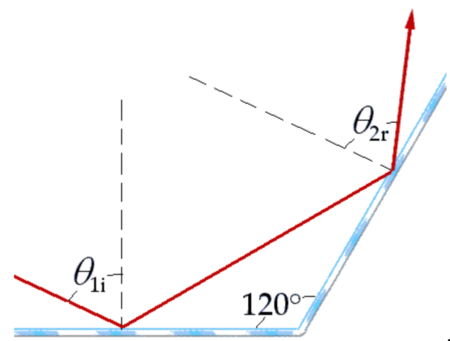
Solutions to Problems : Chapter 26
Problems appeared on the end of chapter 26 of the Textbook

(Problem 2, 26, 32, 41, 42, 48, 64, 65, 67, 74)

2. **Picture the Problem**: The image shows two mirrors oriented at 120° with respect to each other. A light ray strikes the first mirror with an incident angle of 55°. The reflected light then reflects off the second mirror.



Strategy: Set the reflected angle from the first mirror equal to the incident angle. The two mirrors and the ray form a triangle. The sum of the interior angles of a triangle is 180°. Two of the interior angles are the complementary angles $(90° - \theta)$ for the incident and reflected rays. Use this relation to calculate the angle of incidence for mirror 2, and set angle of reflection for mirror 2 equal to the angle of incidence for mirror 2.

Solution: 1. Write the angle of reflection for mirror 1: $\theta_{1r} = \theta_{1i} = 55°$

2. Use the interior angles of the triangle to calculate the incident angle of the second mirror:

$$(90° - \theta_{1r}) + 120° + (90° - \theta_{2i}) = 180°$$
$$\theta_{2i} = 120° - \theta_{1r} = 120° - 55° = 65°$$

3. Set the reflected angle equal to the incident angle: $\theta_{2r} = \theta_{2i} = \boxed{65°}$

Insight: For any incident angle, the sum of the incident angle and the reflected angle will equal the angle between the two mirrors.

26. **Picture the Problem**: A 2.74-m tall virtual image is to be created from a 50.0-cm tall object using a spherical mirror.

Strategy: Use equation 26-4 to calculate the image distance. Then insert the image and object distances into equation 26-6 to calculate the focal length. Then use equation 26-3 to find the radius of curvature from the focal length.

Solution: 1. (a) To form a virtual, upright, and enlarged image, the mirror should be $\boxed{\text{concave}}$.

2. (b) Calculate the image distance from the magnification:

$$\frac{h_i}{h_o} = -\frac{d_i}{d_o}$$
$$d_i = -d_o \frac{h_i}{h_o} = -(3.00 \text{ m})\frac{2.74 \text{ m}}{0.500 \text{ m}} = -16.4 \text{ m}$$

3. Calculate the focal length: $f = (1/d_i + 1/d_o)^{-1} = [1/3.00 \text{ m} + 1/(-16.44 \text{ m})]^{-1} = 3.67 \text{ m}$

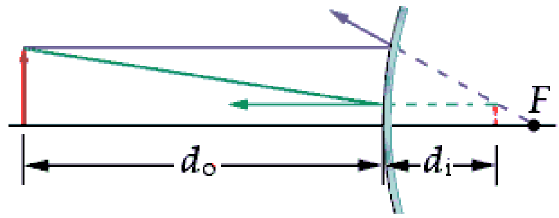
4. Calculate the radius of curvature: $R = -2f = -2(3.67 \text{ m}) = \boxed{7.34 \text{ m}}$

5. (c) The image will be formed $\boxed{\text{16.4 m behind the mirror}}$.

Insight: A convex lens would form a virtual, upright, and reduced image. It cannot produce an enlarged image as a concave lens can.

32. **Picture the Problem**: A convex mirror produces a virtual, upright, and reduced image of an object.

Strategy: Use the magnification equation (equation 26-8) to calculate the image distance from the mirror, and then solve equation 26-6 for the focal length.



Solution: 1. (a) Calculate the image distance:

$$d_i = -md_o = -\frac{1}{4}(32\text{ cm}) = \boxed{-8.0\text{ cm}}$$

2. (b) Calculate the focal length from equation 26-6:

$$f = \left(\frac{1}{d_o} + \frac{1}{d_i}\right)^{-1} = \left(\frac{1}{32\text{ cm}} + \frac{1}{-8.0\text{ cm}}\right)^{-1} = \boxed{-11\text{ cm}}$$

Insight: As expected, the image distance is negative, indicating a virtual image, and the focal length is negative, indicating a convex mirror.

