Exercise walk-through

Interference ▪ 8.3

eXercise

You must be able to

- explain **interference** and **coherence 相干**, and how fringes form
- use **path difference** for constructive/destructive interference
- use $\lambda = \dfrac{ax}{D}$, finding x by measuring across **several** fringes
- go on to the **frequency** with $c = f\lambda$

Method — Interference and coherence

Interference is the superposition of two **coherent** waves giving a steady pattern. **Coherent** $=$ a **constant phase difference** (so the same frequency). Two separate lamps are **not** coherent — their phase changes randomly.

Method — Path difference

At a point, the result depends on the **path difference** Δx from the two sources:

- constructive (bright): $\Delta x = n\lambda$; destructive (dark): $\Delta x = (n + \frac{1}{2})\lambda$.

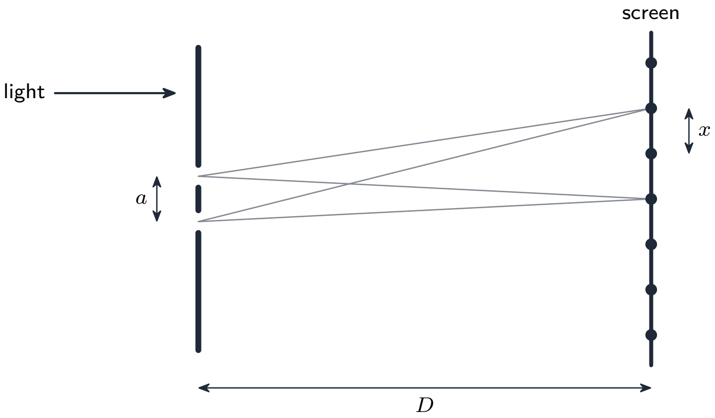
So bright fringes appear where the waves arrive **in phase**, dark fringes where they arrive **exactly out of phase**.

Method — Young's double slit

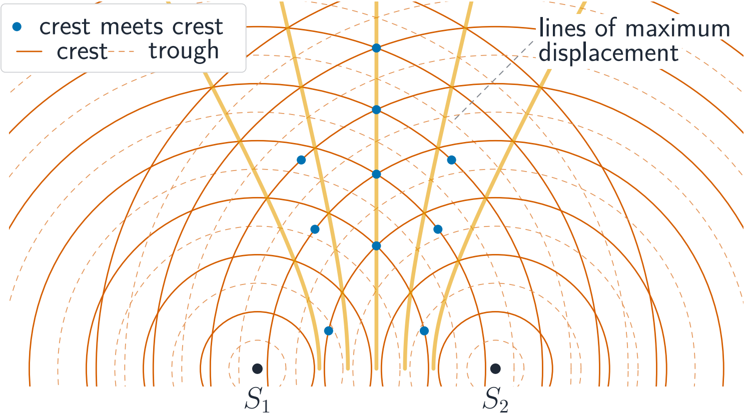
$$\lambda = \frac{ax}{D}, \qquad x = \frac{\lambda D}{a},$$

where $a =$ slit separation, $D =$ slit-to-screen distance, $x =$ fringe spacing. A single slit before the double slit makes the two slits coherent.

Method — Young's double slit



Method — Young's double slit



Two-source interference of waves

Method — Measuring \$x\$ accurately

The fringes are close together, so you **never** measure one gap. Measure across **several** fringes and divide:

Worked example. 9 bright fringes span 18 mm. That is **8 gaps**, so
$x = \dfrac{18}{8} = 2.25$ mm. With $a = 0.40$ mm and $D = 1.5$ m:
$\lambda = \dfrac{ax}{D} = \dfrac{(0.40 \times 10^{-3})(2.25 \times 10^{-3})}{1.5} = 6.0 \times 10^{-7}$ m.

Method — Frequency from wavelength

Light is an EM wave, so $f = \dfrac{c}{\lambda}$. For the example above,
$f = \dfrac{3.0 \times 10^{8}}{6.0 \times 10^{-7}} = 5.0 \times 10^{14}$ Hz.

Practice 2.1 ▪ 1 mark

Define **interference**.

Solution 2.1

Worked steps

The superposition of two **coherent** waves to give a **steady pattern** of constructive (high) and destructive (low) amplitude B1.

Practice 2.2 ▪ 1 mark

State what it means for two sources to be **coherent**.

Solution 2.2

Worked steps

They have a **constant phase difference** (and the same frequency) **B1**.

Practice 2.3 ▪ 2 marks

State the **path difference** for constructive and for destructive interference.

Solution 2.3

Method: Path difference

Worked steps

Constructive: $\Delta x = n\lambda$; destructive: $\Delta x = (n + \frac{1}{2})\lambda$ **B1** **B1**.

Practice 2.4 ▪ 1 mark

State why **two separate lamps** do not give a steady interference pattern.

Solution 2.4

Method: Interference and coherence

Worked steps

Their phases change **randomly** (they are not coherent), so any pattern flickers and averages out B1.

Practice 2.5 ▪ 1 mark

In a double-slit pattern, 11 bright fringes span 20 mm. State the **fringe spacing** x.

Solution 2.5

Method: Young's double slit

Worked steps

11 fringes $= 10$ gaps, so $x = 20/10 = 2.0$ mm **B1**.

Exam-style 3.1 ▪ 1 mark

For **destructive** interference, the path difference is:

A $n\lambda$

B $(n + \frac{1}{2})\lambda$

C $\lambda/4$

D zero only

Solution 3.1

Method: Path difference

A $n\lambda$

B $(n + \frac{1}{2})\lambda$ ✓

C $\lambda/4$

D zero only

Worked steps

B — $(n + \frac{1}{2})\lambda$.

Exam-style 3.2 ▪ 1 mark

A laser shines on a double slit. The slits are 0.40 mm apart and the screen is 1.5 m away. On the screen, 9 bright fringes span 18 mm.

(a) Calculate the **fringe spacing** x.

(b) Calculate the **wavelength** of the laser light.

(c) Hence calculate the **frequency** of the light. ($c = 3.0 \times 10^8$ m s^{-1}.)

Solution 3.2

Method: Young's double slit

Worked steps

(c) $f = \dfrac{c}{\lambda} = \dfrac{3.0 \times 10^{8}}{6.0 \times 10^{-7}}$ **M1** $= 5.0 \times 10^{14}$ Hz **A1**.

Exam-style 3.3 ▪ 3 marks

Explain how the pattern of **bright and dark fringes** is formed in the double-slit experiment, using the idea of **path difference**.

Solution 3.3

Method: Path difference

Worked steps

Light from the two slits is **coherent** and overlaps on the screen **B1**; where the **path difference** is a whole number of wavelengths the waves arrive **in phase** and reinforce $\rightarrow$ a **bright** fringe **B1**; where it is an odd number of half-wavelengths they arrive **out of phase** and cancel $\rightarrow$ a **dark** fringe **B1**.

Exam-style 3.4 ▪ 2 marks

State what happens to the **fringe spacing** if (a) the slit separation a is **increased**, (b) the screen distance D is **increased**.

Solution 3.4

Method: Young's double slit

Worked steps

(a) fringe spacing **decreases** ($x = \lambda D/a$, so $x \propto 1/a$) **B1**; (b) fringe spacing **increases** ($x \propto D$) **B1**.