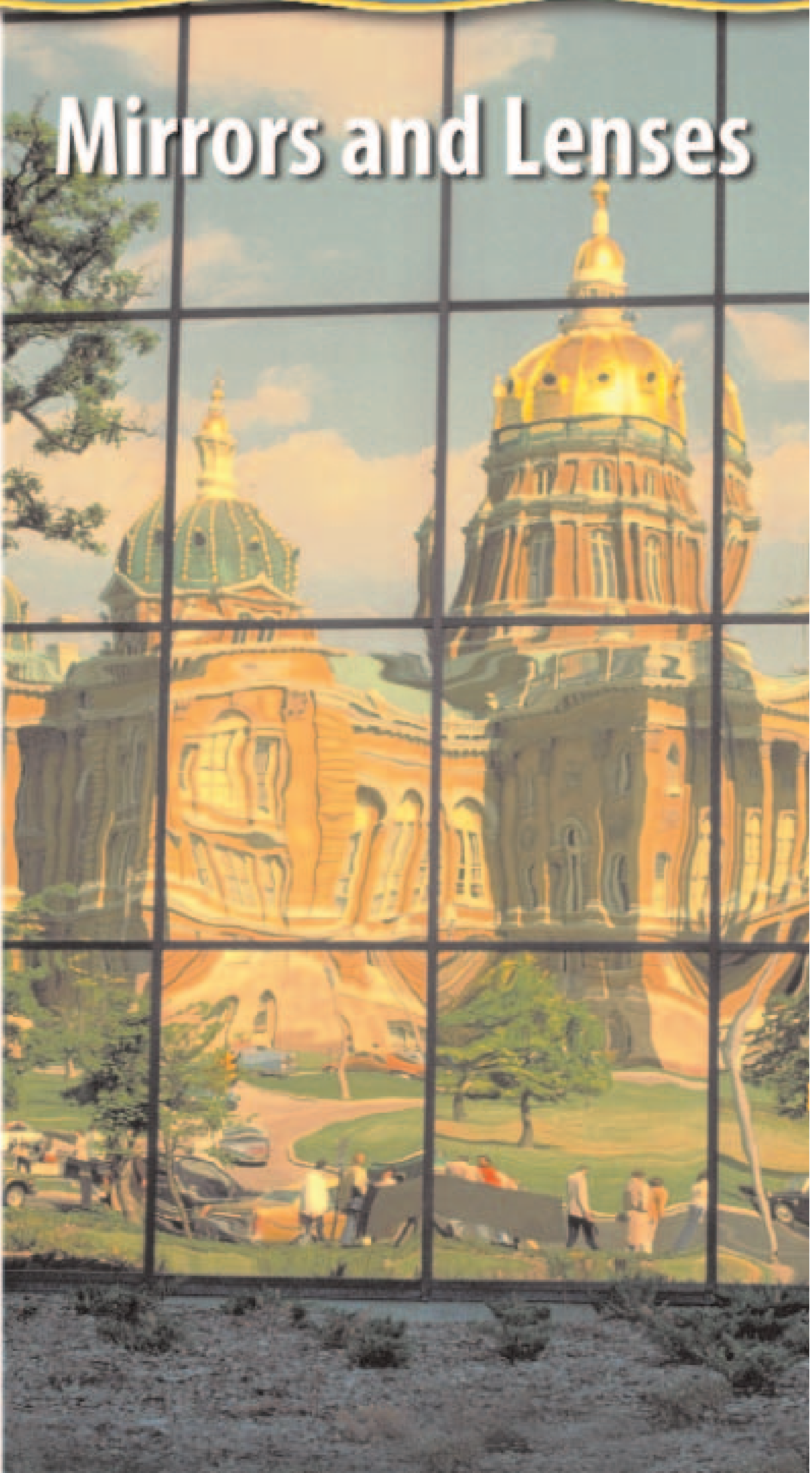
chapter 14

Mirrors and Lenses



BIG Idea

Mirrors and lenses form images by causing light rays to change direction.

14.1 Mirrors

MAIN Idea Light rays change direction when they are reflected by a mirror.

14.2 Lenses

MAIN Idea Light rays are bent when they pass through a lens.

14.3 Optical Instruments

MAIN Idea Lenses and mirrors are used to make objects easier to see.

Wavy Reflections

The dark-tinted glass panes of this office building are acting as mirrors. Depending on how the surface of a mirror is curved, a mirror can distort the image of an object and make it look larger or smaller.

Science Journal

Write a paragraph describing how you use mirrors every day.

Start-Up Activities

Launch LAB

Making a Water Lens

Have you ever used a magnifying glass, a camera, a microscope, or a telescope? If so, you were using a lens to create an image. A lens is a transparent material that bends rays of light and forms an image. In this activity, you will use water to create a lens.

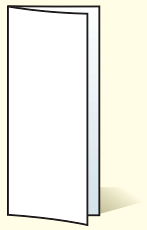
1. Cut a 10-cm × 10-cm piece of plastic wrap. Set it on a page of printed text.
2. Place a small water drop on the plastic. Look at the text through the drop. What do you observe?
3. Make your water drop larger and observe the text through it again.
4. Carefully lift the piece of plastic wrap a few centimeters above the text and look at the text through the water drop again.
5. **Think Critically** Describe how the text looked in steps 2, 3, and 4. Why do you think water affects the way the text looks? What other materials might you use to change the appearance of the text?

Science Online: Preview this chapter's content and activities at gpscience.com

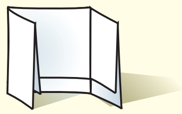
FOLDABLES™ Study Organizer

Types of Mirrors Make the following Foldable to help identify the three different types of mirrors and their characteristics.

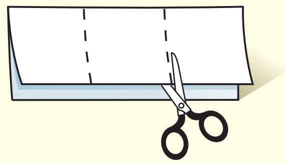
STEP 1 **Fold** a vertical sheet of paper from side to side. Make the front edge about 1.25 cm shorter than the back edge.



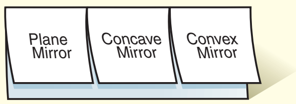
STEP 2 **Turn** lengthwise and fold into thirds.



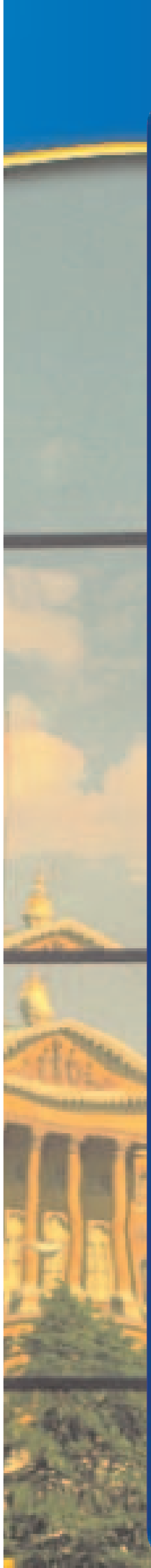
STEP 3 **Unfold and cut** only the top layer along both folds to make three tabs.



STEP 4 **Label** each tab as shown.



Read and Write As you read Section 1 of this chapter, write down important information under the appropriate tab about each type of mirror.



John Elk III/Stock Boston/PictureQuest

SPS9d. Investigate the phenomena of reflection, refraction, interference, and diffraction. **Also covers:** SCSh1a–c, 3c, 3e–f, 4a, 9c

section 1

Mirrors

Reading Guide

What You'll Learn

- **Describe** how an image is formed in three types of mirrors.
- **Explain** the difference between real and virtual images.
- **Identify** examples and uses of plane, concave, and convex mirrors.

