Inquiry Investigation 11.1

INQUIRY SKILLS	
● Questioning	○ Hypothesizing
● Predicting	○ Planning
● Conducting	● Recording
● Analyzing	● Evaluating
● Communicating	

Reflecting Light off a Plane Mirror

Mirrors—dentists use them to examine your teeth, drivers use them to monitor traffic, decorators use them to make rooms seem larger, and you use them to check that you don't have the remains of your lunch on your nose. Regular, flat mirrors are called **plane mirrors**. (Here, the word *plane* means "a flat, two-dimensional surface," just as it does in mathematics.) In this Investigation, you will study how light reflects off a plane mirror.

You will use a protractor to measure angles in this Investigation. Whenever you measure an angle, always estimate its value first. Then, you can check that the result of your measurement makes sense.

Question

(a) Write a question that will be answered in this Investigation.

Prediction

(b) Look at **Figure 1**. Make a prediction about the relationship between the angle of incidence and the angle of reflection.

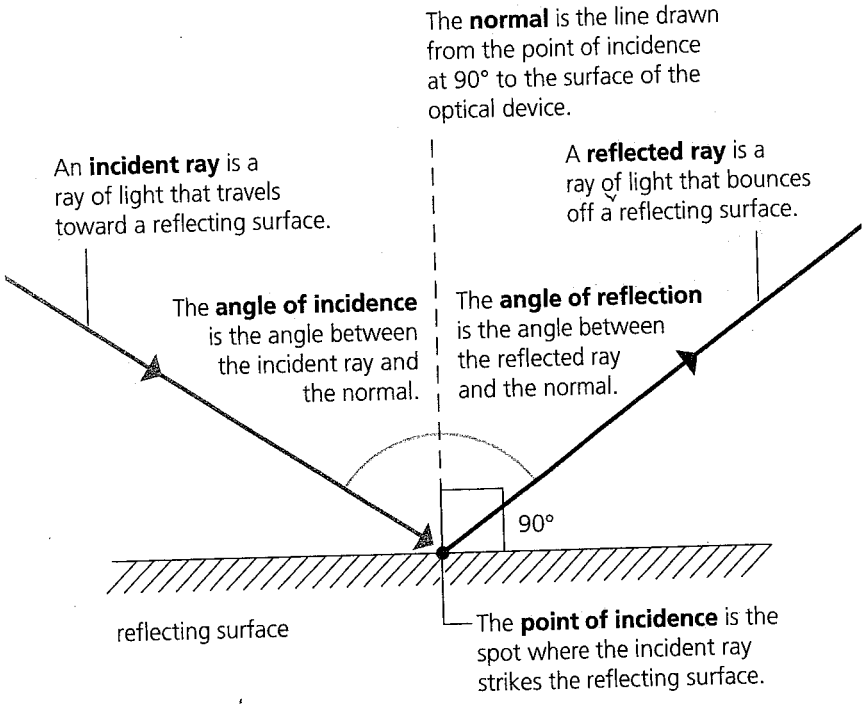


Figure 1
Vocabulary related to the reflection of light: Light travels in straight lines and can be represented using rays.

LEARNING TIP

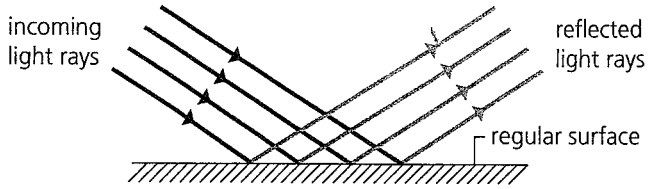
For help with writing a question and a prediction, see "Questioning" and "Predicting" in the Skills Handbook section **Conducting an Investigation**.

