5.2 Using Mirrors to Form Images

All mirrors reflect light according to the law of reflection. Plane mirrors form an image that is upright and appears to be as far behind the mirror as the object is in front of it. Depending on the distance of the object, a concave mirror can form an image that is inverted or right side up, and that can be larger or smaller than the object. Convex mirrors form images that are upright and smaller than the object.

Key Terms

concave
converging
convex
diverging
focal point

You can see yourself as you glance into a quiet pool of water or walk past a shop window. You can see unusual reflections of yourself in the wavy mirrors at amusement parks. You can even see reflections of yourself in a spoon. Most of the time, however, you probably look for your image in a flat, smooth mirror called a **plane mirror**.

5-6 Reflections of Reflections

Find Out ACTIVITY

In this activity, you will find out how many reflections you can see in two plane mirrors.

Materials

- 2 plane mirrors
- protractor
- masking tape
- paper clip

Safety

- Handle glass mirrors and bent paper clips carefully.

Count the images in each mirror.

What to Do

1. Create a table to record your data. Give your table a title.
2. Lay one mirror on top of the other with the mirror surfaces inward. Tape them together so they will open and close. Use tape to label them "L" (left) and "R (right)."
3. Stand the mirrors up on a sheet of paper. Using a protractor, close the mirrors to an angle of 72°.
4. Bend one leg of a paper clip up 90° and place it close to the front of the R mirror.
5. Count the number of images of the clip you see in the R and L mirrors. Record these numbers in your data table.
6. Hold the R mirror still. Slowly open the L mirror to 90°. Count and record the images of the paper clip in each mirror.
7. Hold the R mirror still. Slowly open the L mirror to 120°. Count and record the images of the paper clip in each mirror.

What Did You Find Out?

1. What is the relationship between the number of reflections and the angle between the two mirrors?
2. How could you use two mirrors to see a reflection of the back of your head?

Plane Mirrors

Looking at yourself in a plane mirror, you can see that your image appears to be the same distance behind the mirror as you are in front of the mirror. How could you test this? Place a ruler between you and the mirror. Where does the image touch the ruler? You also see that your image is oriented as you are and matches your size. This type of reflection is where the expression "mirror image" comes from. If you move toward the mirror, your image moves toward the mirror. If you move away, your image also moves away.

How do reflected rays form an image that we can see in a mirror? Study Figure 5.14 to answer this question. Light from a lamp shines on a blueberry. This light reflects off all points on the blueberry, in all directions. In the figure, only the rays coming from one point are shown. All of the rays from the blueberry that strike the mirror reflect according to the law of reflection. The rays that reach your eye appear to be coming from a point behind the mirror. The same process occurs for every point on the blueberry. Your brain "knows" that light travels in straight lines. Therefore, your brain interprets the pattern of light that reaches your eye as an image of a blueberry behind the mirror. In fact, it might even be possible to trick the observer into thinking the blueberry was behind a glass window, rather than in front of a very good mirror. A house of mirrors uses this trick to create a maze.

Did You Know?

The mirror on the Hubble Space Telescope is one of the smoothest mirrors ever made. If the mirror were as large as Earth, the biggest bump on it would be only 15 cm tall.

