

Exercise walk-through

8.3

Interference

A-Level Physics

8.3 Interference, coherence and the double slit

Name: _____ Class: _____ Date: _____ **Total: 28 marks**

KEY WORDS interference • coherent • path difference • fringe
• double slit

Objective

Answer exam questions on **interference** : coherence, path difference, the two-source experiments with water, sound, microwaves and light, the conditions for visible fringes, and **Young's double slit** with $\lambda = \frac{ax}{D}$. Syllabus 8.3, learning outcomes 1 to 4.

You must be able to:

- define interference and coherence
- decide from the path difference whether two waves meet in phase or in antiphase
- describe two-source interference with water waves, sound, microwaves and light, and state the conditions for observable fringes

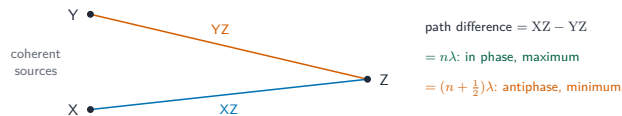
- use $\lambda = \frac{ax}{D}$, and say how the fringes change when a , D or λ changes

1 Key knowledge and worked examples

■ Key knowledge: interference and coherence

Term	Meaning
interference	the superposition of waves from two (or more) coherent sources, giving regions of greater and smaller amplitude
coherent	having a constant phase difference (and so the same frequency)
path difference	the difference in the distances from the two sources to a point

Sources in phase; path difference	Waves meet	Result
$0, \lambda, 2\lambda, \dots = n\lambda$	in phase	constructive: a maximum (bright fringe, loud, strong signal)
$\frac{1}{2}\lambda, \frac{3}{2}\lambda, \dots = (n + \frac{1}{2})\lambda$	in antiphase	destructive: a minimum (dark fringe, quiet)



The path difference decides what happens at Z

Conditions for observable fringes: the sources are **coherent**; the waves have similar amplitudes, so the minima are dark; for light, the slit separation is small (about 1 mm or less) and the screen is far away, so the fringes are wide enough to see.

■ Key knowledge: source phase and path phase

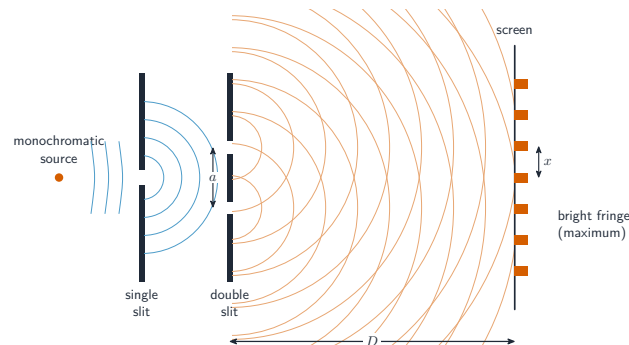
Coherent sources have a **fixed** phase difference; they need not emit in phase. The phase difference at an observation point combines the initial source phase with the phase change due to the path difference. Use a consistent sign convention and reduce the result modulo 360° .

For a lagging second source, $\delta_{\text{arrival}} = \delta_{\text{source}} + 360^\circ(r_2 - r_1)/\lambda$. A multiple of 360° gives a maximum; 180° modulo 360° gives a minimum (zero only for equal amplitudes).

Worked example. Sources emit 180° apart. An extra path of $\lambda/2$ adds 180° , giving 360° at arrival: a **maximum**, not a minimum. In a wavefront diagram, a crossing of two crests is a maximum; a crest meeting a trough is a minimum.

