Problems:

Section 35.1 The Nature of Light

Section 35.2 Measurements of the Speed of Light

1. Find the energy of (a) a photon having a frequency of 5.00×10^{17} Hz and (b) a photon having a wavelength of 3.00×10^{2} nm. Express your answers in units of electron volts, noting that 1 eV = 1.60×10^{-19} J.

Section 35.3 The Ray Approximation in Ray Optics

Section 35.4 Analysis Model: Wave Under Reflection

Section 35.5 Analysis Model: Wave Under Refraction

5. The wavelength of red helium–neon laser light in air is 632.8 nm. (a) What is its frequency? (b) What is its wavelength in glass that has an index of refraction of 1.50? (c) What is its speed in the glass?

7. A ray of light is incident on a flat surface of a block of crown glass that is surrounded by water. The angle of refraction is 19.6°. Find the angle of reflection.

8. Figure P35.8 shows a refracted light beam in linseed oil making an angle of $\emptyset = 20.0°$ with the normal line *NN*´.

The index of refraction of linseed oil is 1.48. Determine the angles (a) θ and (b) θ'.

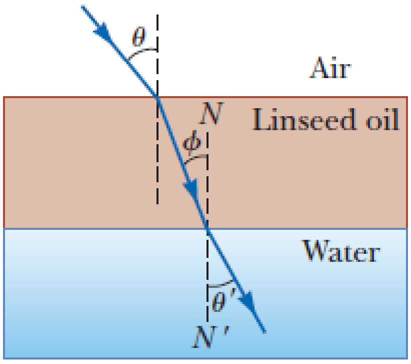


Figure P35.8

15. A light ray initially in water enters a transparent substance at an angle of incidence of 37.0°, and the transmitted ray is refracted at an angle of 25.0°. Calculate the speed of light in the transparent substance.

21. The two mirrors illustrated in Figure P35.21 meet at a right angle. The beam of light in the vertical plane indicated by the dashed lines strikes mirror 1 as shown. (a) Determine the distance the reflected light beam travels before striking mirror 2. (b) In what direction does the light beam travel after being reflected

from mirror 2?

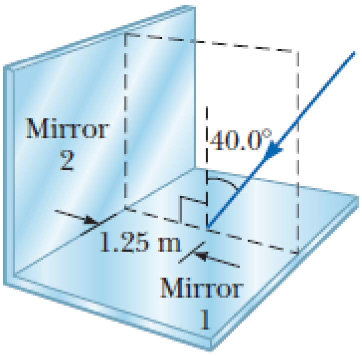


Figure P35.21

22. When the light ray illustrated in Figure P35.22 passes through the glass block of index of refraction *n* 5 1.50, it is shifted laterally by the distance *d.* (a) Find the value of *d.* (b) Find the time interval required for the light to pass through the glass block.

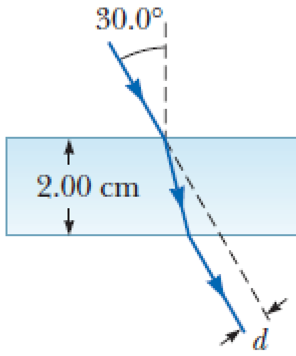


Figure P35.22

28. A triangular glass prism with apex angle 60.0° has an index of refraction of 1.50. (a) Show that if its angle of incidence on the first surface is θ_1 =48.6°, light will pass symmetrically through the prism as shown in Figure 35.17. (b) Find the angle of deviation δ_{min} for θ_1 = 48.6°. (c) **What If?** Find the angle of deviation if the angle of incidence on the first surface is 45.6°. (d) Find the angle of deviation if θ_1 = 51.6°.

29. Light of wavelength 700 nm is incident on the face of a fused quartz prism (n=1.458 at 700 nm) at an incidence angle of 75.0°. The apex angle of the prism is 60.0°. Calculate the angle (a) of refraction at the first surface, (b) of incidence at the second surface, (c) of refraction at the second surface, and (d) between the incident and emerging rays.

39. The index of refraction for violet light in silica flint glass is 1.66, and that for red light is 1.62. What is the angular spread of visible light passing through a prism of apex angle 60.0° if the angle of incidence is 50.0°? See Figure P35.39.

40. The index of refraction for violet light in silica flint glass is n_V, and that for red light is n_R. What is the angular spread of visible light passing through a prism of apex angle ϕ if the angle of incidence is θ? See Figure P35.39.

