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Where Minds Pollinate

Class 12

Physics

Chapter 18

Exercise Solution

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Short Questions

1) How is an intereference pattern formed by a diffraction grating different from the pattern formed by a double slit?

	Double Slit	Diffraction Grat.
No. of slits	Only 2 slits, so pattern comes from superposition of light from 2 sources.	Has many slits, so many waves interefere together.
Sharpness of maxima	Bright fringes are relatively broad and not very sharp.	Maxima are very sharp, narrow, and bright, while regions between them are almost completely dark.
Order of Maxima	Many fringes appear, but secondary maxima are faint and central region dominates.	Only sharp maxima at certain angles, higher orders are well separated.
Uses in Measurement	Mainly to study intereference and fringe width.	Used to measure wavelength very precesily because sharp lines make angular measurement easier.

2) A beam of light always spreads out. Why can a beam not be produced with parallel rays to prevent spreading?

A beam cannot have perfectly parallel rays because of the wave nature of light. According to Huygens' principle, every point on a wavefront acts as a source of secondary waves, causing ~~t~~ spreading (diffraction). The uncertainity principle also forbids an exactly defined direction and position simultaneously. Thus, some divergence is unavoidable so a perfectly parallel, non-spreading beam is impossible.

3) In the sunlight, the shadow of a building has fuzzy edges even if the building does not. Is this a refraction effect? Explain.

No, this is not due to refraction. The fuzzy edges of the shadow are caused by diffraction and the finite angular size of the Sun. Sunlight is not from a point source, but extends over a disk, so light from different parts of the Sun slightly overlaps at the shadow's edge, creating a blurred shadow. Refraction bends light but does not primarily cause this fuzziness.

4) A laser pointer emits a coherent beam of parallel light rays. Does the light from such a source spread out at all? Explain.

Yes, even a laser beam spreads out slightly. Laser light is highly coherent and collimated, so its divergence is very small. But due to the wave nature of light and diffraction, it cannot remain perfectly parallel forever. Over long distances, the beam gradually widens into a small cone. Thus, a laser beam spreads out, but far less than ordinary light sources.

5) A beam of light passes through a single slit to create a diffraction pattern. How will the spacing of the bands in the pattern change if the width of the slit is increased?

If the slit width is increased, the diffraction bands become closer together. Reason: The angular position of minima is given by

$d\sin\theta = m\lambda$

$d = m\lambda/\sin\theta$

This shows that d is inversely propotional to θ. If d is large then the θ is small hence fringes get narrower. If d is small then the θ is larger hence fringes spread out more.

6) Describe a diffraction grating and the interference pattern it produces.

A diffraction grating is an optical device with many closely spaced parallel slits or grooves. When light passes through it, each slit acts as a source of secondary wavefronts. These waves interefere constructively at specific angles, producing bright maxima. The condition for maxima is given by $d\sin\theta = m\lambda$, where d is grating spacing. The result is a sharp, colorful intereference pattern with multiple bright lines.

7) Suppose a monochromatic light falls on a diffraction grating. What happens to the intereference pattern if the same light falls on a grating that has more lines per centimeter.

If the grating has more lines per centimeter, the spacing d between lines becomes smaller. Since the condition is $d\sin\theta = m\lambda$. The maxima shift to larger angles (further apart). The bright lines become sharper and narrower because more slits reinforce the intereference. The overall pattern is more distinct and better resolved.

8) Compare the intereference patterns of single-slit diffraction, double slit diffraction and a diffraction grating.

Single-slit diffraction: Produces a broad central bright fringe with weaker, gradually fading side fringes.

Double-slit diffraction: Produces evenly spaced bright and dark fringes, but the entire pattern is modulated (enveloped) by single-slit diffraction.

Diffraction grating: Produces very sharp, narrow, and intense bright fringes at specific angles.

with dark regions in between.

9) What is the effect of following aspects of diffraction grating on the resulting intereference pattern: (a) number of slits (b) width of the slits?

If the number of slits increases, the fringes become sharper, narrower, and brighter. If the slit width increases, more light passes through, so the intensity increases but diffraction decreases. This makes the fringes appear closer together.

10) Describe the conditions necessary for sustained intereference patterns to be observed in Young's double-slit experiment?