■ Key knowledge: the experiments

Waves	Two coherent sources	What is observed
water	two dippers on one vibrating bar in a ripple tank	lines of still water between lines of large ripples
sound	two loudspeakers driven by one signal generator	loud and quiet regions as you walk across
microwaves	one transmitter and a metal sheet with two slits	maxima and minima on a detector moved sideways
light	a laser (or a single slit before the double slit) lighting two narrow slits	bright and dark fringes on a screen



Young's double slit: the single slit makes the two slits coherent sources

$$\lambda = \frac{ax}{D} \quad a = \text{slit separation, } x = \text{fringe separation, } D = \text{slits to screen}$$

- measure **several** fringe spacings and divide, for a smaller percentage uncertainty in x
- $x = \frac{\lambda D}{a}$: a larger D or λ spreads the fringes; a larger a packs them closer; blue light gives narrower fringes than red

■ Worked example: path difference

Two dippers in phase make waves of wavelength 3.0 cm. Point P is 12.0 cm from one dipper and 16.5 cm from the other.

1. **Path difference** – $16.5 - 12.0 = 4.5$ cm.
2. **In wavelengths** – $\frac{4.5}{3.0} = 1.5$: an odd number of half wavelengths, so the waves arrive in antiphase.
3. **Result** – destructive interference: the water at P hardly moves.

■ Worked example: Young's double slit

Laser light passes two slits 0.50 mm apart onto a screen 2.40 m away. Ten fringe spacings measure 29 mm.

1. **Fringe separation** – $x = \frac{29 \text{ mm}}{10} = 2.9 \times 10^{-3} \text{ m}$.
2. **Wavelength** – double-slit equation, $\lambda = \frac{ax}{D} = \frac{0.50 \times 10^{-3} \times 2.9 \times 10^{-3}}{2.40} = 6.0 \times 10^{-7} \text{ m}$.
3. **Frequency** – $f = \frac{c}{\lambda} = \frac{3.0 \times 10^8}{6.0 \times 10^{-7}} = 5.0 \times 10^{14} \text{ Hz}$.

■ Worked example: two loudspeakers

Two loudspeakers 1.5 m apart are driven by one signal generator at 680 Hz. The speed of sound is $340 \frac{\text{m}}{\text{s}}$. A student walks along a line 5.0 m in front of them.

1. **Wavelength** – $\lambda = \frac{v}{f} = \frac{340}{680} = 0.50 \text{ m}$.
2. **Spacing of the loud regions** – the same geometry as the double slit: $x = \frac{\lambda D}{a} = \frac{0.50 \times 5.0}{1.5} = 1.7 \text{ m}$.
3. **Why one generator** – it keeps the two sources coherent, with a constant phase difference.

Exercises 2.1·2.2

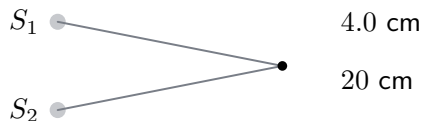
2.1 Define **coherence**.

[1]

coherence

2.2 Two sources in phase emit waves of wavelength 4.0 cm. A point is 20 cm from one source and 26 cm from the other. State and explain whether there is a maximum or a minimum at the point.

[2]



Exercises 2.1·2.2

2.1 Define **coherence**.

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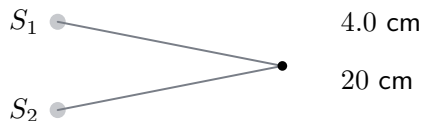
coherence

2.1

- two sources (or waves) are coherent when they have a **constant phase difference**
-

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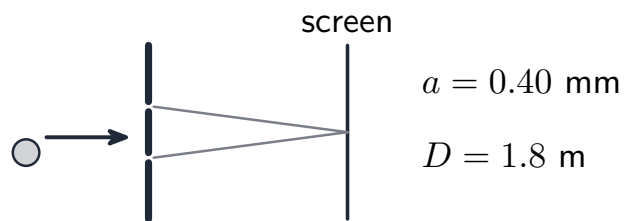


2.2

- path difference = $26 - 20 = 6 \text{ cm} = 1.5\lambda$
- the waves arrive in antiphase, so there is a **minimum**