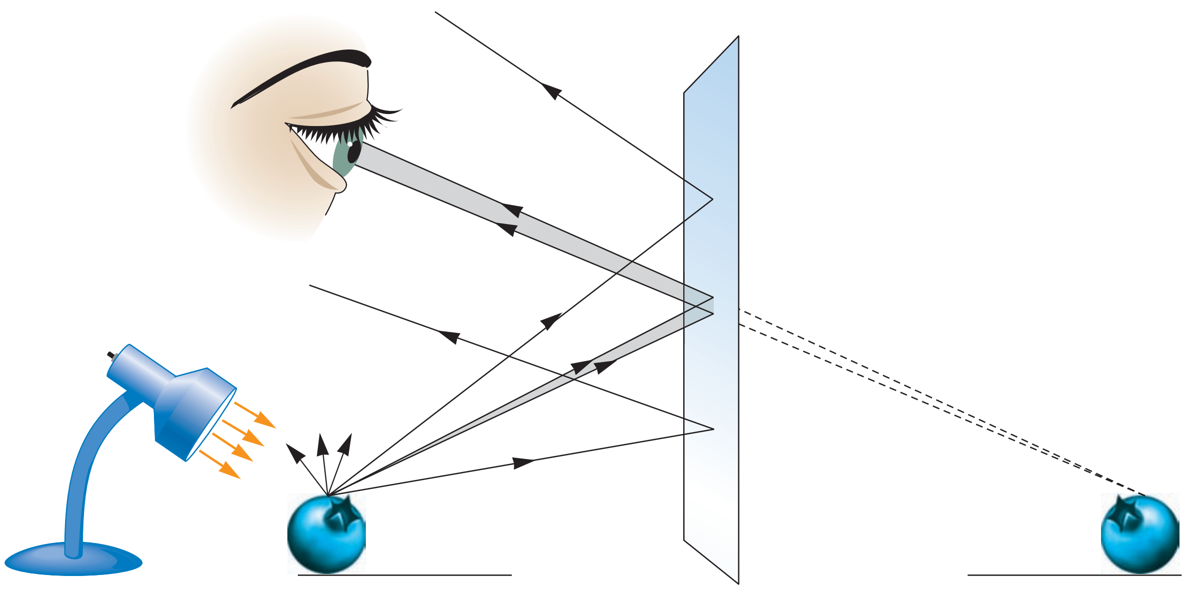

Figure 5.14 Only a small fraction of the light reflecting from an object enters the eye of the observer.

Image size and distance

Another important feature of images in plane mirrors is demonstrated in Figure 5.15. Rays are shown coming from three different points on the bird. These rays reflect off the mirror and back to the bird's eye.

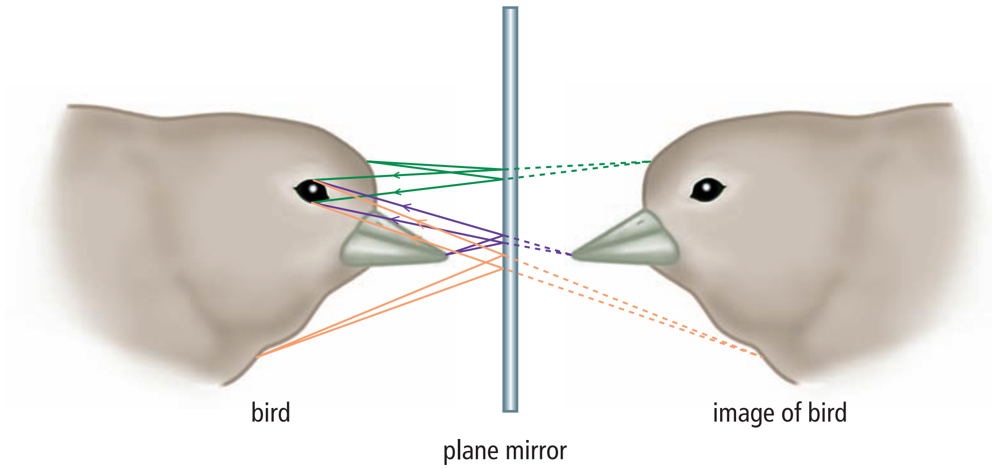

Figure 5.15 We know that what we see in a mirror is just an image. However, a pet bird will chatter for hours to a "friend" in the mirror.

Notice that the points appear to be coming from behind the mirror. Each point appears to be coming from a point that is as far behind the mirror as the real point is in front of the mirror. Also notice that the three points are exactly the same distance apart in the image as they are on the object, the bird. These observations explain why an image in a plane mirror is the same size as the object and appears to be the same distance from the mirror as the object.

Image orientation

A plane mirror produces an image with the same orientation as the object. If you are standing on your feet, a plane mirror produces an image of you standing on your feet. If you are doing a headstand, the mirror shows you doing a headstand. However, there is a difference between you and the appearance of your image in the mirror. Follow the sight lines in Figure 5.16. The ray that diverges from the right hand of the boy converges at what appears to be the left hand of his image. Left and right appear to be reversed by a plane mirror.