Why It's Important

Mirrors enable you to check your appearance, see objects behind you, and produce beams of light.

Review Vocabulary

reflection: occurs when waves change direction after striking a surface

New Vocabulary

- plane mirror
- virtual image
- concave mirror
- optical axis
- focal point
- focal length
- real image
- convex mirror

How do you use light to see?

Have you tried to read a book under the covers with only a small flashlight? Or have you ever tried to find an address number on a house or an apartment at night on a poorly lit street? It's harder to do those activities in the dark than it is when there is plenty of light. Your eyes see by detecting light, so anytime you see something, it is because light has come from that object to your eyes. Light is emitted from a light source, such as the Sun or a lightbulb, and then reflects off an object, such as the page of a book or someone's face. When light travels from an object to your eye, you see the object. Light can reflect more than once. For example, light can reflect off of an object into a mirror and then reflect into your eyes. When no light is available to reflect off of objects and into your eye, your eyes cannot see anything. This is why it is hard to read a book or see an address in the dark.

Figure 1 A light source, like a candle, sends out light rays in all directions.

Light Rays Light sources send out light waves that travel in all directions. These waves spread out from the light source just as ripples on the surface of water spread out from the point of impact of a pebble.

You also could think of the light coming from the source as being many narrow beams of light. Each narrow beam of light travels in a straight line and is called a light ray. **Figure 1** shows how a light source, such as a candle, gives off light rays that travel away from the source in all directions. Even though light rays can change direction when they are reflected or refracted, your brain interprets images as if light rays travel in a single direction.

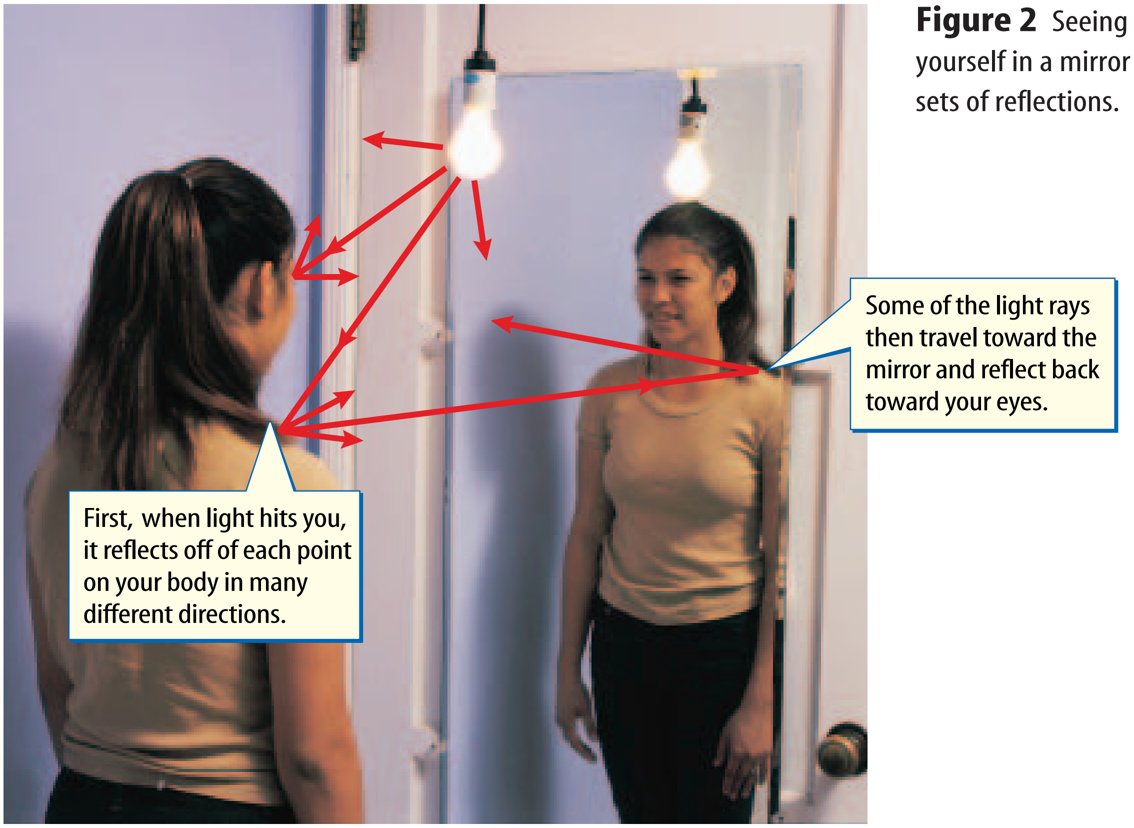


Figure 2 Seeing an image of yourself in a mirror involves two sets of reflections.

Seeing Reflections with Plane Mirrors

Greek mythology tells the story of a handsome young man named Narcissus who noticed his image in a pond and fell in love with himself. Like pools of water, mirrors are smooth surfaces that reflect light to form images. Just as Narcissus did, you can see yourself as you glance into a quiet pool of water or walk past a shop window. Most of the time, however, you probably look for your image in a flat, smooth mirror called a **plane mirror.**

Reading Check *What is a plane mirror?*

Reflection from Plane Mirrors What do you see when you look into a plane mirror? Your reflection appears upright. If you were 1 m from the mirror, your image would appear to be 1 m behind the mirror, or 2 m from you. In fact, your image is what someone standing 2 m from you would see. **Figure 2** shows how your image is formed by a plane mirror. First, light rays from a light source strike you. Every point that is struck by the light rays reflects these rays so they travel outward in all directions. If your friend were looking at you, these reflected light rays coming from you would enter her eyes so she could see you. However, if a mirror is placed between you and your friend, the light rays are reflected from the mirror back to your eyes.

INTEGRATE Life Science

Mirror Images Your left hand and right hand are mirror images of each other. Some of the molecules in your body exist in two forms that are mirror images. However, your body uses some molecules only in the left-handed form and other molecules only in the right-handed form. Using different colors of gumdrops and toothpicks, make a model of a molecule that has a mirror image.