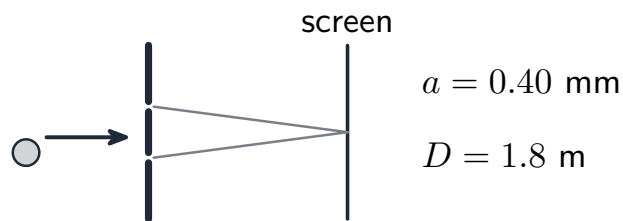
Exercise 2.3

2.3 In a double-slit experiment, $a = 0.40$ mm, $D = 1.8$ m and the fringe separation is 2.7 mm. Calculate the wavelength of the light. [2]



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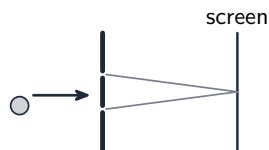
2.3

- double-slit equation, $\lambda = \frac{ax}{D}$

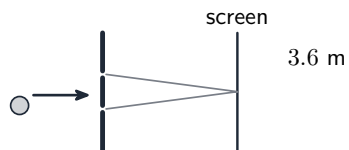
$$\lambda = \frac{ax}{D} = \frac{0.40 \times 10^{-3} \times 2.7 \times 10^{-3}}{1.8} = \mathbf{6.0 \times 10^{-7} \text{ m}}$$

Exercises 2.4·2.5

2.4 State **two** conditions needed for two-source interference fringes to be observed. [2]



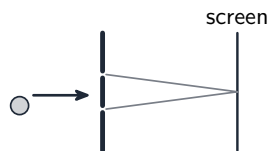
2.5 The screen in **2.3** is moved to 3.6 m from the slits. State the new fringe separation.[1]



3.6 m

Exercises 2.4·2.5

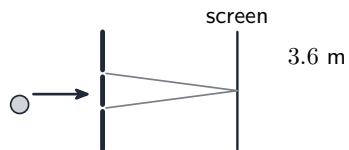
2.4 State **two** conditions needed for two-source interference fringes to be observed. [2]



2.4

- the sources are coherent
- the waves have similar amplitudes (or: for light, the slits are close together and the screen far away)

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3.6 m

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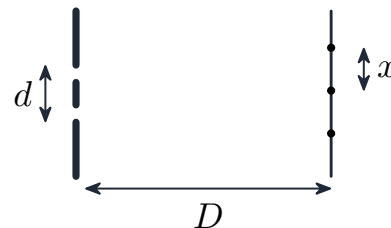
- $x \propto D$, so doubling D doubles x : **5.4 mm**

Exercise 3.1

3.1 Which change makes the fringes in a double-slit experiment with light **further apart**? [1]

☐

- A** using slits that are further apart
- B** moving the screen closer to the slits
- C** using blue light instead of red light
- D** moving the screen further from the slits

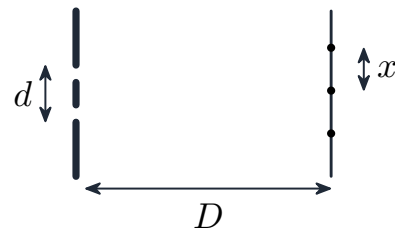


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- D** moving the screen further from the slits



3.1 D

- $x = \frac{\lambda D}{a}$: a larger D makes x larger
- **A**, **B** and **C** all make the fringes closer together

Exercise 3.2

3.2 Two coherent sources emit waves in phase. At a point, the path difference is 2.5 wavelengths. What happens at the point? [1]

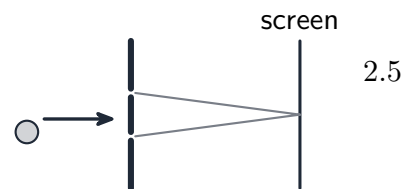
☐

A constructive interference, because the path difference is more than two wavelengths

B destructive interference, because the waves arrive in antiphase

C constructive interference, because the waves arrive in phase

D no interference, because the path difference is not a whole number of wavelengths



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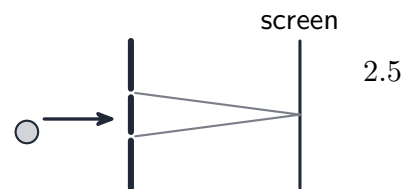
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A constructive interference, because the path difference is more than two wavelengths

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3.2 B

- 2.5 wavelengths is an odd number of half wavelengths, so the waves arrive in antiphase and cancel
- **D**: interference still happens; it is destructive

Exercise 3.3 (a)

3.3 Microwaves of wavelength 2.8 cm from one transmitter pass through two slits 6.0 cm apart in a metal sheet. A detector is moved along a line 0.80 m beyond the sheet, parallel to it.