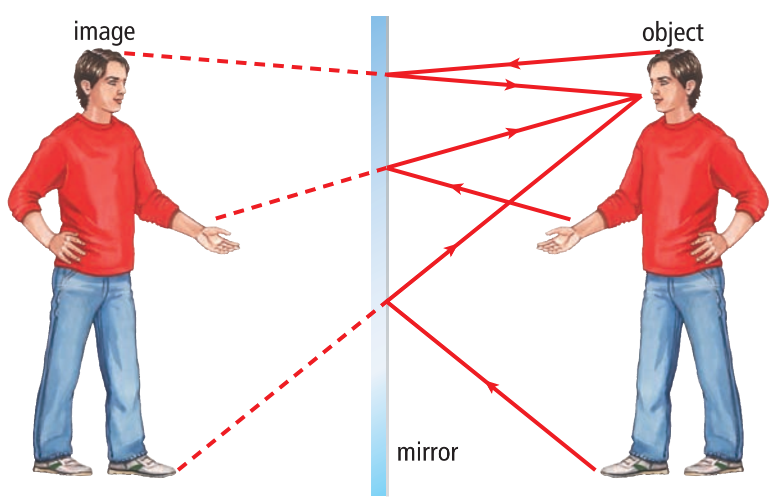

Figure 5.16 When the boy blinks his right eye, the left eye of his image blinks.

Concave Mirrors

A **concave mirror** is a mirror that curves inward. Concave mirrors, like plane mirrors, reflect light rays to form images. The difference is that the curved surface of a concave mirror reflects light in a unique way. As shown in Figure 5.17, parallel light rays bounce off the curved surface of a concave mirror and then meet at a single point called the **focal point**. Light rays that are coming together at a focal point are described as **converging**.

The image formed by a concave mirror depends on how far the object is from the focal point of the mirror (see Figure 5.18). If a distant object is reflected in a concave mirror, its image is small and upside down. As the object approaches the focal point, its image remains inverted but gets ever larger. If the object is between the focal point and the mirror, then the image appears to be larger than the object and is upright.

Concave mirrors have many uses (see Figure 5.19). If a bright light is placed at the focal point, then all the light rays bounce off the mirror and are reflected parallel to each other. This makes an intense, focussed beam of light. Spotlights, flashlights, lighthouses, and car headlights use this kind of mirror. The largest telescopes all use concave mirrors to collect light because the mirror concentrates the light so effectively. Shaving mirrors and make-up mirrors are also concave mirrors. They form an enlarged, upright image of a person's face so it is easier to see small details.

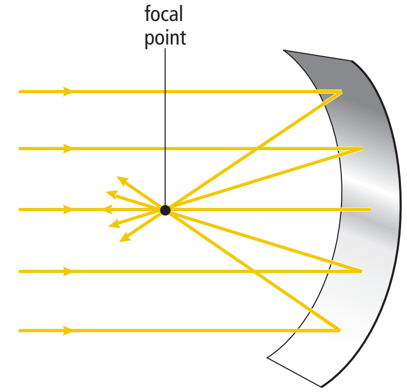

Figure 5.17 Light rays collected by a concave mirror converge on a focal point before spreading out again.

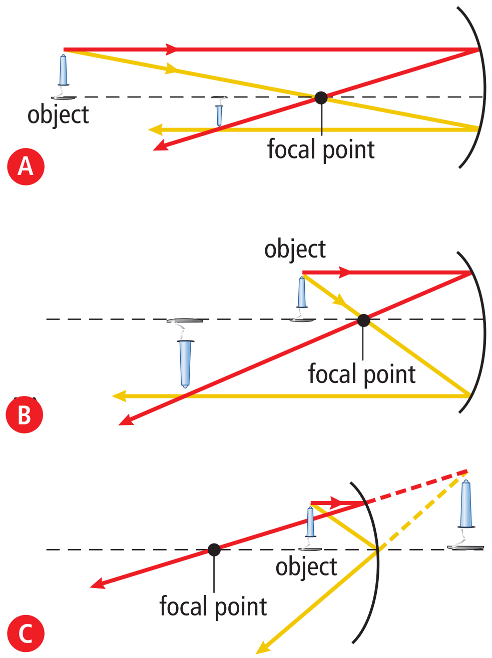

Figure 5.18 The image formed by a concave mirror depends on how far away the object is.

