SOLUTION The distance d from the camera to the image of the bird can be obtained using the Pythagorean theorem:

$$d = \sqrt{(3.7\text{ m} + 2.1\text{ m})^2 + (4.3\text{ m})^2} = \boxed{7.2\text{ m}}$$

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4. ***REASONING*** According to the discussion about relative velocity in Section 3.4, the velocity $\mathbf{v}_{IY}$ of your image relative to you is the vector sum of the velocity $\mathbf{v}_{IM}$ of your image relative to the mirror and the velocity $\mathbf{v}_{MY}$ of the mirror relative to you: $\mathbf{v}_{IY} = \mathbf{v}_{IM} + \mathbf{v}_{MY}$. As you walk perpendicularly toward the stationary mirror, you perceive the mirror moving toward you in the opposite direction, so that $\mathbf{v}_{MY} = -\mathbf{v}_{YM}$. The velocities $\mathbf{v}_{YM}$ and $\mathbf{v}_{IM}$ have the same magnitude. This is because the image in a plane mirror is always just as far behind the mirror as the object is in front of it. For instance, if you move 1 meter perpendicularly toward the mirror in 1 second, the magnitude of your velocity relative to the mirror is 1 m/s. But your image also moves 1 meter toward the mirror in the same time interval, so that the magnitude of its velocity relative to the mirror is also 1 m/s. The two velocities, however, have opposite directions.

   SOLUTION According to the discussion in the ***REASONING***,

$$\mathbf{v}_{IY} = \mathbf{v}_{IM} + \mathbf{v}_{MY} = \mathbf{v}_{IM} - \mathbf{v}_{YM} \qquad (1)$$

   Remembering that the magnitudes of both velocities $\mathbf{v}_{YM}$ and $\mathbf{v}_{IM}$ are the same and that the direction in which you walk is positive, we have

$$\mathbf{v}_{YM} = +0.90\text{ m/s} \quad \text{and} \quad \mathbf{v}_{IM} = -0.90\text{ m/s}$$

   The velocity $\mathbf{v}_{IM}$ is negative, because its direction is opposite to the direction in which you walk. Substituting these values into Equation (1), we obtain

$$\mathbf{v}_{IY} = (-0.90\text{ m/s}) - (+0.90\text{ m/s}) = \boxed{-1.80\text{ m/s}}$$

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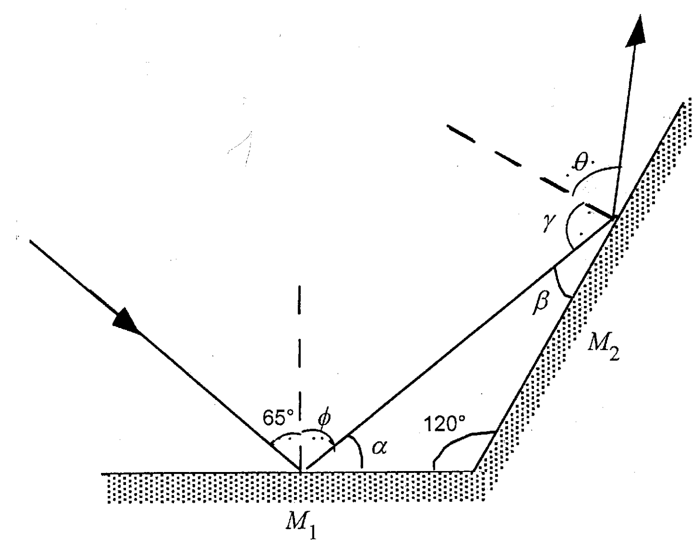
5. SSM ***REASONING*** The geometry is shown below. According to the law of reflection, the incident ray, the reflected ray, and the normal to the surface all lie in the same plane, and the angle of reflection θ_r equals the angle of incidence θ_i. We can use the law of reflection and the properties of triangles to determine the angle θ at which the ray leaves M_2.