LEARNING TIP

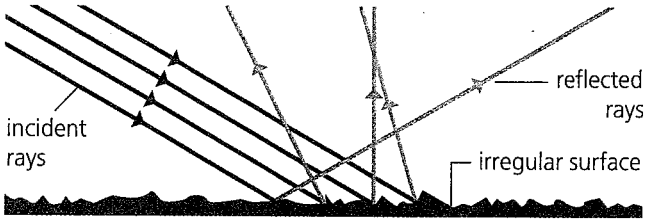
Figure 1 contains important vocabulary. Take your time looking at **Figure 1** and making connections between the labels and what the diagram shows.

11.2 Reflecting Light off Surfaces

When shooting hoops outdoors, have you ever tried bouncing the ball on the grass instead of the asphalt? When the ball bounces off a smooth driveway or a gym floor, you can predict the direction it will travel. But when it bounces off the grass, you cannot predict where it will go. The same is true of light, as shown in **Figure 1**.



(a)



(b)

Figure 1
Light acts somewhat like a basketball when it hits a surface. If the surface is smooth and regular **(a)**, like a mirror, you can predict the direction of the reflected light more easily than if the surface is irregular **(b)**.

Specular Reflection

You've learned that a smooth, shiny surface reflects light more predictably than a rough, dull surface. The reflection of light off a smooth, shiny surface is called **specular reflection**. When light reflects off a smooth, shiny surface, you can see an image. For example, specular reflection occurs off mirrors, shiny metal, and the surface of still water (**Figure 2**).

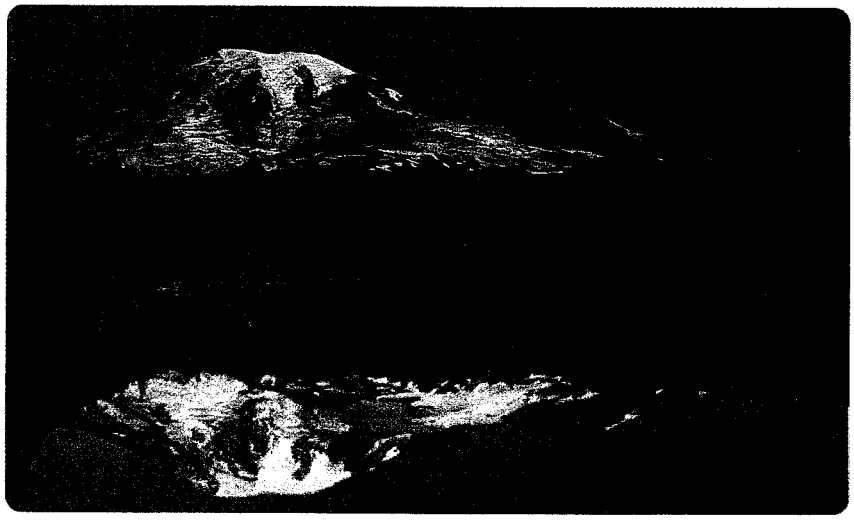


Figure 2
Which way is up? Turn the book upside down and see if that helps you decide.

The Laws of Reflection

You have used rays to represent light as it travels from a ray box to a mirror and as it is reflected in a straight line off the mirror. Experiments like yours always yield the same results. When experimental results are consistent, scientists create "laws" to summarize the results. They have created two **laws of reflection**:

- The angle of incidence equals the angle of reflection.
- The incident ray, normal, and reflected ray all lie in the same plane.

The laws of reflection can be used to learn why the eye sees an image in a plane mirror (**Figure 3**). When you look in a mirror, you see an image that appears to be behind the mirror. If you extended the reflected rays behind the mirror, the image is where the rays appear to come from. For each set of incident and reflected rays, the angle of incidence equals the angle of reflection.

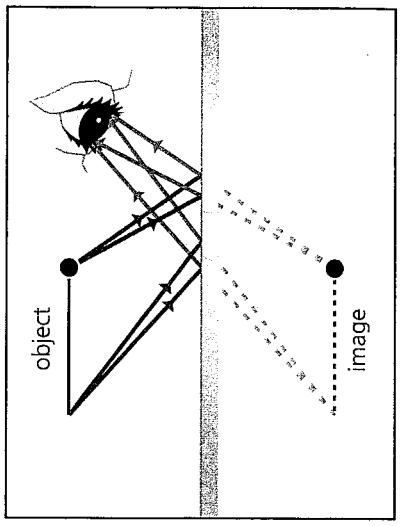


Figure 3
Your eye can see an image in a plane mirror.

