

Exercise walk-through

3.1

Waves and optics

GRE · GRE Subject Test · GRE Physics

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,

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

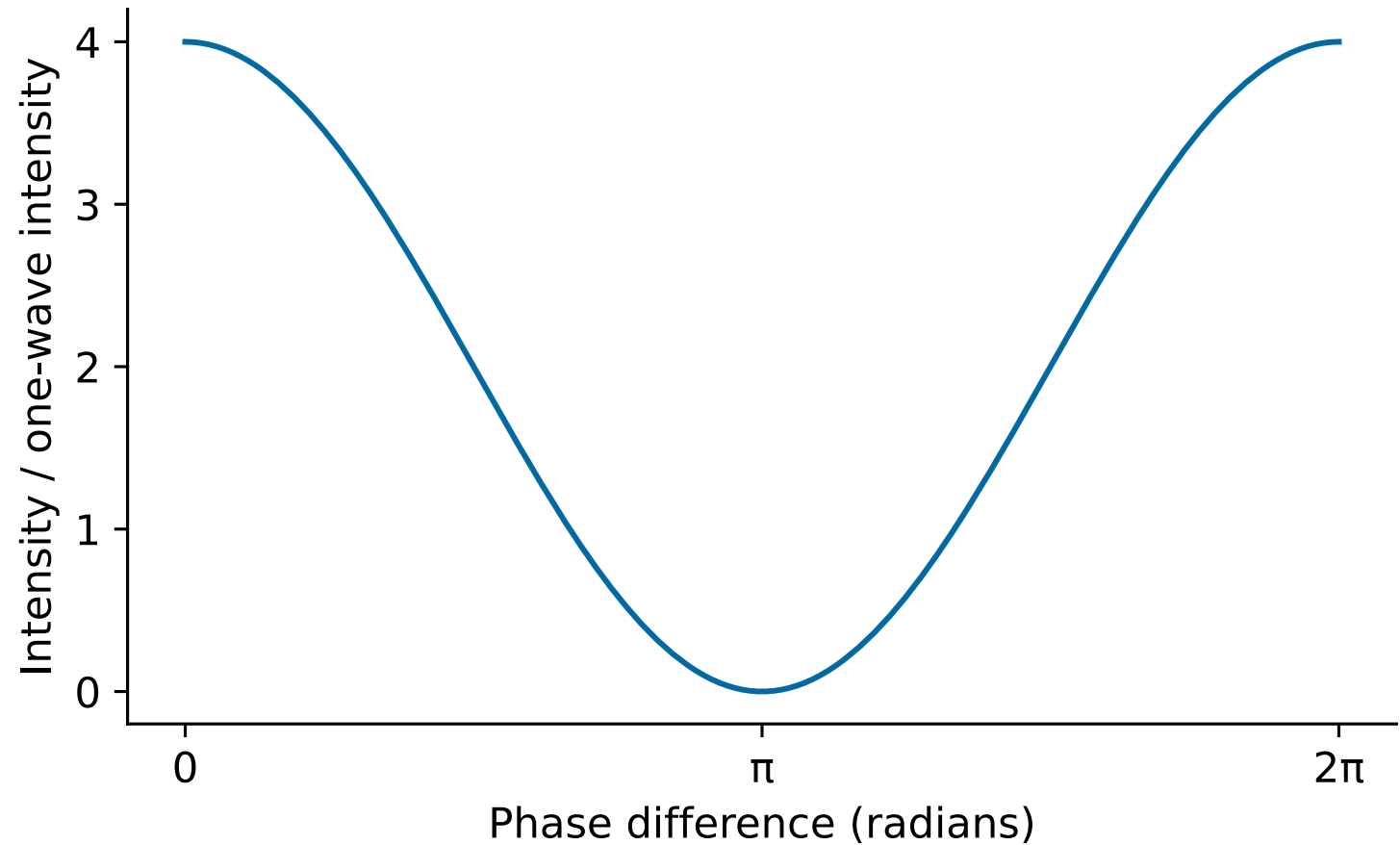
$$I = 2I_0(1 + \cos \delta) = 2I_0(1 + \cos(\pi/2)) = 2I_0.$$

This is neither a maximum nor a minimum. Random relative phase removes the cross

term in a long time average; stable coherence convention.

is a physical condition, not a drawing

Two equal coherent waves: $I/I_0 = 2 + 2 \cos \phi$



Exercises 2.1·2.2

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

- **A** larger
- **B** smaller
- **C** unchanged

2.2 Choose one answer. An ideal polariser transmits unpolarised intensity I as: [1]

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

Exercises 2.1·2.2

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

- **A** larger
- **B** smaller
- **C** unchanged

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

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

2.2 Choose one answer. An ideal polariser transmits unpolarised intensity I as: [1]

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

2.2 B Averaging the squared projection gives half.

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

Exercises 2.3-3.1

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

2.4 Decide whether this claim is true. Justify it: Wave intensities can always be added without considering phase. [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]

Exercises 2.3-3.1

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

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

2.4 Decide whether this claim is true. Justify it: Wave intensities can always be added without considering phase. [2]

2.4 False. Coherent waves interfere through amplitude addition.

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]

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.