(a) **Explain** why the two slits act as coherent sources.

[2]

Exercise 3.3 (a)

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(a) **Explain** why the two slits act as coherent sources. [2]

(a) both slits are lit by the same transmitter

- so the waves leaving them have the same frequency and a constant phase difference

Exercise 3.3 (b)

3.3 Microwaves of wavelength 2.8 cm from one transmitter pass through two slits 6.0 cm apart in a metal sheet. A detector is moved along a line 0.80 m beyond the sheet, parallel to it.

(b) State what the detector records as it moves along the line.

[1]

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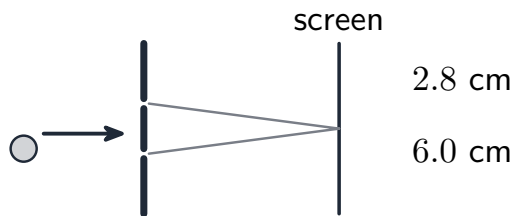
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(b) a series of maxima and minima (the signal rises and falls)

Exercise 3.3 (c)

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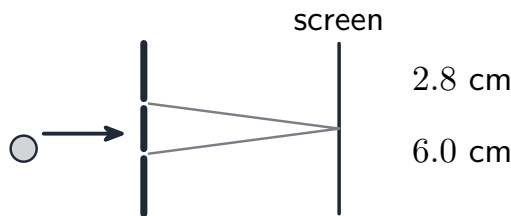
(c) Calculate the distance between neighbouring positions of maximum signal. [2]



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$$(c) \ x = \frac{\lambda D}{a}$$

$$x = \frac{\lambda D}{a} = \frac{0.028 \times 0.80}{0.060} = \mathbf{0.37 \text{ m}}$$

Exercise 3.3 (d)

3.3 Microwaves of wavelength 2.8 cm from one transmitter pass through two slits 6.0 cm apart in a metal sheet. A detector is moved along a line 0.80 m beyond the sheet, parallel to it.

(d) At a point the path difference is 4.2 cm. State and explain the signal there. [2]

Exercise 3.3 (d)

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(d) $4.2 \text{ cm} = 1.5\lambda$: the waves arrive in antiphase

- so there is a **minimum**

Exercise 3.4 (a)

3.4 A student uses a laser and a double slit to measure the wavelength of the laser light. The slit separation is 0.30 mm and the screen is 2.00 m from the slits.

(a) **Define** interference.

[1]

Exercise 3.4 (a)

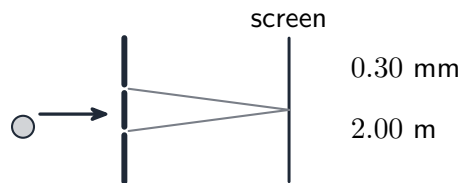
3.4 A student uses a laser and a double slit to measure the wavelength of the laser light. The slit separation is 0.30 mm and the screen is 2.00 m from the slits.

