10.4 Images in Convex Mirrors

Key Terms
convex mirror

The sculpture in **Figure 10.24** is called *Cloud Gate*. Like *Sky Mirror* in Section 10.3, it is a piece of art created by artist Anish Kapoor. It is in the city of Chicago, Illinois, in the United States. *Cloud Gate*'s convex surfaces are made of polished stainless steel, and they act like a **convex mirror**. Convex mirrors bulge, or curve outward. The convex curves reflect the skyline and the clouds. *Cloud Gate* is 10 m high, 20 m long, and has a mass of about 110 t. The 3.6 m high arch allows visitors to touch the surface and see their reflections.

The images in various parts of the sculpture in the photograph are different, but there are some general similarities. Notice that each image is upright and smaller than the object. Also notice that the image near the centre of a convex portion is shaped much like the object. Like an image in a concave mirror, however, the image becomes distorted near the edge of a convex portion.

As you can see, the images that are produced by convex mirrors make them interesting sculptures. In this section, you will learn about some of the practical uses of convex surfaces. You will also learn about the characteristics of images in convex mirrors by drawing ray diagrams.

convex mirror a mirror whose reflecting surface curves outward

Sense of scale

The mass of *Cloud Gate* is about the same mass as 84 small cars.

Figure 10.24 *Cloud Gate*, also called The Bean, is located in Chicago, Illinois.

Figure 10.25 The outside surface of a sphere is a convex surface.

Properties of Convex Mirrors

A convex mirror is a spherical mirror, just as a concave mirror is. **Figure 10.25** shows the same diagram of a basketball that you saw in **Figure 10.19**. But if you covered the outside of the cut-out piece with a reflecting surface instead of the inside, you would have a convex mirror. Convex mirrors, like concave mirrors, also have spherical aberration. Only the small centre region of a convex mirror gives images that are not distorted.

Ray Diagrams for Convex Mirrors

Think about the principal axis of a convex mirror in the same way you think about the principal axis of a concave mirror. When you shine rays of light parallel to the principal axis onto a convex mirror, the reflected rays travel out and away from each other, as you can see in **Figure 10.26**. How can a convex mirror have a focal point? Recall how you found the image behind a concave mirror. You extended the reflected rays backward, behind the mirror, until they met. Similarly, the focal point of a convex mirror is behind the mirror.

Suggested Investigation

Inquiry Investigation 10-C, Testing for Real and Virtual Images, on page 442

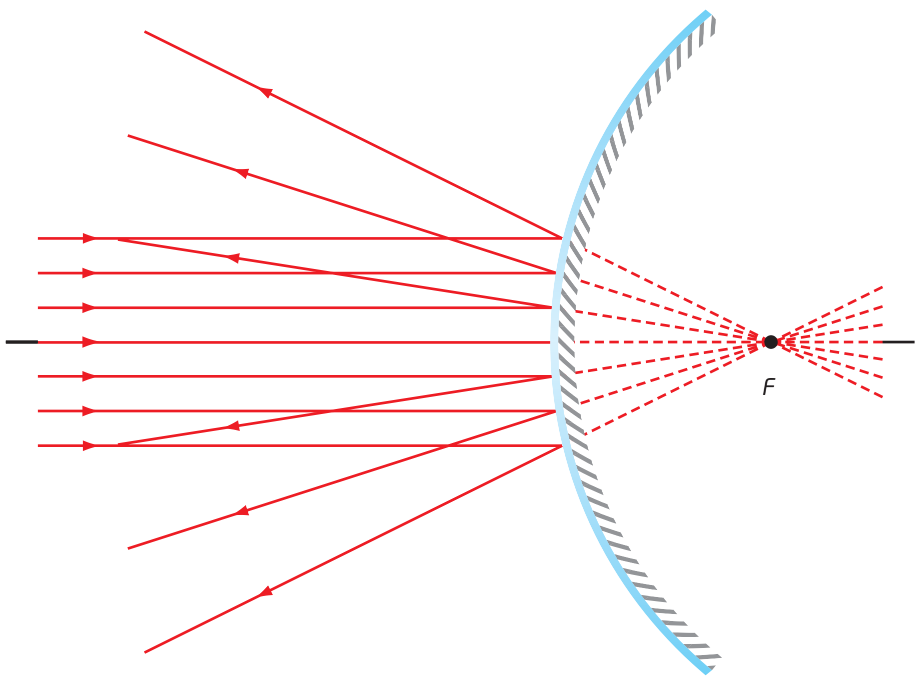


Figure 10.26 The focal point of a convex mirror is behind the mirror.

