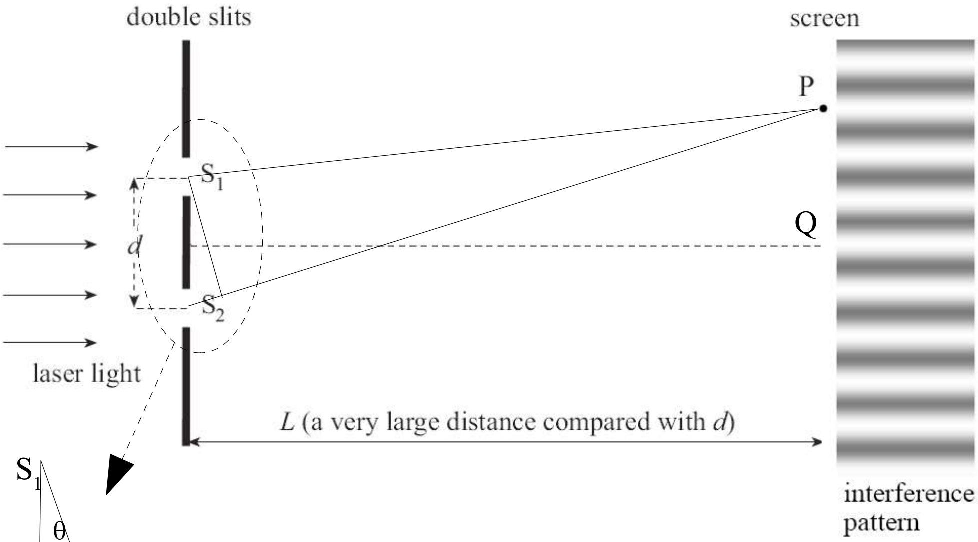
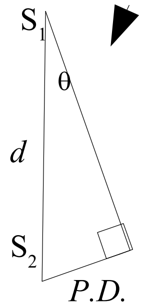
Year 12 Physics - Light and Waves **SOLUTIONS**

Wave Behaviour of Light, Photoelectric Effect, Wave Behaviour of Particles

1. (a) Vertical
   (b) Vertical

2. (a) (i)



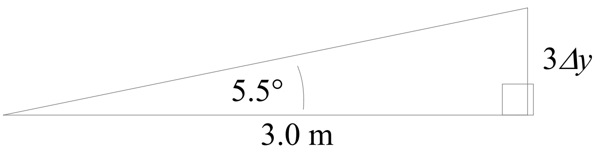


The path difference between the light coming from each of the slits is P.D. = $S_2P - S_1P$.
As as d << L, lines S_1P and S_2P are nearly parallel, so a right angled triangle can be constructed as shown. From the triangle, $\sin\theta = \frac{P.D.}{d}$ which leads to the path difference $P.D. = d \sin \theta$.

(ii) 3λ

(iii) The waves that meet at point P have a path difference which is a whole number of wavelengths. Since the sources are in phase (due to laser light) the waves meet at point P will be in phase and therefore constructively interfere to produce a wave the sum of amplitudes of the individual waves.

(iv)



$$\tan(5.5°) = \frac{3\Delta y}{3.0}$$

$$\therefore \Delta y = \tan(5.5°) = 9.6\times10^{-2}\ \text{m}$$

or

$$\Delta y = \frac{\lambda L}{d} = \frac{\frac{1}{3} d\sin\theta L}{d} \quad \{\text{since } d\sin\theta = 3\lambda\}$$

$$= \frac{L\sin\theta}{3} = \frac{3.0\sin 5.5°}{3} = 9.6\times10^{-2}\ \text{m}$$

angle too large for this formula

(v) $d\sin\theta = m\lambda$

$$\therefore \lambda = \frac{d\sin\theta}{m} = \frac{2.0\times10^{-5}\times\sin(5.5°)}{3} = 6.4\times10^{-7}\ \text{m}$$

or

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

$$\therefore \lambda = \frac{d\Delta y}{L} = \frac{2.0\times10^{-5}\times9.6\times10^{-2}}{3} = 6.4\times10^{-7}\ \text{m}$$

(b) The light will need to be passed through a single slit before it passes through the double slit.

