Exercise walk-through

Diffraction ▪ 8.2

eXercise

You must be able to

- explain **diffraction** and where it occurs
- describe how the **gap width** relative to the **wavelength** changes the spreading

Method — Diffraction

Diffraction is the **spreading** of a wave as it passes through a gap or around an obstacle. **All** waves diffract. The spreading depends on the **gap width compared with the wavelength**:

- gap **much wider** than $\lambda \to$ little spreading;
- gap **about** $\lambda \to$ strong spreading.

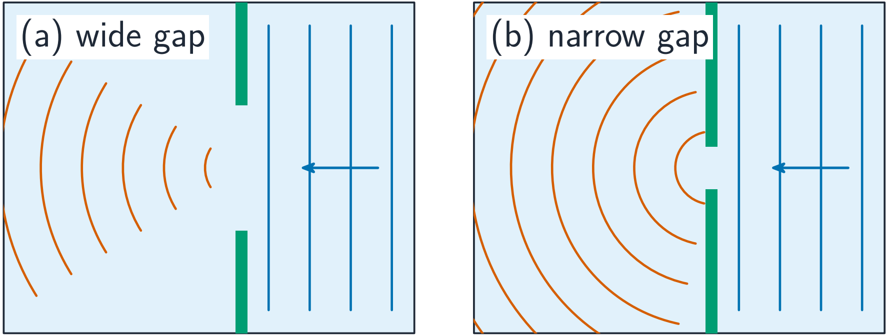
This is why you can **hear** around a corner (sound $\lambda \approx 1$ m, near a doorway's width) but cannot **see** around it (light $\lambda \approx 500$ nm, far smaller). The wavelength and speed are **unchanged** by diffraction.

Method — Diffraction

(a) wide gap

(b) narrow gap

Method — Diffraction



gap $\gg \lambda$: little spreading

gap $\approx \lambda$: strong spreading

Diffraction of waves through a gap

Practice 2.1 ▪ 1 mark

Define **diffraction**.

Solution 2.1

Worked steps

The **spreading** of a wave as it passes through a gap or around an obstacle **B1**.

Practice 2.2 ▪ 1 mark

State what happens to the amount of diffraction as a gap is made **narrower** (towards the size of λ).

Solution 2.2

Method: Diffraction

Worked steps

The diffraction (spreading) **increases** B1.

Practice 2.3 ▪ 2 marks

State why you can **hear** but not **see** around a corner.

Solution 2.3

Method: Diffraction

Worked steps

Sound has a wavelength **close to** the doorway/gap size, so it diffracts a lot **B1**; light's wavelength is **far smaller** than the gap, so it diffracts negligibly **B1**.

Practice 2.4 ▪ 1 mark

State which kinds of wave can **diffract**.

Solution 2.4

Method: Diffraction

Worked steps

All waves (water, sound, light, microwaves, ...) **B1**.

Exam-style 3.1 ▪ 1 mark

Noticeable diffraction occurs when the gap width is:

A much larger than the wavelength

B about the same as the wavelength

C exactly zero

D a thousand times the wavelength

Solution 3.1

Method: Diffraction

A much larger than the wavelength

B about the same as the wavelength ✓

C exactly zero

D a thousand times the wavelength

Worked steps

B — about the same as the wavelength.

Exam-style 3.2 ▪ 3 marks

Explain, using diffraction, why **sound** passes through a doorway and spreads into the room, but **light** does not noticeably spread.

Solution 3.2

Method: Diffraction

Worked steps

Sound's wavelength is **similar** to the doorway width, so it diffracts strongly and spreads into the room **B1** **B1**; light's wavelength is **much smaller** than the doorway, so its diffraction is negligible **B1**.

Exam-style 3.3 ▪ 3 marks

Describe a **ripple-tank** experiment to show that diffraction depends on the gap width.

Solution 3.3

Method: Diffraction

Worked steps

Send straight water waves at a barrier with a gap **B1**; observe how much they spread after the gap **B1**; make the gap narrower and see the waves spread **more** (compare wide vs narrow gap) **B1**.

Exam-style 3.4 ▪ 1 mark

State the effect of diffraction on the **wavelength** and **speed** of the wave.

Solution 3.4

Method: Diffraction

Worked steps

Both the **wavelength** and the **speed** are **unchanged** B1.

Exam-style 3.5 ▪ 2 marks

A parallel beam of light of wavelength 540 nm falls normally on a diffraction grating whose lines are 5.0×10^{-6} m apart. The grating sits at the centre of a circular screen, and the central bright fringe forms at $\theta = 0$ with intensity I_0.

(a) **State** what is meant by the **diffraction** of a wave.

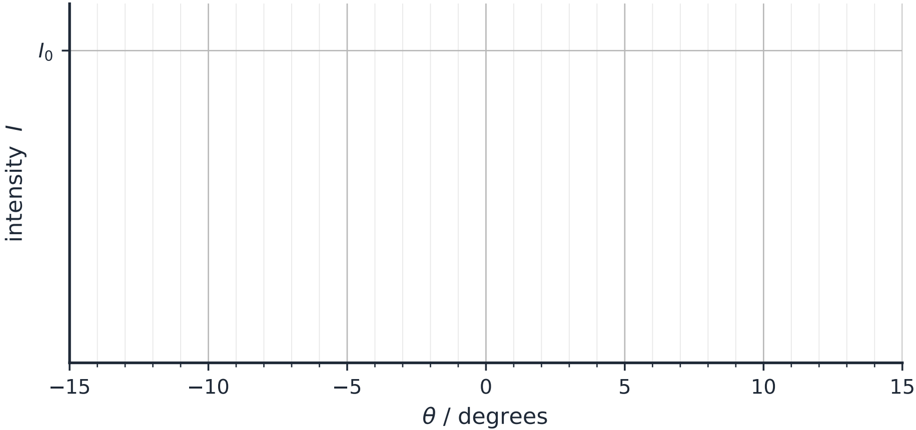
(b) **Show that** the first-order bright fringe forms at $\theta = 6.2°$.

(c) **Determine** the angle at which the **second-order** fringe forms.

(d) On the axes below, **sketch** how the intensity I varies with θ between $-15°$ and $+15°$.

(e) A polarising filter is now placed in the beam **before** the grating. **Suggest** how the pattern on the screen changes.

Exam-style 3.5 ▪ 2 marks



Solution 3.5

Method: Diffraction

Worked steps

(a) A wave passing through a **gap** (or round an edge) B1 **spreads out** into the region beyond it B1.

(b) $n\lambda = d\sin\theta$ with $n = 1$ M1, so $\sin\theta = \dfrac{540 \times 10^{-9}}{5.0 \times 10^{-6}} = 0.108$ and $\theta = 6.2°$ A1.

(c) $\sin\theta = \dfrac{2 \times 540 \times 10^{-9}}{5.0 \times 10^{-6}} = 0.216$, so $\theta = 12°$ A1. (Note it is **not** exactly twice $6.2°$, though it is close at small angles.)

(d) Maxima at $\theta = 0, \pm 6.2°$ and $\pm 12°$ B1; intensity **zero** between them, so the pattern is a set of separated peaks, not a continuous curve B1; the central peak has

Solution 3.5

intensity I_0 and the outer peaks are equal to or lower than it **B1**.
(e) The maxima stay at the **same angles** — the filter changes neither the wavelength nor the grating **B1** — but every peak is **less intense**, because the filter removes the component of the light polarised at right angles to its transmission axis; for unpolarised light the intensity roughly halves **B1**.