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Light and Our World

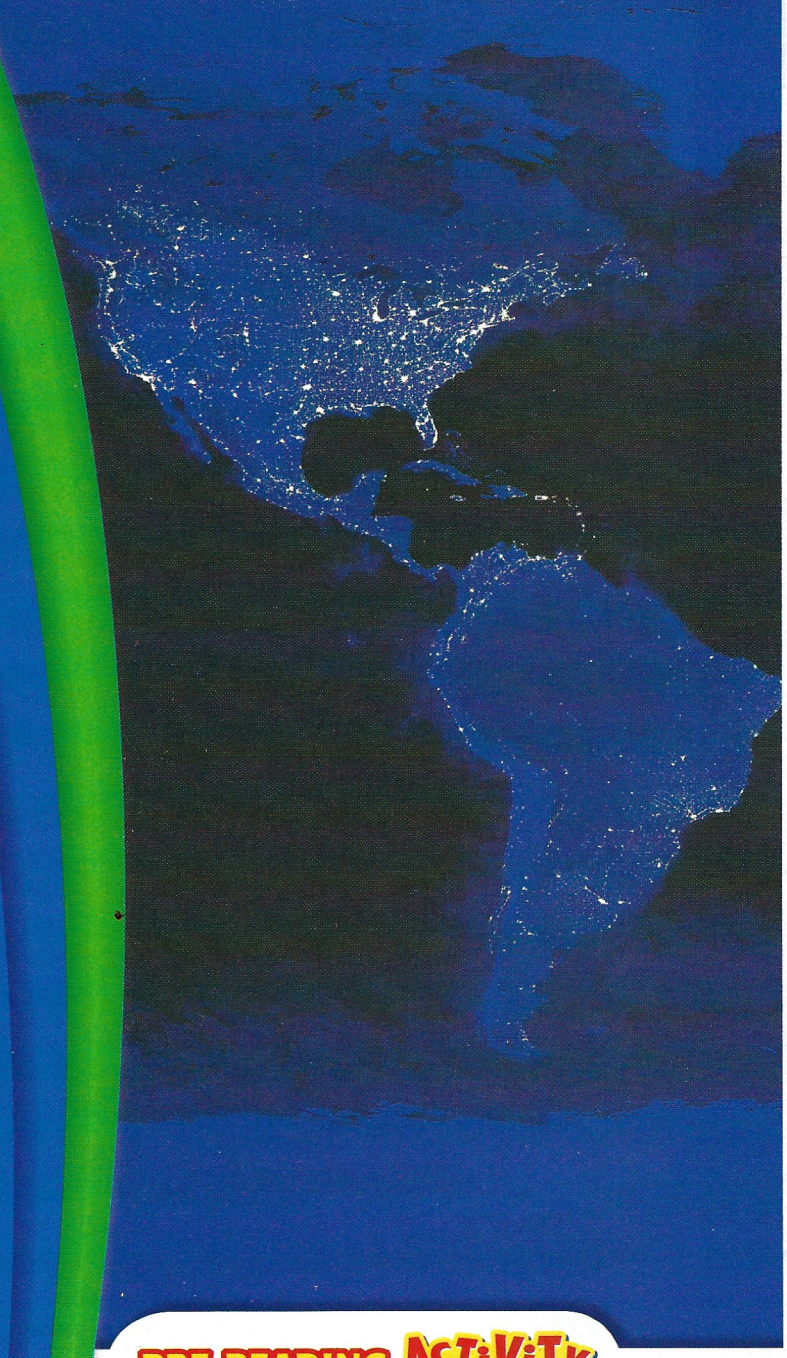
The Big Idea

Mirrors and lenses change the path of light waves and affect the images that you see.

SECTION

About the PHOTO

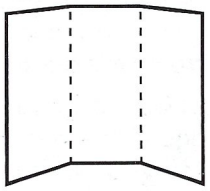
This photo of Earth was taken by a satellite in space. All of the dots of light in this photo are lights in cities around the world. In areas with many dots, people live in cities that are close together. Light is very important in your everyday life. Not only does light help you see at night but light waves can also be used to send information over long distances. In fact, the satellite that took this picture sent the picture to Earth by using light waves!



PRE-READING ACTIVITY

FOLDNOTES

Tri-Fold Before you read the chapter, create the FoldNote entitled "Tri-Fold" described in the **Study Skills** section of the Appendix. Write what you know about light in the column labeled "Know." Then, write what you want to know in the column labeled "Want." As you read the chapter, write what you learn about light in the column labeled "Learn."