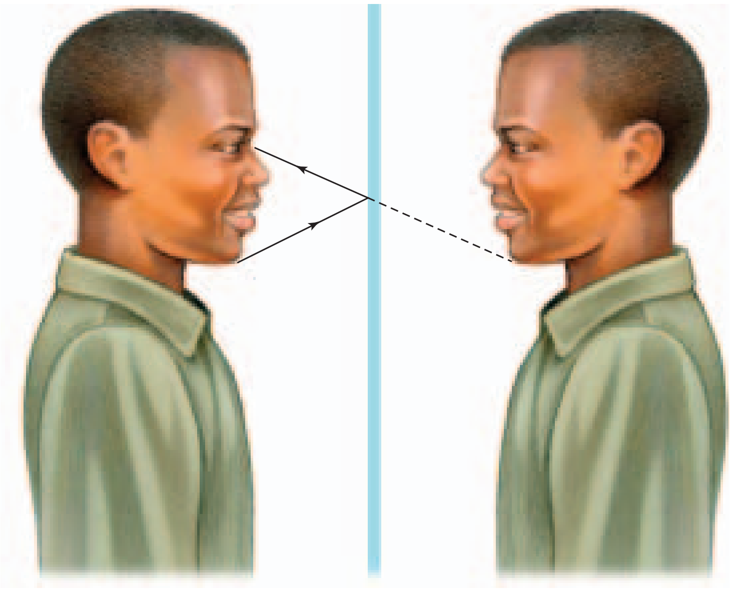


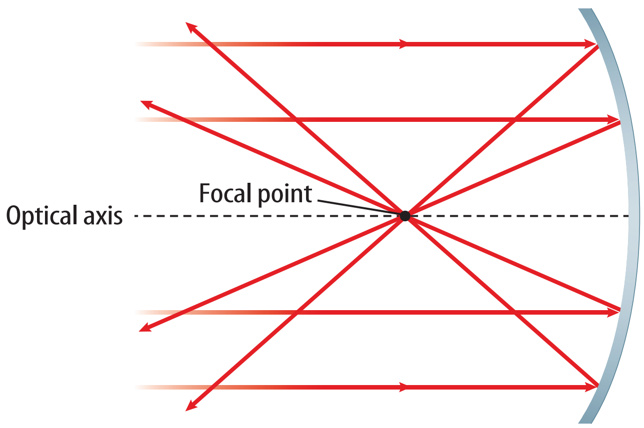
Figure 3 Your brain thinks that the light rays that reflect off of the mirror come from a point behind the mirror.
Infer *how the size of your image in a plane mirror depends on your distance from the mirror.*

Virtual Images You can understand how your brain interprets your reflection in a mirror by looking at **Figure 3.** The light waves that are reflected off of you travel in all directions. Light rays reflected from your chin strike the mirror at different places. Then, they reflect off of the mirror in different directions. Recall that your brain always interprets light rays as if they have traveled in a straight line. It doesn't realize that the light rays have been reflected and that they changed direction. If the reflected light rays were extended back behind the mirror, they would meet at a single point. Your brain interprets the rays that enter your eye as coming from this point behind the mirror. You seem to see the reflected image of your chin at this point. An image like this, which your brain perceives even though no light rays pass through it, is called a **virtual image.** The virtual image formed by a plane mirror is always upright and appears to be as far behind the mirror as the object is in front of it.

Concave Mirrors

Not all mirrors are flat like plane mirrors are. If the surface of a mirror is curved inward, it is called a **concave mirror.** Concave mirrors, like plane mirrors, reflect light waves to form images. The difference is that the curved surface of a concave mirror reflects light in a unique way.

Figure 4 A concave mirror has an optical axis and a focal point. When light rays travel toward the mirror parallel to the optical axis, they reflect through the focal point.



Features of Concave Mirrors A concave mirror has an optical axis. The **optical axis** is an imaginary straight line drawn perpendicular to the surface of the mirror at its center. Every light ray traveling parallel to the optical axis as it approaches the mirror is reflected through a point on the optical axis called the **focal point.** Using the focal point and the optical axis, you can diagram how some of the light rays that travel to a concave mirror are reflected, as shown in **Figure 4.** On the other hand, if a light ray passes through the focal point before it hits the mirror, it is reflected parallel to the optical axis. The distance from the center of the mirror to the focal point is called the **focal length.**

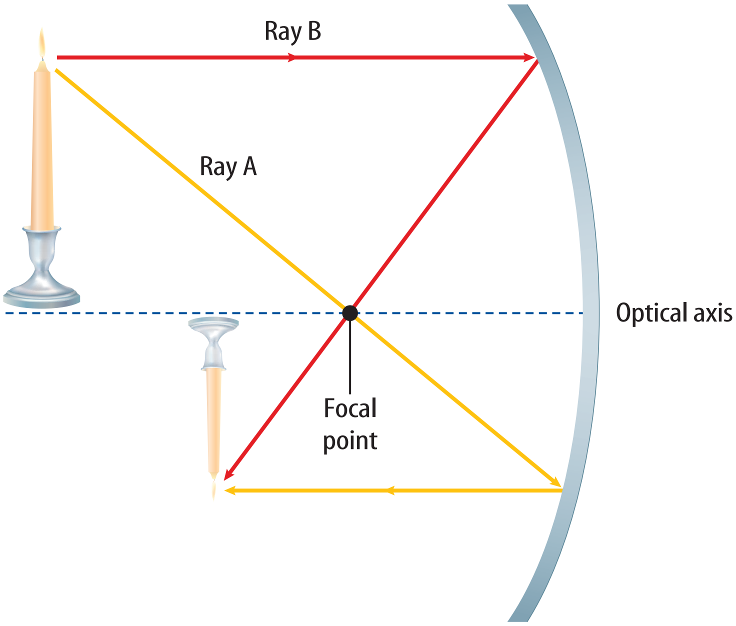


Figure 5 Rays A and B start from the same place on the candle, travel in different directions, and meet again on the reflected image.
Diagram *how other points on the image of the candle are formed.*

How a Concave Mirror Works The image that is formed by a concave mirror changes depending on where the object is located relative to the focal point of the mirror. You can diagram how an image is formed. For example, suppose that the distance between the object, such as the candle in **Figure 5,** and the mirror is a little greater than the focal length. Light rays bounce off of each point on the candle in all directions. One light ray, labeled Ray A, starts from a point on the flame of the candle and passes through the focal point on its way to the mirror. Ray A is then reflected so it travels parallel to the optical axis. Another ray, Ray B, starts from the same point on the candle's flame but travels parallel to the optical axis as it moves toward the mirror. When Ray B is reflected by the mirror, it passes through the focal point. The place where Ray A and Ray B meet after they are reflected forms a point on the flame of the reflected image.

More points on the reflected image can be located in this way. From each point on the candle, one ray can be drawn that passes through the focal point and is reflected parallel to the optical axis. Another ray can be drawn that travels parallel to the optical axis and passes through the focal point after it is reflected. The point where the two rays meet is on the reflected image.

Real Images The image that is formed by the concave mirror is not virtual. Rays of light pass through the location of the image. A **real image** is formed when light rays converge to form the image. You could hold a sheet of paper at the location of a real image and see the image projected on the paper. When an object is farther from a concave mirror than twice the focal length, the image that is formed is real, smaller, and upside down, or inverted.

Mini LAB

Observing Images in a Spoon

Procedure

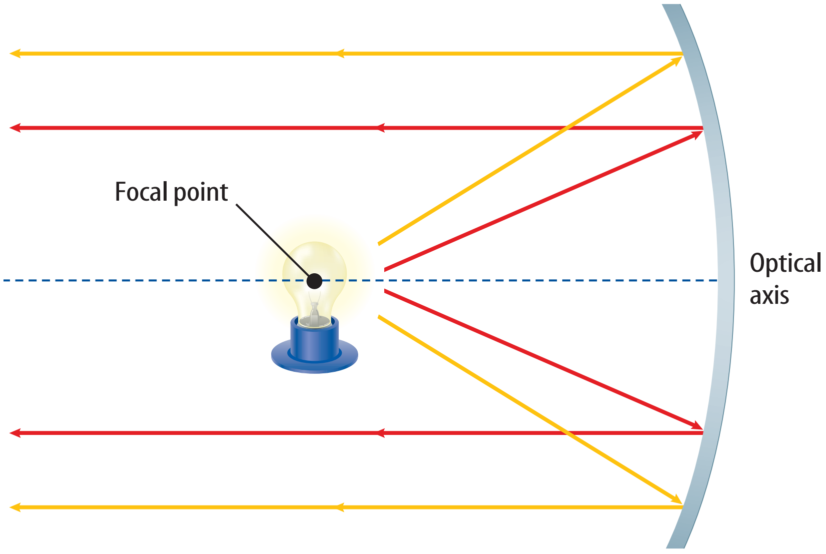
1. Look at the inside of a shiny **spoon**. Move it close to your face and then far away. The place where your image changes is the focal point.
2. Hold the inside of the spoon facing a bright **light,** a little farther away than the focal length of the spoon.
3. Place a piece of **poster board** between the light and the spoon without blocking all of the light.
4. Move the poster board between the spoon and the light until you see the reflected light on it.