   SOLUTION From the law of reflection, we know that $\phi = 65°$. We see from the figure that $\phi + \alpha = 90°$, or $\alpha = 90° - \phi = 90° - 65° = 25°$. From the figure and the fact that the sum of the interior angles in any triangle is 180°, we have $\alpha + \beta + 120° = 180°$. Solving for β, we find that $\beta = 180° - (120° + 25°) = 35°$. Therefore, since $\beta + \gamma = 90°$, we find that the angle γ is given by $\gamma = 90° - \beta = 90° - 35° = 55°$. Since γ is the angle of incidence of the ray on mirror M_2, we know from the law of reflection that $\boxed{\theta = 55°}$.

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6. ***REASONING AND SOLUTION***

   a. The height of the shortest mirror would be one-half the height of the person. Therefore,

$$h = H/2 = (1.70\text{ m} + 0.12\text{ m})/2 = \boxed{0.91\text{ m}}$$

   b. The bottom edge of the mirror should be above the floor by

$$h' = (1.70\text{ m})/2 = \boxed{0.85\text{ m}}$$

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7. ***REASONING AND SOLUTION*** The two arrows, A and B are located in front of a plane mirror, and a person at point P is viewing the image of each arrow. As discussed in Conceptual Example 1, light emanating from the arrow is reflected from the mirror and is reflected toward the observer at P. In order for the observer to see the arrow in its entirety, both rays, the one from the top of the arrow and the one from the bottom of the arrow, must pass through the point P.

c. Since h_i is negative, the image is inverted relative to the object. Thus, to make the pi[illegible] on the wall appear normal, the slide must be oriented $\boxed{\text{upside down}}$ in the projector.

22. ***REASONING*** For an image that is in front of a mirror, the image distance is posi[illegible] Since the image is inverted, the image height is negative. Given the image distance [illegible] mirror equation can be used to determine the focal length, but to do so a value for the obj[illegible] 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 gi[illegible] 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

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

Substituting this result into the mirror equation, we obtain

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

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

23. ***REASONING*** Since the image is behind the mirror, the image is virtual, and the image distance is negative, so that $d_i = -34.0$ cm. The object distance is given as $d_o = 7.50$ 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

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i} \quad \text{or} \quad f = \frac{1}{\frac{1}{d_o} + \frac{1}{d_i}} = \frac{1}{\frac{1}{7.50\text{ cm}} + \frac{1}{(-34.0\text{ cm})}} = \boxed{9.62\text{ cm}}$$

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

SSM ***REASONING*** The object distance d_o is the distance between the object and the mirror. It is found from $\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$ (Equation 25.3), where d_i is the distance between the mirror and the image, and f is the focal length of the mirror. We are told that the image appears in front of the mirror, so, according to the sign conventions for spherical mirrors, the image distance must be positive: $d_i = +97$ cm.

SOLUTION Solving $\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$ (Equation 25.3) for d_o yields

$$\frac{1}{d_o} = \frac{1}{f} - \frac{1}{d_i} \quad \text{or} \quad d_o = \frac{1}{\frac{1}{f} - \frac{1}{d_i}} = \frac{1}{\frac{1}{(+42\text{ cm})} - \frac{1}{(+97\text{ cm})}} = \boxed{74\text{ cm}}$$

REASONING Since the focal length f and the object distance d_o are known, we will use the mirror equation to determine the image distance d_i. Then, knowing the image distance as well as the object distance, we will use the magnification equation to find the magnification m.

SOLUTION

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

$$\frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o} \quad \text{or} \quad d_i = \frac{1}{\frac{1}{f} - \frac{1}{d_o}} = \frac{1}{\frac{1}{(-7.0\text{ m})} - \frac{1}{11\text{ m}}} = \boxed{-4.3\text{ m}}$$

The image distance is negative because the image is a virtual image behind the mirror.

b. According to the magnification equation (Equation 25.4), the magnification is

$$m = -\frac{d_i}{d_o} = -\frac{(-4.3\text{ m})}{11\text{ m}} = \boxed{0.39}$$

26. ***REASONING*** 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. The object distance is known, and we can obtain the image distance from the mirror equation:

$$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f} \qquad (25.3)$$

$$d_i = \frac{d_o f}{d_o - f} = \frac{d_o\left(-\frac{1}{2}R\right)}{d_o - \left(-\frac{1}{2}R\right)} = \frac{-\frac{1}{2}d_o R}{d_o + \frac{1}{2}R} = \frac{-\frac{1}{2}\left(1.22\times10^5\ \text{m}\right)\left(1.74\times10^6\ \text{m}\right)}{1.22\times10^5\ \text{m} + \frac{1}{2}\left(1.74\times10^6\ \text{m}\right)} = -1.07\times10^5\ \text{m}$$