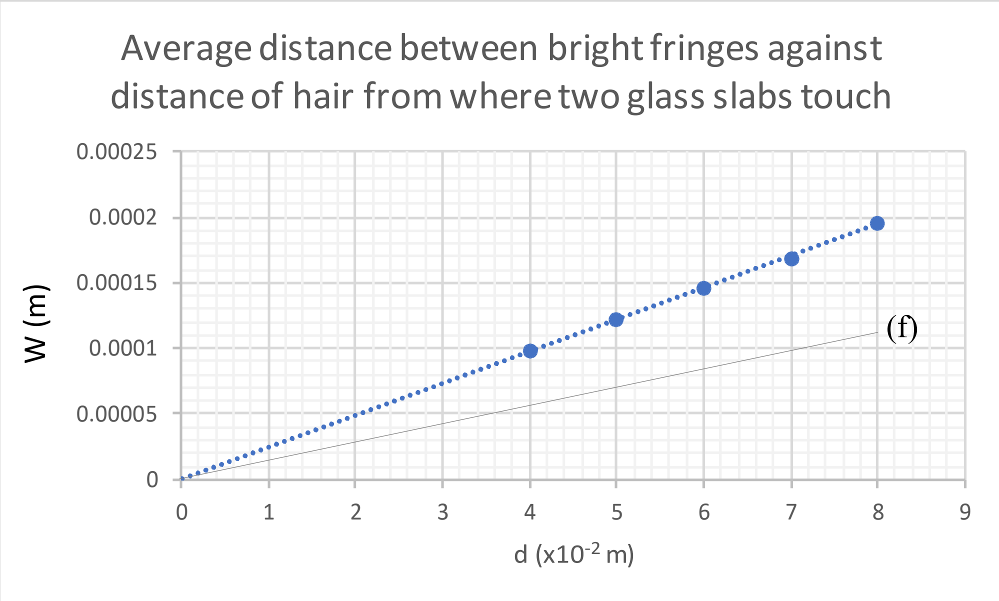
(c) The charges in the filament of an incandescent light vibrate randomly, meaning the waves given off do not have a constant phase relationship so they are not coherent, and have random frequencies so are not monochromatic.

3. (a) Reduces the effect of random error.

(b) 9.80×10^{-5}
1.2×10^{-4}
1.5×10^{-4}
1.7×10^{-4}
2.0×10^{-4}

(c)(i) *d*, because that's the variable being directly changed (manipulated)

(ii) *(graph should fill the page)*



(d) *(working on graph must show points chosen for rise/run are far apart on line of best fit)*
2.5×10^{-3} m/m

(e) $W = \dfrac{\lambda}{2t} d$

$\therefore \dfrac{\lambda}{2t} = \text{gradient}$

$\therefore t = \dfrac{\lambda}{2 \times \text{gradient}} = \dfrac{589 \times 10^{-9}}{2 \times 2.5 \times 10^{-3}} = 1.2 \times 10^{-4}\ \text{m}$

4. (a) $N = 600$ lines/mm = 600000 lines/m

$d = \dfrac{1}{N} = \dfrac{1}{600000} = 1.67 \times 10^{-6}\ \text{m}$

$d \sin\theta = m\lambda$

$\therefore m = \dfrac{d \sin\theta}{\lambda} = \dfrac{d}{\lambda}$ $\quad \{\text{since } \theta = 90° \text{ for maximum angle and } \sin(90°) = 1\}$

$\therefore m = \dfrac{1.67 \times 10^{-6}}{4.9 \times 10^{-7}} = 3.4$

There would a maximum of 3 orders (Note that this would be 3+3+1 = 7 total maxima)

(b) White maximum in the centre. Next to the central maximum is a dark area, followed by a continuous spectrum (violet to red), then another area of annulment followed by another spectrum and so on. These spectra will be fainter and fainter and start to overlap (no area of annulment) by the third order.

5.

(a) $E = hf$

$$\therefore f = \frac{E}{h} = \frac{8.62\times10^{-19}}{6.63\times10^{-34}} = 1.30\times10^{15}\ \text{Hz}$$