- (a) **Define** interference. [1]
- (a) the superposition of waves from coherent sources, giving regions of maximum and minimum amplitude

Exercise 3.4 (b)

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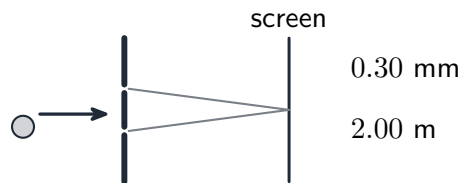
(b) The student measures the distance across 8 fringe spacings as 34 mm. **Determine** the wavelength. [3]



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$$(b) \ x = \frac{\text{width measured}}{\text{number of spacings}} = \frac{34 \text{ mm}}{8} = 4.25 \times 10^{-3} \text{ m}$$

- double-slit equation, $\lambda = \frac{ax}{D}$

$$\lambda = \frac{ax}{D} = \frac{0.30 \times 10^{-3} \times 4.25 \times 10^{-3}}{2.00} = \mathbf{6.4 \times 10^{-7} \text{ m}}$$

Exercise 3.4 (c)

3.4 A student uses a laser and a double slit to measure the wavelength of the laser light. The slit separation is 0.30 mm and the screen is 2.00 m from the slits.

(c) **Explain** why the student measures across several fringes rather than one. [1]

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(c) **Explain** why the student measures across several fringes rather than one. [1]

(c) the percentage uncertainty in one small spacing is large; measuring several and dividing reduces it

Exercise 3.4 (d)

3.4 A student uses a laser and a double slit to measure the wavelength of the laser light. The slit separation is 0.30 mm and the screen is 2.00 m from the slits.

(d) The slit separation is changed to 0.60 mm. State and explain the effect on the fringes. [2]

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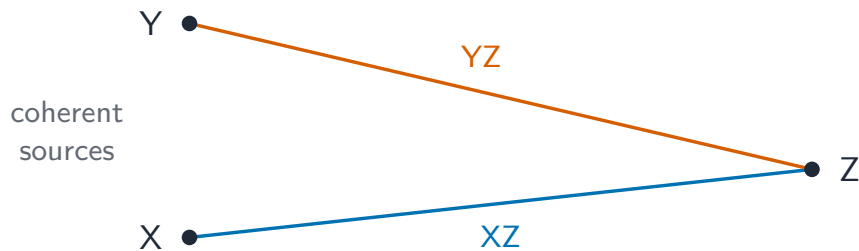
(d) The slit separation is changed to 0.60 mm. State and explain the effect on the fringes. [2]

(d) the fringes become **closer together**: the fringe separation halves

- because $x = \frac{\lambda D}{a}$, so $x \propto \frac{1}{a}$

Exercise 3.5

3.5 Two equal-amplitude coherent sources emit 180° apart. Their paths to P differ by 1.5 wavelengths. Find the arrival phase difference modulo 360° and state whether P is a maximum or minimum. What happens when the path difference becomes one wavelength? [4]



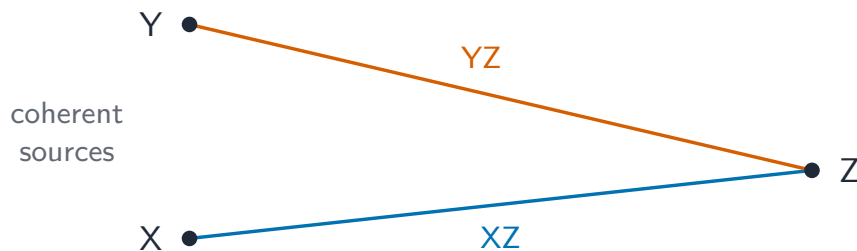
$$\text{path difference} = XZ - YZ$$

$$= n\lambda: \text{in phase, maximum}$$

$$= (n + \frac{1}{2})\lambda: \text{antiphase, minimum}$$

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$$= n\lambda: \text{ in phase, maximum}$$

$$= (n + \frac{1}{2})\lambda: \text{ antiphase, minimum}$$

3.5

- Path phase $\delta_{\text{path}} = 360^\circ \Delta r / \lambda = 360^\circ \times 1.5 = 540^\circ$.
- Total phase $\delta = 180^\circ + 540^\circ = 720^\circ$, equivalent to 0° , so a maximum.
- At one wavelength the total is $180^\circ + 360^\circ = 540^\circ$, equivalent to 180° : a minimum.