Past-paper walk-through

The diffraction grating ▪ 8.4

eXercise

Questions in this set

- 9702/11 N25 Q30 ▪ 1 mark
- 9702/12 N25 Q29 ▪ 1 mark
- 9702/14 N25 Q30 ▪ 1 mark
- 9702/11 J25 Q30 ▪ 1 mark
- 9702/12 J25 Q29 ▪ 1 mark
- 9702/14 J25 Q28 ▪ 1 mark
- 9702/23 J25 Q6 ▪ 8 marks
- 9702/12 M25 Q29 ▪ 1 mark

Reading the mark scheme

- **B1** a mark that stands on its own – the point is either made or not.
- **M1** a *method* mark: the right approach, even if the number is wrong.
- **A1** an *answer* mark, and it usually needs its M mark first.
- **C1** a working mark on the way to the answer.
- // separates answers the examiner accepts equally.
- **ecf** = error carried forward: a later part is marked on your own earlier answer.
- **owtte** = "or words to that effect" – the wording need not match.

Question 30

9702/11 N25 ▪ Q30 ▪ 1 mark

Green laser light passes through a diffraction grating and forms an interference pattern.

The diffraction grating contains 400 lines per mm.

The wavelength of the laser light is 550 nm.

What is the highest order diffraction maximum produced by the grating? **[1]**

A 4

B 5

C 8

D 9

Solution 30

- **A** 4 ✓
- **B** 5
- **C** 8
- **D** 9

Why

- The largest possible diffraction angle is 90°, where $\sin\theta = 1$.
- So $n_{\max} = d/\lambda = (2.5 \times 10^{-6})/(550 \times 10^{-9}) = 4.5$.
- The order has to be a whole number, so the highest one produced is the 4th.

Question 29

9702/12 N25 ▪ Q29 ▪ 1 mark

The equation $n\lambda = d\sin\theta$ can be used with a diffraction grating to find the wavelength of visible light. Which quantity is **not** correct for use in this equation?

	symbol	quantity
A	d	distance from grating to screen
B	λ	wavelength of light
C	n	order of intensity maximum
D	θ	diffraction angle of intensity maximum

Question 29

[1]

A d / distance from grating to screen

B λ / wavelength of light

C n / order of intensity maximum

D θ / diffraction angle of intensity maximum

Question 29

	symbol	quantity
A	d	distance from grating to screen
B	λ	wavelength of light
C	n	order of intensity maximum
D	θ	diffraction angle of intensity maximum

Solution 29

A d / distance from grating to screen ✓

B λ / wavelength of light

C n / order of intensity maximum

D θ / diffraction angle of intensity maximum

Why

- In $n\lambda = d\sin\theta$, d is the spacing between adjacent slits of the grating.
- The distance from the grating to the screen does not appear in the equation at all.
- The other three symbols are described correctly.

Question 30

9702/14 N25 ▪ Q30 ▪ 1 mark

A parallel beam of red light of wavelength 700 nm is incident normally on a diffraction grating that has 400 lines per millimetre.

What is the total number of intensity maxima from the grating? **[1]**

A 6

B 7

C 8

D 9

Solution 30

A 6

B 7 ✓

C 8

D 9

Why

- $d = 1/400$ mm $= 2.5 \times 10^{-6}$ m, so $n_{\max} = d/\lambda = 3.57$ – the third order.
- Maxima appear on *both* sides at orders 1, 2 and 3, plus the straight-through zero order.
- Total $= 2 \times 3 + 1 = 7$.

Question 30

9702/11 J25 ▪ Q30 ▪ 1 mark

Light of wavelength 680 nm is incident normally on a diffraction grating with 450 lines mm^{-1}.

What is the angle of diffraction of the second-order maximum in the diffraction pattern that is produced? **[1]**

A $1.8°$

B $3.5°$

C $18°$

D $38°$

Solution 30

- **A** $1.8°$
- **B** $3.5°$
- **C** $18°$
- **D** $38°$ ✓

Why

- $d = 1/450$ mm $= 2.22 \times 10^{-6}$ m.
- $\sin\theta = n\lambda/d = 2(680 \times 10^{-9})/(2.22 \times 10^{-6}) = 0.612$.
- $\theta = 37.7°$, which rounds to $38°$.

