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

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

1. (a) Horizontal
   (b) Vertical

2. (a) The waves produced have a constant phase relationship.
(b) Monochromatic light only has one frequency, but incandescent light produces light by random vibration due to heat, so it produces a range of frequencies.

3. (a) Measuring distance B reduces the effect of random errors by averaging over a larger distance, leading to a more precise result.

(b) (i) Distance B covers the space between 9 maxima, so $\frac{91\times10^{-3}}{9}=0.010$ m

(ii) $\tan\theta=\frac{\Delta y}{L}$

$$\therefore\theta=\tan^{-1}\left(\frac{\Delta y}{L}\right)=\tan^{-1}\left(\frac{1.0\times10^{-2}}{1.9}\right)=0.30°$$

$$d\sin\theta=m\lambda$$

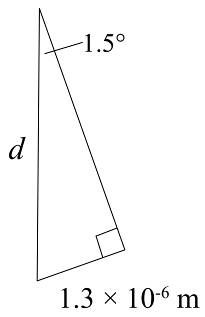
$m=1$ at Δy either side of centre

$$\therefore\lambda=d\sin\theta=1.2\times10^{-4}\sin0.30°=6.3\times10^{-7}\,m$$

4. (a) (i) The distance between S2 and P is the path difference. Since P is halfway between the second and third maxima, the path difference is 2.5λ therefore $2.5\times532\times10^{-9}$ m $=1.3\times10^{-6}$ m

(ii) L is much greater than d

(iii) 1.5°



(iv) $\sin\theta=\frac{1.3\times10^{-6}}{d}$

$$\therefore d=\frac{1.3\times10^{-6}}{\sin1.5°}=5.1\times10^{-5}\text{ m}$$

$$N=\frac{1}{d}=\frac{1}{5.1\times10^{-5}}=2.0\times10^{4}\text{ slits/m}$$

$$\div100=2.0\times10^{2}\text{ slits/cm}$$

(v) Maximum possible order is when $\theta=90°\therefore\sin\theta=1$

$$d\sin\theta=m\lambda$$

$$\therefore m=\frac{d}{\lambda}=\frac{51\times10^{-5}}{532\times10^{-9}}=95.9\text{ i.e. 95 maximum orders}$$

(b) Areas of negligible intensity (dark fringes) occur due to destructive interference. A diffraction grating has many slits so the destructive interference is very complete due to waves from different parts of the grating arriving out of phase.

(c) The intensity of the outer dots will decrease. This is because the light diffracts less than before (will not overlap to as wide an angle).

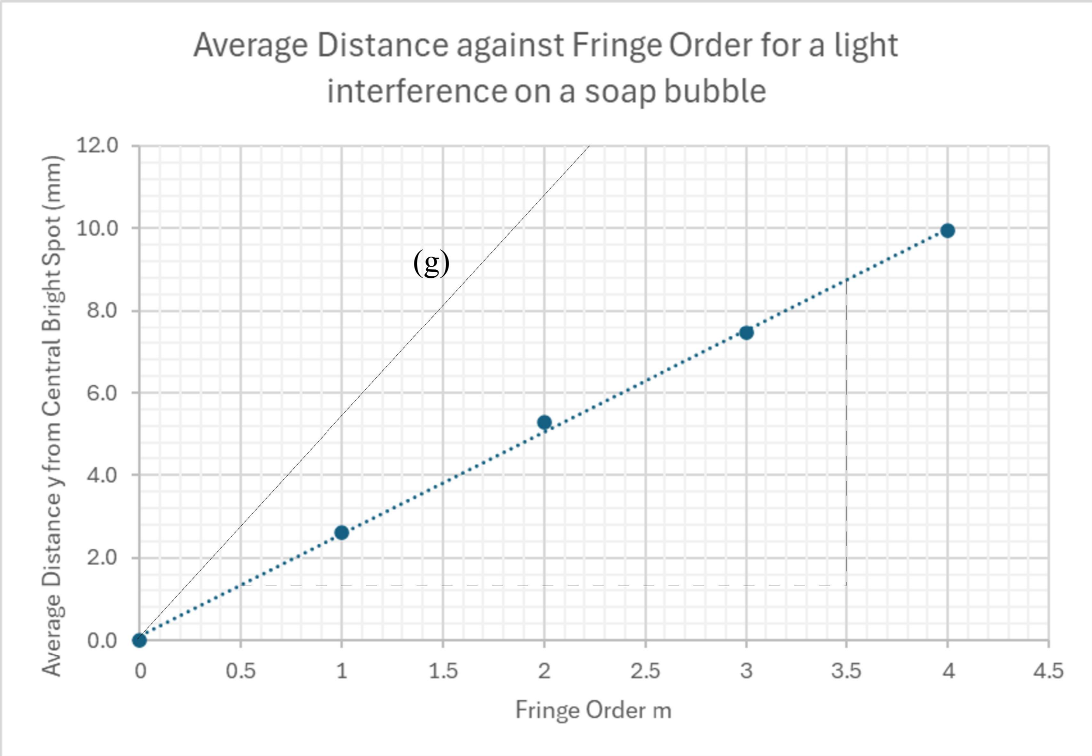
(d) Laser light is already coherent.

