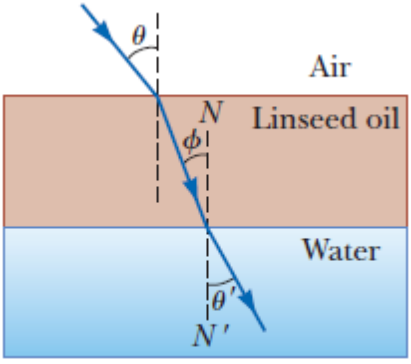
Problems:

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 Ø=20.0° with the normal line *NN´*. The index of refraction of linseed oil is 1.48. Determine the angles (a) ɵ and (b) ɵ´.
 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?

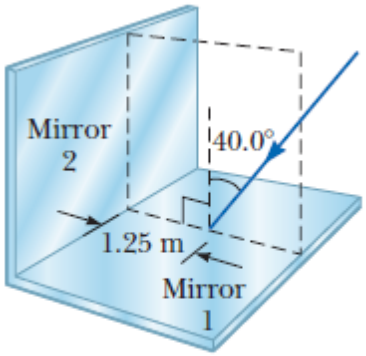
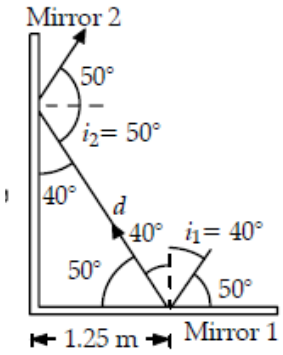


Figure P35.21



22. When the light ray illustrated in Figure P35.22 passes through the glass block of index of refraction n = 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.

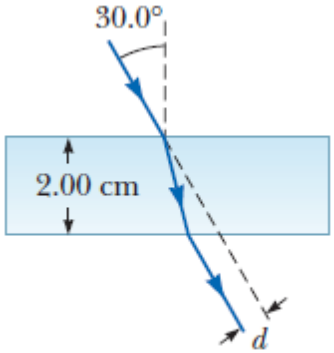
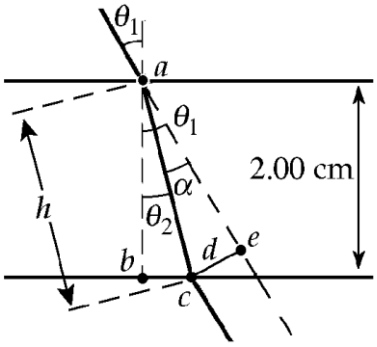


Figure P35.22



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°.

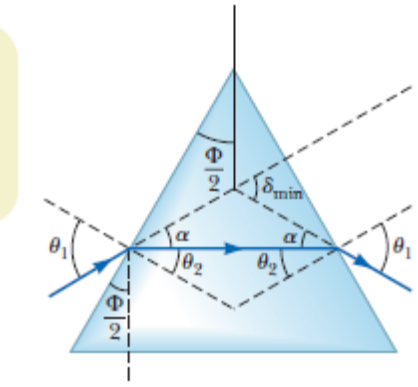
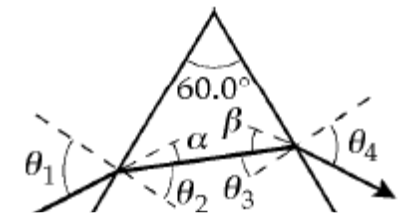


Figure 35.17 (Example 35.5) A light ray passing through a prism at the minimum angle of deviation δ_{min}.



$$\Phi + (90.0° - \theta_2) + (90.0° - \theta_3) = 180°$$

$$\theta_3 = \Phi - \theta_2 .$$

is $\alpha = \theta_1 - \theta_2 .$

$$\beta = \theta_4 - \theta_3 .$$

$$\delta = \alpha + \beta = \theta_1 + \theta_4 - \theta_2 - \theta_3 = \theta_1 + \theta_4 - \Phi .$$

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.