SECTION 1

Mirrors and Lenses

When walking by an ambulance, you notice that the letters on the front of the ambulance look strange. Some letters are backward, and they don't seem to spell a word!

Look at **Figure 1.** The letters spell the word *ambulance* when viewed in a mirror. Images in mirrors are reversed left to right. The word *ambulance* is spelled backward so that people driving cars can read it when they see an ambulance in their rearview mirrors. To understand how images are formed in mirrors, you must first learn how to use rays to trace the path of light waves.

What You Will Learn

- Use ray diagrams to show how light is reflected or refracted.
- Compare plane mirrors, concave mirrors, and convex mirrors.
- Use ray diagrams to show how mirrors form images.
- Describe the images formed by concave and convex lenses.

Vocabulary

plane mirror
concave mirror
convex mirror
lens
convex lens
concave lens

READING STRATEGY

Reading Organizer As you read this section, make a concept map by using the terms above.

Rays and the Path of Light Waves

Light waves are electromagnetic waves. Light waves travel from their source in all directions. If you could trace the path of one light wave as it travels away from a light source, you would find that the path is a straight line. Because light waves travel in straight lines, you can use an arrow called a *ray* to show the path and the direction of a light wave.

Rays and Reflected and Refracted Light

Rays help to show the path of a light wave after it bounces or bends. Light waves that bounce off an object are reflected. Light waves that bend when passing from one medium to another are refracted. So, rays in ray diagrams show changes in the direction light travels after being reflected by mirrors or refracted by lenses.

Figure 1 *If you hold this photo up to the mirror in your bathroom, you will see the word* AMBULANCE.

Mirrors and Reflection of Light

Have you ever looked at your reflection in a metal spoon? The spoon is like a mirror but not like a bathroom mirror! If you look on one side of the spoon, your face is upside down. But on the other side, your face is right side up. Why? Read on to find out!

The shape of a mirror affects the way light reflects from it. So, the image you see in your bathroom mirror differs from the image you see in a spoon. Mirrors are classified by their shape. Three shapes of mirrors are plane, concave, and convex.

Figure 2 *Rearview mirrors in cars are plane mirrors. This mirror shows the reflection of the front of the ambulance shown in* ***Figure 1.***

Plane Mirrors

Most mirrors, such as the one in your bathroom, are plane mirrors. A **plane mirror** is a mirror that has a flat surface. When you look in a plane mirror, your reflection is right side up. The image is also the same size as you are. Images in plane mirrors are reversed left to right, as shown in **Figure 2.**

plane mirror a mirror that has a flat surface

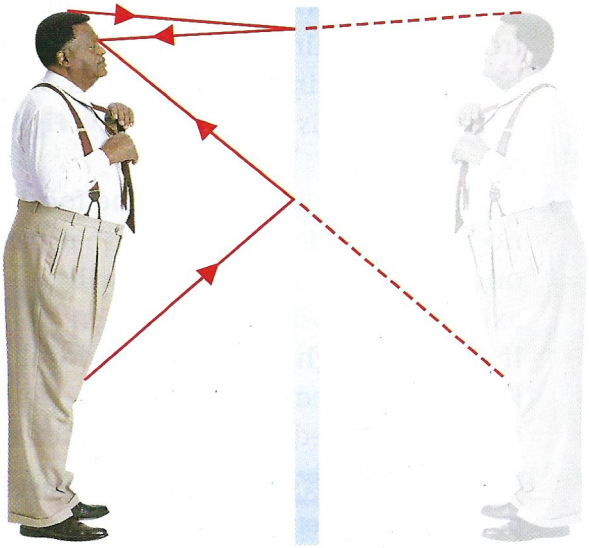
In a plane mirror, your image appears to be the same distance behind the mirror as you are in front of it. Why does your image seem to be behind the mirror? When light reflects off the mirror, your brain thinks the reflected light travels in a straight line from behind the mirror. The ray diagram in **Figure 3** explains how light travels when you look into a mirror. The image formed by a plane mirror is a virtual image. A *virtual image* is an image through which light does not travel.

Reading Check **What is a virtual image?** (*See the Appendix for answers to Reading Checks.*)

Figure 3 **How Images Are Formed in Plane Mirrors**

The rays show how light reaches your eyes. The dotted lines show where the light appears to come from.

Light reflects off you and strikes the mirror. The light then reflects off the mirror at an angle equal to the angle at which the light hit the mirror. Some of the reflected light enters your eyes.



