FREE SAMPLE: THE FIRST QUESTION

Question One (15 marks)

(a) A diffraction grating has 300 lines per millimetre. Light of wavelength 5.00×10^{-7} m shines normally on the grating.

(i) Calculate the angle to the second order maximum.

(ii) Calculate the highest order that can be seen, and explain why no higher order appears.

[5 marks]

(b) Monochromatic light of wavelength 5.00×10^{-7} m passes through two narrow slits 3.00×10^{-4} m apart. The interference pattern is seen on a screen 2.00 m away.

(i) Calculate the distance between adjacent bright fringes.

(ii) Explain what happens to the fringe spacing if the slit separation is halved.

[5 marks]

(c) Light of wavelength 6.50×10^{-7} m passes through 6 equally spaced narrow slits, with a spacing of 2.00×10^{-6} m between neighbouring slits, and falls on a distant screen.

(i) Calculate the angle to the first order principal maximum.

(ii) The number of slits is increased to 8 with the same spacing. Describe and explain what happens to the positions and the sharpness of the principal maxima, and to the number of weak secondary maxima between them.

[5 marks]

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THE WORKED ANSWER TO THAT QUESTION

Question 1 (15 marks) [Interference and gratings]

(a) A diffraction grating has 300 lines per millimetre. Light of wavelength 5.00×10^{-7} m shines normally on the grating. (i) Calculate the angle to the second order maximum. (ii) Calculate the highest order that can be seen, and explain why no higher order appears.

(a) Answer: (i) 17.5°; (ii) highest order 6

- Evidence level: Excellence (find the grating spacing, apply $d \sin\theta = n\lambda$, and find the limit on n).
- (i) $d = 1 \div (300 \times 10^{3}) = 3.33 \times 10^{-6}$ m. $\sin\theta = n\lambda/d = 2 \times 5.00 \times 10^{-7} \div 3.33 \times 10^{-6} = 0.300$, so $\theta = 17.5°$.
- (ii) $\sin\theta$ cannot exceed 1, so $n\lambda/d \le 1$ and $n \le d/\lambda = 3.33 \times 10^{-6} \div 5.00 \times 10^{-7} = 6.67$. The highest whole order is n = 6.
- Achievement: (ii) States that the maximum order is 6.
- Merit: Links to the relationship: $n\lambda/d = \sin\theta$ must be less than or equal to 1.
- Excellence: Full explanation: the order $n\lambda/d$ would need $\sin\theta > 1$ for n = 7, which is impossible, so the light for that order would have to travel along an angle beyond 90°; no such maximum can form.

> **KEY TAKEAWAY**
> Diffraction grating: $d \sin\theta = n\lambda$ with $d = \frac{1}{\text{lines per metre}}$; the number of orders is limited because $\sin\theta \le 1$, so $n \le d/\lambda$.

(b) Monochromatic light of wavelength 5.00×10^{-7} m passes through two narrow slits 3.00×10^{-4} m apart. The interference pattern is seen on a screen 2.00 m away. (i) Calculate the distance between adjacent bright fringes. (ii) Explain what happens to the fringe spacing if the slit separation is halved.

(b) Answer: (i) 3.33×10^{-3} m; (ii) the spacing increases by a factor of 2.00

- Evidence level: Excellence (use the double-slit relationship $dx/L = \lambda$, and reason from the proportionality).
- (i) $x = \lambda L/d = (5.00 \times 10^{-7} \times 2.00) \div 3.00 \times 10^{-4} = 3.33 \times 10^{-3}$ m (3.33 mm).
- Achievement: (ii) States whether the fringes get closer together or further apart.
- Merit: States the change and links it to the relationship: $x = \lambda L/d$, so x is proportional to L and λ and inversely proportional to d.
- Excellence: Full explanation: the slit separation is halved, so x changes by a factor of 2.00 (new spacing 6.67×10^{-3} m); a longer path from the slits lets the path difference between rays grow more slowly across the screen, or a different λ/d changes the angle θ at which each order of constructive interference occurs.

> **KEY TAKEAWAY**
> Double slit: fringe spacing $x = \lambda L/d$ — larger wavelength or screen distance spreads the fringes; larger slit separation brings them closer together.

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(c) Light of wavelength 6.50×10^{-7} m passes through 6 equally spaced narrow slits, with a spacing of 2.00×10^{-6} m between neighbouring slits, and falls on a distant screen. (i) Calculate the angle to the first order principal maximum. (ii) The number of slits is increased to 8 with the same spacing. Describe and explain what happens to the positions and the sharpness of the principal maxima, and to the number of weak secondary maxima between them.

(c) Answer: (i) 19.0°; (ii) same positions, narrower and brighter, 6 weak secondary maxima instead of 4

- Evidence level: Excellence (apply $d \sin \theta = n\lambda$ and explain how more slits sharpen the pattern).
- (i) $\sin \theta = \lambda/d = 6.50 \times 10^{-7} \div 2.00 \times 10^{-6} = 0.325$, so $\theta = 19.0°$.
- Achievement: (ii) States that the maxima stay in the same places but get sharper (narrower).
- Merit: Links to the cause: the positions depend only on d and λ ($d \sin \theta = n\lambda$), so they do not move; more slits make the maxima narrower and brighter.
- Excellence: Full explanation: the principal maxima need the path difference between ADJACENT slits to be nλ, which does not depend on the number of slits, so their positions are unchanged. Away from the maxima, more sources provide more possible phase combinations that cancel, so the maxima become narrower and brighter, and the number of weak secondary maxima between neighbouring principal maxima is N − 2 (here 4 increasing to 6).

KEY TAKEAWAY

Multi-slit patterns: principal maxima are at $d \sin\theta = n\lambda$ whatever the number of slits N; more slits sharpen them and put N − 2 weak secondary maxima between them.

LOS: Interference and gratings (91523)

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