Answer to Essential Question 23.6: The mirror must be concave, because a convex mirror cannot produce an image that is larger than the object. A concave mirror produces an image larger than the object only when the object is between the mirror and twice the focal length. So, twice the focal length must be at least +20 cm, and the focal length must be at least +10 cm. All we can say is that the focal length is greater than or equal to +10 cm.

23-7 An Example Problem

Let's begin by discussing a general approach we can use to solve problems involving mirrors. We will then apply the method to a particular situation.

A general method for solving problems involving mirrors

1. Sketch a ray diagram, showing rays leaving the tip of the object and reflecting from the mirror. Where the reflected rays meet is where the tip of the image is located. The ray diagram gives us qualitative information about the location and size of the image and about the characteristics of the image.
2. Apply the mirror equation and/or the magnification equation. Make sure that the signs you use match those listed in the sign convention in section 23-5. The equations provide quantitative information about the location and size of the image and about the image characteristics.
3. Check the results of applying the equations with your ray diagram, to see if the equations and the ray diagram give consistent results.

Rays that are easy to draw the reflections for

To locate an image on a ray diagram, you need a minimum of two rays. If you draw more than two rays, however, you can check the image location you find with the first two rays. Remember, too, that you can draw any number of rays reflecting from the mirror, and that all the rays should obey the law of reflection. There are at least four rays that are easy to draw the reflections for. These rays are shown on Figure 23.34, and include:

1. The ray that goes parallel to the principal axis, and reflects so that it passes through the focal point (concave mirror), or away from the focal point (convex mirror).
2. The ray that reflects from the point on the principal axis that intersects the surface of the mirror. The principal axis is perpendicular to the surface of the mirror, so the angle between the incident ray and the principal axis is the same as the angle between the reflected ray and the principal axis.
3. The ray that travels along the straight line connecting the tip of the object and the mirror's center of curvature. This ray is incident on the mirror along the normal to the mirror's surface, and thus reflects straight back along the same line.
4. The ray that travels along the straight line connecting the tip of the object and the focal point. This ray reflects to go parallel to the principal axis.

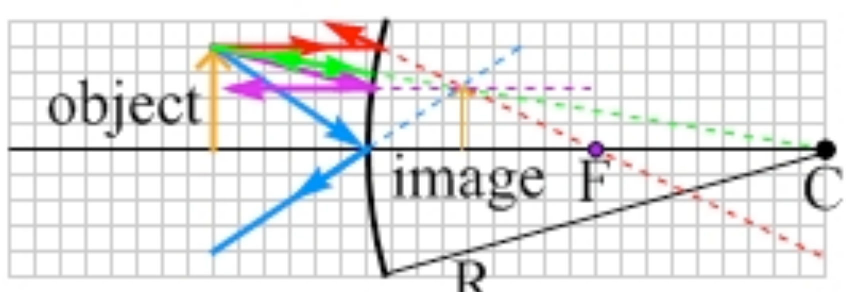

Figure 23.34: An example of the four rays that are easy to draw the reflections for. All the reflected rays meet at the tip of the image.

EXAMPLE 23.7 – Applying the general method

When you stand in front of a mirror that has a radius of curvature of 40 cm, you see an image that is half your size. What kind of mirror is it? How far from the mirror are you? Sketch a ray diagram to check your calculations.

SOLUTION

In this case, let's first apply the equations and then draw the ray diagram. The mirror could be convex, because convex mirrors always produce images that are smaller than the object. A convex mirror produces a virtual, upright image, so the sign of the magnification is positive. Applying the magnification equation, we get:

$$m = +\frac{1}{2} = -\frac{d_i}{d_o}, \text{ which tells us that } \frac{1}{d_i} = -\frac{2}{d_o}.$$

For a convex mirror, the focal length is –*R*/2, which in this case is –20 cm. Applying the mirror equation:

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{d_o} - \frac{2}{d_o} = -\frac{1}{d_o}.$$

Thus, we find that $d_o = -f = +20 \text{ cm}$, and we can show that $d_i = -10 \text{ cm}$.

The ray diagram for this situation is shown in Figure 23.35, confirming the calculations.

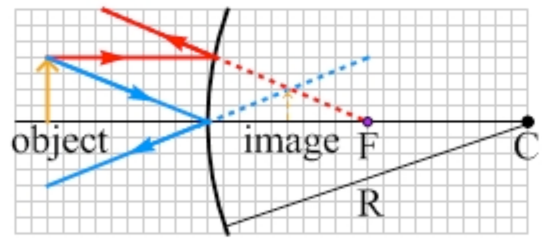

Figure 23.35: A ray diagram for the solution involving a convex mirror. Each box on the grid measures 2 cm × 2 cm.

The solution above is only one of the possible answers. The mirror could also be concave, because a concave mirror can produce a real, inverted image, so the sign of the magnification is negative. Applying the magnification equation, we get:

$$m = -\frac{1}{2} = -\frac{d_i}{d_o}, \text{ which tells us that } \frac{1}{d_i} = \frac{2}{d_o}.$$

For a concave mirror the focal length is +*R*/2, which in this case is +20 cm. Applying the mirror equation:

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{d_o} + \frac{2}{d_o} = \frac{3}{d_o}.$$

Thus, we find that $d_o = 3f = +60 \text{ cm}$, and we can show that $d_i = +30 \text{ cm}$.

The ray diagram for this situation is shown in Figure 23.36, again confirming the calculations above.

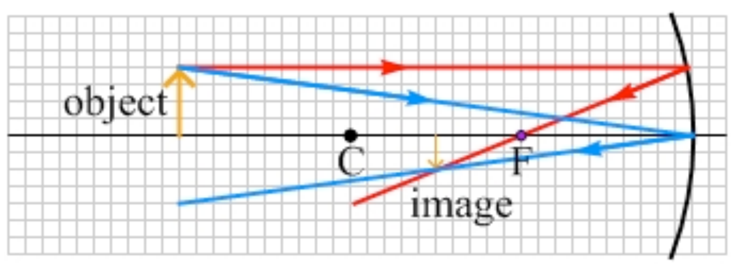

Figure 23.36: A ray diagram for the situation involving a concave mirror. Each box on the grid measures 2 cm × 2 cm.

Related End-of-Chapter Exercises: 20, 21, 23, 24, 43.

Essential Question 23.7: Return to the situation described in Example 23.7. Would there still be two solutions if the image was larger than the object? Explain.