A-LEVEL PHYSICS • EXERCISE SHEET

8.4 The diffraction grating

Name: _____ Class: _____ Date: _____ **Total: 18 marks**

KEY WORDS diffraction grating 衍射光栅 • wavelength 波长 • diffraction 衍射 • normal 法线 • order 级次

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**

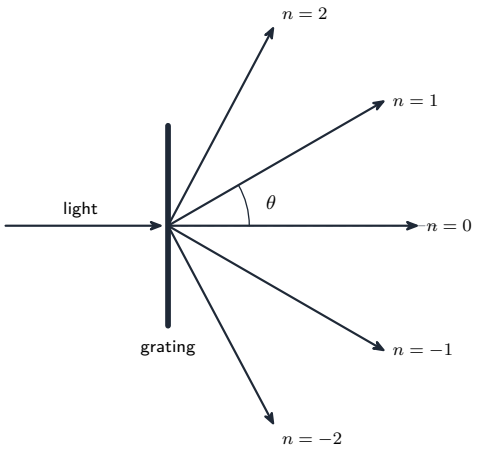
1 Worked examples

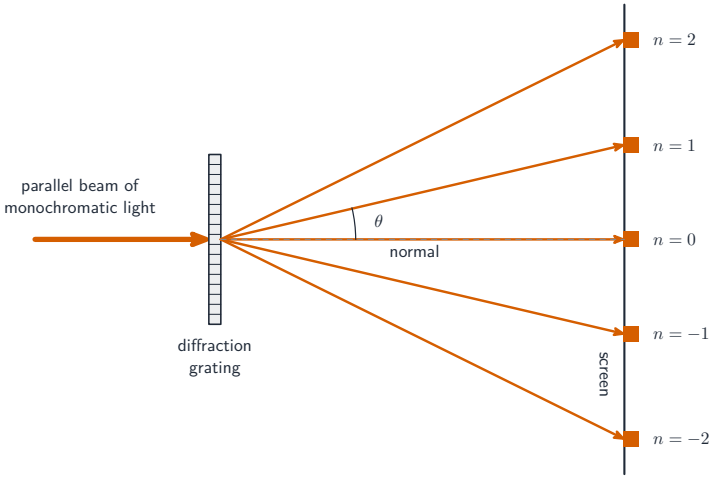
Study these first. Each one shows the method for a question type used later — follow the steps and you can do the Practice and Exam-style questions yourself.

■ 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: $d = \dfrac{1}{500}$ mm $= 2.0\times10^{-6}$ m; $\sin\theta = \dfrac{n\lambda}{d} = \dfrac{600\times10^{-9}}{2.0\times10^{-6}} = 0.30$, so $\theta \approx 17°$.

■ **Working backwards — find the grating**

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

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

■ **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 A grating has 600 lines per mm. Light of wavelength 590 nm is incident normally on it. **Determine** the highest order of maximum that can be observed, and **explain** what limits it. [4]

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

Solutions

Each answer shows the steps, then the **result**.

2.1

- the **slit spacing** — the centre-to-centre distance between adjacent slits

2.2

- $d = 1/N$ per millimetre

$$d = \frac{1.0 \times 10^{-3}\ \text{m}}{500} = \mathbf{2.0 \times 10^{-6}}\ \text{m}$$

2.3

- many slits contribute, so the maxima are **sharper / brighter** and other directions are more completely cancelled

2.4

- $n_{\max} = \lfloor d/\lambda \rfloor$ — the largest integer with $\sin\theta \le 1$

3.1

- $d = 2.0 \times 10^{-6}$ m

$$\sin\theta = \frac{(1)(600 \times 10^{-9}\ \text{m})}{2.0 \times 10^{-6}\ \text{m}} = 0.30$$

- $\theta = \mathbf{17}^\circ$

3.2

$$\frac{d}{\lambda} = \frac{2.0 \times 10^{-6}\ \text{m}}{600 \times 10^{-9}\ \text{m}} = 3.33$$

- highest order $n = \mathbf{3}$ ($n = 4$ needs $\sin\theta > 1$)

3.3

$$d = \frac{1.0 \times 10^{-3}\ \text{m}}{600} = 1.67 \times 10^{-6}\ \text{m}$$

- largest angle is 90°, where $\sin\theta = 1$

$$n_{\max} = \frac{d}{\lambda} = \frac{1.67 \times 10^{-6}\ \text{m}}{590 \times 10^{-9}\ \text{m}} = 2.8$$

- an order must be a whole number and $\sin\theta$ cannot exceed 1, so the highest observed is the **2nd order**

3.4

- shine **parallel monochromatic** light normally on the grating
- measure the **angle** θ of a known order n from the straight-through beam

- calculate $\lambda = d\sin\theta/n$

3.5 B

- more lines per mm ⇒ smaller d ⇒ larger $\sin\theta$ for each order ⇒ **larger** angle