Homework-11

Chapter 25

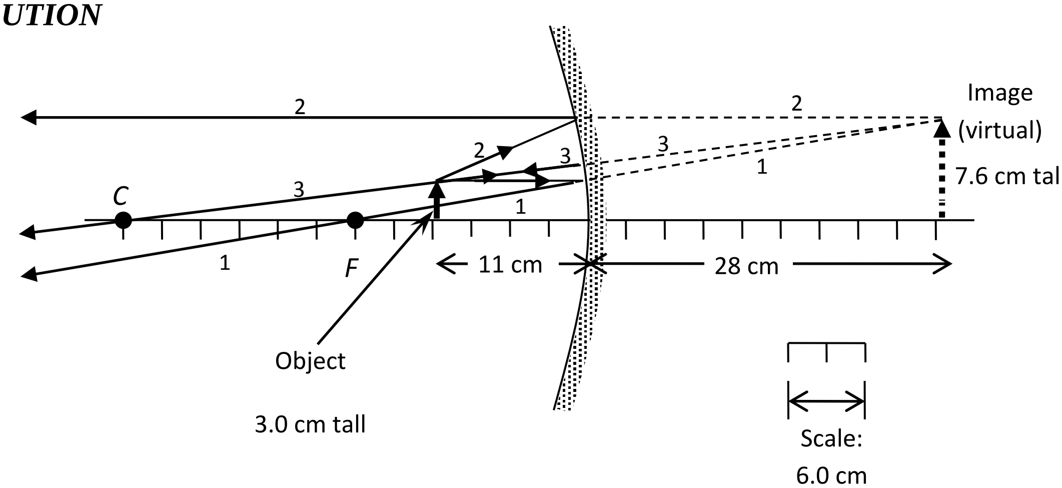
14. ***REASONING*** The object distance (d_o = 11 cm) is shorter than the focal length (f = 18 cm) of the mirror, so we expect the image to be virtual, appearing behind the mirror. Taking Figure 25.18a as our model, we will trace out: three rays from the tip of the object to the surface of the mirror, then three reflected rays, and finally three virtual rays extending behind the mirror and meeting at the tip of the image. The scale of the ray tracing will determine the location and height of the image. The three sets of rays are:

1. An incident ray from the object to the mirror, parallel to the principal axis and then reflected through the focal point *F*.

2. An incident ray from the object to the mirror, directly *away* from the focal point *F* and then reflected parallel to the principal axis. (The incident ray cannot pass from the object through the focal point, as this would take it away from the mirror, and it would not be reflected.)

3. An incident ray from the object to the mirror, directly away from the center of curvature *C*, then reflected back through *C*.

SOLUTION



a. The ray diagram indicates that the image is 28 cm behind the mirror.

b. We see from the ray diagram that the image is 7.6 cm tall.

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16. ***REASONING*** We will start by drawing the two situations in which the object is 25 cm and 5 cm from the mirror, making sure that all distances (including the radius of curvature of the mirror) and heights are to scale. For each location of the object, we will draw several rays to locate the image (see the Reasoning Strategy for convex mirrors in Section 25.5). Once the images have been located, we can readily answer the questions regarding their positions and heights.

SOLUTION The following two ray diagrams illustrate the situations where the objects are at different distances from the convex mirror.