Analysis

Which of the images you observed were real and which were virtual?

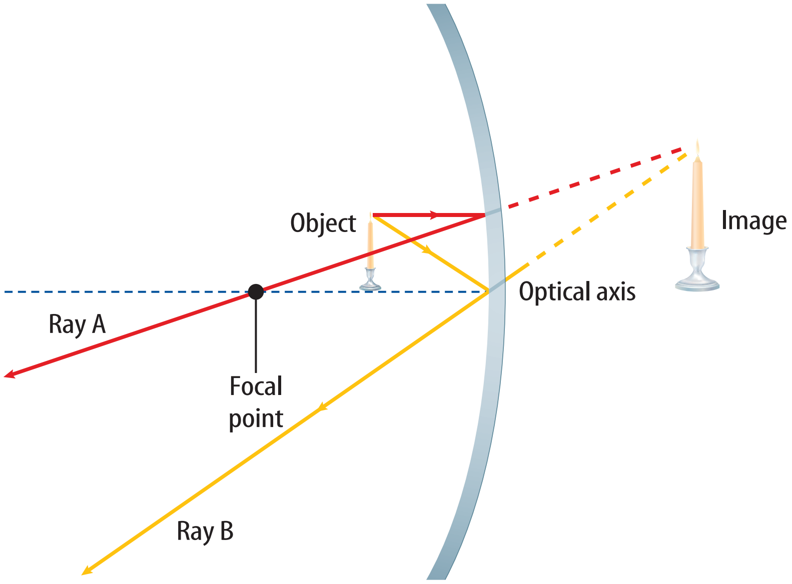
Try at Home

Figure 6 A flashlight uses a concave mirror to create a beam of light.
Explain *why the reflected rays of light in the diagram are parallel to each other.*



Creating Light Beams What happens if you place an object exactly at the focal point of the concave mirror? **Figure 6** shows that if the object is at the focal point, the mirror reflects all light rays parallel to the optical axis. No image forms because the rays never meet—not even if the rays are extended back behind the mirror. Therefore, a light placed at the focal point is reflected in a beam. Car headlights, flashlights, lighthouses, spotlights, and other devices use concave mirrors in this way to create concentrated light beams of nearly parallel rays.

Figure 7 If the candle is between the mirror and its focal point, the reflected image is enlarged and virtual.
Infer *why this image couldn't be projected on a screen.*



Mirrors That Magnify The image formed by a concave mirror changes again when you place an object between it and its focal point. The location of the reflected image again can be found by drawing two rays from each point. **Figure 7** shows that in this case, these rays never meet after they are reflected. Instead, the reflected rays diverge. Just as it does with a plane mirror, your brain interprets the diverging rays as if they came from one point behind the mirror. You can find this point by extending the rays behind the mirror until they meet. Because no light rays are behind the mirror where the image seems to be, the image formed is virtual. The image also is upright and enlarged.

Shaving mirrors and makeup mirrors are concave mirrors. They form an enlarged, upright image of a person's face so it's easier to see small details. The bowl of a shiny spoon also forms an enlarged, upright image of your face when it is placed close to your face.

Convex Mirrors

Why do you think the security mirrors in banks and stores are shaped the way they are? The next time you are in a store, look up to one of the back corners or at the end of an aisle to see if a large, rounded mirror is mounted there. You can see a large area of the store in the mirror. A mirror that curves outward like the back of a spoon is called a **convex mirror.** Light rays that hit a convex mirror diverge, or spread apart, after they are reflected. Look at **Figure 8** to see how the rays from an object are reflected to form an image. The reflected rays diverge and never meet, so the image formed by a convex mirror is a virtual image. The image also is always upright and smaller than the actual object is.

Reading Check ***Describe the image formed by a convex mirror.***

Uses of Convex Mirrors Because convex mirrors cause light rays to diverge, they allow large areas to be viewed. As a result, a convex mirror is said to have a wide field of view. In addition to increasing the field of view in places like grocery stores and factories, convex mirrors can widen the view of traffic that can be seen in rearview or side-view mirrors of automobiles. However, because the image created by a convex mirror is smaller than the actual object, your perception of distance can be distorted. Objects look farther away than they truly are in a convex mirror. Distances and sizes seen in a convex mirror are not realistic, so most convex side mirrors carry a printed warning that says "Objects in mirror are closer than they appear."

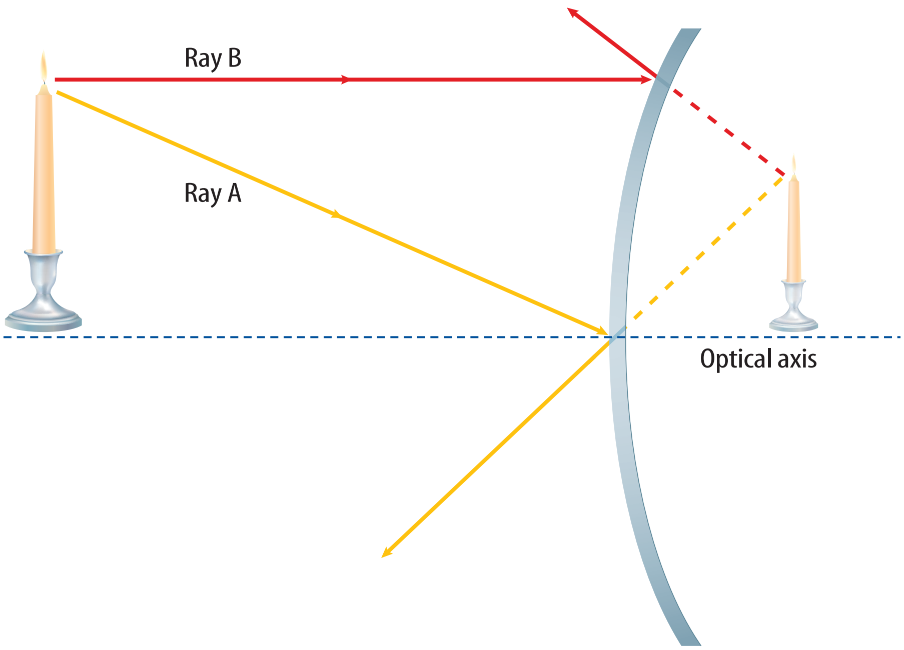


Figure 8 A convex mirror forms a reduced, upright, virtual image.

Paul A. Souders/CORBIS

Table 1 Images Formed by Mirrors

Mirror Shape	Position of Object	Virtual/Real	Image Created Upright/Upside Down	Size
Plane		virtual	upright	same as object
Concave	Object more than two focal lengths from mirror	real	upside down	smaller than object
	Object between one and two focal lengths	real	upside down	larger than object
	Object at focal point	none	none	none
	Object within focal length	virtual	upright	larger than object
Convex		virtual	upright	smaller than object

Mirror Images The different shapes of plane, concave, and convex mirrors cause them to reflect light in distinct ways. Each type of mirror has different uses. **Table 1** summarizes the images formed by plane, concave, and convex mirrors.

section 1 review

Summary

How do you use light to see?