For sustained intereference patterns in Young's double slit experiment, the light sources must be coherent (constant phase difference), monochromatic (single wave-length), and have equal or nearly equal amplitudes. Additionally, the slits must be narrow and close together, and the screen must be far from the slits.

Numerical Problems

1) The light with wavelength (λ) 633 nm is used at a distance of 2 m from the screen. The separation between the slits is 10 µm. Find the distance between adjacent maxima (fringe width) for the first ($m=1$) and second ($m=2$) order of intereference?

Data:

$\lambda = 633\,nm = 633 \times 10^{-9} m$

$L = 2m$

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

$\Delta y = y_2 - y_1 = ?$

$m_1 = 1$

$m_2 = 2$

Solution:

$\Delta y = y_2 - y_1$

$\Delta y = m_2 \lambda L/d - m_1 \lambda L/d$

$\Delta y = 2 \lambda L/d - 1 \lambda L/d$

$\Delta y = \lambda L/d$

$$\Delta y = \frac{(633 \times 10^{-9})(2)}{10 \times 10^{-6}}$$

$\Delta y = 126.6 \times 10^{-3}$

$\Delta y = 0.1266 m$

2) Find the distance from the central maximum to the third minimum on the screen, if the light of wavelength 400 nm is used. The distance between the slits and screen is 0.5 m and slit separation is 5 µm?

Data:

$y = y_2 - y_0 = ?$

$m_0 = 0$

$m_2 = 2$

$\lambda = 400nm = 400 \times 10^{-9} m$

$L = 0.5m$

$d = 5\mu m = 5 \times 10^{-6} m$

Solution:

$y = y_2 - y_0$

$y = (m_2 + 1/2)\lambda L/d - m_0 \lambda L/d$

$y = (2 + 1/2)\lambda L/d - (0)\lambda L/d$

$y = (5/2)\lambda L/d - 0$

$y = 5\lambda L/2d$

$$y = \frac{5(400 \times 10^{-9})(0.5)}{2(5 \times 10^{-6})}$$

$y = 100 \times 10^{-3}$

$y = 0.1 m$

3) The distance between the slits and screen is 1m, fringe spacing on screen is 1mm. Find the slit separation when light wavelength is 500nm.

Data:

$L = 1m$

$\Delta y = 1mm = 1 \times 10^{-3} m$

$d = ?$

$\lambda = 500nm = 500 \times 10^{-9} m$

Solution:

$\Delta y = \lambda L/d$

$d = \lambda L/\Delta y$

$$d = \frac{(500 \times 10^{-9})(1)}{1 \times 10^{-3}}$$

$d = 500 \times 10^{-6}$

$d = 0.5 \times 10^{-3} m$

$d = 0.5 mm$

4) Find the minimum angle for non-zero diffracted light, having slit spacing 2.0 µm with 400nm light wavelength.

Data:

$\theta = ?$

$m = 1$

$d = 2\mu m = 2 \times 10^{-6} m$

$\lambda = 400nm = 400 \times 10^{-9} m$

Solution:

$d\sin\theta = m\lambda$

$\sin\theta = m\lambda/d$

$$\sin\theta = \frac{(1)(400 \times 10^{-9})}{2 \times 10^{-6}}$$

$\sin\theta = 200 \times 10^{-3}$

$\sin\theta = 0.2$

$\theta = \sin^{-1}(0.2)$

$\theta = 11.54°$

5) The deviation of second order diffracted image formed by an optical grating having 5000 lines per centimeter is 32°. Calculate the wavelength of light used.

Data:

Grating lines $N = 5000$ lines per cm

Order of diffraction $m = 2$

Angle of deviation $\theta = 32°$

$\lambda = ?$

Solution:

$m\lambda = d\sin\theta$

$\lambda = d\sin\theta / m$

Finding d,

$d = 1/N$

$d = 1/5000 \text{ cm}$

$d = 1/5000 \times 10^{-2} \text{ m}$

$d = 2 \times 10^{-6} \text{ m}$

Now,

$$\lambda = \frac{(2 \times 10^{-6}) \times (0.5299)}{2}$$

$\lambda \approx 5.3 \times 10^{-5} \text{ cm}$

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