2021 Ph H2 Q10

Section: Particles and Waves

Topic: Interference and Diffraction Grating

A laser is used with a diffraction grating. (a)(i) Calculate mean angle θ and its uncertainty. (a)(ii) Use grating equation with $d = 4.00\times10^{-6}$ m and $n = 2$ to find λ. (a)(iii) Explain why measuring 3rd order maximum improves precision. (b) White light produces central white maximum: explain in terms of path difference.

Worked solution

(a)(i)

Measurements: [14.0, 15.0, 14.5, 14.5, 15.0]
Mean $\theta = (14.0+15.0+14.5+14.5+15.0)/5 = 14.60°$
Uncertainty $\approx$ (max−min)/2 = $(15.0-14.0)/2 = 0.5°$

Answer: $\theta = 14.6° \pm 0.5°$

(a)(ii)

Grating equation: $d \sin\theta = n\lambda$
$\lambda = d \sin\theta / n = (4.00\times10^{-6} \times \sin(14.6°)) / 2$
= 5.04e-07 m

Answer: 5.0×10^{-7} m (500 nm)

(a)(iii) Using 3rd order maximum increases the angle measured, so the same absolute measurement uncertainty corresponds to a smaller percentage uncertainty in sinθ. This gives a more precise value for λ.

(b) At the central maximum, the path difference for all wavelengths is zero. So all wavelengths constructively interfere in phase, producing white light.

Final answers

(a)(i) θ = 14.6° ± 0.5°

(a)(ii) λ ≈ 5.0×10^{-7} m (500 nm, green)

(a)(iii) Higher order = smaller % uncertainty

(b) Central maximum is white: all λ have zero path difference → in phase

Revision tips

- For random uncertainty in repeated measures, use (max−min)/2.
- Diffraction grating: d sinθ = nλ.
- Higher-order fringes give greater precision (smaller % error).
- White light central maximum: zero path difference for all wavelengths.
- Visible λ range ~400–700 nm (violet to red).