

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**

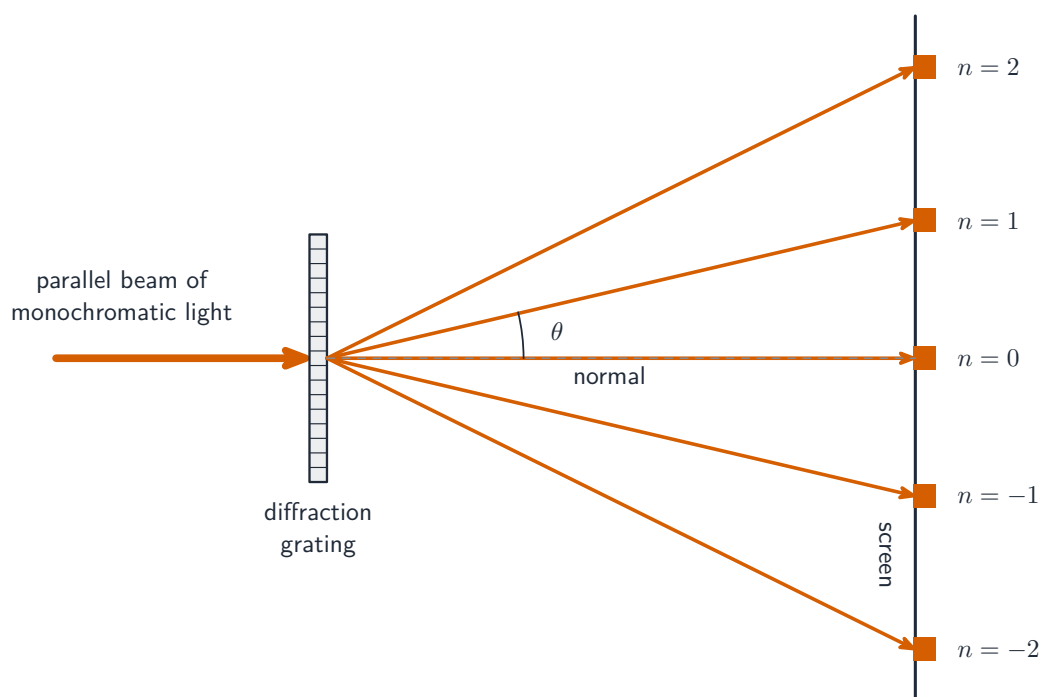
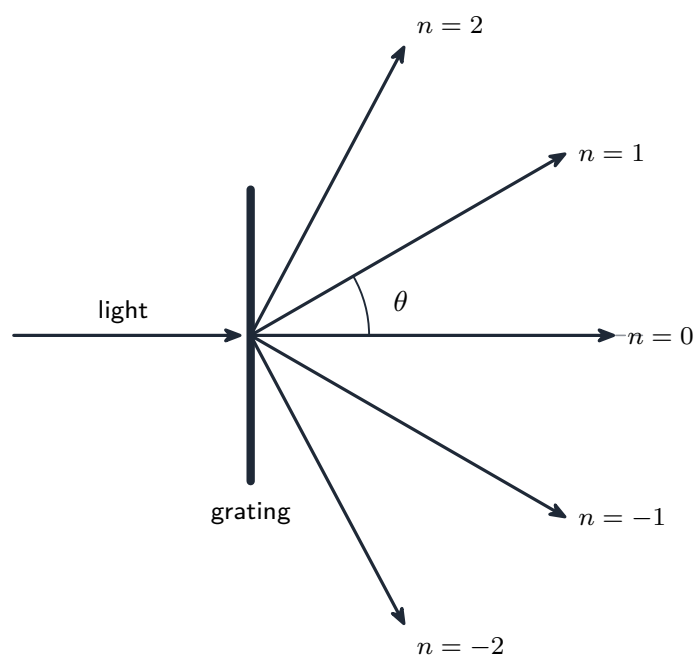
1 Worked examples

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, $\lambda = 600 \text{ nm}$: $d = \frac{1}{500} \text{ mm} = 2.0 \times 10^{-6} \text{ m}$; $\sin \theta = \frac{n\lambda}{d} = \frac{600 \times 10^{-9}}{2.0 \times 10^{-6}} = 0.30$, so $\theta \approx 17^\circ$.

■ 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 $\lambda = 730 \text{ nm}$ is at $\theta = 35^\circ$. Then $d = \frac{2 \times 730 \times 10^{-9}}{\sin 35^\circ} = \frac{1.46 \times 10^{-6}}{0.574} = 2.55 \times 10^{-6} \text{ m}$. In mm, $d = 2.55 \times 10^{-3} \text{ mm}$, so **lines per mm** = $\frac{1}{2.55 \times 10^{-3}} \approx 390$.

■ Slit spacing and highest order

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

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

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

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 $\sin \theta \leq 1$).

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

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

3.3 $d = \frac{1 \text{ mm}}{600} = 1.67 \times 10^{-6} \text{ m}$; the largest possible diffraction angle is 90° , where $\sin \theta = 1$, so $n_{\max} = \frac{d}{\lambda} = \frac{1.67 \times 10^{-6}}{590 \times 10^{-9}} = 2.8$. An order must be a whole number, so the highest observed is the **2nd order** — n cannot be rounded up, because $\sin \theta$ can never exceed 1.

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 $\lambda = \frac{d \sin \theta}{n}$.

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