Question 29

9702/12 J25 ▪ Q29 ▪ 1 mark

A student uses a diffraction grating to determine the wavelength of visible light from a source.

The diffraction grating has 300 lines per mm. The student measures the angle θ of each order n of the intensity maxima. A graph of n against $\sin\theta$ is plotted. The line of best fit for the plotted points is shown and has gradient G.

Which expression represents the wavelength, in m, of the visible light in terms of G? **[1]**

A $3 \times 10^5 G$

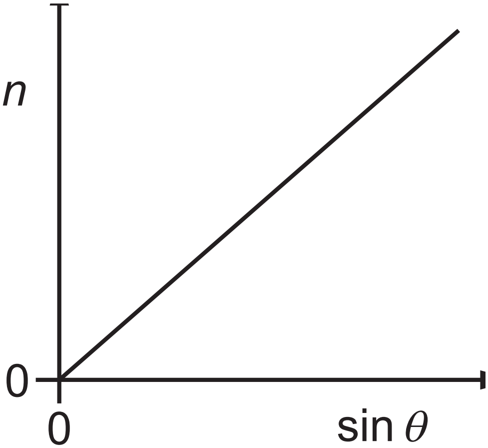
B $3.3 \times 10^{-6} G$

C $\frac{3.3 \times 10^{-6}}{G}$

Question 29

D $\frac{300}{G}$

Question 29



Solution 29

- **A** $3 \times 10^5 G$
- **B** $3.3 \times 10^{-6} G$
- **C** $\frac{3.3 \times 10^{-6}}{G}$ ✓
- **D** $\frac{300}{G}$

Why

- Rearranging $n\lambda = d \sin\theta$ gives $n = (d/\lambda)\sin\theta$.
- So a graph of n against $\sin\theta$ has gradient $G = d/\lambda$, and $\lambda = d/G$.
- With 300 lines per mm, $d = 3.33 \times 10^{-6}$ m, so $\lambda = 3.33 \times 10^{-6}/G$.

Question 28

9702/14 J25 ▪ Q28 ▪ 1 mark

28 An electromagnetic wave is incident normally on a diffraction grating.

A second-order maximum is produced at an angle of 30° to the direction of the incident light.

The grating has 5000 lines per cm.

What is the wavelength of the wave?

A 2.5×10^{-7} m **B** 5.0×10^{-7} m **C** 1.0×10^{-6} m **D** 5.0×10^{-5} m

Solution 28

Answer: **B**

Why

- $d = 1/5000$ cm $= 2.0 \times 10^{-6}$ m.
- $n\lambda = d\sin\theta$, so $2\lambda = (2.0 \times 10^{-6})(0.5) = 1.0 \times 10^{-6}$.
- $\lambda = 5.0 \times 10^{-7}$ m; A forgets to divide by the order.

Question 6

9702/23 J25 ▪ Q6 ▪ 8 marks

6 (a) State what is meant by diffraction [1]
(b) Light of wavelength 720 nm in a vacuum is incident normally on a diffraction grating as shown in Fig. 6.1. second-order maxima 52° diffraction grating light, wavelength 720 nm screen Fig. 6.1 (not to scale)
A screen is parallel to the grating. An interference pattern is seen on the screen and the angle between the second-order maxima is 52°.
(i) Calculate the frequency of the light.
frequency = Hz [2] , ,
(ii) Calculate the number of lines per unit length in the diffraction grating.
number per unit length = m−1 [3]

Question 6

(iii) The light in Fig. 6.1 is now replaced with light of a different wavelength λ. It is observed that the third-order maxima of this light are at the same positions as the second-order maxima of the light in Fig. 6.1.
Calculate, in nm, the wavelength λ.
$\lambda =$ nm [2]