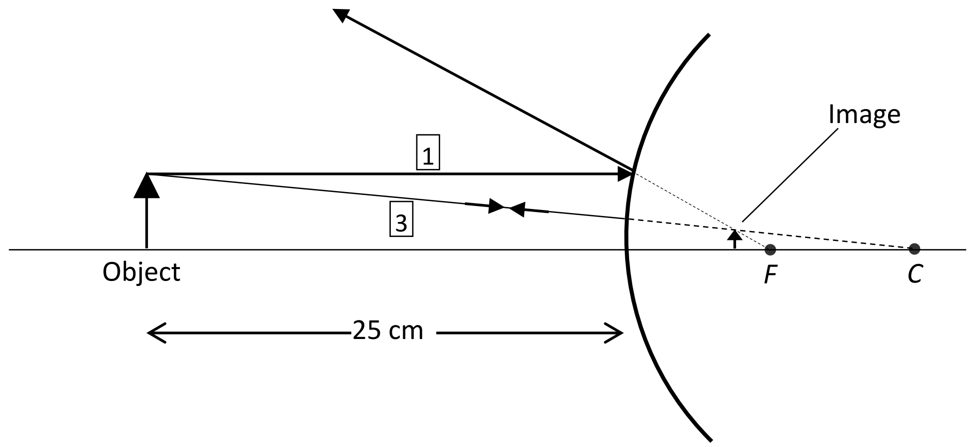

Image
1
3
Object
F
C
25 cm

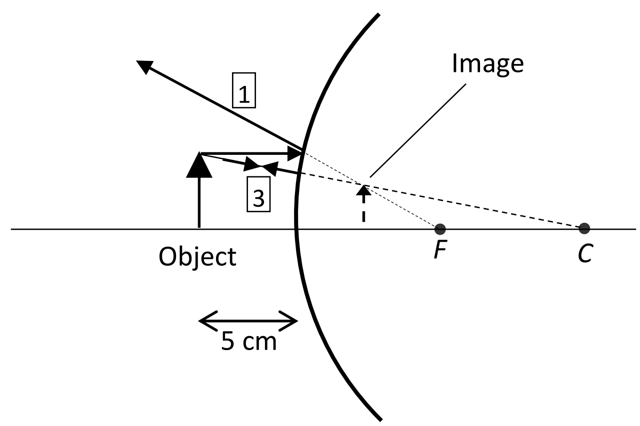

Image
1
3
Object
F
C
5 cm

a. As the object moves closer to the mirror, it can be seen that the magnitude of the image distance becomes $\boxed{\text{smaller}}$.

b. As the object moves closer to the mirror, the magnitude of the image height becomes $\boxed{\text{larger}}$.

c. By measuring the image heights, we find that the ratio of the image height when the object distance is 5 cm to that when the object distance is 25 cm is $\boxed{3}$.

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22. ***REASONING*** For an image that is in front of a mirror, the image distance is positive. Since the image is inverted, the image height is negative. Given the image distance, the mirror equation can be used to determine the focal length, but to do so a value for the object distance is also needed. The object and image heights, together with the knowledge that the image is inverted, allows us to calculate the magnification m. The magnification m is given by $m = -d_i/d_o$ (Equation 25.4), where d_i and d_o are the image and object distances, respectively.

SOLUTION According to Equation 25.4, the magnification is

$$m = \frac{h_i}{h_o} = -\frac{d_i}{d_o} \qquad \text{or} \qquad d_o = -\frac{d_i h_o}{h_i}$$

Substituting this result into the mirror equation, we obtain

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i} = -\frac{h_i}{d_i h_o} + \frac{1}{d_i} = \frac{1}{d_i}\left(-\frac{h_i}{h_o} + 1\right)$$

$$= \left(\frac{1}{13\text{ cm}}\right)\left[-\left(\frac{-1.5\text{ cm}}{3.5\text{ cm}}\right) + 1\right] = 0.11\text{ cm}^{-1} \quad \text{or} \quad \boxed{f = 9.1\text{ cm}}$$

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23. ***REASONING*** Since the image is behind the mirror, the image is virtual, and the image distance is negative, so that $d_\mathrm{i} = -34.0\ \mathrm{cm}$. The object distance is given as $d_\mathrm{o} = 7.50\ \mathrm{cm}$. The mirror equation relates these distances to the focal length *f* of the mirror. If the focal length is positive, the mirror is concave. If the focal length is negative, the mirror is convex.

SOLUTION According to the mirror equation (Equation 25.3), we have

$$\frac{1}{f} = \frac{1}{d_\mathrm{o}} + \frac{1}{d_\mathrm{i}} \quad \text{or} \quad f = \frac{1}{\dfrac{1}{d_\mathrm{o}} + \dfrac{1}{d_\mathrm{i}}} = \frac{1}{\dfrac{1}{7.50\ \mathrm{cm}} + \dfrac{1}{(-34.0\ \mathrm{cm})}} = \boxed{9.62\ \mathrm{cm}}$$

Since the focal length is positive, the mirror is $\boxed{\text{concave}}$.

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26. ***REASONING*** The magnification *m* is given by $m = -d_\mathrm{i}/d_\mathrm{o}$ (Equation 25.4), where d_i and d_o are the image and object distances, respectively. The object distance is known, and we can obtain the image distance from the mirror equation:

$$\frac{1}{d_\mathrm{o}} + \frac{1}{d_\mathrm{i}} = \frac{1}{f} \qquad (25.3)$$

SOLUTION Solving the mirror equation (Equation 25.3) for the image distance d_i gives

$$\frac{1}{d_\mathrm{o}} + \frac{1}{d_\mathrm{i}} = \frac{1}{f} \quad \text{or} \quad \frac{1}{d_\mathrm{i}} = \frac{1}{f} - \frac{1}{d_\mathrm{o}} = \frac{d_\mathrm{o} - f}{f d_\mathrm{o}} \quad \text{or} \quad d_\mathrm{i} = \frac{f d_\mathrm{o}}{d_\mathrm{o} - f}$$