Figure 5.19 The boy is between the concave mirror and its focal point.

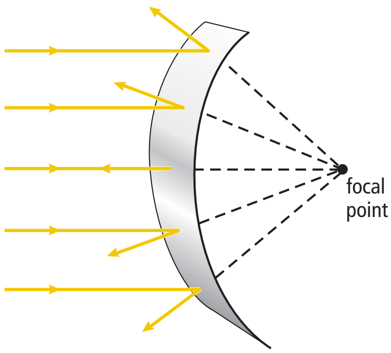

Figure 5.20 The reflected rays from a convex mirror diverge and do not meet.

Convex Mirrors

A **convex mirror** is a mirror that curves outwards. Convex mirrors also reflect light rays to form an image, but they do so in an opposite way to concave mirrors. A convex mirror reflects parallel light rays as if they came from a focal point behind the mirror (see Figure 5.20). Light rays that spread apart after reflecting are described as **diverging**. The image formed is always upright and smaller than the actual object.

The reflection from a convex mirror has two main characteristics:

1. Objects appear to be smaller than they are.
2. More objects can be seen in a convex mirror than in a plane mirror of the same size.

Security mirrors, such as those in convenience stores, are large convex mirrors. Convex mirrors make it possible to monitor a large region of the store from a single location. Convex mirrors can also widen the view of traffic that can be seen in rearview or side-view mirrors of automobiles. However, because distances and sizes seen in a convex mirror are not realistic, most convex side-view mirrors carry a printed warning that the objects viewed are closer than they appear to be (see Figure 5.21).

Suggested Activity

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Figure 5.21 Convex mirrors are used in stores as security mirrors (A), and in cars as rearview and side-view mirrors (B).

Explore More

Find out about the centre of curvature and radius of curvature for a concave lens. What is the relationship between the radius of curvature and the focal length? If a person stands at the centre of curvature in front of a large concave mirror, where will his or her image form and what will be its size and orientation? Visit **www.bcscience8.ca.**

Reading Check

1. What size does the image in a plane mirror appear to be?
2. What distance from the mirror does an image in a plane mirror appear to be?
3. How is a concave mirror shaped differently from a plane mirror?
4. What are some uses for concave mirrors?
5. How is a convex mirror shaped differently from a plane mirror?
6. What are some uses for convex mirrors?

5-7 Observing Images

Conduct an INVESTIGATION

Inquiry Focus

SkillCheck

- Observing
- Communicating
- Explaining systems
- Evaluating information

Materials

- ray box
- convex mirror
- concave mirror
- ruler
- protractor

A ray box can cast several light rays at the same time. This helps to visualize how an image is changed as light rays are reflected from a curved mirror.

Question

How is an image affected when light rays from an object bounce off a curved mirror?

Procedure

1. Use a ray box to shine several light rays at a concave mirror. Observe how the rays are affected. Make a diagram of the ray paths.
2. Hold the concave mirror directly in front of you at arm's length and view your own reflection. Bring the mirror gradually closer to one eye and observe as the image of your eye disappears. Keep moving the mirror closer until the image of your eye reappears. Record your observations.
3. Shine the ray box at a convex mirror and observe how the rays are affected. Make a diagram of the ray paths.
4. Hold the convex mirror directly in front of you at arm's length and view your own reflection. Bring the mirror gradually closer to one eye. Observe the image. Keep moving the mirror closer until the image of your eye reappears. Record your observations.

Analyze

1. (a) Explain how the orientation of the image of your eye changes as the concave mirror gets closer to your eye.
   (b) Explain why there is a certain point at which the image of your eye disappears completely.
2. (a) Do the light rays reflecting off the convex mirror ever cross each other? Explain.
   (b) Explain why your image never disappears and never flips over as you bring the convex mirror close to your eye.
3. Does the angle of incidence equal the angle of reflection in the case of curved mirrors?

Conclude and Apply

1. Mirrors are placed behind the light in car headlight systems to reflect the light ahead of the car. Explain why a concave mirror would be more useful for this purpose than a convex mirror.
2. Explain why an object appears farther away than it really is when the object is viewed through a convex mirror.

Mirrors in Time and Space

Have you looked at yourself in a mirror today? Ever since the first humans gazed at their images in a pond, mirrors have been used to tell us something about ourselves.

