3. **REASONING** The drawing shows the bird in the plane mirror, as seen by the camera. Note that the image is as far behind the mirror as the bird is in front of it. We can find the distance \( d \) between the camera and the image by noting that this distance is the hypotenuse of a right triangle. The triangle has a length of 3.7 m + 2.1 m and the height of the triangle is 4.3 m.

**SOLUTION** The distance \( d \) from the camera to the image of the bird can be obtained by using the Pythagorean theorem:

\[
d = \sqrt{(3.7\,\text{m} + 2.1\,\text{m})^2 + (4.3\,\text{m})^2} = 7.2\,\text{m}
\]

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 \( \theta_r \) equals the angle of incidence \( \theta_i \). We can use the law of reflection and the properties of triangles to determine the angle \( \theta \) at which the ray leaves \( M_2 \).

**SOLUTION** From the law of reflection, we know that \( \phi = 65^\circ \). We see from the figure that \( \phi + \alpha = 90^\circ \), or \( \alpha = 90^\circ - \phi = 90^\circ - 65^\circ = 25^\circ \). From the figure and the fact that the sum of the interior angles in any triangle is \( 180^\circ \), we have \( \alpha + \beta + 120^\circ = 180^\circ \). Solving for \( \beta \), we find that \( \beta = 180^\circ - (120^\circ + 25^\circ) = 35^\circ \). Therefore, since \( \beta + \gamma = 90^\circ \), we find that the angle \( \gamma \) is given by \( \gamma = 90^\circ - \beta = 90^\circ - 35^\circ = 55^\circ \). Since \( \gamma \) is the angle of incidence of the ray on mirror \( M_2 \), we know from the law of reflection that \( \theta = 55^\circ \).
13. **REASONING** When an object is located very far away from a spherical mirror (concave or convex), the image is located at the mirror’s focal point. Here, the image of the distant object is located 18 cm behind the convex mirror, so that the focal length $f$ of the mirror is $f = -18$ cm and is negative since the mirror is convex.

**SOLUTION** In constructing a ray diagram, we will need to know the radius $R$ of the mirror. The focal length of a convex mirror is related to the radius by $f = -\frac{1}{2}R$ (Equation 25.2). We can use this expression to determine the radius:

$$f = -\frac{1}{2}R \quad \text{or} \quad R = -2f = -2(-18 \text{ cm}) = 36 \text{ cm}$$

In the ray diagram that follows, we denote the focal point by $F$ and the center of curvature by $C$. Note that the horizontal and vertical distances in this drawing are to scale. This means that the mirror is represented by a circular arc that is also drawn to scale. Note that we have used only rays 1 and 3 in constructing this diagram. Only two of the three rays discussed in the text are needed.

![Ray Diagram](image)

From the drawing, we see that the image is located 6.0 cm behind the mirror.

19. **SSM REASONING** This problem can be solved using the mirror equation, Equation 25.3.

**SOLUTION** Using the mirror equation with $d_i = +26$ cm and $f = 12$ cm, we find

$$\frac{1}{d_o} = \frac{1}{f} - \frac{1}{d_i} = \frac{1}{12 \text{ cm}} - \frac{1}{26 \text{ cm}} \quad \text{or} \quad d_o = +22 \text{ cm}$$
23. **REASONING** Since the image is behind the mirror, the image is virtual, and the image distance is negative, so that \( d_i = -34.0 \text{ cm} \). The object distance is given as \( d_o = 7.50 \text{ cm} \). 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

\[
\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i} \quad \text{or} \quad \frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{7.50 \text{ cm}} + \frac{1}{(-34.0 \text{ cm})}
\]

Since the focal length is positive, the mirror is concave.

27. **SSM WWW REASONING** When paraxial light rays that are parallel to the principal axis strike a convex mirror, the reflected rays diverge after being reflected, and appear to originate from the focal point \( F \) behind the mirror (see Figure 25.16). We can treat the sun as being infinitely far from the mirror, so it is reasonable to treat the incident rays as paraxial rays that are parallel to the principal axis.

**SOLUTION**

a. Since the sun is infinitely far from the mirror and its image is a virtual image that lies behind the mirror, we can conclude that the mirror is a convex mirror.

b. With \( d_i = -12.0 \text{ cm} \) and \( d_o = \infty \), the mirror equation (Equation 25.3) gives

\[
\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{\infty} + \frac{1}{d_i} = \frac{1}{d_i}
\]

Therefore, the focal length \( f \) lies 12.0 cm behind the mirror (this is consistent with the reasoning above that states that, after being reflected, the rays appear to originate from the focal point behind the mirror). In other words, \( f = -12.0 \text{ cm} \). Then, according to Equation 25.2, \( f = -\frac{1}{2} R \), and the radius of curvature is

\[
R = -2f = -2(-12.0 \text{ cm}) = 24.0 \text{ cm}
\]