8.3 Interference

Name: ____________ Class: ________ Date: __________ **Total: 17 marks**

Objective

Build the skills to answer exam questions on **interference** 干涉—coherence, path difference, and the **double-slit** experiment.

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 $c = f\lambda$

1 Worked examples

Study these first. Each one shows the method for a question type used later —follow the steps and you can do the Practice and Exam-style questions yourself.

■ 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.

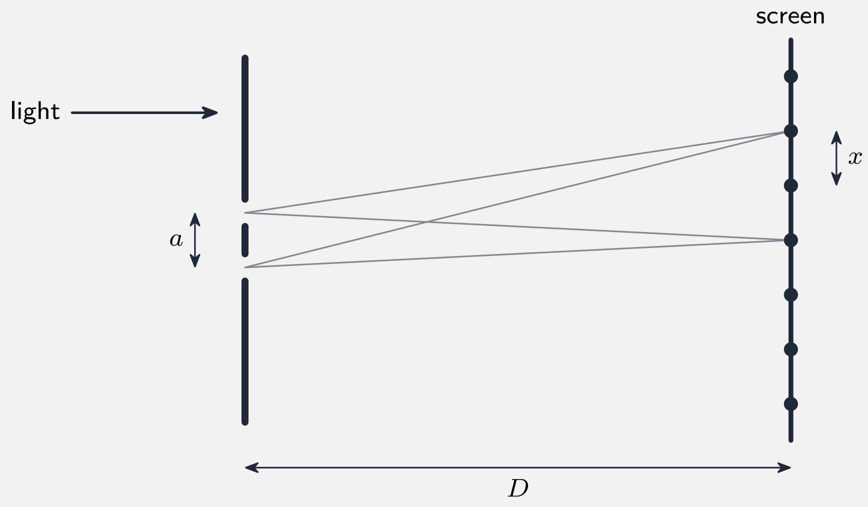
■ Path difference

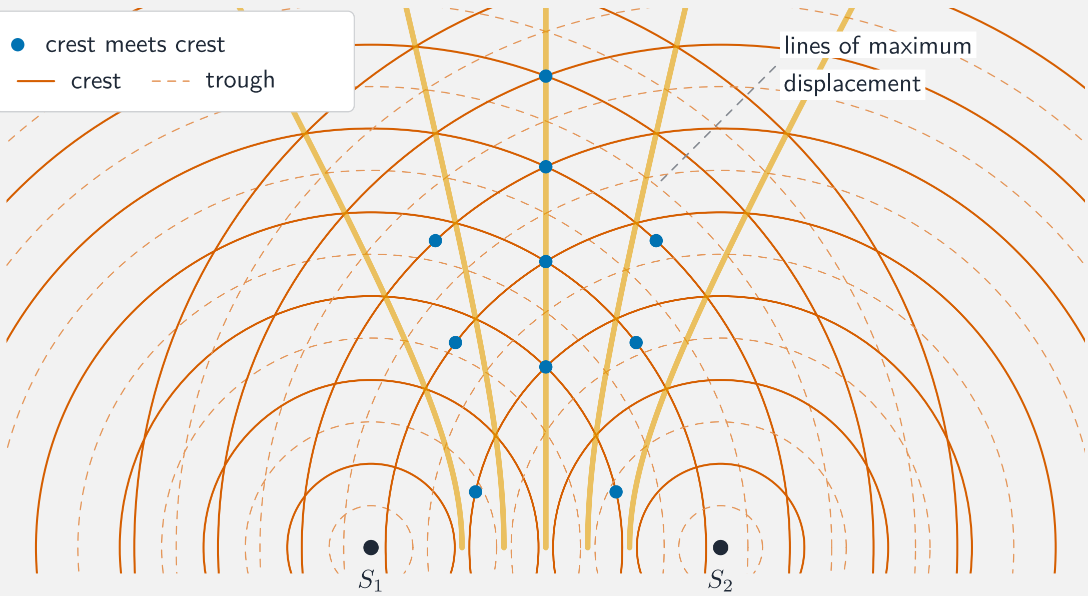
At a point, the result depends on the **path difference** Δx from the two sources:

- 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**.

■





Two-source interference of waves

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

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

■ **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 $x = \frac{18}{8} = 2.25$ mm. With $a = 0.40$ mm and $D = 1.5$ m: $\lambda = \frac{ax}{D} = \frac{(0.40 \times 10^{-3})(2.25 \times 10^{-3})}{1.5} = 6.0 \times 10^{-7}$ m.

■ **Frequency from wavelength**

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

2 Practice

Now apply the methods above.

2.1 Define **interference**. [1]

2.2 State what it means for two sources to be **coherent**. [1]

2.3 State the **path difference** for constructive and for destructive interference. [2]

2.4 State why **two separate lamps** do not give a steady interference pattern. [1]

2.5 In a double-slit pattern, 11 bright fringes span 20 mm. State the **fringe spacing** x. [1]

3 Exam-style questions

3.1 For **destructive** interference, the path difference is: [1]

- **A** $n\lambda$
- **B** $(n + \frac{1}{2})\lambda$
- **C** $\lambda/4$
- **D** zero only

3.2 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. [1]

(b) Calculate the **wavelength** of the laser light. [2]

(c) Hence calculate the **frequency** of the light. ($c = 3.0 \times 10^8$ m s^{-1}.) [2]

3.3 Explain how the pattern of **bright and dark fringes** is formed in the double-slit experiment, using the idea of **path difference**. [3]

3.4 State what happens to the **fringe spacing** if (a) the slit separation a is **increased**, (b) the screen distance D is **increased**. [2]

4 Go further

You are now ready for the real exam questions on this subtopic. Open the **8.3 Interference** past-paper sheet in the Library, or try these in **Practice mode**:

- 9702/22 N25 —Q4 (double-slit interference, structured)
- 9702/21 N24 —Q6 (double-slit calculation)

- 9702/21 J25 —Q4 (superposition and double slit)
- 9702/11 N25 —Q28 (interference, multiple choice)
- 9702/13 J25 —Q28 (interference, multiple choice)

Solutions

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

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

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

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

2.5 11 fringes = 10 gaps, so $x = 20/10 = 2.0$ mm.

3.1 B —$(n + \frac{1}{2})\lambda$.

3.2 (a) 9 fringes = 8 gaps; $x = 18/8 = 2.25$ mm.

3.2 (b) $\lambda = \dfrac{ax}{D} = \dfrac{(0.40 \times 10^{-3})(2.25 \times 10^{-3})}{1.5} = 6.0 \times 10^{-7}$ m.

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

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

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