The most ancient manufactured mirrors known are about 8000 years old and were found in Turkey. These mirrors were made of obsidian, which is a hard, black glass produced from molten sand in the fiery heart of volcanoes and shot out of the volcano during eruptions. The glass was gathered and polished. In later ages in the ancient world, copper, bronze, and other metals were used for mirrors. Because the metals could be melted and then poured out, they formed very flat surfaces. Metal mirrors were also resistant to breakage.

This Roman mirror was made over 2000 years ago.

Roman artisans made mirrors by covering one side of a piece of glass with gold or silver, or mixtures of metals such as mercury and tin. Sharp, well-defined, reflected images were not possible until 1857, when Jean Foucault, a French scientist, developed a method of coating glass with silver. High quality, inexpensive mirrors did not become available until around 1900 when it became possible to make large amounts of extremely flat plate glass.

Modern mirrors are produced by evaporating aluminum or silver onto highly polished glass. Clear reflections in modern, optical instruments require smooth surfaces compared to the wavelengths being reflected.

Mirrors designed to go into space have a special restriction: they must be lightweight. If you have ever tried to lift a large sheet of glass or a mirror, you will know that large amounts of glass are very heavy. The first optical space telescope was the Hubble Space Telescope, which was launched into space in 1990. Mirrors are now available that are 10 times lighter than the one used in Hubble.

You probably know that aluminum is much less dense than iron, which is why aluminum is commonly used in aircraft. Beryllium is a metal that is even less dense than aluminum, and research is under way to make mirrors completely out of this metal.

The mirrors on space telescopes do not only look out into space. More and more, we turn the mirrors around and point them back at Earth. We can use mirrors on space telescopes to measure the growth of cities, the destruction of rain forests, and the melting of glaciers. We can also see the majesty of our planet and the potential for preserving and improving our environment. We humans have come a long way from gazing into a pond. Have you looked at your Earth in the mirror today?

Questions

1. What are some advantages of a metal mirror compared to one made of glass?
2. Mirrors located in orbit are in microgravity, which means they weigh almost nothing. Why, then, is it important to construct mirrors from materials like beryllium that are light in weight?
3. List five reasons (other than the ones listed in the article) why it might be useful to be able to see images of our Earth from space.

Check Your Understanding

Checking Concepts

1. Describe how your image changes as you move closer to:
   (a) a plane mirror
   (b) a concave mirror
   (c) a convex mirror
2. One side of a soupspoon is convex and the other is concave. Imagine you are having soup and you lift the spoon out of the soup bowl, holding some soup. Is the part of the spoon touching the soup convex or concave?
3. Do convex and concave mirrors obey the law of reflection? Explain.
4. Explain the difference between divergent and convergent light rays.
5. Draw and label a mirror that produces:
   (a) divergent light rays
   (b) convergent light rays
6. Suppose you find a shiny metal bowl that has been left outside in the sunlight.
   (a) Are you more likely to see the reflection of direct sunlight by viewing the outside or the inside of the bowl?
   (b) Is it more dangerous to look at the outside or the inside of the bowl? Explain.

Understanding Key Ideas

7. Why is an image in a plane mirror the same size as the object that is reflected?
8. List several uses of:
   (a) plane mirrors
   (b) concave mirrors
   (c) convex mirrors
9. (a) Draw a ray diagram that shows an arrangement of mirrors that would allow you to see the back of your own head. Draw the diagram as if looking down from above. The rays should leave the back of your head and end in your eye. Show the normal and angles of incidence and reflection.
   (b) Will left and right be reversed in the image? Explain.
10. Design and label an arrangement of mirrors to do each of the following:
    (a) see over the top of a fence without having to raise your eyes above the top of the fence
    (b) read a book by reflected light without having the words backwards in a "mirror image"
    (c) collect and concentrate the Sun's light into a small space and then conduct the light around two corners to a solar panel

Pause and Reflect

When you look across a lake, you might see the reflection of the distant mountains and trees in the water. The image of the trees and mountains appears to be upside down. However, when you look straight down at the surface of the lake, you see an upright reflection of yourself. Why would your image be upright while the image of the mountains is upside down?