Diffuse Reflection

Most surfaces are not regular. You cannot see a reflected image in cardboard or broccoli. When light hits an irregular surface, you see **diffuse reflection** as the reflected light scatters in many directions.

Both direct light from a source and reflected light from a regular surface can strain the eyes. A room with a bright light source and mirrors on every wall would be very hard on the eyes. The glare from a transparent glass lamp would also be hard on the eyes. Diffuse light is easier on the eyes. Homes, schools, and places of work are designed with this in mind. Ceilings are often coated with an irregular surface, such as stucco, that causes diffuse reflection. Lamps often have frosted bulbs that diffuse the light. Lampshades diffuse the light even more.

Figure 4 shows how indirect lighting and irregular surfaces help to diffuse the light in a room. In indirect lighting, the light bulbs cannot be seen. The light from the bulbs reflects off the ceiling or walls before it reaches your eyes.

LEARNING TIP

Check your understanding of specular and diffuse reflection. Explain how they are different in your own words to a partner.

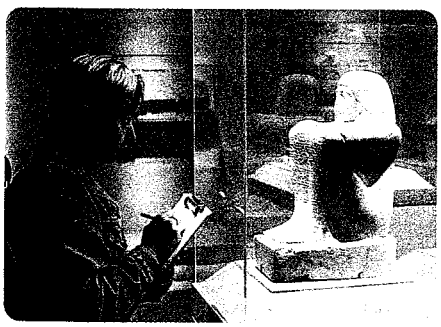


Figure 4
How many examples of diffuse reflection and specular reflection of light can you find in this photograph?

TRY THIS: Specular and Diffuse Reflection

Skills Focus: predicting, observing, communicating

In this activity, you will use shiny aluminum foil to study specular and diffuse reflection.

(a) Predict what will happen when you shine a flashlight on three pieces of aluminum foil, as shown in **Figure 5**.

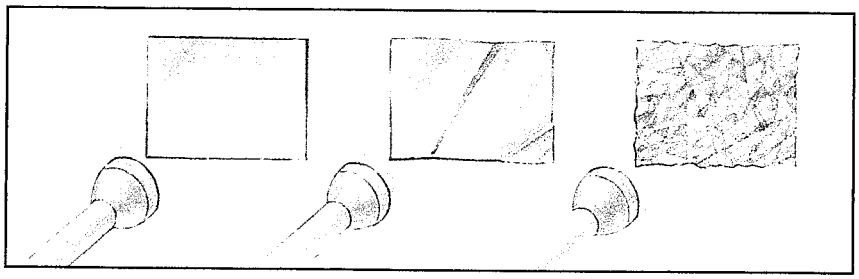


Figure 5

1. Set up the materials, and make your observations. You will see the effect best if the room is dark.

(b) Explain your observations using a diagram.

2. Repeat step 1, but use three different fabrics instead of the aluminum foil. Choose fabrics that are the same colour and have smooth, textured, and very rough surfaces.

(c) Write a brief report to summarize your findings.

11.2 CHECK YOUR UNDERSTANDING

1. In your own words, describe specular reflection and diffuse reflection.
2. Draw a ray diagram that shows a plane mirror and an incident ray with an angle of incidence of 37°. Then, draw the reflected ray. Draw ray diagrams using angles of incidence of 77° and 0°, as well.
3. (a) What is the largest possible angle of incidence for a light ray travelling toward a mirror?
   (b) What is the smallest possible angle of incidence?
4. Give examples of how an interior designer might benefit from a knowledge of diffuse reflection. Choose an example of direct light and an example of indirect light in your home. Briefly summarize their effectiveness.