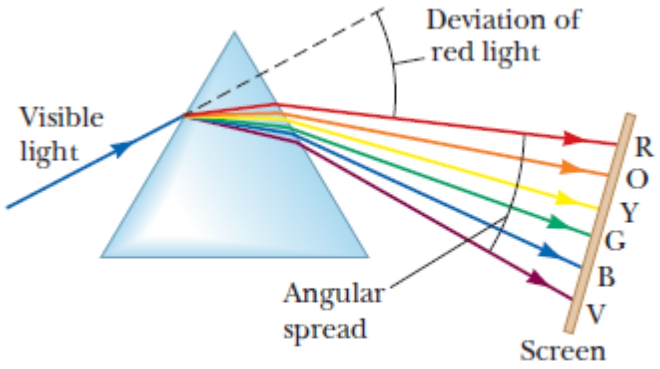


Figure P35.39 Problems 39 and 40.

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 μm 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 the rod.

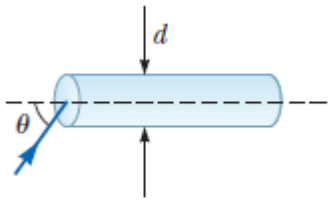
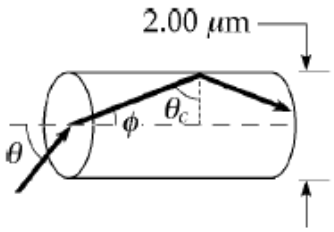


Figure P35.45



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, assuming the fiber diameter is 100 μm and its index of refraction is 1.40.

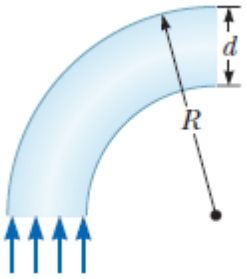
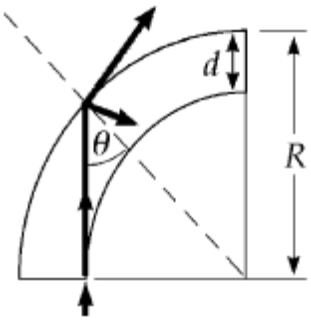
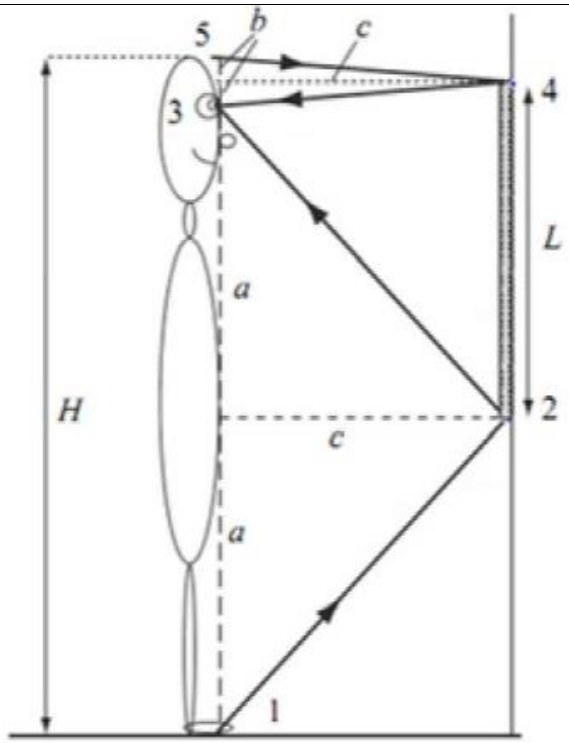


Figure P35.49



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 (مقعر) 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 real(حقيقي) or virtual(افتراضي)? (d) Is the image upright (معتدل) or inverted(مقلوب)?

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 (محدب) 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 = 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.

35. A glass sphere (n 5 1.50) with a radius of 15.0 cm has a tiny air bubble 5.00 cm above its center. The sphere is viewed looking down along the extended radius containing the bubble. What is the apparent depth of the bubble below the surface of the sphere?

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?

40. An object is located 20.0 cm to the left of a diverging lens having a focal length f 5 232.0 cm. Determine (a) the location and (b) the magnification of the image.

42. An object's distance from a converging lens is 5.00 times the focal length. (a) Determine the location of the image. Express the answer as a fraction of the focal length. (b) Find the magnification of the image and indicate whether it is (c) upright or inverted and (d) real or virtual.

43. A contact lens is made of plastic with an index of refraction of 1.50. The lens has an outer radius of curvature of 12.00 cm and an inner radius of curvature of 12.50 cm. What is the focal length of the lens?

