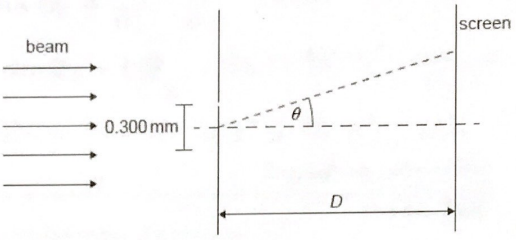
SPH4U1 Task – Waves and Light Name: Soln

1. A series of dark and bright fringes appears on the screen. Explain how a dark fringe is formed. Be very specific, and reference physics concepts discussed in class such as interference, phase, superposition etc. *[3 marks]*

- Dark fringe is the result of DESTRUCTIVE interference.
- two waves that are out of phase by $\frac{1}{2}\lambda$ will have a crest and trough interaction which will cancel the amplitude
- the destruction of the wave causes the dark fringe

2. A beam of coherent monochromatic light is used in an optics experiment on Earth.

The beam is incident normally on a double slit. The distance between the slits is 0.300 mm. A screen is at a distance D from the slits. The diffraction angle θ is labelled.

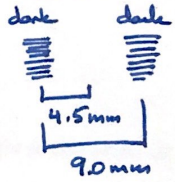


Outline why the beam must be **coherent** in order for the fringes to be visible. *[1 mark]*

- "Coherent" means the waves have the same frequency, amplitude & phase
- for a "predictable" interference pattern to be created, a coherent source must be used; if not, interference may not occur in a visible pattern

3. The wavelength of the beam as observed on Earth is 633.0 nm. The separation between a dark and a bright fringe on the screen is 4.50 mm. Calculate D *(distance to the screen)*. *[2 mark]*

careful



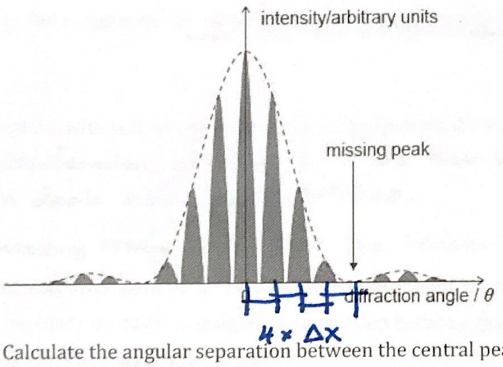
$$D = \frac{\Delta x \cdot d}{\lambda}$$

$$D = \frac{(9\times10^{-3})(0.3\times10^{-3})}{(633\times10^{-9})}$$

$\lambda = 633\text{nm}$ $\quad d = 0.300\text{mm}$ $\quad D = 4.27\text{m}$

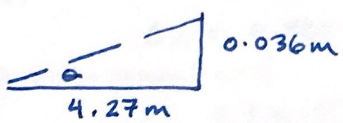
$\Delta x = 4.5\text{mm} \times 2 = 9\text{mm}$

4. The graph of variation of intensity with diffraction angle for this experiment is shown.



* distance from central to missing peak
$4 \times \Delta x = 4 \times 9 = 36\text{mm}$

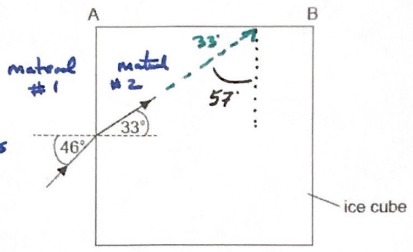
Calculate the angular separation between the central peak and the missing peak in the double-slit interference intensity pattern. State your answer to an appropriate number of significant figures. *[3 marks]*



$$\tan\theta = \frac{0.036}{4.27} \quad \text{or}$$

$\theta = 0.483°$ $\quad \theta = 0.00843$ rad

A large cube is formed from ice. A light ray is incident from a vacuum at an angle of 46° to the normal on one surface of the cube. The light ray is parallel to the plane of one of the sides of the cube. The angle of refraction inside the cube is 33°.



$V = c = 3 \times 10^8$ m/s

1. Calculate the speed of light inside the ice cube. *[2 marks]*

$\frac{\sin\theta_2}{\sin\theta_1} = \frac{v_2}{v_1}$ $\quad \frac{\sin 33^\circ}{\sin 46^\circ} = \frac{v_2}{3\times10^8}$

$v_2 = 2.3 \times 10^8$ m/s (inside ice)

2. Show that no light emerges from side AB. *[3 marks]*

$n_{ice} = \frac{c}{v_{ice}}$ $\quad n_{ice} = 1.3$ (index of ice)

$n_{ice} = \frac{3\times10^8}{2.3\times10^8}$

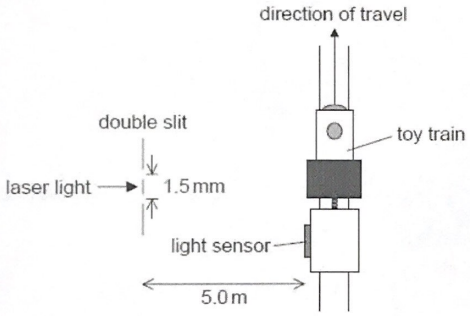
$\sin\theta_c = \frac{n_2}{n_1}$ air / ice @ AB

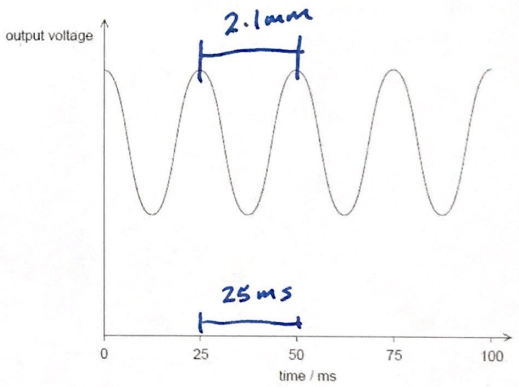
$\sin\theta_c = \frac{1}{1.3}$ $\quad \theta_c = 50.3^\circ$ critical angle

3. Sketch, on the diagram, the subsequent path of the light ray. *[2 marks]*

$57^\circ > 50.3^\circ$ ∴ all light is internally reflected.

A student investigates how light can be used to measure the speed of a toy train.





Light from a laser is incident on a double slit. The light from the slits is detected by a light sensor attached to the train.

The graph shows the variation with time of the output voltage from the light sensor as the train moves parallel to the slits. The output voltage is proportional to the intensity of light incident on the sensor.

1. Explain, with reference to the light passing through the slits, why a series of voltage peaks occurs. *[2 marks]*

The interference pattern will be similar to → ▬ ▬ ▬, with dark and light patches.

The moving train will pass the sensor through these variations in light and dark.

2. The slits are separated by 1.5 mm and the laser light has a wavelength of 6.3×10^{-7} m. The slits are 5.0 m from the train track. Calculate the separation between two adjacent positions of the train when the output voltage is at a maximum. *[2 marks]*

(d = 1.5 mm, λ = 6.3×10^{-7} m, L = 5.0 m, Δx)

$\Delta x = \frac{\lambda L}{d}$ $\quad \Delta x = \frac{(6.3\times10^{-7})(5)}{(1.5\times10^{-3})}$

$\Delta x = 0.0021$ m or 2.1 mm

3. Estimate the speed of the train. *[2 marks]*

$v = \frac{d}{t}$ $\quad v = \frac{2.1\times10^{-3}}{25\times10^{-3}}$ m/s

$v = 0.084$ m/s or 8.4 cm/s