PERFORMANCE TASK

Is specular or diffuse reflection important in your optical device? Is it a problem or an advantage?

Describing Images 11.3

When your teacher shows you slides, you see images produced by the projector on the screen. When you look at the letters in this sentence, an image of the letters forms at the back of your eyes. An image is the likeness of an object. An **optical device** produces an image of an object.

Real and Virtual

Images can be real or virtual. What does this mean? A **real image** can be placed on a screen. A **virtual image** cannot be placed on a screen. A virtual image can be seen only by looking at or through an optical device.

The four main characteristics listed in **Table 1** are generally used to study and compare images. These characteristics are used to describe the image in **Figure 1**.

LEARNING TIP

Make connections to your prior knowledge. What do you already know about real and virtual images? Is there any new information here?

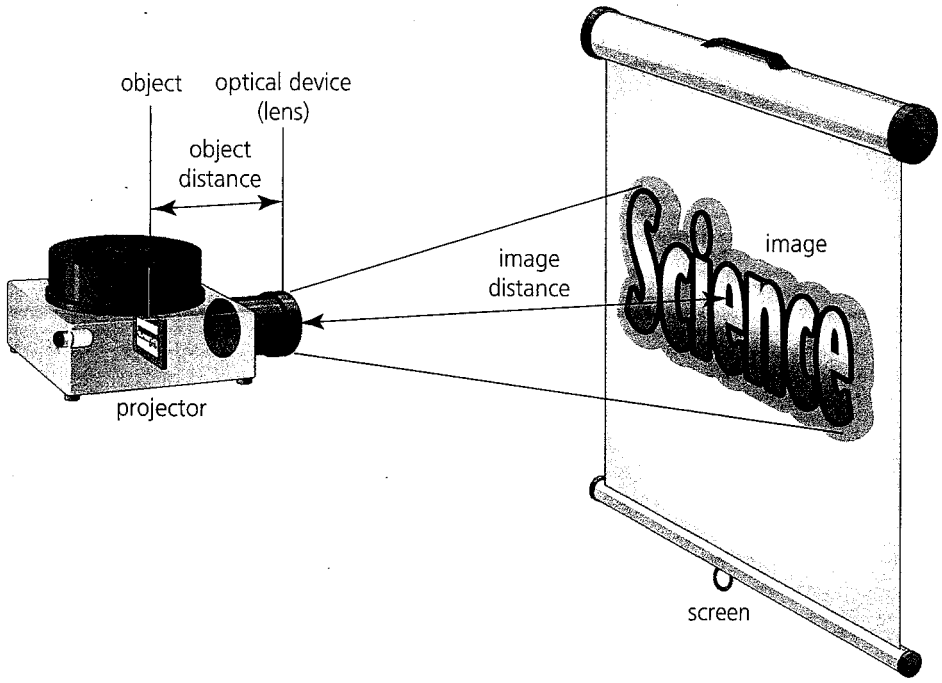


Figure 1
A slide projector shows a real image on a screen. The image is larger than the object viewed and is upright. It is closer to the optical device than to the object.

LEARNING TIP

Refer to **Table 1** when you complete the Try This activity on this page.

Table 1 Characteristics of Images

Characteristic	Possible descriptions
size	• smaller than the object viewed • larger than the object viewed • same size as the object viewed
attitude	• upright (right-side up) • inverted (upside down)
location	• several choices • examples: on the side of the lens opposite the object; closer to the optical device than to the object
type	• real image (can be placed on a screen) • virtual image (can be seen only by looking at or through an optical device)

Do not look at the Sun or any other bright source of light with a pinhole camera. The light could damage your eyes.

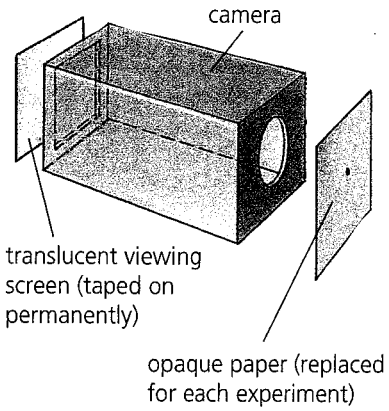


Figure 2
This type of pinhole camera is easy to make. Aim the pinhole toward the object you want to see, and look at the screen.