- You see an object because your eyes detect the light reflected from that object.

Seeing with Plane Mirrors

- Plane mirrors are smooth and flat.
- A plane mirror forms upright, virtual images.
- No light rays pass through the location of a virtual image.

Concave Mirrors

- A concave mirror curves inward.
- The image formed by a concave mirror depends on the location of an object.

Convex Mirrors

- A convex mirror curves outward.
- Convex mirrors produce virtual, upright images that are smaller than the object.

Self Check

1. **Describe** how your image in a plane mirror changes as you move closer to the mirror.
2. **Diagram** how light rays from an object are reflected by a convex mirror to form an image.
3. **Describe** the image of an object that is 38 cm from a concave mirror that has a focal length of 10 cm.
4. **Infer** An object is less than one focal length from a concave mirror. How does the size of the image change as the object gets closer to the mirror?
5. **Think Critically** Determine whether or not a virtual image can be photographed.

Applying Math

6. **Calculate Angle of Reflection** A light ray from a flashlight strikes a plane mirror so that the angle between the mirror's surface and the light ray is 60°. What is the angle of reflection?

Science Online gpscience.com/self_check_quiz

LAB

Reflections of Reflections

How can you see the back of your head? You can use two mirrors to view a reflection of a reflection of the back of your head.

Real-World Question

How many reflections can you see with two mirrors?

Goals

- **Infer** how the number of reflections depends on the angle between mirrors.

Materials

plane mirrors (2)
masking tape
protractor
paper clip

Safety Precautions

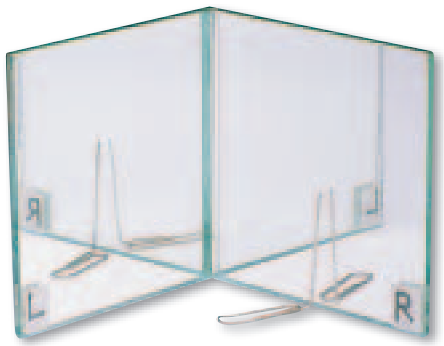
Handle glass mirrors and paper clips carefully.

Procedure

1. 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* and *R*.
2. Stand the mirrors up on a sheet of paper. Using the protractor, close the mirrors to an angle of 72°.

Images and Wedges Seen in the Mirrors

Angle of Mirrors	Number of Paper Clip Images		Number of Wedges
	R	L	
72°			
90°	Do not write in this book.		
120°			



3. Bend one leg of a paper clip up 90° and place it close to the front of the R mirror.
4. Count the number of images of the clip you see in the *R* and *L* mirrors. Record these numbers in the data table.
5. The mirror arrangement creates an image of a circle divided into wedges by the mirrors. Record the number of wedges.
6. Hold the *R* mirror still and slowly open the *L* mirror to 90°. Count and record the images of the clip and the wedges in the circle. Repeat, this time opening the mirrors to 120°.

Conclude and Apply

1. **Infer** the relationship between the number of wedges and paper clip images you can see.
2. **Determine** the angle that would divide a circle into six wedges. Hypothesize how many images would be produced.

Communicating Your Data

Demonstrate for younger students the relationship between the angle of the mirrors and the number of reflections.

Matt Meadows

SPS9d. Investigate the phenomena of reflection, refraction, interference, and diffraction. **Also covers: SCSh9c**

Lenses

Reading Guide

What You'll Learn

- **Describe** the shapes of convex and concave lenses.
- **Explain** how convex and concave lenses form images.
- **Explain** how lenses are used to correct vision problems.

Why It's Important

Even if you don't wear eyeglasses or contacts, you still use lenses to see.

Review Vocabulary

transparent: a material that transmits almost all the light that strikes it

New Vocabulary

- convex lens
- concave lens
- cornea
- retina

What is a lens?

What do your eyes have in common with cameras, eyeglasses, and microscopes? Each of these things contains at least one lens. A lens is a transparent material with at least one curved surface that causes light rays to bend, or refract, as they pass through. The image that a lens forms depends on the shape of the lens. Like curved mirrors, a lens can be convex or concave.

Convex Lenses

A **convex lens** is thicker in the middle than at the edges. Its optical axis is an imaginary straight line that is perpendicular to the surface of the lens at its thickest point. When light rays approach a convex lens traveling parallel to its optical axis, the rays are refracted toward the center of the lens, as in **Figure 9.** All light rays traveling parallel to the optical axis are refracted so they pass through a single point, which is the focal point of the lens. The focal length of the lens depends on the shape of the lens. If the sides of a convex lens are less curved, light rays are bent less. As a result, lenses with flatter sides have longer focal lengths. **Figure 9** also shows that light rays traveling along the optical axis are not bent at all.

Figure 9 Convex lenses are thicker in the middle than at the edges. A convex lens focuses light rays at a focal point. A light ray that passes straight through the center of the lens is not refracted.

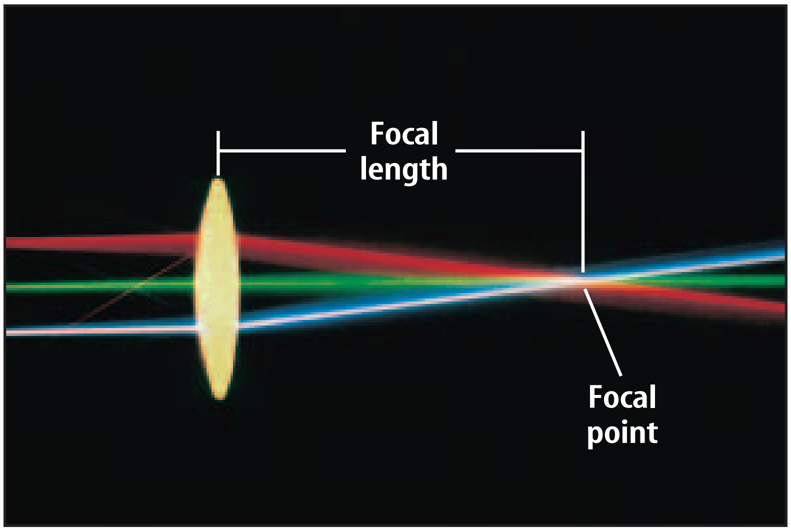
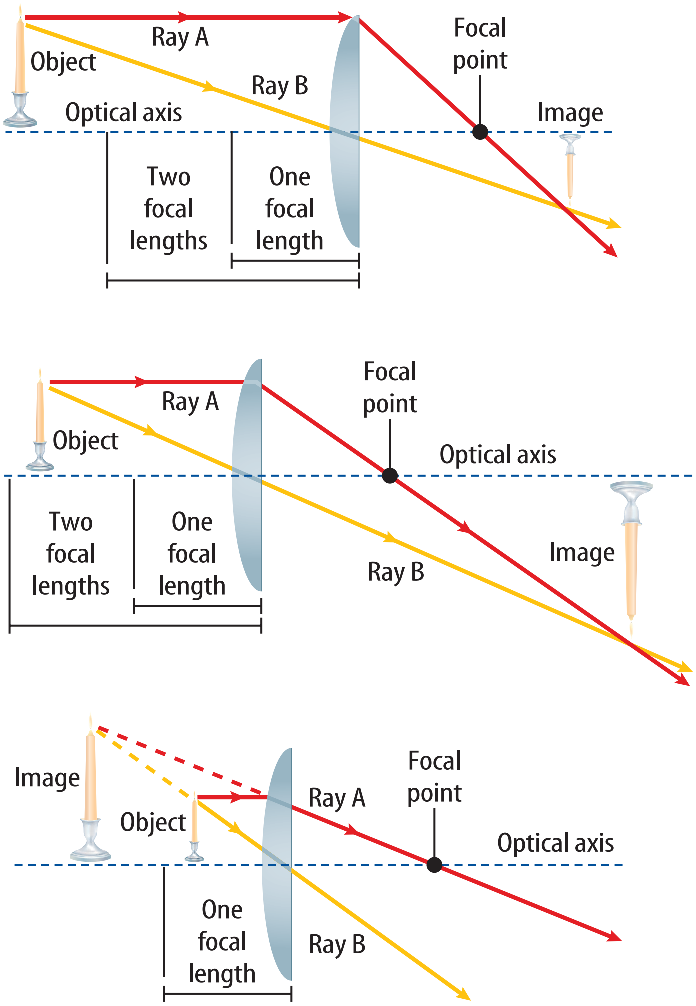


