1

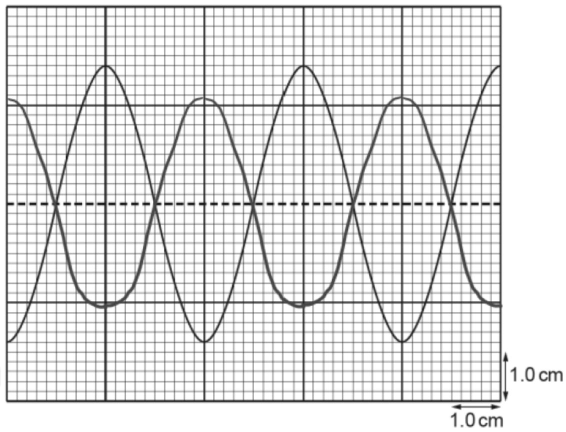
(b) **(i)** The incident sound wave travels towards the metal sheet and get reflected off the sheet. The incident and reflected waves travelling in opposite directions towards each another superpose, resulting in the formation of stationary wave

(ii) Microphone passes through 3 node-to-node separations
Node-to-node separation is $\lambda/2$
$d = 1.5\,\lambda$
Any of the above line
$\lambda = 1.05\ /\ 1.5 = 0.70\ m$

(c) **(i)**

$$A \propto \frac{1}{r}$$
$$\frac{A_2}{A_1} = \frac{r_1}{r_2}$$
$$A_2 = \frac{1.05}{1.40} \times 2.8 = 2.1\ cm$$

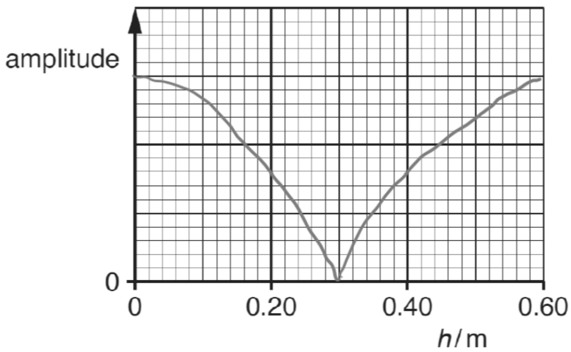
(ii)



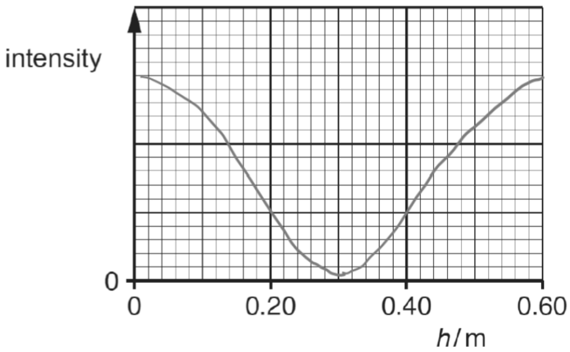
2

(a) incident wave reflects at top of tube and the reflected wave will superpose with the incident wave. The two progressive waves have same frequency, wavelength and speed, hence forming the stationary wave.

(b) **(i)**



(ii)



(c) **(i)** vertical/along length of tube/along axis of tube

(ii) phase difference = 0

(iii) phase difference = 180°

(d) $v = f\lambda$
$f = \dfrac{340}{2 \times 0.60}$
$= 280\ Hz$

(e) **(i)** $f = \dfrac{340}{0.60}$
$= 560\ Hz$

(ii) $\dfrac{0.60}{4} = 0.15\ m$

3

(a) 5 mm corresponds to 3 fringe separations.

$3\Delta y = 5.0$
$\Delta y = 1.67\ mm$

$\Delta y = \dfrac{\lambda D}{a}$
$a = \dfrac{0.980(633 \times 10^{-9})}{1.67 \times 10^{-3}}$
$a = 3.7 \times 10^{-4}\ m$

(b) From Fig. 4.2, the first minimum for single slit diffraction envelope coincides with the 6^{th} maximum for double slit interference (missing order).

$\sin\theta = \dfrac{\lambda}{b}$
$d\sin\theta = n\lambda$
$b = \dfrac{d}{n}$
$= \dfrac{3.7 \times 10^{-4}}{6}$
$= 6.2 \times 10^{-5}\ m$

(c) **(i)** Increase slit separation a.

From $\Delta y = \frac{\lambda D}{a}$, a smaller a makes the fringe separation Δy wider, spreading the interference pattern.

(ii) Make the slits narrower.
Narrower slits produce a much wider single-slit diffraction envelope with lower overall intensity, so the bright fringes vary less in intensity.

4

(a) Approximately the same amplitude/intensity and the light sources must be coherent.

