

Exercise walk-through

8.2

Diffraction

A-Level Physics

Sheet 8.4 – what you need to know

You must be able to:

- use $d \sin \theta = n\lambda$ both ways: find an angle, or find the grating
- find the slit spacing from the lines per mm, and the **highest order**
- describe how a grating measures a wavelength

What the exam asks

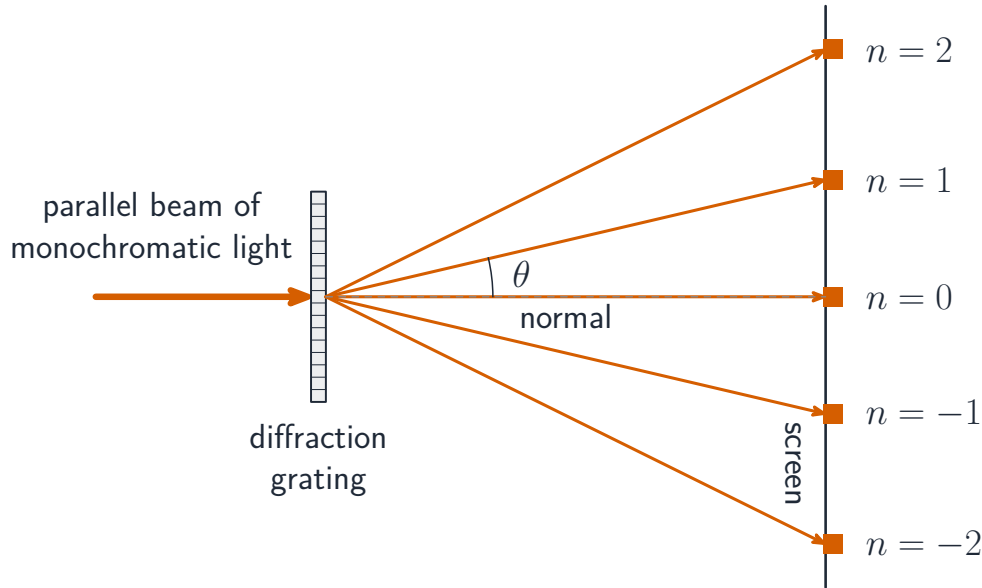
“Describe the diffraction of the light waves at the grating.” [2]

“Calculate the number of lines per unit length in the diffraction grating.” [3]

“Determine the value of θ at which the second-order bright fringe is formed.” [1]

Practise on exercise sheet 8.4, then try the real exam questions on past-paper sheet 8.4.

The diffraction grating



Many slits, spacing d – maxima where

$$d \sin \theta = n\lambda.$$

**500 lines/mm, $\lambda = 600 \text{ nm}$,
 $n = 1$**

$$d = \frac{1}{N} = \frac{1}{500 \text{ mm}^{-1}} \\ = 2.0 \times 10^{-6} \text{ m}$$

$$\sin \theta = \frac{n\lambda}{d} = \frac{600 \times 10^{-9} \text{ m}}{2.0 \times 10^{-6} \text{ m}} \\ = 0.30, \text{ so } \theta \approx 17^\circ$$

Working with a grating

slit spacing

$$N \text{ lines/mm} \Rightarrow d = 10^{-3}/N \text{ m}$$

highest order

$n_{\max} = \lfloor d/\lambda \rfloor$: at $d/\lambda = 3.27$
you see up to $n = 3$, never $n = 4$

sharper maxima

more slits add $\Rightarrow$ narrower,
brighter lines than two slits

To **find** an unknown λ : shine it straight at the grating, measure θ_1 to the first-order **maximum**, then $\lambda = d \sin \theta_1$. Averaging over higher orders cuts the error.

Working backwards: find the grating

Exam questions often give an angle and ask for the grating. Rearrange:

$$d = \frac{n\lambda}{\sin \theta}, \quad N = \frac{1}{d}$$

Highest order: $\sin \theta \leq 1$, so $n_{\max}$ is $\frac{d}{\lambda}$ rounded **down**.