Therefore, the image of the spacecraft would appear $\boxed{1.07\times10^5\ \text{m}}$ below the surface of the moon.

b. Solving the first of Equations (1) for ω yields $\omega = \frac{v_o}{r_o}$. Substituting this result into the second of Equations (2), we find that

$$v_i = r_i\omega = r_i\left(\frac{v_o}{r_o}\right) = \left(\frac{r_i}{r_o}\right)v_o \qquad (5)$$

Substituting Equations (2) and (3) into Equation (5) yields

$$v_i = \left(\frac{r_i}{r_o}\right)v_o = \left(\frac{R+d_i}{R+d_o}\right)v_o = \left[\frac{1.74\times10^6\ \text{m} + \left(-1.07\times10^5\ \text{m}\right)}{1.74\times10^6\ \text{m} + 1.22\times10^5\ \text{m}}\right](1620\ \text{m/s}) = \boxed{1420\ \text{m/s}}$$

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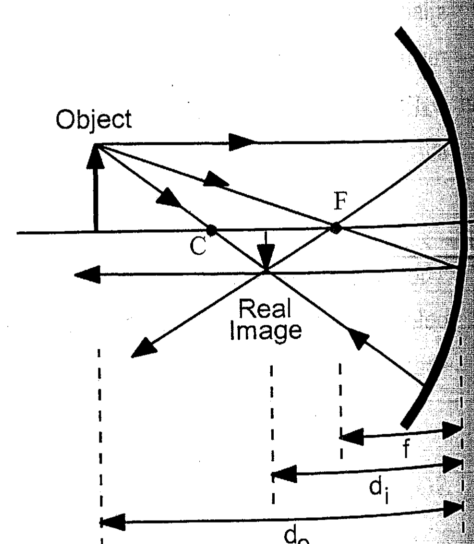
36. ***REASONING AND SOLUTION*** The ray diagram is shown in the figure (Note: f = 5.0 cm and d_o = 15.0 cm).



a. The ray diagram indicates that the $\boxed{\text{image distance is 7.5 cm}}$ in front of the mirror.

b. $\boxed{\text{The image height is 1.0 cm}}$, and the image is inverted relative to the object.

SSM ***REASONING*** We have seen that a convex mirror always forms a *virtual image* as shown in Figure 25.21*a* of the text, where the image is *upright* and *smaller* than the object. These characteristics should bear out in the results of our calculations.

SOLUTION The radius of curvature of the convex mirror is 68 cm. Therefore, the focal length is, from Equation 25.2, $f = -(1/2)R = -34$ cm. Since the image is virtual, we know that $d_i = -22$ cm.

a. With $d_i = -22$ cm and $f = -34$ cm, the mirror equation gives

$$\frac{1}{d_o} = \frac{1}{f} - \frac{1}{d_i} = \frac{1}{-34\ \text{cm}} - \frac{1}{-22\ \text{cm}} \qquad \text{or} \qquad \boxed{d_o = +62\ \text{cm}}$$

b. According to the magnification equation, the magnification is

$$m = -\frac{d_i}{d_o} = -\frac{-22\ \text{cm}}{62\ \text{cm}} = \boxed{+0.35}$$

c. Since the magnification m is positive, the image is $\boxed{\text{upright}}$.

d. Since the magnification m is less than one, the image is $\boxed{\text{smaller}}$ than the object.

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38. ***REASONING***

a. We are given that the focal length of the mirror is f = 45 cm and that the image distance is one-third the object distance, or $d_i = \frac{1}{3}d_o$. These two pieces of information, along with the mirror equation, will allow us to find the object distance.

b. Once the object distance has been determined, the image distance is one-third that value, since we are given that $d_i = \frac{1}{3}d_o$.