, ,

(a) State what is meant by diffraction. **[1]**

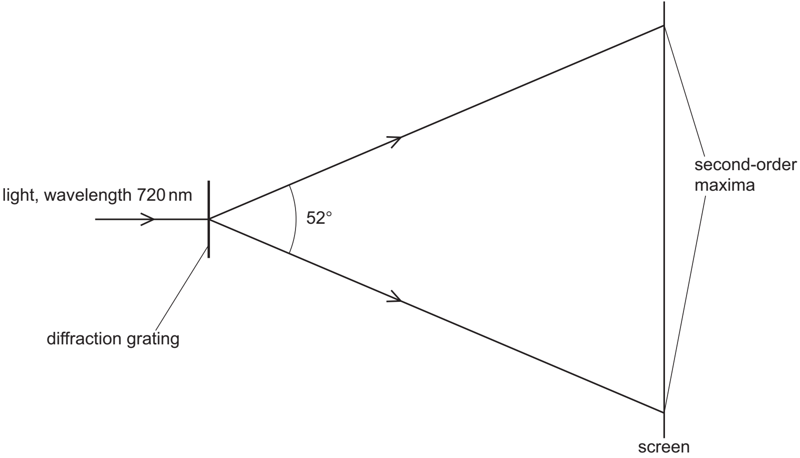
(b)(i) Light of wavelength 720 nm in a vacuum is incident normally on a diffraction grating. Calculate the frequency of the light. **[2]**

(b)(ii) A screen is parallel to the grating and the angle between the second-order maxima is $52°$. Calculate the number of lines per metre of the grating. **[3]**

Question 6

(b)(iii) The light is replaced by light of a different wavelength λ. The third-order maxima of this light are at the same positions as the second-order maxima of the original light. Calculate λ. **[2]**

Question 6


light, wavelength 720 nm
52°
second-order
maxima
diffraction grating
screen

Solution 6

(a)

Mark scheme

- wave passes (through) an aperture and spreads
- or
- wave passes (by / through / around) an edge and spreads

Solution 6

(b)(i)

Worked steps

- $c = f\lambda$, so $f = \dfrac{c}{\lambda} = \dfrac{3.00 \times 10^{8}}{720 \times 10^{-9}}$
- $f = 4.2 \times 10^{14}$ Hz

Mark scheme

- v = fλ
- f = 3.00 × 108 / 720 × 10—9
- = 4.2 × 1014 Hz

Solution 6

(b)(ii) Worked steps

The trap is the angle: 52° is measured **between** the two second-order maxima, one either side of the centre, so the angle from the normal is half of it.

- $\theta = \dfrac{52}{2} = 26^\circ$
- $d \sin\theta = n\lambda$, so $d = \dfrac{n\lambda}{\sin\theta} = \dfrac{2 \times 720 \times 10^{-9}}{\sin 26^\circ}$
- $d = 3.3 \times 10^{-6}$ m
- Lines per metre $= \dfrac{1}{d} = \dfrac{1}{3.3 \times 10^{-6}} = 3.0 \times 10^{5}$ m^{-1}

Solution 6

Mark scheme

- d $=$ nλ / sin θ
- d $=$ (2 $\times$ 720 $\times$ 10—9) / sin 26
- (= 3.3 $\times$ 10—6 m)
- number of lines per m $=$ 1 / (3.3 $\times$ 10—6)
- $=$ 3.0 $\times$ 105 m—1

Solution 6

(b)(iii) Worked steps

Same grating, same angle — so $d\sin\theta$ is unchanged, and therefore $n\lambda$ is unchanged.

- $3\lambda = 2 \times 720$ nm
- $\lambda = \dfrac{1440}{3}$
- $\lambda = 480$ nm

Mark scheme

- $\lambda \times 3 = 720 \times 2$ or
- 5

Solution 6

- 1
- sin 26/3 3.0 10
- $= \lambda$
- $\times$
- $\lambda = 480$ nm

Question 29

9702/12 M25 ▪ Q29 ▪ 1 mark

29 Light of wavelength 567 nm is incident normally on a diffraction grating. The grating has 400 lines per mm. A number of diffraction maxima are observed on the far side of the grating.

What is the angle between the second-order maximum and the third-order maximum?

A 13.1° **B** 13.9° **C** 15.9° **D** 27.0°

Solution 29

Answer: **C**

Why

- $d = 1/400$ mm $= 2.50 \times 10^{-6}$ m.
- $\sin\theta_2 = 2\lambda/d = 0.4536$ gives $\theta_2 = 27.0°$; $\sin\theta_3 = 0.6804$ gives $\theta_3 = 42.9°$.
- The angle *between* them is $42.9 - 27.0 = 15.9°$; D is simply θ_2 itself.