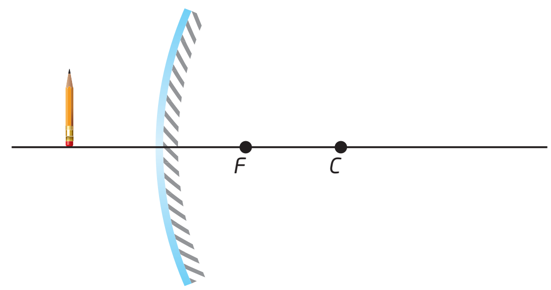
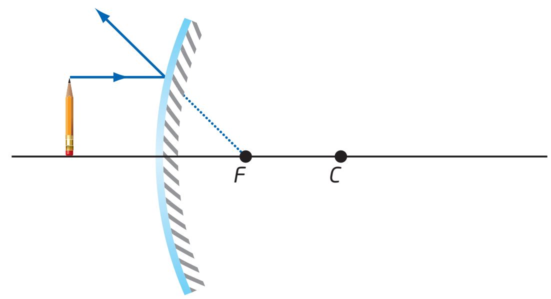
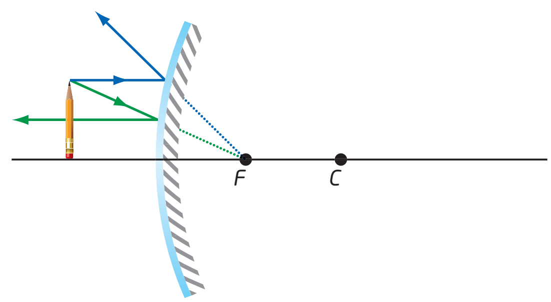
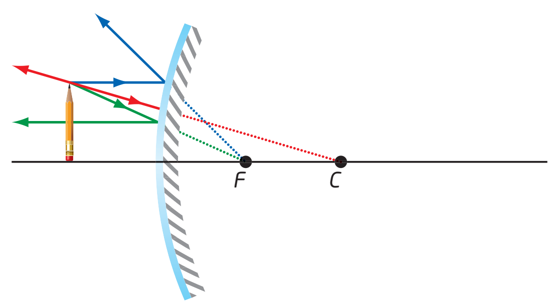
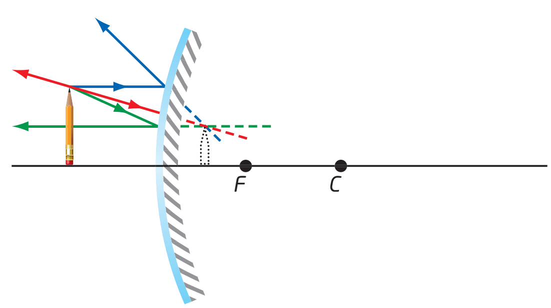
Drawing Ray Diagrams for Convex Mirrors

Drawing ray diagrams for convex mirrors is very similar to drawing ray diagrams for concave mirrors. Follow the steps in **Table 10.5** to learn how to draw these ray diagrams.

Study Toolkit

Comparing and Contrasting
A Venn diagram or a table like the one on page 402 can help you clarify the differences between concave and convex mirrors.

Table 10.5 **Drawing a Ray Diagram for a Convex Mirror**

Directions	Diagram
1. Draw the principal axis and a curve to represent the convex mirror. • Mark a focal point and *C*. • Draw the object so that the bottom is on the principal axis.	
2. Draw a ray (shown in blue) from the top of the object toward the mirror parallel to the principal axis. Draw the reflected ray back, as though it is coming from the focal point. Draw a dotted line behind the mirror to show that the reflected ray appears to be coming from the focal point.	
3. Draw a ray (shown in green) that is directed toward the focal point, but stop when it reaches the mirror. Draw the reflected ray backward, parallel to the principal axis. Draw a dotted line behind the mirror to show that the incident ray seems to be travelling toward the focal point.	
4. Draw a ray (shown in red) that is directed toward *C*, but stop when it reaches the mirror. Draw a dotted line behind the mirror to show that the ray seems to be travelling toward *C*. Draw the reflected ray backward, along the incident ray.	
5. The reflected rays are directed away from each other, so they will never meet. Draw dashed lines to extend the rays backward, behind the mirror, until they meet. This is the top of the image. Draw the image, with the bottom of the image on the principal axis. (Note that the dotted lines are not in this diagram.)	

