Answer to Essential Question 23.7: Yes, there would still be two solutions, but we would not have a solution associated with a convex mirror, because the convex mirror cannot produce an image that is larger than the object. Instead, both solutions would be associated with a concave mirror. One solution would be for a real image, and the other solution would be for a virtual image.

Chapter Summary

Essential Idea: Reflection and Mirrors.

To understand the image that is created by a mirror, we make use of a simple model of light called the ray model. In the ray model, a ray of light travels in a straight line until it encounters an object. When a ray of light reflects from an object, the light obeys the Law of Reflection.

The Law of Reflection

The angle of incidence is equal to the angle of reflection. These angles are generally measured from the normal to the surface.

Image Formation

For a mirror to form an image of an object, light rays must leave the object and be reflected by the mirror. If the rays leaving a single point on the object are reflected so that they pass through a single point, a real image is formed. If, instead, such reflected rays appear to diverge from a single point behind the mirror (as is the case for a typical bathroom mirror), a virtual image is formed.

Ray Diagrams

When drawing a ray diagram, we generally show 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 image characteristics. All rays obey the Law of Reflection when they reflect from the mirror, but some reflected rays are particularly easy to draw. A summary of four such rays is given in section 23-7.

Plane and Spherical Mirrors

Type of mirror	Focal length	Image characteristics
Plane	∞	The image is virtual, upright, the same size as the object, and the same distance behind the mirror that the object is in front of the mirror.
Convex (diverging)	$-R/2$, R being the mirror's radius of curvature	The image is virtual, upright, smaller than the object, and located between the mirror and the mirror's focal point.
Concave (converging)	$+R/2$	The image can be real or virtual, and larger than, smaller than, or the same size as the object. See the table below for details.

Table 23.1: A summary of the mirrors we investigated in this chapter.

Images formed by a Concave (Converging) Mirror

Object position	Image position	Image characteristics
∞	At the focal point.	Real image with height of zero.
Moving from ∞ toward the center of curvature.	Moving from the focal point toward the center of curvature.	The image is real, inverted, and smaller than the object. The image moves closer to the center of curvature, and increases in height, as the object is moved closer to the center of curvature.
At the center of curvature.	At the center of curvature.	The image is real, inverted, and the same size as the object.
Moving from the center of curvature toward the focal point.	Moving from the center of curvature toward infinity.	The image is real, inverted, and larger than the object. The image moves farther from the mirror, and increases in height, as the object is moved closer to the focal point.
At the focal point.	At infinity.	The image is at infinity, and is infinitely tall.
Closer to the mirror than the focal point.	Behind the mirror	The image is virtual, upright, and larger than the object. The image moves closer to the mirror, and decreases in height, as the object is moved closer to the mirror.

Table 23.2: A summary of the image positions and characteristics for various object positions with a concave mirror.

The mirror equation

The mirror equation relates the object distance, d_o, the image distance, d_i, and the mirror's focal length, f. The mnemonic "If I do I di" can help you to remember the mirror equation.

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}.$$ (Equation 23.4: **The mirror equation**)

$$d_i = \frac{d_o \times f}{d_o - f}$$ (Equation 23.5: **The mirror equation, solved for the image distance**)

Sign conventions

The focal length is positive for a concave mirror, and negative for a convex mirror.

The image distance is positive if the image is on the reflective side of the mirror (a real image), and negative if the image is behind the mirror (a virtual image).

The image height is positive when the image is above the principal axis, and negative when the image is below the principal axis. A similar rule applies to the object height.

The image height is positive when the image is upright, and negative when the image is inverted. A similar rule applies to the object height.

Magnification

The magnification, m, is the ratio of the image height (h_i) to the object height (h_o).

$$m = \frac{h_i}{h_o} = -\frac{d_i}{d_o}.$$ (Equation 23.6: **Magnification**)

- The image is larger than the object if $|m| > 1$.
- The image and object have the same size if $|m| = 1$.
- The image is smaller than the object if $|m| < 1$.

The magnification is positive if the image is upright, and negative if the image is inverted.