Wave Interference: Young's Double-Slit Experiment

Practice

Understanding Concepts

1. A student performing Young's experiment with a single-colour source finds the distance between the first and the seventh nodal lines to be 6.0 cm. The screen is located 3.0 m from the two slits. The slit separation is 2.2×10^2 μm. Calculate the wavelength of the light.
2. Single-colour light falling on two slits 0.042 mm apart produces the fifth-order fringe at a 3.8° angle. Calculate the wavelength of the light.
3. An interference pattern is formed on a screen when helium–neon laser light ($\lambda = 6.3 \times 10^{-7}$ m) is directed toward it through two slits. The slits are 43 μm apart. The screen is 2.5 m away. Calculate the separation of adjacent nodal lines.
4. In an interference experiment, reddish light of wavelength 6.0×10^2 nm passes through a double slit. The distance between the first and eleventh dark bands, on a screen 1.5 m away, is 13.2 cm.
   (a) Calculate the separation of the slits.
   (b) Calculate the spacing between adjacent nodal lines using blue light of wavelength 4.5×10^2 nm.
5. A parallel beam of light from a laser, with a wavelength 656 nm, falls on two very narrow slits, 0.050 mm apart. How far apart are the fringes in the centre of the pattern thrown upon a screen 2.6 m away?
6. Light of wavelength 6.8×10^2 nm falls on two slits, producing an interference pattern where the fourth-order dark fringe is 48 mm from the centre of the interference pattern on a screen 1.5 m away. Calculate the separation of the two slits.
7. Reddish light of wavelength 6.0×10^{-7} m passes through two parallel slits. Nodal lines are produced on a screen 3.0 m away. The distance between the first and the tenth nodal lines is 5.0 cm. Calculate the separation of the two slits.
8. In an interference experiment, reddish light of wavelength 6.0×10^{-7} m passes through a double slit, hitting a screen 1.5 m away. The distance between the first and eleventh dark bands is 2.0 cm.
   (a) Calculate the separation of the slits.
   (b) Calculate the spacing between adjacent nodal lines using blue light ($\lambda_{blue} = 4.5 \times 10^{-7}$ m).

Answers

1. 7.3×10^{-7} m
2. 6.2×10^2 nm
3. 3.7 cm
4. (a) 68 μm
   (b) 1.0 cm
5. 3.4 cm
6. 7.4×10^{-2} mm
7. 3.2×10^{-4} m
8. (a) 1.5×10^{-3} m
   (b) 4.5×10^{-4} m

220.

SUMMARY Wave Interference: Young's Double-Slit Experiment

- Early attempts to demonstrate the interference of light were unsuccessful because the two sources were too far apart and out of phase, and the wavelength of light is very small.
- Thomas Young's crucial contribution consisted of using one source illuminating two closely spaced openings in an opaque screen, thus using diffraction to create two sources of light close together and in phase.
- In Young's experiment a series of light and dark bands, called interference fringes, was created on a screen, placed in the path of light, in much the same way as those created in the ripple tank.
- The relationships $\sin\theta_n = \frac{x_n}{L} = \left(n - \frac{1}{2}\right)\frac{\lambda}{d}$ and $\frac{\Delta x}{L} = \frac{\lambda}{d}$ permit unknowns to be calculated, given any three of λ, Δx, L, θ, d, and n.
- Young's experiment supported the wave theory of light, explaining all the properties of light except transmission through a vacuum.

Section 9.5 Questions, p. 475

5. 16
6. (a) 4.2×10^2 nm
   (b) 8.0×10^{-3} m
7. (a) 5.4×10^{-7} m
   (b) 4.4×10^{-4} m
8. 4.4×10^{-7} m
9. 1.1°, 2.2°, 3.3°

Section 9.5 Questions

Understanding Concepts

1. Explain why the discoveries of Grimaldi were so important to Young's work.
2. Explain why the observation of the double-slit interference pattern was more convincing evidence for the wave theory of light than the observation of diffraction.
3. Monochromatic red light is incident on a double slit and produces an interference pattern on a screen some distance away. Explain how the fringe pattern would change if the red light source is replaced with a blue light source.
4. If Young's experiment were done completely under water, explain how the interference pattern would change from that observed in air, using the same equipment and experimental setup.
5. In a Young's double-slit experiment, the angle that locates the second dark fringe on either side of the central bright fringe is 5.4°. Calculate the ratio of the slit separation d to the wavelength λ of the light.
6. In measuring the wavelength of a narrow, monochromatic source of light, you use a double slit with a separation of 0.15 mm. Your friend places markers on a screen 2.0 m in front of the slits at the positions of successive dark bands in the pattern. Your friend finds the dark bands to be 0.56 cm apart.
   (a) Calculate the wavelength of the source in nanometres.
   (b) Calculate what the spacing of the dark bands would be if you used a source of wavelength 6.0×10^2 nm.
7. Monochromatic light from a point source illuminates two parallel, narrow slits. The centres of the slit openings are 0.80 mm apart. An interference pattern forms on a screen placed parallel to the plane of the slits and 49 cm away. The distance between two adjacent dark interference fringes is 0.30 mm.
   (a) Calculate the wavelength of the light.
   (b) What would the separation of the nodal lines be if the slit centre were narrowed to 0.60 mm?
8. Monochromatic light falls on two very narrow slits 0.040 mm apart. Successive nodal points on a screen 5.00 m away are 5.5 cm apart near the centre of the pattern. Calculate the wavelength of the light.
9. A Young's double-slit experiment is performed using light that has a wavelength of 6.3×10^2 nm. The separation between the slits is 3.3×10^{-5} m. Find the angles, with respect to the slits, that locate the first-, second-, and third-order bright (not dark) fringes on the screen.

Applying Inquiry Skills

10. A thin piece of glass is placed in front of one of the two slits in a Young's apparatus so that the waves exit that slit 180° out of phase with respect to the other slit. Describe, using diagrams, the interference pattern on the screen.