Activity 10-4

Reflection from the Convex Surface of a Spoon

In this activity, you will use a simple kitchen tablespoon as a convex mirror.

Materials

- kitchen tablespoon with two shiny, reflective surfaces

Procedure

1. Hold up the back of the spoon in front of your face. Look at the image of your face.
2. Bring the spoon as close to your face as you can and still see your image. Describe the characteristics of your image in the spoon.
3. Slowly move the spoon away from your face. Observe any changes in your image as the spoon gets farther away. If you can still see your image when the spoon is at arm's length, have someone else move the spoon farther away. Describe any changes in the image of your face.

Questions

1. How is the image of your face on the back of the spoon different from your image in a plane mirror?
2. Compare and contrast how lateral inversion happens in a plane mirror and a convex mirror.

Learning Check

1. Using a Venn diagram, compare and contrast convex mirrors and concave mirrors.
2. Explain how you would find the focal point of a convex mirror. Use a diagram and **Figure 10.26** as a guide.
3. An object is 3 cm in front of a convex mirror, and the focal length is 4 cm. Draw a ray diagram to show the image characteristics.
4. An object is 1 cm in front of a convex mirror, whose focal length is 3 cm. Draw a ray diagram to show the image characteristics.

Mirror and Magnification Equations

The mirror and magnification equations that are used for concave mirrors are also used for convex mirrors. However, since the focal point is behind the mirror, the focal length, f, for a convex mirror is negative.

Mirror Equation

$$\frac{1}{f} = \frac{1}{d_i} + \frac{1}{d_o}$$

The image distance, d_i, is negative if the image is behind the mirror (a virtual image).

Magnification Equation

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

The image height, h_i, is negative if the image is inverted relative to the object.

Sample Problem: Mirror Equations and Convex Surfaces

Problem

A convex surveillance mirror in a convenience store has a focal length of −0.40 m. A customer, who is 1.7 m tall, is standing 4.5 m in front of the mirror.

a. Calculate the image distance.
b. Calculate the image height.

Solution

a. Use the mirror equation to find the image distance.

$$\frac{1}{f} = \frac{1}{d_i} + \frac{1}{d_o}$$

$$\frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o}$$

$$= \frac{1}{-0.40\text{ m}} - \frac{1}{4.5\text{ m}}$$

$$= \frac{-4.5}{1.8\text{ m}} - \frac{0.4}{1.8\text{ m}}$$

$$= \frac{-4.9}{1.8\text{ m}}$$

$$d_i = \frac{1.8\text{ m}}{-4.9}$$

$$= -0.367\text{ m}$$

The image is −0.37 m (after rounding) from the mirror. The sign of the image distance is negative, so the image is behind the mirror and is thus a virtual image.

b. Use the magnification equation to find h_i.

$$\frac{h_i}{h_o} = \frac{-d_i}{d_o}$$

$$h_i = \frac{(h_o)(-d_i)}{d_o}$$

$$= \frac{(1.7\text{ m})(-(-0.367))}{4.5\text{ m}}$$

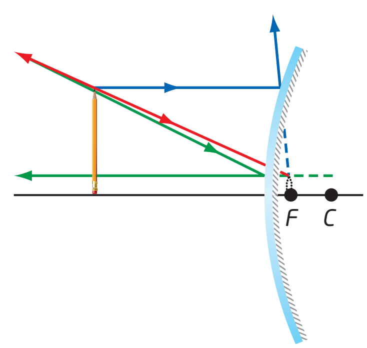
$$= 0.1386\text{ m}$$

The image height is 0.14 m (after rounding). The image height is positive, so the image is upright.