45. A converging lens has a focal length of 10.0 cm. Locate the object if a real image is located at a distance from the lens of (a) 20.0 cm and (b) 50.0 cm. What If? Redo the calculations if the images are virtual and located at a distance from the lens of (c) 20.0 cm and (d) 50.0 cm.

46. A diverging lens has a focal length of magnitude 20.0 cm. (a) Locate 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) For each case, find the magnification.

Section 36.5 Lens Aberrations

54. The magnitudes of the radii of curvature are 32.5 cm and 42.5 cm for the two faces of a biconcave lens.

The glass has index of refraction 1.53 for violet light and 1.51 for red light. For a very distant object, locate (a) the image formed by violet light and (b) the image formed by red light.

55. Two rays traveling parallel to the principal axis strike a large plano-convex lens having a refractive index of 1.60(Fig. P36.55). If the convex face is spherical, a ray near the edge does not pass through the focal point (spherical aberration occurs). Assume this face has a radius of curvature of R 5 20.0 cm and the two rays are at distances h1 5 0.500 cm and h2 5 12.0 cm from the principal axis. Find the difference Δx in the positions where each crosses the principal axis.

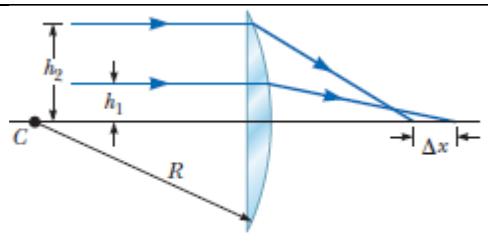


Figure P36.55

Section 36.6 The Camera

56. A camera is being used with a correct exposure at f/4 and a shutter speed of 1 15 s. In addition to the f –numbers listed in Section 36.6, this camera has f -numbers f/1, f/1.4, and f/2. To photograph a rapidly moving subject, the shutter speed is changed to 1 125 s. Find the new f -number setting needed on this camera to maintain satisfactory exposure.

Section 36.7 The Eye

58. A nearsighted person cannot see objects clearly beyond 25.0 cm (her far point). If she has no astigmatism and contact lenses are prescribed for her, what (a) power and (b) type of lens are required to correct her vision?

59. The near point of a person's eye is 60.0 cm. To see objects clearly at a distance of 25.0 cm, what should be the (a) focal length and (b) power of the appropriate corrective lens? (Neglect the distance from the lens to the eye.)

60. A person sees clearly wearing eyeglasses that have a power of −4.00 diopters when the lenses are 2.00 cm in front of the eyes.

(a) What is the focal length of the lens?

(b) Is the person nearsighted or farsighted?

(c) If the person wants to switch to contact lenses placed directly on the eyes, what lens power should be prescribed?

65. A patient has a near point of 45.0 cm and far point of 85.0 cm.

(a) Can a single pair of glasses correct the patient's vision? Explain the patient's options.

(b) Calculate the power lens needed to correct the near point so that the patient can see objects 25.0 cm away. Neglect the eye–lens distance.

(c) Calculate the power lens needed to correct the patient's far point, again neglecting the eye–lens distance.

Section 36.8 The Simple Magnifier

66. A lens that has a focal length of 5.00 cm is used as a magnifying glass.

(a) To obtain maximum magnification and an image that can be seen clearly by a normal eye, where should the object be placed?

(b) What is the magnification?

Section 36.9 The Compound Microscope

67. The distance between the eyepiece and the objective lens in a certain compound microscope is 23.0 cm. The focal length of the eyepiece is 2.50 cm and that of the objective is 0.400 cm.

What is the overall magnification of the microscope?

Section 36.10 The Telescope

68. The refracting telescope at the Yerkes Observatory has a 1.00-m diameter objective lens of focal length 20.0 m.

Assume it is used with an eyepiece of focal length 2.50 cm.

(a) Determine the magnification of Mars as seen through this telescope.

(b) Are the Martian polar caps right side up or upside down?

69. A certain telescope has an objective mirror with an aperture diameter of 200 mm and a focal length of 2 000 mm. It captures the image of a nebula on photographic film at its prime focus with an exposure time of 1.50 min.

To produce the same light energy per unit area on the film, what is the required exposure time to photograph the same nebula with a smaller telescope that has an objective with a 60.0-mm diameter and a 900-mm focal length?