(b) **(i)** Distance between orders = 1.8 cm

$$\tan\theta = \frac{0.018}{3.0}$$
$$\theta = 0.0060\ rad$$

(ii)
$$d\sin\theta = n\lambda$$
$$d\sin(0.060) = 1(4.5\times10^{-7})$$
$$d = 7.5\times10^{-5}\ m$$
$$\frac{N}{mm} = \frac{1}{7.5\times10^{-5}}\times10^{-3} = 13$$

(c) **(i)** Any 2 points directly above the heap.

(ii)
$$v = f\lambda$$
$$\lambda = \frac{330}{3.5\times10^{3}} = 0.09429\ m$$
Distance between adjacent heaps is 0.5λ
$$0.5\times0.09429 = 0.047\ m$$

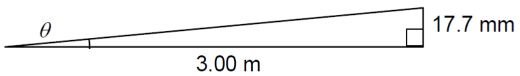
5

(a) **(i)** When the path difference between the waves that meet at the screen is integer multiple of wavelength of the light, they meet in phase and there is constructive interference, forming bright fringe.

When the path difference between the waves that meet at the screen is odd integer multiple of half wavelength of the light, they meet in antiphase and there is destructive interference, forming dark fringe.

(ii) The single slit diffraction pattern from each slit forms the envelope of the double slit interference pattern. Where the minima of the single slit diffraction pattern coincide with the bright fringes of the double slit interference pattern, these bright fringes cannot be observed and will be seen missing from the interference pattern.

(b) **(i)**



$$b\sin\theta = \lambda$$
$$b = \frac{\lambda}{\tan\theta}\ (\sin\theta \approx \tan\theta)$$
$$= \frac{590\times10^{-9}}{\left(\frac{35.4\times10^{-3}}{2}\right)\left(\frac{1}{3.00}\right)}$$
$$= 0.100\ mm$$

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(ii) According to the Rayleigh criterion, the two diffraction patterns are just resolved if the central maximum of one diffraction pattern coincides with the first minimum of the other diffraction pattern. This means the minimum angular separation θ_{min} of the two central maxima for the patterns to be resolved is $\theta_{\min} \approx \frac{\lambda}{b} = \frac{590\times10^{-9}}{0.100\times10^{-3}} = 0.0059\ rad$.

Since the angle between the two beams of light is smaller than $0.0059\ rad$, the two diffraction patterns are unresolved.

6

(a) $\lambda = \frac{v}{f}$
$= \frac{330}{1780}$
$= 0.185\ m$

(b) $S_1D = \sqrt{12^2 + 4^2}$
$= 12.649\ m$
Path Difference $= 12.649 - 12$
$= \frac{0.649}{0.18539}\lambda$
$= 3.5\lambda$

(c) Since the two sources are in antiphase, the waves meet at D exactly in phase and there is constructive interference. Hence a maximum intensity is detected.

(d) Since path difference remains unchanged and there are two more changes in sound intensity,
Path difference $= (3.5 + 2)\lambda_{new}$
$= 5.5\lambda_{new}$
$5.5\lambda_{new} = 3.5\lambda$
$5.5\left(\frac{v}{f_{new}}\right) = 3.5(0.18539)$
$f_{new} = 2797\ Hz$
$= 2800\ Hz$

7

(a) Waves must meet $\pi\ rad$ out of phase and waves must have approximately equal amplitude.

(b) **(i)** Wavetrains from S_1 and S_2 are coherent and superpose at points along YZ. When path difference is an integral multiple of λ, the waves meet in phase, constructive interference takes place to give a series of maxima.

(ii) It decreased to one quarter of the original x.

(iii) The line YZ is not parallel to the slits or the slits not normal to the incident microwaves.

(iii) The line YZ is not parallel to the slits or the slits not normal to the incident microwaves.

(iv) Place a polariser in front of the transmitter and rotate through 90° OR rotate transmitter/detector through 90°. If this causes minimal/zero intensity at some angles, the wave is plane polarized.