41. **Picture the Problem**: A light ray refracts as it travels from air to water ice.

Strategy: Solve Snell's Law (equation 26-11) for the angle of incidence using the index of refraction for ice given in table 26-2.

Solution: Solve equation 26-11 for the angle of incidence:

$$n_{\text{air}} \sin\theta_i = n_{\text{ice}} \sin\theta_2$$

$$\theta_i = \sin^{-1}\left(\frac{n_{\text{ice}}}{n_{\text{air}}}\sin\theta_2\right) = \sin^{-1}\left(\frac{1.31}{1.000}\sin 31°\right) = \boxed{42°}$$

Insight: Because the index of refraction for ice is greater than the index for air, the refracted angle is smaller than the incident angle.

42. **Picture the Problem**: A light ray refracts as it travels from air to liquid water.

Strategy: Solve Snell's Law (equation 26-11) for the angle of incidence using the index of refraction for water given in table 26-2. The index of refraction for water is slightly larger than the index of refraction for ice.

Solution: 1. (a) Since $\sin\theta_i$ is proportional to n_w in Snell's Law, and since $\sin\theta_i$ increases as θ_i increases for the range $0 \le \theta_i \le 90°$, a greater index of refraction $(n_w > n_{\text{ice}})$ requires an angle of incidence for water that is $\boxed{\text{greater than}}$ it was for ice.

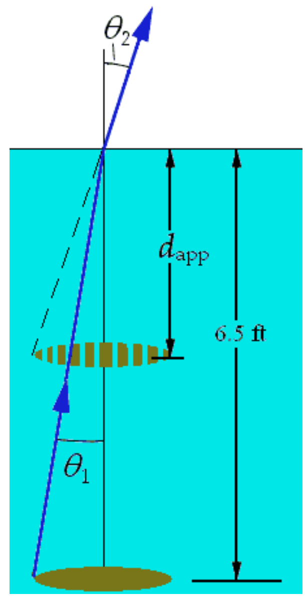
2. (b) Solve equation 26-11 for the angle of incidence:

$$n_{\text{air}} \sin\theta_i = n_w \sin\theta_2$$

$$\theta_i = \sin^{-1}\left(\frac{n_w}{n_{\text{air}}}\sin\theta_2\right) = \sin^{-1}\left(\frac{1.33}{1.000}\sin 31°\right) = \boxed{43°}$$

Insight: The angle of incidence is greater in water than it is in ice (42°, see problem 41) for the same refracted angle, as expected.

48. **Picture the Problem**: The image shows a coin at the bottom of a 6.5-ft pool of water. The coin appears to be at a depth d_{app} when viewed from above the surface of the water.



Strategy: The radius of the coin is equal to its depth times the tangent of the incident angle θ_1. This radius is also equal to the apparent depth times the tangent of the refracted angle θ_2. Since the radius of the coin is much smaller than the water depth, the approximation $\tan\theta \cong \sin\theta$ is appropriate. Use Snell's Law (equation 26-11) to write the actual depth d in terms of the indices of refraction and solve for d_{app}.

Solution: 1. Write the coin radius in terms of d and d_{app}:

$$r = d\ \tan\theta_1 = d_{app}\tan\theta_2$$
$$r \cong d\ \sin\theta_1 = d_{app}\sin\theta_2$$

2. Substitute for $\sin\theta_1$ using Snell's Law and then divide by $\sin\theta_2$:

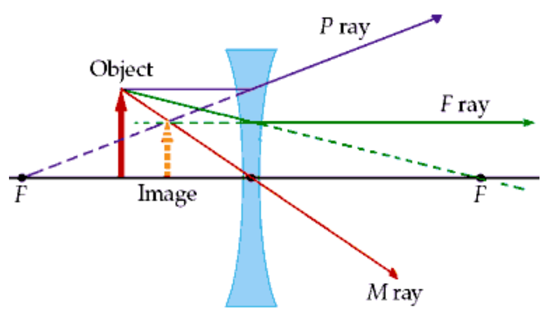
$$d\left(\frac{n_{air}\sin\theta_2}{n_w}\right) = d_{app}\sin\theta_2$$
$$\frac{d}{n_w} = \frac{d_{app}}{n_{air}}$$

3. Solve for the apparent depth:

$$d_{app} = d\frac{n_{air}}{n_w} = (6.5\text{ ft})\frac{1.00}{1.33} = \boxed{4.7\text{ ft}}$$

Insight: The angular size of the coin appears larger to the viewer by the same factor with which the apparent depth appears smaller than the actual depth.