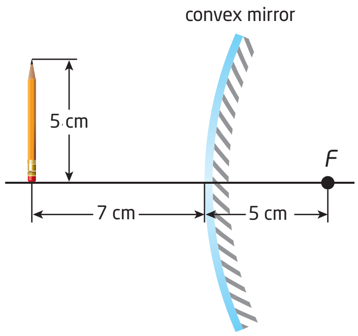
Check Your Solution

An image in a convex mirror is smaller than the object, virtual, and upright. All of these characteristics agree with the answers. The diagram on the right supports the solution.

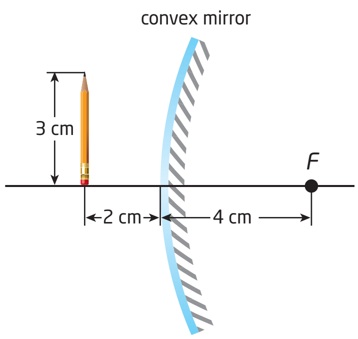
GRASP
Go to **Science Skills Toolkit 11** to learn about an alternative problem solving method.



Draw a ray diagram to check your solution.



Use this diagram to solve problem 2.



Use this diagram to solve problem 3.

Practice Problems

1. A convex mirror has a focal length of −0.90 m. An object with a height of 0.40 m is 2.5 m from the mirror.
   a. Calculate the image distance.
   b. Calculate the image height.
2. Use the data in the diagram on the left to answer the questions below.
   a. Calculate the image distance.
   b. Calculate the image height of the image.
3. Use the data in the diagram on the left to answer the questions below.
   a. Calculate the image distance.
   b. Calculate the image height.
4. A convex security mirror in a warehouse has a focal length of −0.50 m. A forklift, which is 2.2 m tall, is 6.0 m from the mirror.
   a. Calculate the image distance.
   b. Calculate the image height.
5. A convex security mirror has a focal length of –0.25 m. A person with a height of 1.5 m is 4.0 m from the mirror.
   a. Calculate the image distance.
   b. Calculate the image height.
6. An object 0.4 m tall is placed 2.5 m in front of a convex mirror that has a focal length of –90 cm.
   a. Calculate the image distance.
   b. Calculate the image height.
7. An object 25 cm tall is placed 80 cm in front of a convex mirror that has a radius of curvature of 1.5 m.
   a. Calculate the image distance.
   b. Calculate the image height.

Figure 10.27 Because this security mirror is convex, it gives the clerk a much wider view of the store than a plane mirror would.

Applications of Convex Surfaces

You have probably seen mirrors like the one in **Figure 10.27** in convenience stores. The image is quite distorted, but this convex security mirror allows a clerk in the store to see a very large area. If the store is small, the clerk can stand at the till and see almost everything in the store. Convex security mirrors are sometimes used on public transportation buses, as well as on roads with sharp curves in some countries.

Convex Mirrors at Border Crossings

At truck inspection stations and border crossings, security guards often need to see the underside of large semitrailers and other vehicles. To do this, a convex mirror is attached to the end of a long handle at an angle, as shown in **Figure 10.28**. By moving the mirror just under the side of the vehicle, the security guard can see everything on the bottom of the vehicle.

Figure 10.28 Using a convex mirror on a long handle enables a security guard to see the underside of a vehicle without crawling under it.

Radar Technology and Convex Surfaces

The rounded, aerodynamic surfaces on a typical airplane act like convex mirrors. When a pulse of radio waves hits an airplane, the rays are nearly perpendicular to many areas on the airplane's surface. As shown in **Figure 10.29**, these rays will be reflected almost directly backward. The radar antenna will detect the reflected rays and locate the aircraft.