Figure 10 The image formed by a convex lens depends on the positions of the lens and the object.



A When the candle is more than two focal lengths away from the lens, its image is real, reduced, and upside down.

B When the candle is between one and two focal lengths from the lens, its image is real, enlarged, and upside down.

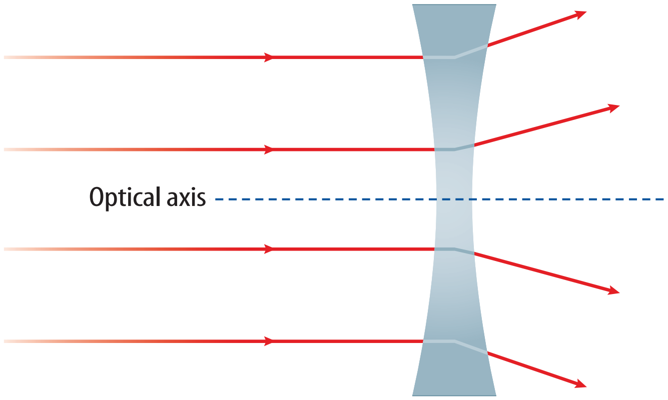
C When the candle is less than one focal length from the lens, its image is virtual, enlarged, and upright.

Forming Images with a Convex Lens The type of image a convex lens forms depends on where the object is relative to the focal point of the lens. If an object is more than two focal lengths from the lens, as in **Figure 10A,** the image is real, reduced, and inverted, and on the opposite side of the lens from the object.

As the object moves closer to the lens, the image gets larger. **Figure 10B** shows the image formed when the object is between one and two focal lengths from the lens. Now the image is larger than the object, but is still inverted.

When an object is less than one focal length from the lens, as in **Figure 10C,** the image becomes an enlarged, virtual image. The image is virtual because light rays from the object diverge after they pass through the lens. When you use a magnifying glass, you move a convex lens so that it is less than one focal length from an object. This causes the image of the object to be magnified.

Figure 11 A concave lens refracts light rays so they spread out.
Classify *Is a concave lens most like a concave mirror or a convex mirror?*



Concave Lenses

A **concave lens** is thinner in the middle and thicker at the edges. As shown in **Figure 11,** light rays that pass through a concave lens bend outward away from the optical axis. The rays spread out and never meet at a focal point, so they never form a real image. The image is always virtual, upright, and smaller than the actual object is. Concave lenses are used in some types of eyeglasses and some telescopes. Concave lenses usually are used in combination with other lenses. A summary of the images formed by concave and convex lenses is shown in **Table 2** on the next page.

Applying Science

Comparing Object and Image Distances

The size and orientation of an image formed by a convex lens depends on the location of the object. What happens to the location of the image formed by a convex lens as the object moves closer to or farther from the lens? The distance from the lens to the object is the object distance, and the distance from the lens to the image is the image distance. How are the focal length, object distance, and image distance related to each other?

Identifying the Problem

A 5-cm-tall object is placed at different lengths from a double convex lens with a focal length of 15 cm. The table above lists the different object and image distances. How are these two measurements related?

Object and Image Distances

Focal Length	Object Distance	Image Distance
15.0 cm	45.0 cm	22.5 cm
15.0 cm	30.0 cm	30.0 cm
15.0 cm	20.0 cm	60.0 cm

Solving the Problem

1. What is the relationship between the object distance and the image distance?
2. The lens equation describes the relationship between the focal length and the image and object distances.
1/focal length = 1/object distance + 1/image distance
Using this equation, calculate the image distance of an object placed at a distance of 60.0 cm from the lens.

Table 2 Images Formed by Lenses

Lens Shape	Location of Object	Type of Image		
		Virtual/Real	Upright/Inverted	Size
Convex	Object beyond 2 focal lengths from lens	real	inverted	smaller than object
	Object between 1 and 2 focal lengths	real	inverted	larger than object
	Object within 1 focal length	virtual	upright	larger than object
Concave	Object at any position	virtual	upright	smaller than object

Lenses and Eyesight

INTEGRATE Life Science

What determines how well you can see the words on this page? If you don't need eyeglasses, the structure of your eye gives you the ability to focus on these words and other objects around you. Look at **Figure 12.** Light enters your eye through a transparent covering on your eyeball called the **cornea** (KOR nee uh). The cornea causes light rays to bend so that they converge. The light then passes through an opening called the pupil. Behind the pupil is a flexible convex lens. The lens helps focus light rays so that a sharp image is formed on your retina. The **retina** is the inner lining of your eye. It has cells that convert the light image into electrical signals, which are then carried along the optic nerve to your brain to be interpreted.

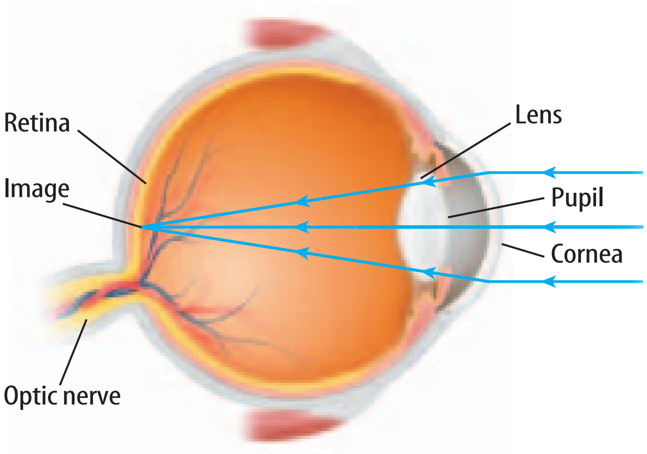


Figure 12 The cornea and lens in your eye focus light rays so that a sharp image is formed on the retina.

Focusing on Near and Far How can your eyes focus both on close objects, like the watch on your wrist, and distant objects, like a clock across the room? For you to see an object clearly, its image must be focused sharply on your retina. However, the retina is always a fixed distance from the lens. Remember that the location of an image formed by a convex lens depends on the focal length of the lens and the location of the object. For example, look back at **Figure 10.** As an object moves farther from a convex lens, the position of the image moves closer to the lens.

For an image to be formed on the retina, the focal length of the lens needs to be able to change as the distance of the object changes. The lens in your eye is flexible, and muscles attached to it change its shape and its focal length. This is why you can see objects that are near and far away.