TRY THIS: Images in a Pinhole Camera

Skills Focus: creating models, observing

You can use a homemade pinhole camera to investigate images. A pinhole camera is a box with a tiny hole at one end and a viewing screen at the other end. It can be as small as a shoebox or as large as a box for packing a new refrigerator. You can even stand inside a large pinhole camera to view the images! **Figure 2** shows how to make a small pinhole camera.

1. Aim the pinhole toward the object you want to see and look at the screen.

(a) What are the characteristics of the image of an object that is a few metres away from the camera?

(b) What happens to the image as the camera gets closer to the object?

(c) What happens if a second pinhole is made about 1 cm below the first pinhole?

(d) Draw a diagram to show how an image is formed in a pinhole camera.

(e) Is the image that is seen in a pinhole camera real or virtual? Why?

11.3 CHECK YOUR UNDERSTANDING

1. Describe the characteristics of the image you see when your teacher uses an overhead projector.
2. The screen in a pinhole camera must be translucent rather than transparent or opaque. Why?

Inquiry Investigation 11.5

INQUIRY SKILLS	
● Questioning	● Hypothesizing
○ Predicting	○ Planning
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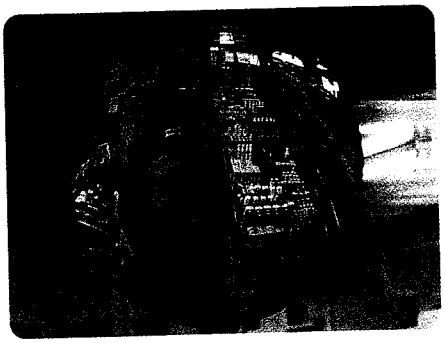
Curved Mirrors

You may have noticed a big curved mirror high in a corner at a local store (**Figure 1**). The store owner uses the convex mirror to watch for shoplifters. A **convex** mirror has the reflecting surface on the outside curve. Why do the images you see in a convex mirror that make it effective for surveillance?



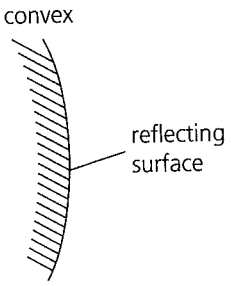
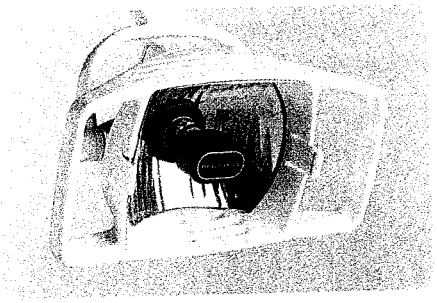


Figure 1
A convex mirror is like the back of a spoon.

The next time you visit a dentist, look closely at the lamp that the dentist uses (**Figure 2**). A concave mirror in the lamp focuses the light into your mouth so that the dentist can work on your teeth. A **concave** mirror has the reflecting surface on the inside curve. What makes a concave mirror effective for working on teeth?



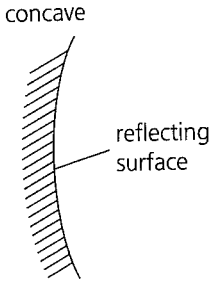


Figure 2
A concave mirror is like the inside of a spoon.

The images you see in curved mirrors look different from the images you see in plane mirrors. In this Investigation, you will explore these differences.