SOLUTION

a. The mirror equation indicates that

$$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f} \qquad (25.3)$$

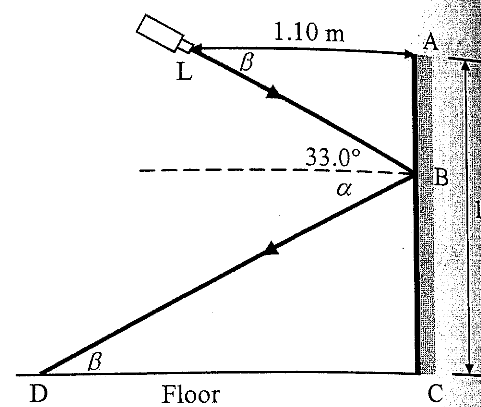
Substituting $d_i = \frac{1}{3}d_o$ and solving for d_o gives

$$\frac{1}{d_o}+\frac{1}{\frac{1}{3}d_o}=\frac{1}{f} \quad \text{or} \quad \frac{4}{d_o}=\frac{1}{f} \quad \text{or} \quad d_o=4f=4(45\text{ cm})=\boxed{180\text{ cm}}$$

b. The image distance is

$$d_i=\tfrac{1}{3}d_o=\tfrac{1}{3}(180\text{ cm})=\boxed{6.0\times10^1\text{ cm}}$$

39. ***REASONING*** The drawing at the right shows the laser beam after reflecting from the plane mirror. The angle of reflection is α, and it is equal to the angle of incidence, which is 33.0°. Note that the angles labeled β in the drawing are also 33.0°, since they are angles formed by a line that intersects two parallel lines. Knowing these angles, we can use trigonometry to determine the distance d_{DC}, which locates the spot where the beam strikes the floor.



SOLUTION Applying trigonometry to triangle DBC, we see that

$$\tan\beta=\frac{d_{BC}}{d_{DC}} \quad \text{or} \quad d_{DC}=\frac{d_{BC}}{\tan\beta} \qquad (1)$$

The distance d_{BC} can be determined from $d_{BC}=1.80\text{ m}-d_{AB}$, which can be substituted into Equation (1) to show that

$$d_{DC}=\frac{d_{BC}}{\tan\beta}=\frac{1.80\text{ m}-d_{AB}}{\tan\beta} \qquad (2)$$

The distance d_{AB} can be found by applying trigonometry to triangle LAB, which shows that

$$\tan\beta=\frac{d_{AB}}{1.10\text{ m}} \quad \text{or} \quad d_{AB}=(1.10\text{ m})\tan\beta$$

Substituting this result into Equation (2), gives

$$d_{DC}=\frac{1.80\text{ m}-d_{AB}}{\tan\beta}=\frac{1.80\text{ m}-(1.10\text{ m})\tan\beta}{\tan\beta}=\frac{1.80\text{ m}-(1.10\text{ m})\tan 33.0°}{\tan 33.0°}=\boxed{1.67\text{ m}}$$

REASONING The magnification of the mirror is related to the image and object distances via the magnification equation. The image distance is give, and the object distance is unknown. However, we can obtain the object distance by using the mirror equation, which relates the image and object distances to the focal length, which is also given.

SOLUTION According to the magnification equation, the magnification m is related to the image distance d_i and the object distance d_o according to

$$m=-\frac{d_i}{d_o} \qquad (25.4)$$

According to the mirror equation, the image distance d_i and the object distance d_o are related to the focal length f as follows:

$$\frac{1}{d_o}+\frac{1}{d_i}=\frac{1}{f} \quad \text{or} \quad \frac{1}{d_o}=\frac{1}{f}-\frac{1}{d_i} \qquad (25.3)$$

Substituting this expression for $1/d_o$ into Equation 25.4 gives

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

$$=-\left(\frac{36\text{ cm}}{12\text{ cm}}\right)+1=\boxed{-2.0}$$

SSM WWW ***REASONING*** This problem can be solved by using the mirror equation, Equation 25.3, and the magnification equation, Equation 25.4.

SOLUTION

a. Using the mirror equation with $d_i=d_o$ and $f=R/2$, we have

$$\frac{1}{d_o}=\frac{1}{f}-\frac{1}{d_i}=\frac{1}{R/2}-\frac{1}{d_o} \quad \text{or} \quad \frac{2}{d_o}=\frac{2}{R}$$

Therefore, we find that $\boxed{d_o=R}$.

b. According to the magnification equation, the magnification is