(c) Distance between two nodes $= \frac{1}{2}\lambda =$ speed of detector
$= \frac{10}{1.5} = 6.7\ mm$

Hence, wavelength $= 13\ mm$

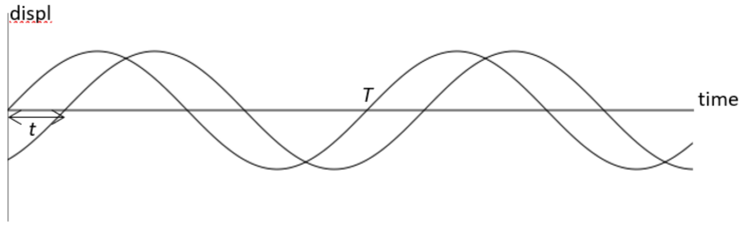
$$f = \frac{c}{\lambda} = \frac{3.00 \times 10^8}{13 \times 10^{-3}} = 2.3 \times 10^{10}\ Hz$$

(d) **(i)** White light diffracts after passing through the slits in the grating. For zeroth order maxima, each of the wavelengths in the white light travels the same path length/ zero path difference. The amplitudes add up vectorially to produce a resultant white colour maxima

(ii) wavelength λ of red light > wavelength blue light ($\lambda_{red} > \lambda_{blue}$) For waves from any two adjacent slits, path difference is $d \sin\theta$, where d is the separation between the slits. To produce a maxima for 1^{st} order, path difference, $d \sin\theta = 1\lambda$ Hence, maxima for different colors occurs at different angle λ , with red light at a larger angle.

8

(a)



Phase difference between two waves is $\Delta\phi = \frac{\Delta t}{T}(2\pi)$, where Δt is the time between two corresponding points, e.g. crest and crest or trough and trough on the two waves and T is the period of the wave.

(b) **(i) 1.**

$$\frac{\Delta\phi}{2\pi} = \frac{x}{y}$$
$$\Delta\phi = \frac{2\pi x}{y}$$

(i) 2.

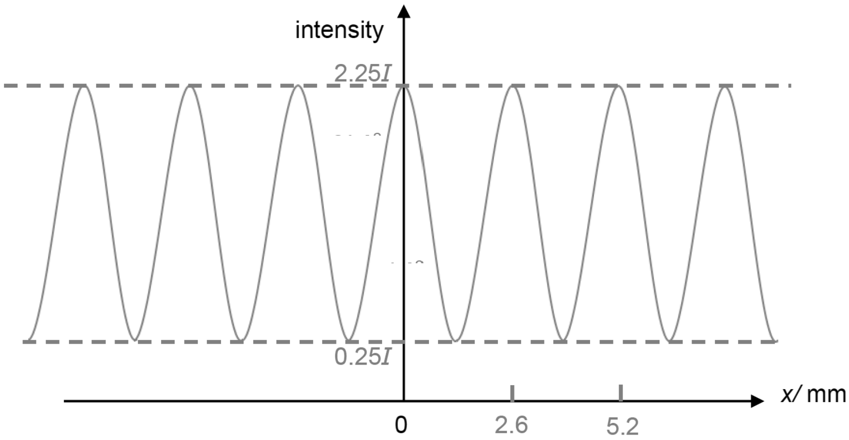
$$\frac{\Delta\phi}{2\pi} = \frac{x}{y}$$
$$y = \frac{2\pi x}{\Delta\phi}$$
$$= \frac{2\pi(5.2)}{12.6}$$
$$y = 2.6\ mm$$

(ii) Intensity $I = kA^2$ where k is a constant.

The amplitude of light from B is then $\frac{A}{2}$

The total intensity at O is thus $k\left(\frac{A}{2} + A\right)^2 = 2.25kA^2 = 2.25\ I$

(iii)



9

(a) When two or more waves meet at the point in space, the resultant displacement at that point is the vector sum of the displacements which would be caused by each wave at the point.

(b) **(i)** From graph, Period of waves $= 40.0 \times 10^{-9}\ s$
Frequency $= \frac{1}{40.0 \times 10^{-9}} = 25.0 \times 10^{6}\ Hz$
$= 25.0\ MHz$

(ii) At M, the waves arrive in phase / path difference is zero, hence constructive interference occurs. Resultant wave amplitude $= 2A$ (where A is the amplitude due to an individual wave), $A = 0.5\ units$

When only one source is on, the amplitude is 0.5 units.
Diagram of waveform with same period, phase and amplitude = 0.5 units drawn.

(iii) Distance from M to N = distance between an antinode to a node
$= \frac{1}{4}\lambda$
$= \frac{1}{4}\left(\frac{c}{f}\right)$
$= \dfrac{\frac{1}{4}(3.00 \times 10^{8})}{25.0 \times 10^{6}}$
$= 3.00\ m$

(iv) Point M is 6.00 m from A and B respectively.
Point N is 9.00 m from A and 3.00 m from B
As A and B are point sources, intensity of wave from each source,

$$I = \frac{Power\ from\ source}{4\pi r^2}$$

(As power from sources are equal and constant), Hence
$I \propto \frac{1}{r^2}$
$\frac{I_A}{I} = \left(\frac{6.00}{9.00}\right)^2$
$I_A = 0.444\ I$
$\frac{I_B}{I} = \left(\frac{6.00}{3.00}\right)^2$
$I_B = 4.00\ I$