Your image appears to be behind the mirror because your brain assumes that the light rays that enter your eyes travel in a straight line from an object to your eyes.

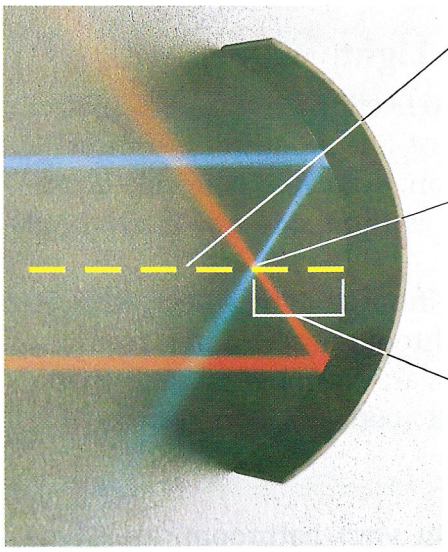


Figure 4 *Concave mirrors are curved like the inside of a spoon. The image formed by a concave mirror depends on the optical axis, focal point, and focal length of the mirror.*

concave mirror a mirror that is curved inward like the inside of a spoon

convex mirror a mirror that is curved outward like the back of a spoon

Concave Mirrors

A mirror that is curved inward is called a **concave mirror.** The images formed by concave mirrors differ from the images formed by plane mirrors. The image formed by a concave mirror depends on three things: the optical axis, focal point, and focal length of the mirror. **Figure 4** explains these terms.

You have already learned that plane mirrors can form only virtual images. Concave mirrors also form virtual images. But they can form real images, too. A *real image* is an image through which light passes. A real image can be projected onto a screen, but a virtual image cannot.

Concave Mirrors and Ray Diagrams

To find out what kind of image a concave mirror forms, you can make a ray diagram. Draw two rays from the top of the object to the mirror. Then, draw rays reflecting from the surface of the mirror. If the reflected rays cross in front of the mirror, a real image is formed. If the reflected rays do not cross in front of the mirror, extend the reflected rays in straight lines behind the mirror. Those lines will cross to show where a virtual image is formed. Study **Figure 5** to better understand ray diagrams.

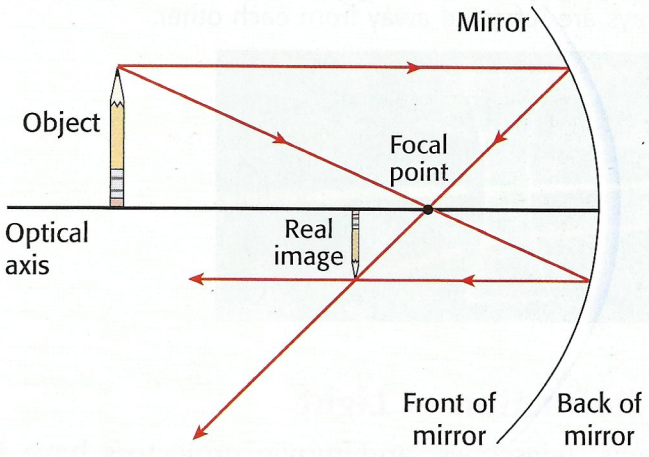
If an object is placed at the focal point of a concave mirror, no image will form. All rays that pass through the focal point on their way to the mirror will reflect parallel to the optical axis. The rays will never cross in front of or behind the mirror. If you put a light source at the focal point of a concave mirror, light will reflect outward in a powerful beam. So, concave mirrors are used in car headlights and flashlights.

Reading Check How can a concave mirror be used to make a powerful beam of light?

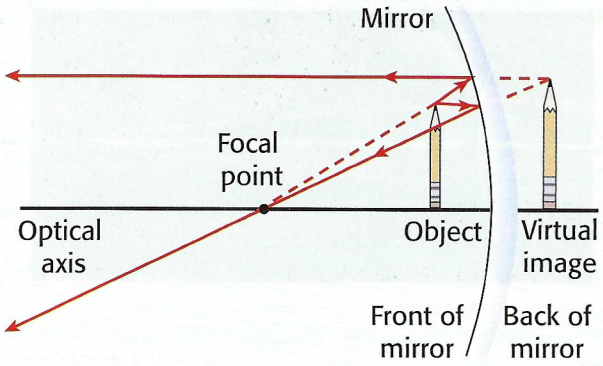
INTERNET ACTIVITY

For another activity related to this chapter, go to **go.hrw.com** and type in the keyword **HP5LOWW.**

Figure 5 *The type of image formed by a concave mirror depends on the distance between the object and the mirror.*



An object more than 1 focal length away from a concave mirror forms an **upside-down, real image.**



An object less than 1 focal length away from a concave mirror forms a **right-side-up, virtual image.** The dotted lines trace the reflected rays behind the mirror to find the virtual image.