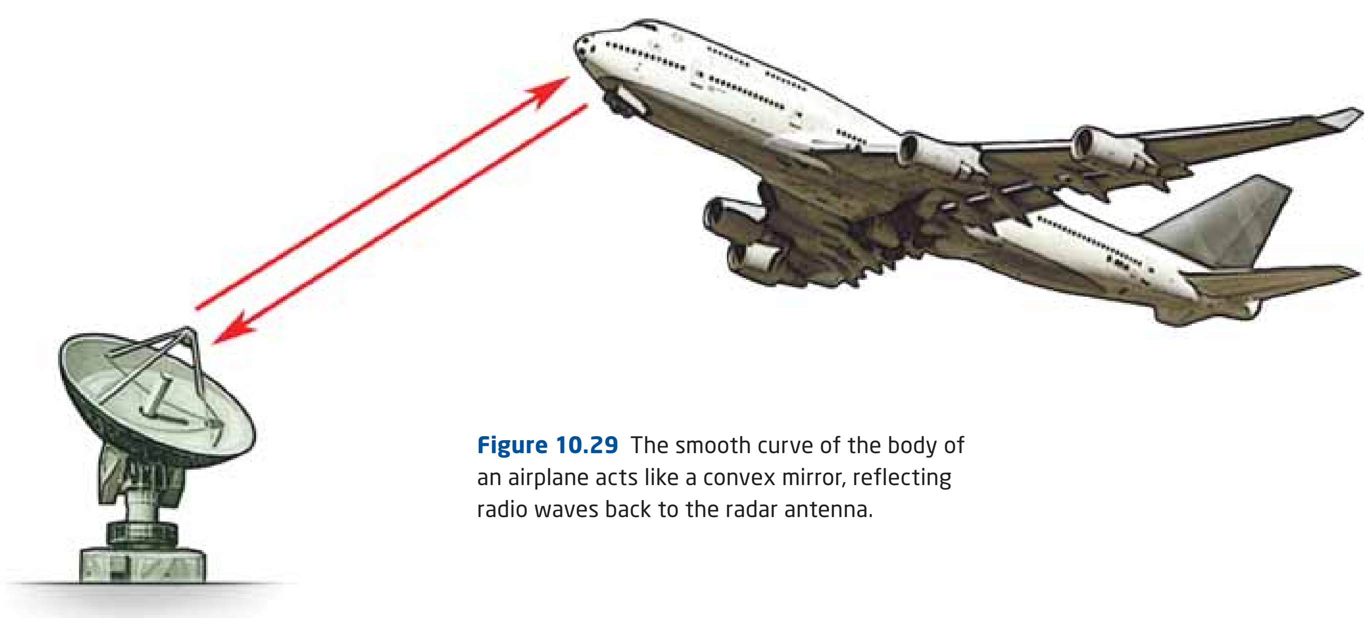


Figure 10.29 The smooth curve of the body of an airplane acts like a convex mirror, reflecting radio waves back to the radar antenna.

Section 10.4 Review

Section Summary

- The reflecting surface of a convex mirror is a mirror that curves outward.
- Rays that travel toward a convex mirror, parallel to and near the principal axis, will reflect back and spread out, away from each other.
- To find *F* for a convex mirror, extend the reflected rays backward until they appear to meet behind the mirror.
- For an object in a convex mirror, the virtual, upright image is smaller than the object.
- You can predict the location and size of an image in a convex mirror by drawing the bottom of the object on the principal axis and drawing at least two rays that travel from the top of the object toward the mirror.
- You can calculate the image distance and size using the mirror equation, $\frac{1}{f} = \frac{1}{d_i} + \frac{1}{d_o}$, and the magnification equation, $m = \frac{h_i}{h_o} = \frac{-d_i}{d_o}$.
- The focal length of a convex mirror is negative because the *F* is virtual and behind the mirror.
- There are many practical uses for convex mirrors and surfaces, such as security mirrors and inspection mirrors.

Review Questions

C **1.** Using a sketch, show how you would draw a ray diagram for a convex mirror. Use **Table 10.5** as a guide.

K/U **2.** The same mirror equations are used for convex mirrors as for concave mirrors. How do you account for the difference in the curvature when using the mirror equations?

K/U **3.** Why is the value of the focal length of a convex mirror negative?

T/I **4.** When considering the characteristics of a concave mirror, you looked at three different cases. Why would it not be possible to consider three similar cases for a convex mirror?

K/U **5.** Convex mirrors are often used as security mirrors in convenience stores. Explain why.

K/U **6.** A convex mirror has a focal length of –5 cm. An object with a height of 4 cm is 3 cm from the mirror. Calculate the image distance and the image height. Check your results by drawing a ray diagram.

C **7.** Imagine that Grade 7 students are looking at a spherical ornament that has a mirror-like surface. The students exclaim how strange the image of their faces look. Explain the distortion to them.

A **8.** Some vehicles have a mirror on the side like the one in the photograph on the right. Why do you think car and truck manufacturers would attach a plane mirror, with a smaller convex mirror embedded in it, to the side of a vehicle?

This side mirror has a smaller convex mirror embedded in it.