Look at **Figure 13.** As an object gets farther from your eye, the focal length of the lens has to increase. The muscles around the lens stretch it so it has a less convex shape. But when you focus on a nearby object, these muscles make the lens more curved, causing the focal length to decrease.

Reading Check *How does the shape of the lens in your eye change when you focus on a nearby object?*

Science Online

Topic: Retina

Visit gpscience.com for Web links to information about diseases that affect the retina.

Activity Make a drawing of what an eye doctor sees when looking in your eyes.

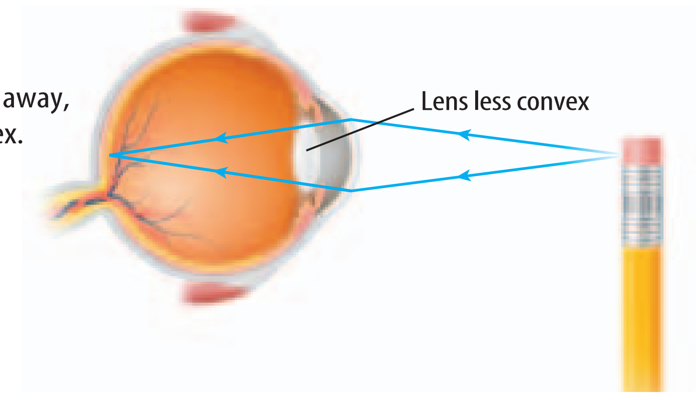
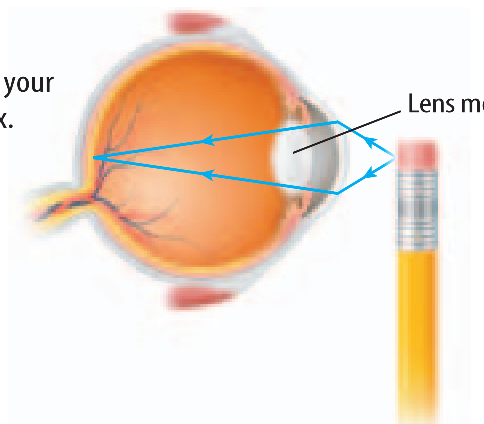
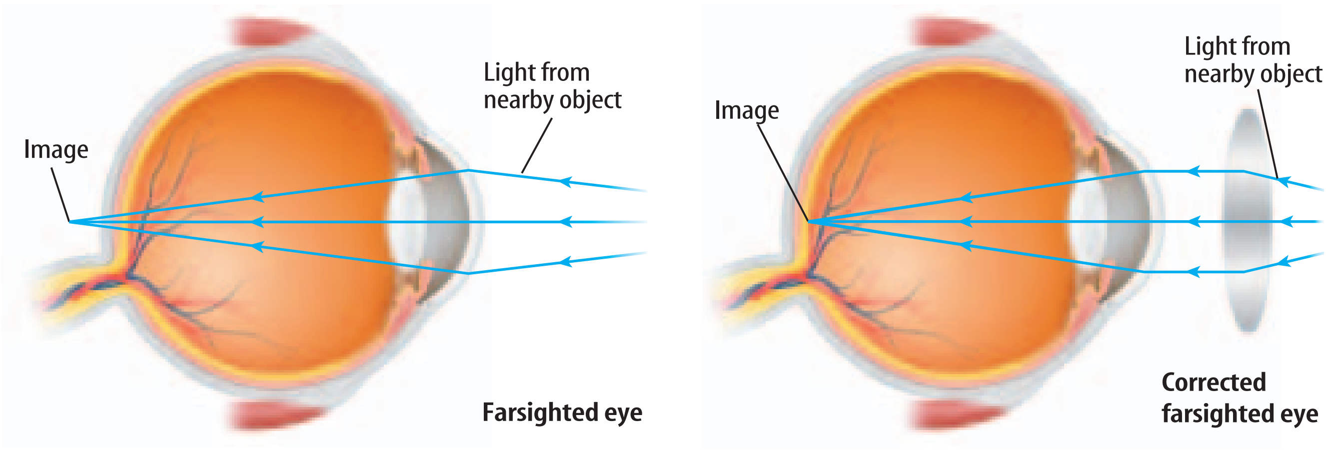


Figure 13 The lens in your eye changes shape so you can focus on objects at different distances.





In a farsighted eye, light rays from nearby objects do not converge enough to form a sharp image on the retina.

A convex lens makes light rays spread out less so that a sharp image can be formed on the retina.

Figure 14 Farsightedness can be corrected by a convex lens.

Vision Problems

People that have good vision can see objects clearly that are about 25 cm or farther away from their eyes. However, people with the most common vision problems see objects clearly only at some distances, or see all objects as being blurry.

Farsightedness A person who is farsighted can see distant objects clearly, but can't bring nearby objects into focus. Light rays from nearby objects do not converge enough after passing through the cornea and the lens to form a sharp image on the retina, as shown in **Figure 14.** The problem can be corrected by using a convex lens that bends light rays so they are less spread out before they enter the eye, as in **Figure 14.**

As many people age, their eyes develop a condition that makes them unable to focus on close objects. The lenses in their eyes become less flexible. The muscles around the lenses still contract as they try to change the shape of the lens. However, the lenses have become more rigid, and cannot be made curved enough to form an image on the retina. People who are more than 40 years old might not be able to focus on objects closer than 1 m from their eyes. Some vision problems are caused by diseases of the retina. **Figure 15** shows how using new technology allows people with diseased retinas to recover some vision.

Astigmatism Another vision problem, called astigmatism occurs when the surface of the cornea is curved unevenly. When people have astigmatism, their corneas are more oval than round in shape. Astigmatism causes blurry vision at all distances. Corrective lenses also have an uneven curvature, canceling out the effect of an uneven cornea.

INTEGRATE History

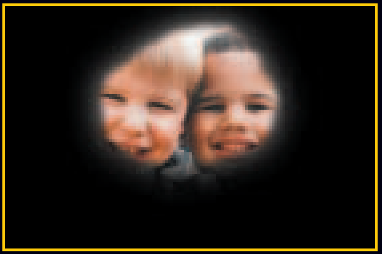
Eyeglasses and the Printing Press
Eyeglasses were first developed in Italy in the thirteenth century and were used mainly by nobles and the clergy. However, in 1456 the printing press was invented in Germany by Johannes Gutenberg. As books became more available, the demand for eyeglasses increased. In turn, the increasing availability of eyeglasses enabled more people to read. This helped increase the demand for books. Research the development of eyeglasses.

NATIONAL GEOGRAPHIC VISUALIZING THE SILICON RETINA

Figure 15

Millions of people worldwide suffer from vision problems associated with diseases of the retina. Until recently, such people had little hope of improving their eyesight. Now, however, scientists are developing specialized silicon chips that convert light into electrical pulses, mimicking the function of the retina. When implanted in the eye, these artificial silicon retinas may restore sight.