Convex Mirrors

If you look at your reflection in the back of a spoon, you will notice that your image is right side up and small. The back of a spoon is a convex mirror. A **convex mirror** is a mirror that curves outward. **Figure 6** shows how an image is formed by a convex mirror. The reflected rays do not cross in front of a convex mirror. So, the reflected rays are extended behind the mirror to find the virtual image. All images formed by convex mirrors are virtual, right side up, and smaller than the original object. Convex mirrors are useful because they make images of large areas. So, convex mirrors are often used for security in stores and factories. Convex mirrors are also used as side mirrors on cars and trucks.

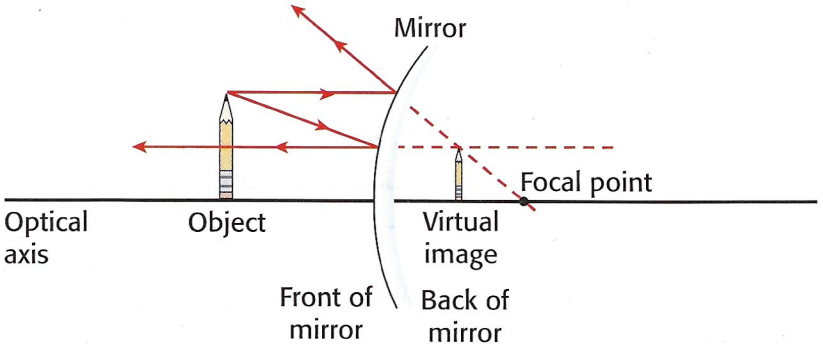


Figure 6 *All images formed by convex mirrors are formed behind the mirror. Therefore, all images formed by convex mirrors are virtual.*

SCHOOL to HOME

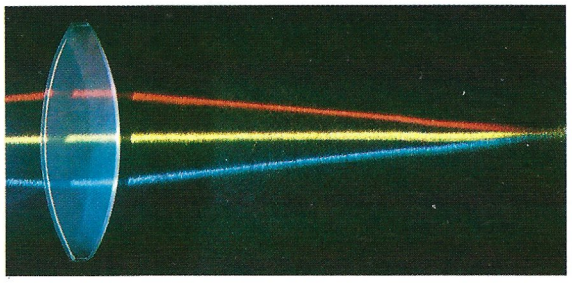
Car Mirrors

Sit in the passenger side of a car. Ask an adult at home to stand one car-length behind the car. Look at the adult's reflection in the passenger side mirror. Then, look at the adult's reflection in the rearview mirror. Make a table comparing the two mirrors and the images you saw in each mirror.

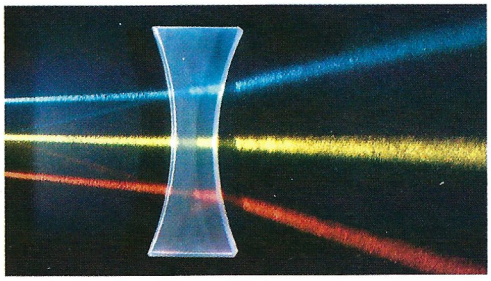
ACTIVITY

Figure 7 How Light Passes Through Lenses

When light rays pass through a **convex lens,** the rays are refracted toward each other.



When light rays pass through a **concave lens,** the rays are refracted away from each other.



Lenses and Refraction of Light

lens a transparent object that refracts light waves such that they converge or diverge to create an image

convex lens a lens that is thicker in the middle than at the edges

concave lens a lens that is thinner in the middle than at the edges

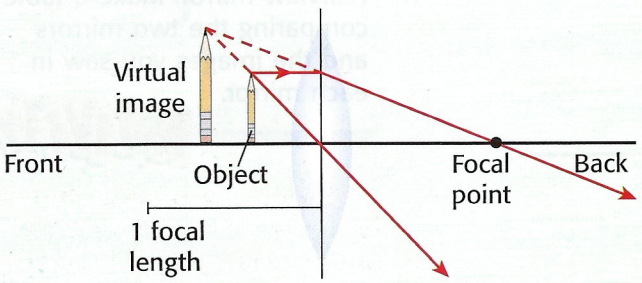
What do cameras, telescopes, and movie projectors have in common? They all use lenses to create images. A **lens** is a transparent object that forms an image by refracting, or bending, light. Lenses are classified by their shape. Two kinds of lenses, convex and concave, are shown in **Figure 7.** The yellow beams in **Figure 7** show that light rays that pass through the center of any lens are not refracted. Like mirrors, lenses have a focal point and an optical axis.

