8.2 Diffraction

Name: ______________ Class: __________ Date: ____________ **Total: 23 marks**

KEY WORDS diffraction 衍射 • wavelength 波长 • obstacle 障碍物 • wave 波

Objective

Build the skills to answer exam questions on **diffraction 衍射** — what it is and how it depends on the gap width.

You must be able to:

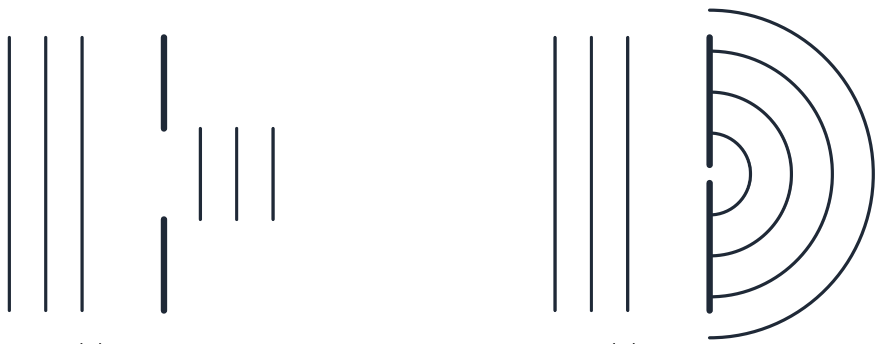
- explain **diffraction** and where it occurs
- describe how the **gap width** relative to the **wavelength** changes the spreading

1 Worked examples

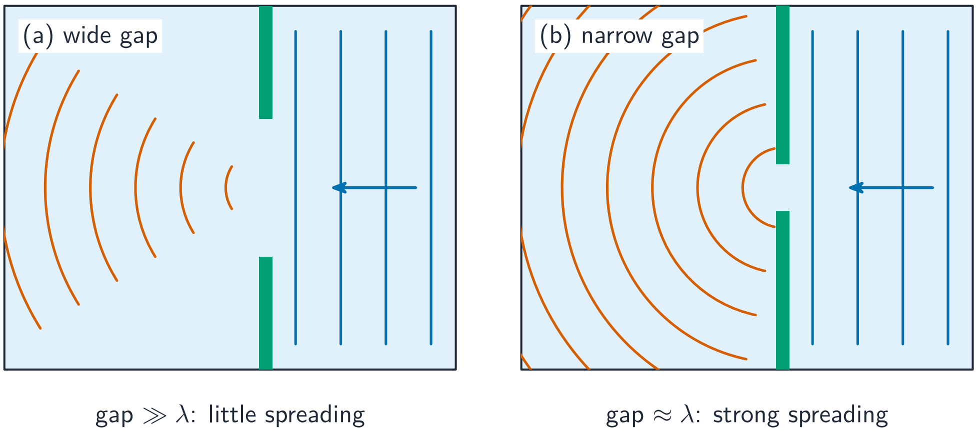
Study these first. Each one shows the method for a question type used later — follow the steps and you can do the Practice and Exam-style questions yourself.

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**:



(a) wide gap (b) narrow gap



Diffraction of waves through a gap

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

2 Practice

Now apply the methods above.

2.1 Define **diffraction**. [1]

2.2 State what happens to the amount of diffraction as a gap is made **narrower** (towards the size of λ). [1]

2.3 State why you can **hear** but not **see** around a corner. [2]

2.4 State which kinds of wave can **diffract**. [1]

3 Exam-style questions

3.1 Noticeable diffraction occurs when the gap width is: [1]

- **A** much larger than the wavelength
- **B** about the same as the wavelength
- **C** exactly zero
- **D** a thousand times the wavelength

3.2 Explain, using diffraction, why **sound** passes through a doorway and spreads into the room, but **light** does not noticeably spread. [3]

3.3 Describe a **ripple-tank** experiment to show that diffraction depends on the gap width. [3]

3.4 State the effect of diffraction on the **wavelength** and **speed** of the wave. [1]

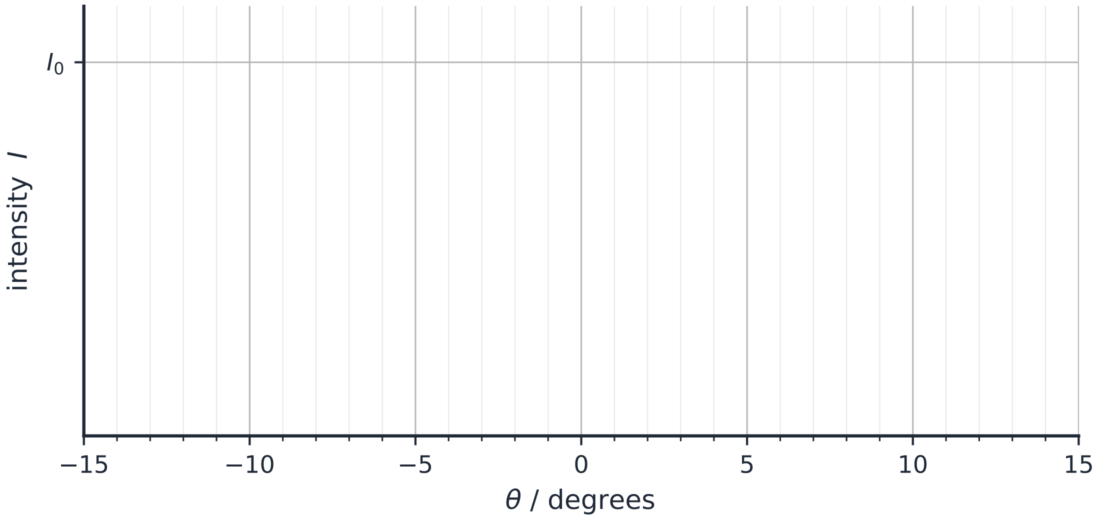
3.5 A parallel beam of light of wavelength 540 nm falls normally on a diffraction grating whose lines are 5.0×10^{-6} m apart. The grating sits at the centre of a circular screen, and the central bright fringe forms at $\theta = 0$ with intensity I_0.

(a) **State** what is meant by the **diffraction** of a wave. [2]

(b) **Show that** the first-order bright fringe forms at $\theta = 6.2°$. [2]

(c) **Determine** the angle at which the **second-order** fringe forms. [1]

(d) On the axes below, **sketch** how the intensity I varies with θ between $-15°$ and $+15°$. [3]



(e) A polarising filter is now placed in the beam **before** the grating. **Suggest** how the pattern on the screen changes. [2]

Solutions

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

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

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

2.4 **All** waves (water, sound, light, microwaves, …).

3.1 **B** — about the same as the wavelength.

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

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

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

3.5 (a) A wave passing through a **gap** (or round an edge) **spreads out** into the region beyond it.
(b) $n\lambda = d\sin\theta$ with $n = 1$, so $\sin\theta = \dfrac{540 \times 10^{-9}}{5.0 \times 10^{-6}} = 0.108$ and $\theta = 6.2°$.
(c) $\sin\theta = \dfrac{2 \times 540 \times 10^{-9}}{5.0 \times 10^{-6}} = 0.216$, so $\theta = 12°$. (Note it is **not** exactly twice 6.2°, though it is close at small angles.)
(d) Maxima at $\theta = 0$, $\pm 6.2°$ and $\pm 12°$; intensity **zero** between them, so the pattern is a set of separated peaks, not a continuous curve; the central peak has intensity I_0 and the outer peaks are equal to or lower than it.
(e) The maxima stay at the **same angles** — the filter changes neither the wavelength nor the grating — 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.