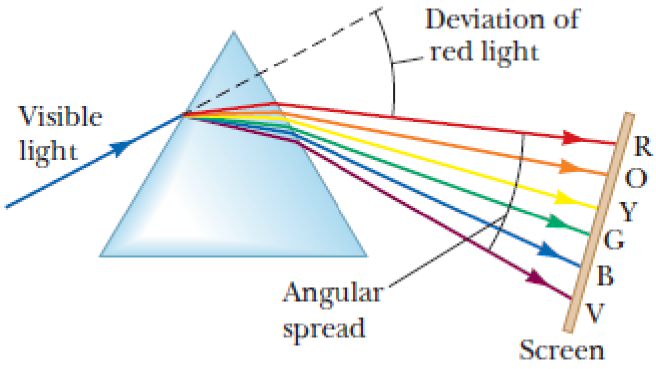


Figure P35.39 Problems 39 and 40.

Section 35.8 Total Internal Reflection

41. A glass optical fiber (n = 1.50) is submerged in water (n = 1.33). What is the critical angle for light to stay inside the fiber?

42. For 589-nm light, calculate the critical angle for the following materials surrounded by air: (a) cubic zirconia, (b) flint glass, and (c) ice.

45. Assume a transparent rod of diameter d = 2.00 mm has an index of refraction of 1.36.

Determine the maximum angle θ for which the light rays incident on the end of the rod in Figure P35.45 are subject to total internal reflection along the walls of the rod. Your answer defines the size of the *cone of acceptance* for

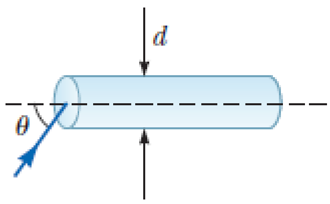
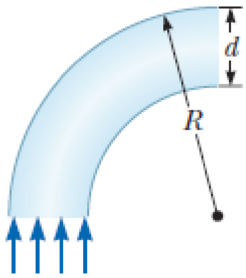


Figure P35.45

49. An optical fiber has an index of refraction n and diameter d. It is surrounded by vacuum. Light is sent into the fiber along its axis as shown in Figure P35.49. (a) Find

the smallest outside radius R_{min} permitted for a bend in the fiber if no light is to escape. (b) **What If?** What result does part (a) predict as *d* approaches zero? Is this behavior reasonable? Explain. (c) As *n* increases? (d) As *n* approaches 1? (e) Evaluate R_{min} assuming the fiber diameter is 100 mm and its index of refraction is 1.40.
 Figure P35.49
Section 36.1 Images Formed by Flat Mirrors
1. Determine the minimum height of a vertical flat mirror in which a person 178 cm tall can see his or her full image. *Suggestion:* Drawing a ray diagram would be helpful.
Section 36.2 Images Formed by Spherical Mirrors
8. An object is placed 50.0 cm from a concave spherical mirror with focal length of magnitude 20.0 cm. (a) Find the location of the image. (b) What is the magnification of the image? (c) Is the image
9. A concave spherical mirror has a radius of curvature of magnitude 20.0 cm. (a) Find the location of the image for object distances of **(i)** 40.0 cm, **(ii)** 20.0 cm, and

(iii) 10.0 cm. For each case, state whether the image is (b) real or virtual and (c) upright or inverted. (d) Find the magnification in each case.
11. A convex spherical mirror has a radius of curvature of magnitude 40.0 cm. Determine the position of the virtual image and the magnification for object distances of (a) 30.0 cm and (b) 60.0 cm. (c) Are the images in parts (a) and (b) upright or inverted?
13. An object of height 2.00 cm is placed 30.0 cm from a convex spherical mirror of focal length of magnitude 10.0 cm. (a) Find the location of the image. (b) Indicate whether the image is upright or inverted. (c) Determine the height of the image.
Section 36.3 Images Formed by Refraction
29. One end of a long glass rod (*n* 5 1.50) is formed into a convex surface with a radius of curvature of magnitude 6.00 cm. An object is located in air along the axis of the rod. Find the image positions corresponding to object distances of (a) 20.0 cm, (b) 10.0 cm, and (c) 3.00 cm from the convex end of the rod.
Section 36.4 Images Formed by Thin Lenses
38. A thin lens has a focal length of 25.0 cm. Locate and describe the image when the object is placed (a) 26.0 cm and (b) 24.0 cm in front of the lens.

39. An object located 32.0 cm in front of a lens forms an image on a screen 8.00 cm behind the lens. (a) Find the focal length of the lens. (b) Determine the magnification. (c) Is the lens converging or diverging?
Section 36.5 Lens Aberrations
Section 36.6 The Camera
Section 36.7 The Eye
Section 36.8 The Simple Magnifier
Section 36.9 The Compound Microscope
Section 36.10 The Telescope