Second order at 35° for 730 nm

$$d = \frac{n\lambda}{\sin \theta} = \frac{2(730 \times 10^{-9} \text{ m})}{\sin 35^\circ} = 2.55 \times 10^{-6} \text{ m}$$

$$N = \frac{1}{d} = \frac{1}{2.55 \times 10^{-3} \text{ mm}} \approx \text{390 lines per mm}$$

Exercises 2.1·2.2

2.1 Define **diffraction**.

[1]

diffraction

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

[1]



Exercises 2.1·2.2

2.1 Define **diffraction**.

[1]

diffraction

2.1

- the **spreading** of a wave as it passes through a gap or around an obstacle
-

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

[1]



2.2

- the diffraction (spreading) **increases**

Exercises 2.3-2.4

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

[2]



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

[1]



Exercises 2.3·2.4

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

[2]



2.3

- sound has λ **close to** the doorway, so it diffracts a lot
- light's λ is **far smaller** than the gap, so it diffracts negligibly

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

[1]



2.4

- **all** waves (water, sound, light, microwaves, ...)

Exercise 3.1

3.1 Noticeable diffraction occurs when the gap width is:

[1]

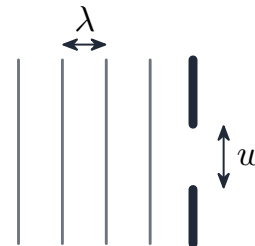
☐

A much larger than the wavelength

B about the same as the wavelength

C exactly zero

D a thousand times the wavelength



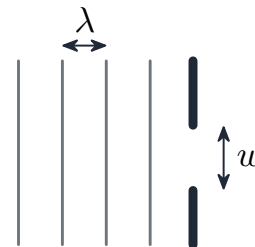
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3.1 Noticeable diffraction occurs when the gap width is:

[1]

☐

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

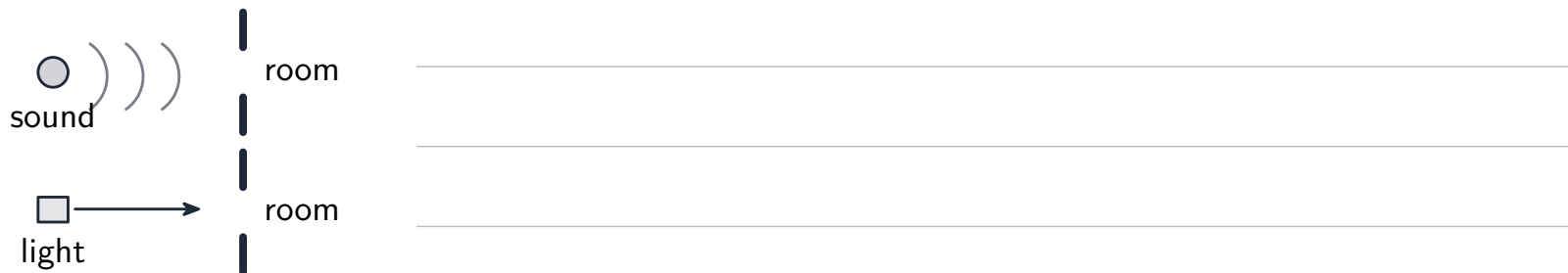


3.1 B

- diffraction is only noticeable when the gap $\approx \lambda$
- **A** / **D**: a much wider gap lets the wave through almost unspread

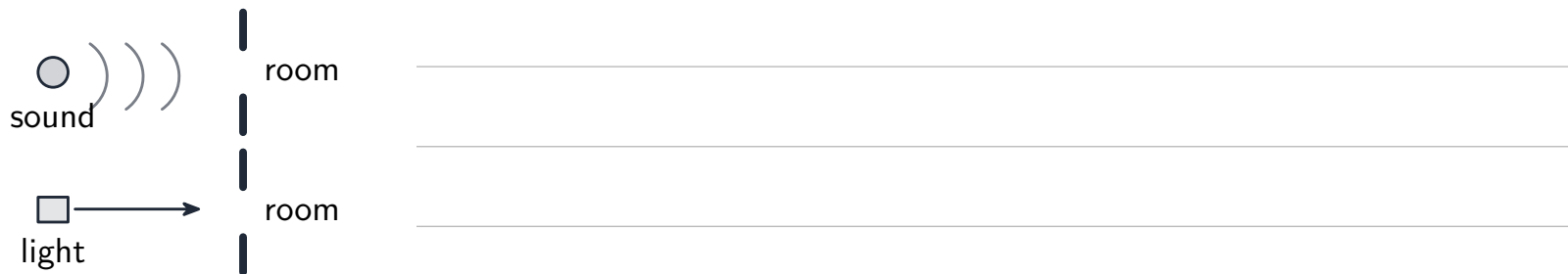
Exercise 3.2

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



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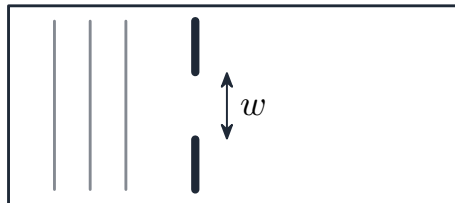
3.2