(v) Using $I \propto A^2$

$$\frac{0.444I}{I} = \left(\frac{A_A}{0.5}\right)^2$$
$$A_A = 0.333\ units$$
$$\frac{4I}{I} = \left(\frac{A_B}{0.5}\right)^2$$
$$A_B = 1.00\ units$$

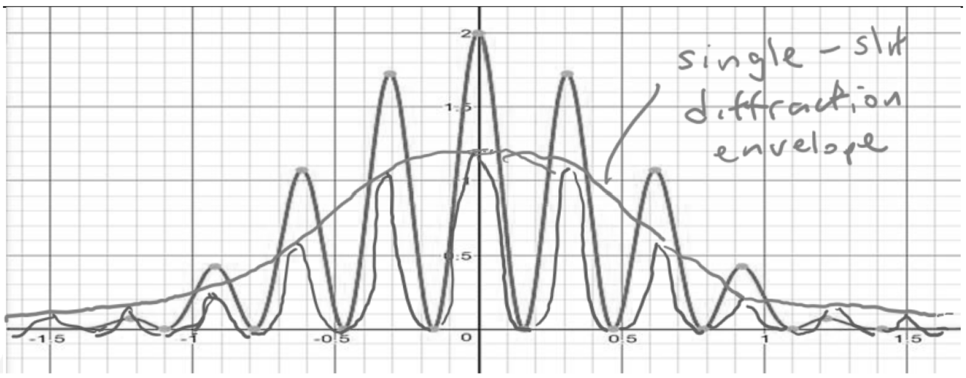
At N, waves source A and B arrive in antiphase, resultant amplitude
$= 1.000 - 0.333 = 0.666\ units$.

(c) **(i)** D must be much larger than a and a must be much larger than λ.

(ii) $x = \dfrac{\lambda D}{a}$

(iii) As the slits have a finite width, the 1st order minima (due to single-slit diffraction) coincides where the 5th order maxima (due to double-slit interference) occurs.

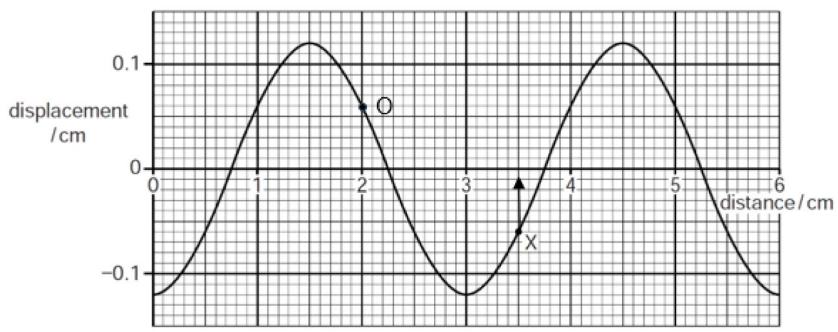
(iv)



10

(a) **(i)** O is on the line in an adjacent segment of X, that is not a node.

(ii)



(iii) distance $= 2 \times 0.06\ cm = 0.120\ cm$

(b) $\frac{1}{2}\lambda = 65.0\ cm$
$speed = 0.650 \times 2 \times 256 = 333\ m\ s^{-1}$

(c) **(i)** $b \sin\theta = \lambda$
$$\sin\theta = \frac{633 \times 10^{-9}}{0.0800 \times 10^{-3}}$$
$\theta = 0.453°$
$w = 2 \times 5.12 \tan\theta = 2 \times 5.12 \times \tan 0.453°$

$= 0.0810\ m$

(c) **(ii) 1.** Destructive interference occurs when light from second slit meets anti-phase with light from first slit.

(ii) 2. $x = \frac{\lambda D}{a}$
$= \frac{(633 \times 10^{-9})(5.12)}{0.240 \times 10^{-3}}$
$= 0.0135\ m$

(ii) 3. $w\ =\ 6x \approx 0.0810\ m$
(The 3rd maxima from the central maxima of the double-slit interference pattern coincides with the 1st order minima of the single slit spectrum due to the width of the slit.) These places are minima of the single slit envelope.

(d) **(i)** $\tan\theta = \frac{38}{165} = 0.230$
$\theta = 12.97°$

$d\sin\theta = \lambda$
$d\sin 13° = 633 \times 10^{-9}$
$d = 2.82 \times 10^{-6} m$
$N = \frac{1}{d}$
$3.5 \times 10^{6}\ m^{-1}$

(ii) Lines are further apart in second order, than in first order.
Lines are brighter and sharper in first order, than in second order.

(e) **(i)** P remains in the same position.
X and Y rotate through 90°.

(ii) screen is not parallel to grating