64. **Picture the Problem**: The figure shows an object that is 23 cm in front of a concave lens that has a focal length of $f = -32$ cm.



Strategy: The object distance is positive in this case because the object is placed in front of the lens (to the left of the lens in the diagram). Solve the thin-lens equation (equation 26-16) for the image distance d_i. Then use the image and object distances in equation 26-18 to calculate the magnification.

Solution: 1. (a) Calculate d_i:

$$d_i = \left(\frac{1}{f} - \frac{1}{d_o}\right)^{-1} = \left(\frac{1}{-32\text{ cm}} - \frac{1}{23\text{ cm}}\right)^{-1} = -13\text{ cm}$$

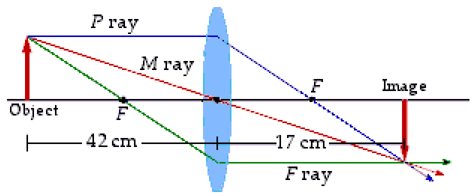
2. The image is located $\boxed{\text{13 cm in front of the lens}}$.

3. (b) Calculate the magnification:

$$m = -\frac{d_i}{d_o} = -\frac{13.4\text{ cm}}{23\text{ cm}} = \boxed{0.58}$$

Insight: The rays in the figure agree with the calculated image distance and magnification.

65. **Picture the Problem**: The diagram (not to scale) shows an object 42 cm in front of a lens that produces an image 17 cm behind the lens.



Strategy: Solve equation 26-16 for the focal length.

Solution: Calculate f:

$$f = \left(\frac{1}{d_i} + \frac{1}{d_o}\right)^{-1} = \left(\frac{1}{17\text{ cm}} + \frac{1}{42\text{ cm}}\right)^{-1} = \boxed{12\text{ cm}}$$

Insight: The image is reduced because the object is farther from the lens than the image. Its magnification is -0.40.

67. **Picture the Problem**: An object is a distance d_o meters in front of a camera lens that has a focal length of f. The image appears on the film a distance d_i behind the lens.

Strategy: Solve equation 26-16 for the image distance. Then use equation 26-18 to calculate the magnification.

Solution: 1. (a) Calculate the image distance:

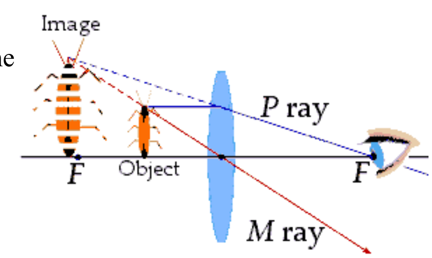
$$d_i = \left(\frac{1}{f} - \frac{1}{d_o}\right)^{-1} = \left(\frac{1}{0.045\text{ m}} - \frac{1}{5.0\text{ m}}\right)^{-1} = \boxed{45\text{ mm}}$$

2. (b) Calculate the magnification:

$$m = -\frac{d_i}{d_o} = -\frac{45.4\text{ mm}}{5.0\text{ m}} = \boxed{-0.0091}$$

Insight: If the object were a 1.6-m tall person, her image on the film would be inverted and 1.5 cm tall.

74. **Picture the Problem**: The figure shows a person looking through a convex lens at an insect. The insect is 1.2 cm from the lens and its image has a magnification of 2.0.



Strategy: Use equation 26-18 to calculate the image distance from the magnification. Then insert the image and object distances into equation
26-16 to calculate the focal length.

Solution: 1. Use the magnification to solve for the image distance:

$$d_i = -md_o = -2.0(1.2\text{ cm}) = -2.4\text{ cm}$$

2. Solve the lens equation for the focal length:

$$f = \left(\frac{1}{d_i} + \frac{1}{d_o}\right)^{-1} = \left(\frac{1}{-2.4\text{ cm}} + \frac{1}{1.2\text{ cm}}\right)^{-1} = \boxed{2.4\text{ cm}}$$

Insight: Note that the object is located at one-half of the focal length. This results in an image at the focal length of magnification 2.0.