

3.1 Waves and optics

Name: _____ Class: _____ Date: _____

Total: 10 marks

KEY WORDS coherence • diffraction

Objective

Analyse wave superposition and interference; Use diffraction, polarisation and optical imaging; Relate phase, frequency and dispersion. Original public practice; not an ETS paper.

1 Key knowledge and worked examples

Add wave amplitudes, then calculate intensity. Intensity is proportional to squared amplitude for the same medium.

A path difference gives phase difference $2\pi\Delta/\lambda$. Coherent sources need stable relative phase.

For a single slit, minima satisfy a $\sin\theta = m\lambda$ for nonzero integers m . A double slit has a different interference condition.

Geometric optics needs a stated sign convention. Wave effects matter when apertures are comparable to wavelength.

■ Worked method

Coherent waves have a stable phase difference. Add amplitudes before squaring.

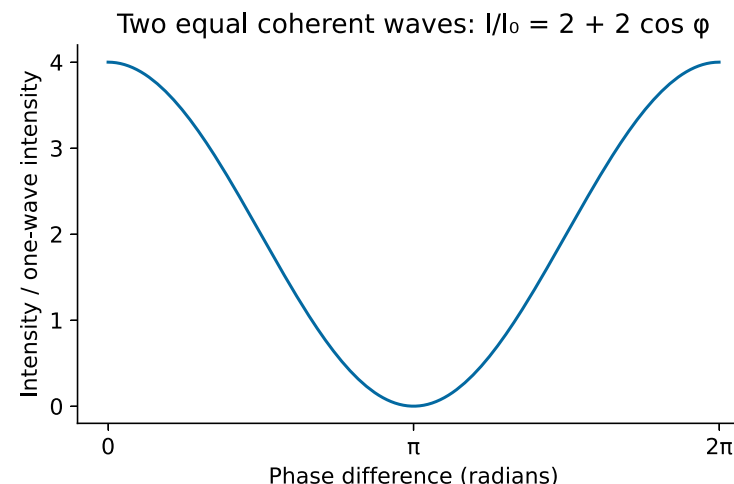
$$I = I_1 + I_2 + 2\sqrt{I_1 I_2} \cos \delta.$$

For equal individual intensities I_0 and a path difference of one quarter wavelength,

$$\delta = 2\pi\Delta/\lambda = 2\pi(\lambda/4)/\lambda = \pi/2.$$

$$I = 2I_0(1 + \cos \delta) = 2I_0(1 + \cos(\pi/2)) = 2I_0.$$

This is neither a maximum nor a minimum. Random relative phase removes the cross term in a long time average; stable coherence is a physical condition, not a drawing convention.



2 Practice

2.1 Doubling wavelength at fixed slit width makes the first minimum angle: [1]

- A. larger
- B. smaller
- C. unchanged

2.2 An ideal polariser transmits unpolarised intensity I as: [1]

- A. I
- B. $I/2$
- C. zero

2.3 For frequency 5 Hz and wavelength 2 m, wave speed is _____ m/s. Show your relation and units. [2]

[2]

3.1 Two coherent beams have individual intensities I and $4I$ in the same polarisation. Find the largest and smallest combined intensity, and the fringe visibility $(I_{max} - I_{min}) / (I_{max} + I_{min})$. Explain why a dark fringe is not perfectly dark. [4]

[4]

Solutions

2.1 Answer: A. $\sin \theta = \lambda/a$ increases.

Compare the rejected options: smaller; unchanged. Use the stated model and conditions.

2.2 Answer: B. Averaging the squared projection gives half.

Compare the rejected options: I; zero. Use the stated model and conditions.

2.3 10. $v = f\lambda = 5 \times 2 = 10$.

2.4 False. Coherent waves interfere through amplitude addition.

3.1 Amplitudes scale as $\sqrt{I}$ and $2\sqrt{I}$. $I_{max} = (\sqrt{I} + 2\sqrt{I})^2 = 9I$ and $I_{min} = (2\sqrt{I} - \sqrt{I})^2 = I$. Visibility is $(9I - I)/(9I + I) = 0.8$. Unequal amplitudes cannot cancel completely. Award maximum, minimum, visibility and explanation: one mark each.