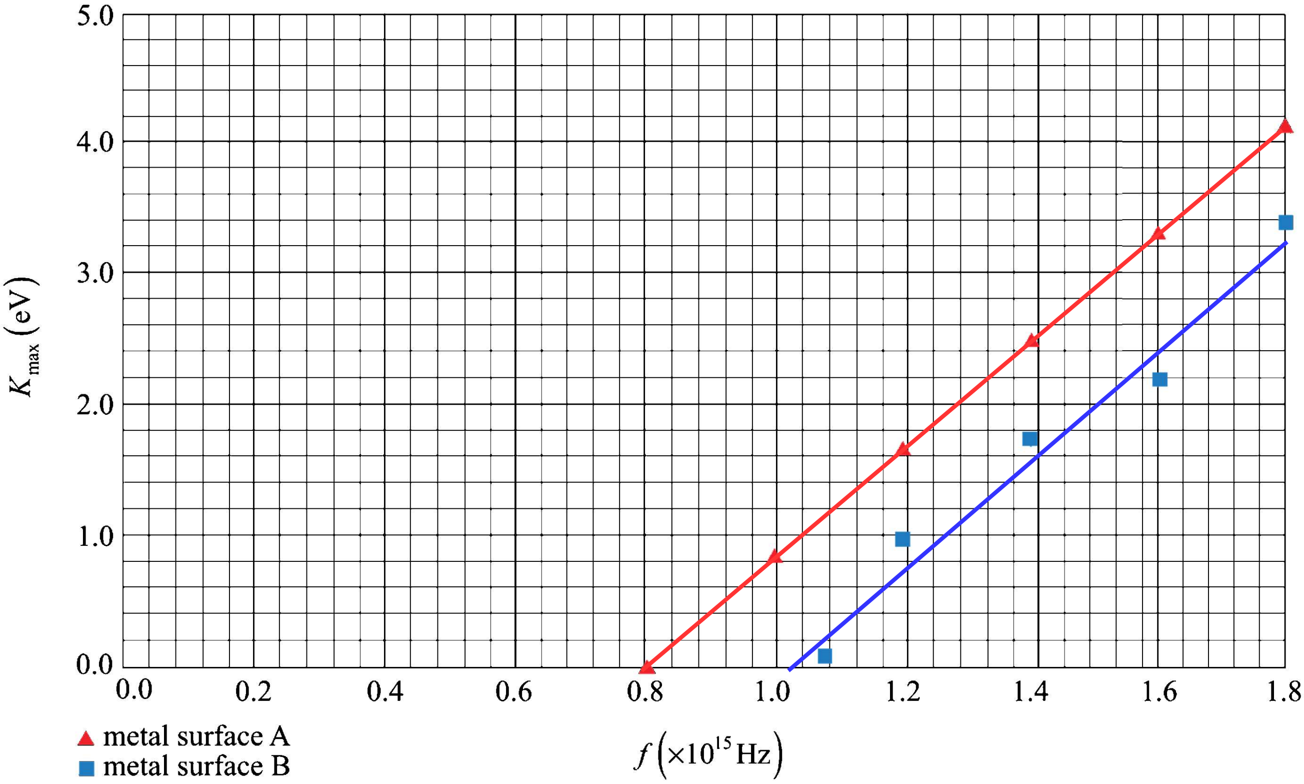
(b) $E_{K_{max}} = hf - W$

$$\therefore eV_s = hf - W$$

$$\therefore V_s = \frac{hf - W}{e} = \frac{6.63\times10^{-34}\times1.30\times10^{15} - 3.6\times10^{-19}}{1.60\times10^{-19}} = 3.1\ \text{V}$$

(c) Increasing the intensity of the light will not affect the stopping voltage. Increasing the intensity increases the number of incident photons but this does not increase the energy of each individual photon. Since each electron emitted only absorbs the energy of one photon, the photoelectrons will still be emitted with the same kinetic energy and therefore the stopping voltage will be the same as before.

6.



(a) (shown above)

(b) Metal surface: A

Reason: The points are less scattered from the line of best fit.

(c) $$f = \frac{c}{\lambda} = \frac{3.00\times10^{8}}{435\times10^{-9}} = 6.90\times10^{14}\ \text{Hz}$$

This frequency is lower than 8×10^{14} Hz, the threshold frequency for metal surface A, so electrons will not be emitted from the metal surface.

7.

(a) $W = E_K = \frac{1}{2}mv^2$

$\therefore e\Delta V = \frac{1}{2}mv^2$

$\therefore v = \sqrt{\frac{e\Delta V}{\frac{1}{2}m}} = \sqrt{\frac{1.60\times10^{-19}\times5.00\times10^{3}}{\frac{1}{2}\times9.11\times10^{-31}}} = 4.19\times10^{7}\ \text{ms}^{-1}$

(b) $\lambda = \frac{h}{p} = \frac{h}{mv} = \frac{6.63\times10^{-34}}{9.11\times10^{-31}\times4.19\times10^{7}} = 1.74\times10^{-11}\ \text{m}$

(c) $d\sin\theta = m\lambda$

$\therefore \theta = \sin^{-1}\left(\frac{m\lambda}{d}\right) = \sin^{-1}\left(\frac{1\times1.74\times10^{-11}}{0.23\times10^{-9}}\right) = 4.33°$