11.6 Using Curved Mirrors

You may not realize it, but curved mirrors are part of your everyday life. Whether you are shopping, riding a school bus, or learning about solar heating, curved mirrors are near. **Figures 1** and **2** show some of the terms that are used to describe curved mirrors.

principal axis: a line through the centre of the mirror that includes the principal focus

principal focus: the position where reflected parallel light rays come together

focal length: the distance from the principal focus to the middle of the mirror

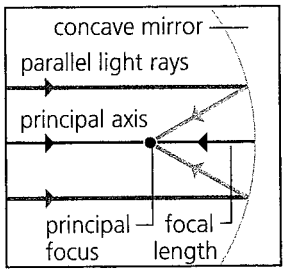
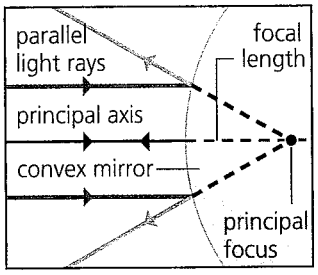


Figure 1



principal axis: a line through the centre of the mirror that includes the principal focus

principal focus: the position where parallel light rays appear to reflect from

focal length: the distance from the principal focus to the middle of the mirror

Figure 2

A concave mirror focuses parallel light rays (**Figure 1**). When an object is beyond the principal focus of a concave mirror, the type of image produced is real. The image is in front of the mirror and can be placed on a screen.

A convex mirror spreads the light rays out (**Figure 2**). Images in a convex mirror are always virtual, because they are behind the mirror and cannot be placed on a screen.

LEARNING TIP

Do not rush when you are looking at illustrations. Look carefully at **Figures 1** to **6** and read the captions. Then check for understanding. Ask yourself, "What does this show? How is this connected to what I am learning?"

Using Concave Mirrors

If you have ever looked through a reflecting telescope, you have used a concave mirror. **Figure 3** shows how a concave mirror gathers light from distant objects and brings it to a focus. The biggest telescopes built, including space telescopes, are based on this design.

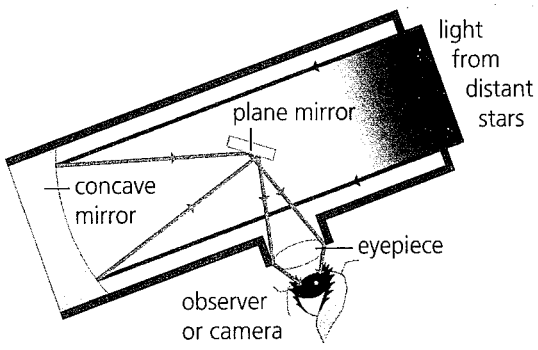


Figure 3
A reflecting telescope creates an image that can be viewed, photographed, or recorded digitally.

Figure 4 shows how a concave cosmetic mirror is used to produce an upright, enlarged image of a nearby object. The person using the mirror must be closer to it than the principal focus.

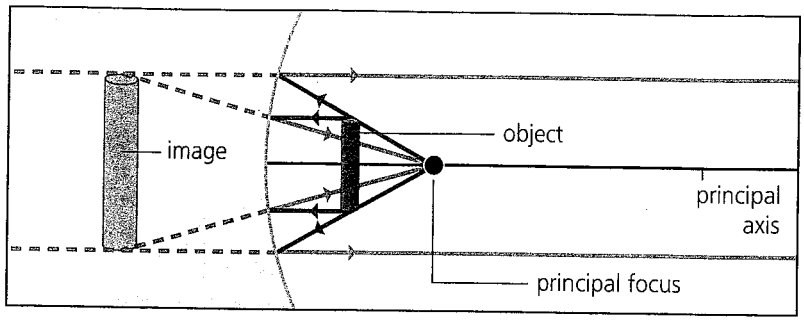


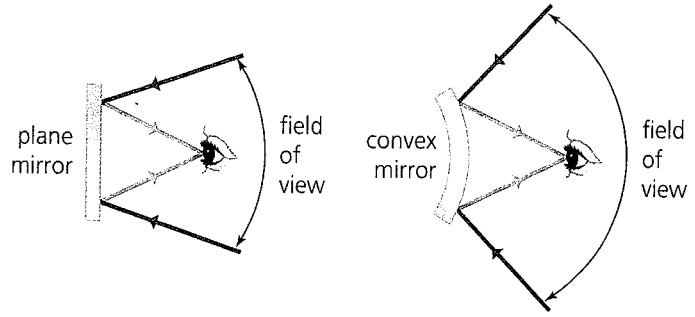
Figure 4
A concave mirror produces an upright, enlarged image when the person using it is closer to the mirror than the principal focus. Could this image be placed on a screen?

