8.4 The diffraction grating

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

Objective

Build the skills to answer exam questions on the **diffraction grating** 衍射光栅.

You must be able to:

- use $d\sin\theta = n\lambda$ in **both** directions (find an angle; find the grating)
- find the slit spacing from **lines per mm** and the **highest order**
- describe using a grating to measure **wavelength**

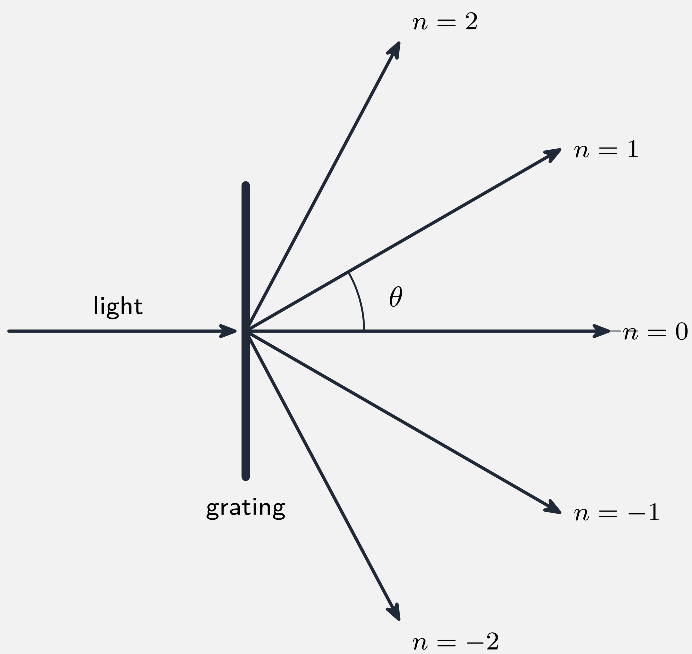
1 Worked examples

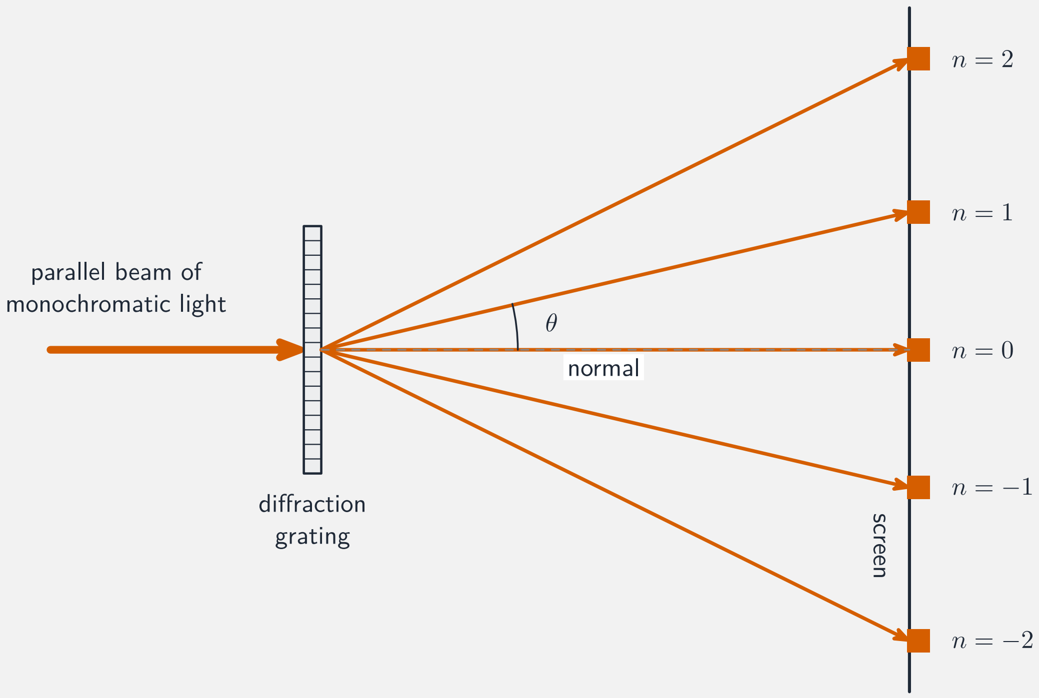
Study these first. Each one shows the method for a question type used later —follow the steps and you can do the Practice and Exam-style questions yourself.