- sound's λ is **similar** to the doorway width, so it diffracts strongly into the room
- light's λ is **much smaller**, so its diffraction is negligible

Exercise 3.3

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

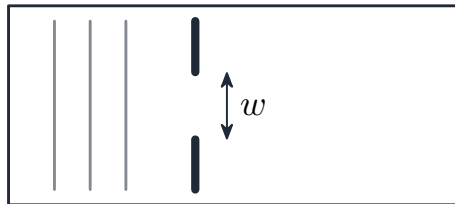
wave source



Exercise 3.3

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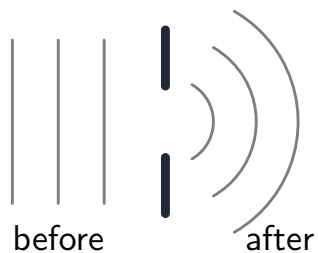
3.3

- send straight water waves at a barrier with a gap
- observe how much they spread after the gap
- make the gap narrower: the waves spread **more**

Exercise 3.4

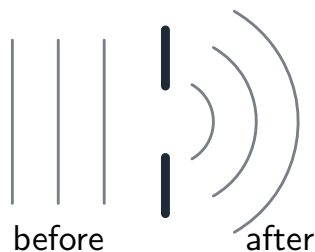
3.4 State the effect of diffraction on the **wavelength** and **speed** of the wave.

[1]



Exercise 3.4

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



3.4

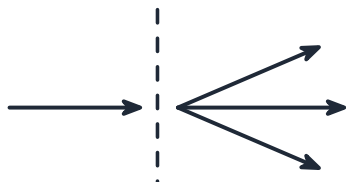
- both the **wavelength** and the **speed** are **unchanged**

Exercise 3.5 (a)

3.5 A parallel beam of light of wavelength 540 nm falls normally on a diffraction grating whose lines are $5.0 \times 10^{-6} \text{ m}$ 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]



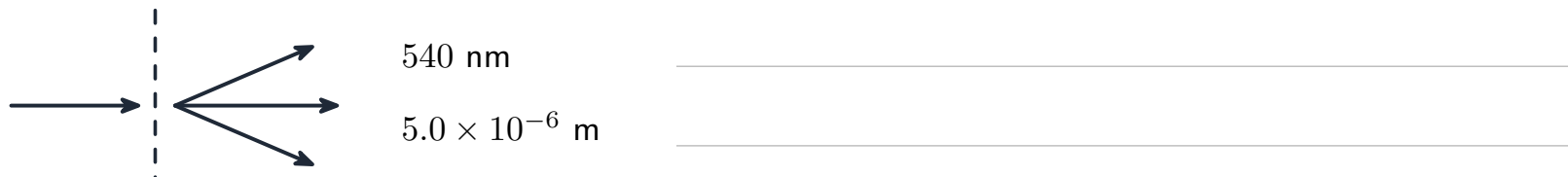
540 nm

$5.0 \times 10^{-6} \text{ m}$

Exercise 3.5 (a)

3.5 A parallel beam of light of wavelength 540 nm falls normally on a diffraction grating whose lines are $5.0 \times 10^{-6} \text{ m}$ 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]



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

Exercise 3.5 (b)

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 .

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

Exercise 3.5 (b)

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 .

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

(b) $n\lambda = d \sin \theta$ with $n = 1$

$$\sin \theta = \frac{n\lambda}{d} = \frac{540 \times 10^{-9} \text{ m}}{5.0 \times 10^{-6} \text{ m}} = 0.108 \Rightarrow \theta = \mathbf{6.2^\circ}$$

Exercise 3.5 (c)

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 .

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

[1]

Exercise 3.5 (c)

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 .