Using Convex Mirrors

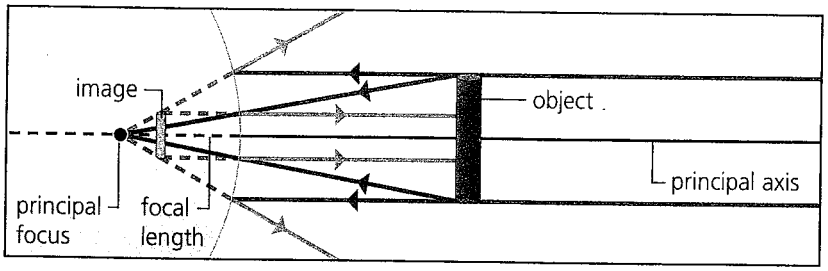
You have probably noticed large surveillance mirrors in many stores. A convex mirror can be used to monitor a very large area because its curved surface reflects light from all parts of a room to a person's eye. Images are always upright and smaller than the object, no matter where the object is located. **Figure 5** shows how a convex mirror produces an image and why it gives a much wider view than any other kind of mirror. **Figure 6** shows another common use of convex mirrors. Can you think of more uses?

LEARNING TIP

Explain the differences between concave and convex mirrors in your own words to a partner.



(a) The reflection in a convex mirror has a much larger field of view than the reflection in a plane mirror.



(b) The characteristics of the image produced by a convex mirror are the same whether the object is near the mirror or far away.

Figure 5

Figure 6
A convex mirror on the front of a school bus allows the driver to see children both beside and in front of the bus.

Table 1 Image Characteristics of Different Mirrors

	Plane mirror	**Concave mirror** (object closer than principal focus)	**Concave mirror** (object beyond principal focus)	**Convex mirror**
Size	• same size as object	• larger than object	• larger than the object but becomes smaller as object distance increases	• smaller than object
Attitude	• upright	• upright	• inverted	• upright
Location	• behind mirror • same distance from mirror as object	• behind mirror • farther from the mirror than the object	• in front of mirror • distance varies depending on distance of object	• behind mirror • farther from the mirror than the object
Type of image	• virtual	• virtual	• real	• virtual

11.6 CHECK YOUR UNDERSTANDING

1. Briefly describe how the principal focus in a concave mirror is the same and how it is different from the principal focus in a convex mirror.
2. How do the characteristics of images in a convex mirror compare to those in a concave mirror
   (a) when the object is close to the mirror?
   (a) when the object is far from the mirror?
3. For each situation, state whether the image produced is real or virtual. Explain how you know.
   (a) A girl is standing close to a cosmetic mirror while applying lipstick.
   (b) An astronomer is looking at an image of the Moon through her telescope, which has a concave mirror.
   (c) A clerk in a drugstore is looking at the image of a customer in a surveillance mirror.
4. Rewrite the following false statements to make them true.
   (a) The image in a convex mirror is always real and upright.
   (b) When an object is inside the principal focus of a concave mirror, its image is inverted and real.
   (c) Real images are always located behind the mirror.
5. Curved mirrors can be used to gather light from the Sun and focus it for solar heating. Draw a diagram that shows how this might work.
6. Do you think the focal length of a concave mirror would increase, decrease, or stay the same if the mirror were made flatter? Use a diagram to help illustrate your explanation.

PERFORMANCE TASK

What is the purpose of the concave and/or convex mirrors in your chosen device?