5. (a) 10 (should be 1 decimal place for all values in the column, since it would be measured with same equipment)

(b) 0.0
2.6
5.3
7.5
9.9

(c) 2

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



(e) *(working on graph must show points chosen for rise/run are far apart on line of best fit)*
Using example working shown above:

$\frac{rise}{run} = \frac{8.8 - 1.3}{3.5 - 0.5} = \frac{7.5}{3.0} = 2.5$ mm $\therefore 2.5 \times 10^{-3}$ m For example above, rise / run = 2.5 mm $\therefore 2.5\times10^{-3}$ m

(f) $y = \frac{\lambda}{2\tan\alpha} m$

$\therefore \frac{\lambda}{2\tan\alpha} = \text{gradient}$

$\therefore \lambda = \text{gradient} \times 2\tan\alpha$

$\therefore \alpha = \tan^{-1}\left(\frac{\lambda}{2 \times \text{gradient}}\right)$

$= \tan^{-1}\left(\frac{6.05\times10^{-7}}{2.5\times10^{-3}}\right)$

$= 0.014$ m

(g) *(see graph above, any line steeper than the line of best bit that still goes through the origin)*

6. (a) The number of emitted electrons would increase, because there are more incident photons and each photon can free up to one electron.
The energy of the emitted electrons would not be affected because each photon still has the same energy and each electron can only absorb the energy from one photon.

(b) (i) $E_{K\max} = hf - W = 6.63\times10^{-34}\times1.9\times10^{15} - 7.3\times10^{-19} = 5.3\times10^{-19}$ J

(ii) $E_{K_{\max}} = eV_s$

$$\therefore V_s = \frac{E_{K_{\max}}}{e}\frac{5.3\times10^{-19}}{1.60\times10^{-19}} = 3.3 \text{ V}$$

7.

(a) A is the work function of the metal
B is the threshold frequency

(b) The line of best fit is in the form $y = mx + c$ where y is E_{Kmax}, m is h, x is f, and c is W, that is, it corresponds to $E_{Kmax} = hf - W$
Hence if the slope is determined, it directly provides the value of h.

8.

(a) Random error, because each measurement will be incorrect by a different amount in any direction, rather than having a consistent effect on all measurements.

(b) $E_K = 100\times1.6\times10^{-19} = 1.60\times10^{-17}$ J

$E_K = \frac{1}{2}mv^2$

$\therefore mE_K = \frac{1}{2}m^2v^2$

$\therefore mE_K = \frac{1}{2}p^2$

$\therefore p = \sqrt{2mE_K} = \sqrt{2\times9.11\times10^{-31}\times1.60\times10^{-17}} = 5.40\times10^{-24}$ kgms^{-1}

(c) $\lambda = \frac{h}{p} = \frac{6.63\times10^{-34}}{5.40\times10^{-24}} = 1.23\times10^{-10}$ m

$d\sin\theta = m\lambda$

$N = 2.4$ atoms/nm $= 2.4\times10^{9}$ atoms/m

$d = \frac{1}{N} = \frac{1}{2.4\times10^{9}} = 4.2\times10^{-10}$ m

$m = 1$

$$\therefore \theta = \sin^{-1}\left(\frac{\lambda}{d}\right) = \sin^{-1}\left(\frac{1.23\times10^{-10}}{4.2\times10^{-10}}\right) = 17°$$