Convex Lenses

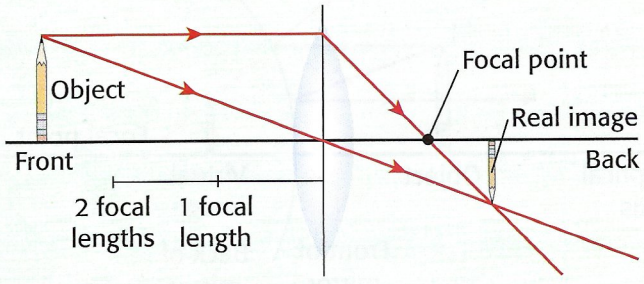
A **convex lens** is a lens that is thicker in the middle than at the edges. Convex lenses form different kinds of images. The ways in which two of these kinds of images are formed are shown in **Figure 8.** In addition, a convex lens can form a real image that is larger than the object if the object is between 1 and 2 focal lengths away from the lens. Convex lenses have many uses. For example, magnifying lenses and camera lenses are convex lenses. And convex lenses are sometimes used in eyeglasses.

Reading Check What is a convex lens?

Figure 8 *The distance between an object and a convex lens determines the size and the kind of image formed.*



If an object is less than 1 focal length away from a convex lens, a **virtual image** is formed. The image is larger than the object.



If an object is more than 2 focal lengths away from the lens, a **real image** is formed. The image is smaller than the object.

Concave Lenses

A **concave lens** is a lens that is thinner in the middle than at the edges. Light rays entering a concave lens parallel to the optical axis always bend away from each other and appear to come from a focal point in front of the lens. The rays never meet. So, concave lenses never form a real image. Instead, they form virtual images, as shown in **Figure 9.** Concave lenses are sometimes combined with other lenses in telescopes. The combination of lenses produces clearer images of distant objects. Concave lenses are also used in microscopes and eyeglasses.

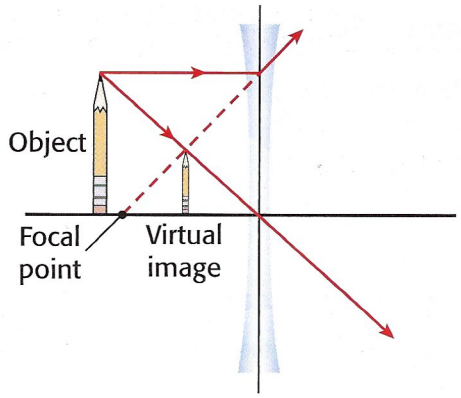


Figure 9 *Concave lenses form virtual images. The image is smaller than the object.*

SECTION Review

Summary

- Rays are arrows that show the path of a single light wave.
- Ray diagrams can be used to find where images are formed by mirrors and lenses.
- Plane mirrors and convex mirrors produce virtual images. Concave mirrors produce both real images and virtual images.
- Convex lenses produce both real images and virtual images. Concave lenses produce only virtual images.

Using Key Terms

For each pair of terms, explain how the meanings of the terms differ.

1. *convex mirror* and *concave mirror*
2. *convex lens* and *concave lens*

Understanding Key Ideas

3. Which of the following can form real images?
   - **a.** a plane mirror
   - **b.** a convex mirror
   - **c.** a convex lens
   - **d.** a concave lens
4. Explain how you can use a ray diagram to determine if a real image or a virtual image is formed by a mirror.
5. Compare the images formed by plane mirrors, concave mirrors, and convex mirrors.
6. Describe the images that can be formed by convex lenses.
7. Explain why a concave lens cannot form a real image.

Critical Thinking

8. **Applying Concepts** Why is an image right side up on the back of a spoon but upside down on the inside of a spoon?
9. **Making Inferences** Teachers sometimes use overhead projectors to show transparencies on a screen. What type of lens does an overhead projector use?

Interpreting Graphics

10. Look at the ray diagram below. Identify the type of lens and the kind of image that is formed.