■ The grating equation

A grating has many equally spaced slits, slit spacing d. Bright maxima (orders n) appear where

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





A diffraction grating spreads the orders

Worked example (find the angle). 500 lines/mm, $\lambda = 600$ nm: $d = \frac{1}{500}$ mm $= 2.0 \times 10^{-6}$ m; $\sin\theta = \frac{n\lambda}{d} = \frac{600 \times 10^{-9}}{2.0 \times 10^{-6}} = 0.30$, so $\theta \approx 17°$.

■ Working backwards —find the grating

Exam questions often **give** an order's angle and ask for the grating. Rearrange to $d = \frac{n\lambda}{\sin\theta}$, then **lines per mm** $= \frac{1}{d \text{ (in mm)}}$.

Worked example. The **second-order** $(n = 2)$ maximum for $\lambda = 730$ nm is at $\theta = 35°$. Then $d = \frac{2 \times 730 \times 10^{-9}}{\sin 35°} = \frac{1.46 \times 10^{-6}}{0.574} = 2.55 \times 10^{-6}$ m. In mm, $d = 2.55 \times 10^{-3}$ mm, so **lines per mm** $= \frac{1}{2.55 \times 10^{-3}} \approx 390$.

■ Slit spacing and highest order

N lines per mm $\rightarrow d = 10^{-3}/N$ m. Since $\sin\theta \leq 1$, the **highest order** is $n_{\max} = \lfloor d/\lambda \rfloor$.

■ Finding wavelength

Shine parallel light normally on the grating, measure θ_1 for the first order, then $\lambda = d\sin\theta_1$. A grating gives **sharper** maxima than a double slit (many slits add).

2 Practice

Now apply the methods above.

2.1 State what d represents in $d \sin\theta = n\lambda$. [1]

2.2 A grating has 500 lines per mm. Find the slit spacing d in metres. [2]

2.3 State **one** reason a grating gives **sharper** maxima than a double slit. [1]

2.4 Write the formula for the **highest order** observable. [1]

3 Exam-style questions

3.1 A grating with 500 lines per mm is illuminated normally by light of wavelength 600 nm. Calculate the angle of the **first-order** maximum. [3]

3.2 For the same grating and wavelength, calculate the **highest order** that can be seen. [2]

3.3 Light of wavelength 730 nm is incident normally on a grating. The **second-order** maximum is observed at 35° to the straight-through direction. Calculate the number of

lines per mm of the grating. [3]

3.4 Describe how a diffraction grating can be used to **measure the wavelength** of light. [3]

3.5 A grating with **more** lines per mm (smaller d) is used. The diffraction angles become: [1]

- **A** smaller
- **B** larger
- **C** unchanged
- **D** zero

4 Go further

You are now ready for the real exam questions on this subtopic. Open the **8.4 The diffraction grating** past-paper sheet in the Library, or try these in **Practice mode**:

- 9702/23 J25 —Q6 (find the lines per mm from an order)
- 9702/21 N25 —Q4 (diffraction grating, structured)
- 9702/23 N25 —Q4 (diffraction grating, structured)
- 9702/11 J25 —Q30 (grating equation, multiple choice)
- 9702/12 N25 —Q29 (orders, multiple choice)

Solutions

2.1 The **slit spacing** —the (centre-to-centre) distance between adjacent slits.

2.2 $d = \dfrac{1}{500}$ mm $= \dfrac{10^{-3}}{500} = 2.0 \times 10^{-6}$ m.

2.3 Many slits contribute, so the maxima are **sharper/brighter** and other directions are more completely cancelled.

2.4 $n_{\text{max}} = \lfloor d/\lambda \rfloor$ (the largest integer with $\sin\theta \le 1$).

3.1 $d = 2.0 \times 10^{-6}$ m; $\sin\theta = \dfrac{(1)(600 \times 10^{-9})}{2.0 \times 10^{-6}} = 0.30$; $\theta = 17°$.

3.2 $d/\lambda = \dfrac{2.0 \times 10^{-6}}{600 \times 10^{-9}} = 3.33$; highest order $n = 3$ ($n = 4$ needs $\sin\theta > 1$).

3.3 $d = \dfrac{n\lambda}{\sin\theta} = \dfrac{2 \times 730 \times 10^{-9}}{\sin 35°} = 2.55 \times 10^{-6}$ m; $d = 2.55 \times 10^{-3}$ mm; lines per mm $= \dfrac{1}{2.55 \times 10^{-3}} \approx 390$.

3.4 Shine **parallel monochromatic** light normally on the grating; measure the **angle** θ of a known order n from the straight-through direction; calculate $\lambda = \dfrac{d\sin\theta}{n}$.

3.5 **B** —larger (smaller d gives larger $\sin\theta$ for each order).