Substituting this result into the magnification equation (Equation 25.4) gives

$$m = -\frac{d_i}{d_o} = -\frac{f d_o / (d_o - f)}{d_o} = \frac{f}{f - d_o}$$

Using this result with the given values for the focal length and object distances, we find

Smaller object distance $\quad m = \frac{f}{f - d_o} = \frac{-27.0\text{ cm}}{(-27.0\text{ cm}) - (9.0\text{ cm})} = \boxed{0.750}$

Greater object distance $\quad m = \frac{f}{f - d_o} = \frac{-27.0\text{ cm}}{(-27.0\text{ cm}) - (18.0\text{ cm})} = \boxed{0.600}$

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28. ***REASONING*** The focal length f of the water drop is given by the mirror equation $\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$ (Equation 25.3), where d_o and d_i are, respectively, the object distance and the image distance. The object distance (d_o = 3.0 cm) is given, and we will determine the image distance d_i from the magnification equation $m = \frac{h_i}{h_o} = -\frac{d_i}{d_o}$ (Equation 25.4), where h_o is the diameter of the flower and h_i is the diameter of its image. The water drop acts as a convex spherical mirror, so the image is upright. Therefore, the image height h_i is positive, and we expect the focal length f to be negative.

SOLUTION Solving $\frac{h_i}{h_o} = -\frac{d_i}{d_o}$ (Equation 25.4) for d_i and taking the reciprocal, we obtain

$$d_i = -\frac{d_o h_i}{h_o} \qquad \text{or} \qquad \frac{1}{d_i} = -\frac{h_o}{d_o h_i} \tag{1}$$

Substituting Equation (1) into $\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$ (Equation 25.3) yields

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{d_o} - \frac{h_o}{d_o h_i} = \frac{1}{d_o}\left(1 - \frac{h_o}{h_i}\right) \qquad (2)$$

Taking the reciprocal of Equation (2), we find that the focal length of the water drop is

$$f = d_o\left(\frac{1}{1 - \frac{h_o}{h_i}}\right) = \frac{d_o}{1 - \frac{h_o}{h_i}} = \frac{3.0\text{ cm}}{1 - \frac{2.0\text{ cm}}{0.10\text{ cm}}} = \boxed{-0.16\text{ cm}}$$

Chapter 26

10. ***REASONING***

a. The refracted ray is shown correctly. When light goes from a medium of lower index of refraction (n = 1.4) to one of higher index of refraction (n = 1.6), the refracted ray is bent toward the normal, as it does in part (a).

b. The refracted ray is shown incorrectly. When light goes from a medium of lower index of refraction (n = 1.5) to one of higher index of refraction (n = 1.6), the refracted ray must bend toward the normal, not away from it, as part (b) of the drawing shows.

c. The refracted ray is shown correctly. When light goes from a medium of higher index of refraction (n = 1.6) to one of lower index of refraction (n = 1.4), the refracted ray bends away from the normal, as it does part (c) of the drawing.

d. The refracted ray is shown incorrectly. When the angle of incidence is 0°, the angle of refraction is also 0°, regardless of the indices of refraction.

SOLUTION

a. The angle of refraction θ_2 is given by Snell's law, Equation 26.2, as

$$\theta_2 = \sin^{-1}\left(\frac{n_1 \sin\theta_1}{n_2}\right) = \sin^{-1}\left[\frac{(1.4)\sin 55°}{1.6}\right] = \boxed{46°}$$

b. The actual angle of refraction is

$$\theta_2 = \sin^{-1}\left(\frac{n_1 \sin\theta_1}{n_2}\right) = \sin^{-1}\left[\frac{(1.5)\sin 55°}{1.6}\right] = \boxed{50°}$$

c. The angle of refraction is

$$\theta_2 = \sin^{-1}\left(\frac{n_1 \sin\theta_1}{n_2}\right) = \sin^{-1}\left[\frac{(1.6)\sin 55°}{1.4}\right] = \boxed{69°}$$

d. The actual angle of refraction is

$$\theta_2 = \sin^{-1}\left(\frac{n_1 \sin\theta_1}{n_2}\right) = \sin^{-1}\left[\frac{(1.6)\sin 0°}{1.4}\right] = \boxed{0°}$$

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12. ***REASONING AND SOLUTION*** The angle of incidence is found from the drawing to be

$$\theta_1 = \tan^{-1}\left(\frac{8.0\text{ m}}{2.5\text{ m}}\right) = 73°$$

Snell's law gives the angle of refraction to be

$$\sin\theta_2 = (n_1/n_2)\sin\theta_1 = (1.000/1.333)\sin 73° = 0.72 \qquad \text{or} \qquad \theta_2 = 46°$$

The distance d is found from the drawing to be

$$d = 8.0\text{ m} + (4.0\text{ m})\tan\theta_2 = \boxed{12.1\text{ m}}$$