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

(c) the same equation with $n = 2$

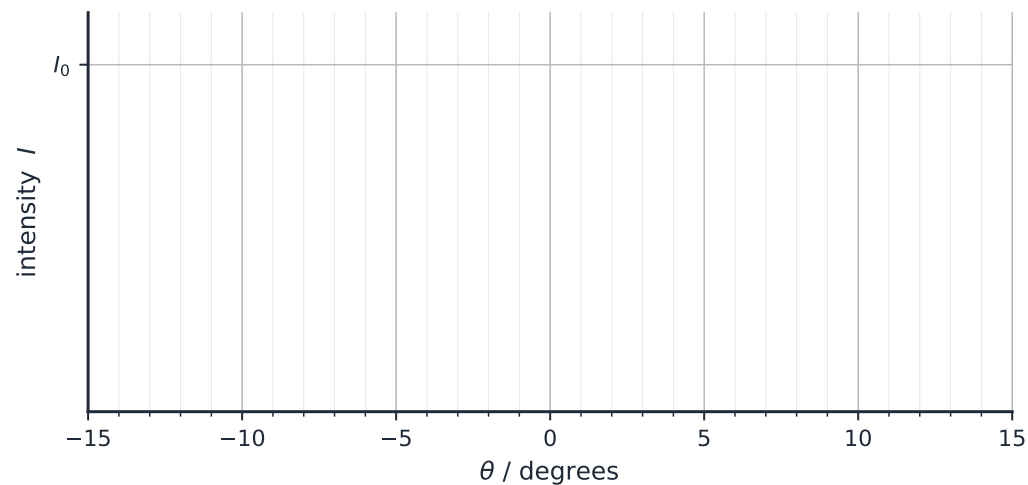
$$\sin \theta = \frac{n\lambda}{d} = \frac{2 \times 540 \times 10^{-9} \text{ m}}{5.0 \times 10^{-6} \text{ m}} = 0.216 \Rightarrow \theta = \mathbf{12^\circ}$$

Setup for exercise 3.5

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 .

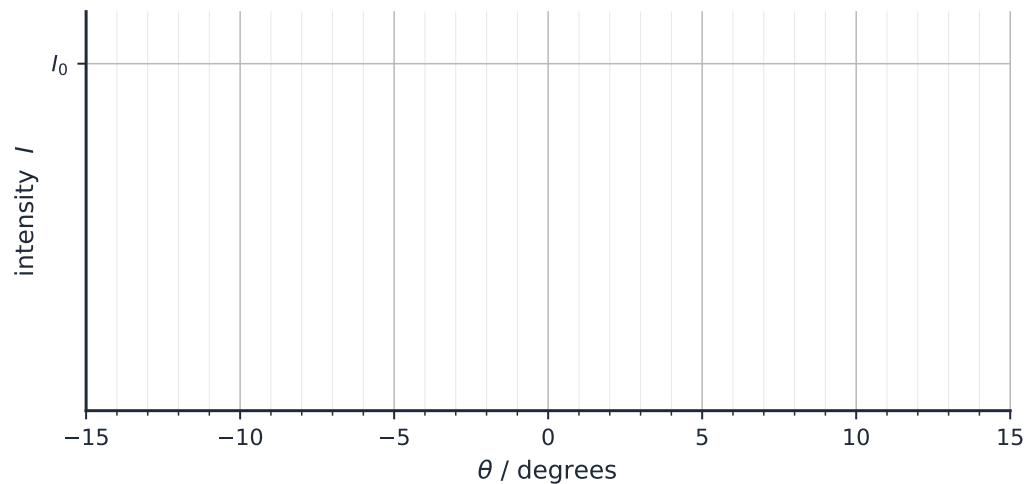
Exercise 3.5 (d)

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



Exercise 3.5 (d)

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(d) maxima at $\theta = 0, \pm 6.2^\circ$ and $\pm 12^\circ$

- intensity **zero** between them – separated peaks, not a continuous curve
- central peak intensity I_0 ; outer peaks $\leq I_0$

Exercise 3.5 (e)

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 .

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

Exercise 3.5 (e)

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 .

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

(e) the maxima stay at the **same angles** (filter changes neither λ nor d)

- every peak is **less intense** (the filter removes the perpendicular polarisation; unpolarised light roughly halves)