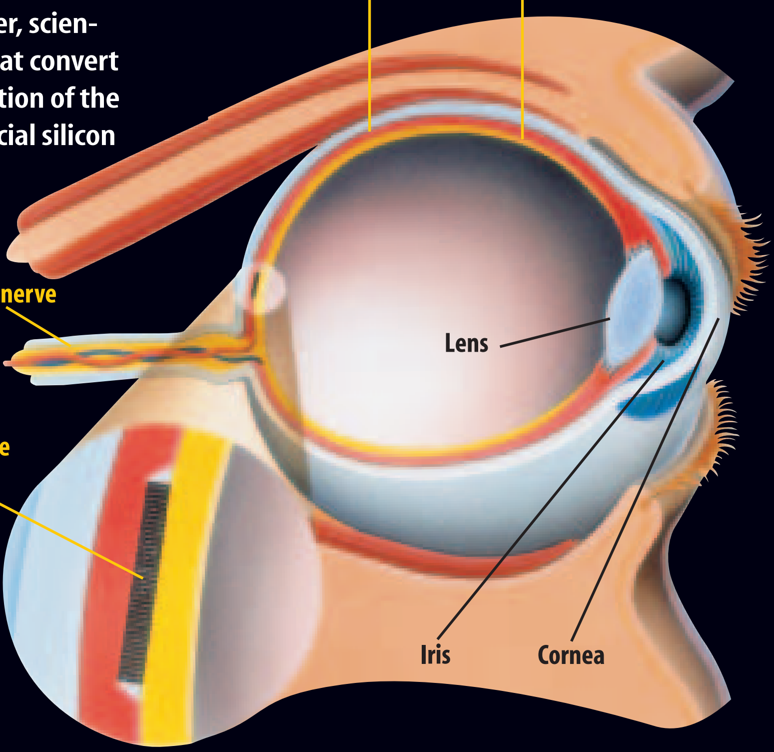
Viewed with normal vision



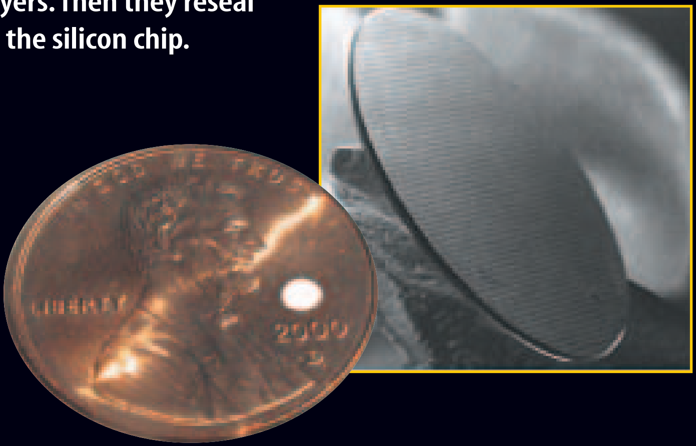
Viewed with retinitis pigmentosa

Viewed with macular degeneration

▲ These three photos show how normal vision can deteriorate as a result of diseases that attack the retina. Retinitis pigmentosa (ret uh NYE tis pig men TOE suh) causes a lack of peripheral vision. Macular degeneration can lead to total blindness.

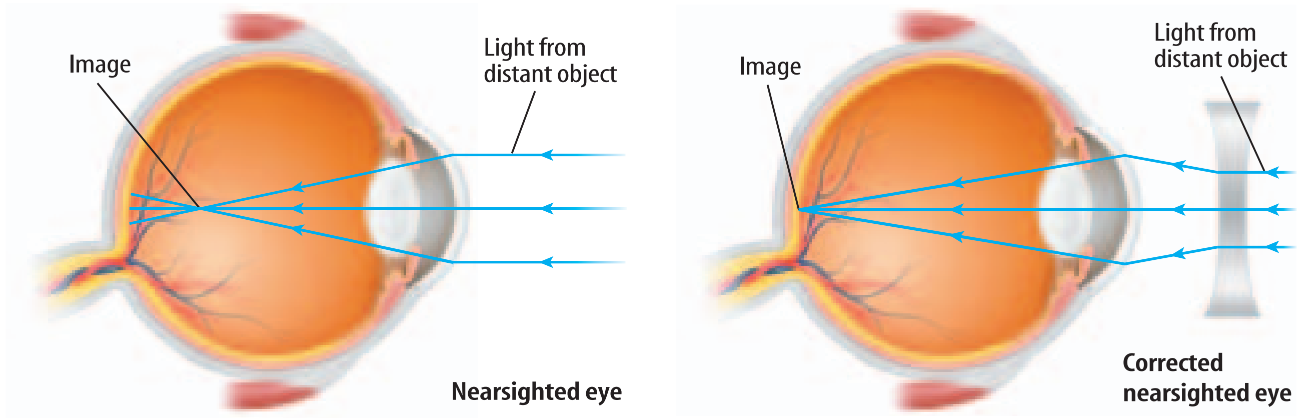


▲ After making a number of incisions, surgeons implant the artificial silicon retina between the outer and inner retinal layers. Then they reseal the retina over the silicon chip.



▲ The artificial silicon retina, above right, is thinner than a human hair and only 2 mm in diameter—the same diameter as the white dot on this penny.

(tl, cl, bl)National Eye Institute, National Institutes of Health, (bc, br)courtesy Optobionics Corp.



In a nearsighted eye, light rays from distant objects converge too much and form a sharp image in front of the retina.

A concave lens makes the light rays more spread out, enabling a sharp image to be formed on the retina.

Figure 16 Nearsightedness can be corrected with a concave lens.

Nearsightedness A person who is nearsighted can see objects clearly only when they are nearby. Objects that are far away appear blurred. In a nearsighted eye, the cornea and the lens form a sharp image of a distant object in front of the retina, as shown in **Figure 16.** To correct this problem, a nearsighted person can wear concave lenses. **Figure 16** shows how a concave lens causes incoming light rays to diverge before they enter the eye. Then the light rays from distant objects can be focused by the eye to form a sharp image on the retina.

section 2 review

Summary

Convex Lenses

- A convex lens is thicker in the middle than at the edges. Light rays are refracted toward the optical axis.
- The image formed by a convex lens depends on the distance of the object from the lens.

Concave Lenses

- A concave lens is thinner in the middle and thicker at the edges. Light rays are refracted away from the optical axis.

The Eye and Vision Problems

- The eye contains a lens that changes shape to produce sharp images on the retina of objects that are at different distances.
- In a farsighted eye, the eye cannot form a sharp image of nearby objects on the retina. In a nearsighted eye, the eye cannot form a sharp image of distant objects on the retina.

Self Check

1. **Explain** how the focal length of a convex lens changes as the sides of the lens become less curved.
2. **Compare** the image of an object less than one focal length from a convex lens with the image of an object more than two focal lengths from the lens.
3. **Describe** the image formed by a concave lens.
4. **Explain** how the focal length of the lens in the eye changes to focus on a nearby object.
5. **Think Critically** If image formation by a convex lens is similar to image formation by a concave mirror, describe the image formed by a light source placed at the focal point of a convex lens.

Applying Math

6. **Calculate Object Distance** If you looked through a convex lens with a focal length of 15 cm and saw a real, inverted, enlarged image, what is the maximum distance between the lens and the object?

Science Online gpscience.com/self_check_quiz

SCSh9c. Students will enhance reading in all curriculum areas by building vocabulary knowledge....
Also covers: 1a–c, 3c, 3e–f, 4a

section 3

Optical Instruments

Reading Guide

What You'll Learn

- **Compare** refracting and reflecting telescopes.
- **Explain** why a telescope in space is useful.
- **Describe** how a microscope uses lenses to magnify small objects.
- **Explain** how a camera creates an image.

Why It's Important

Optical instruments, such as microscopes and telescopes, enable your eyes to see objects that otherwise would be too small or far away to see.

Review Vocabulary

refraction: the change in direction of a wave when it changes speed as it moves from one medium to another

New Vocabulary

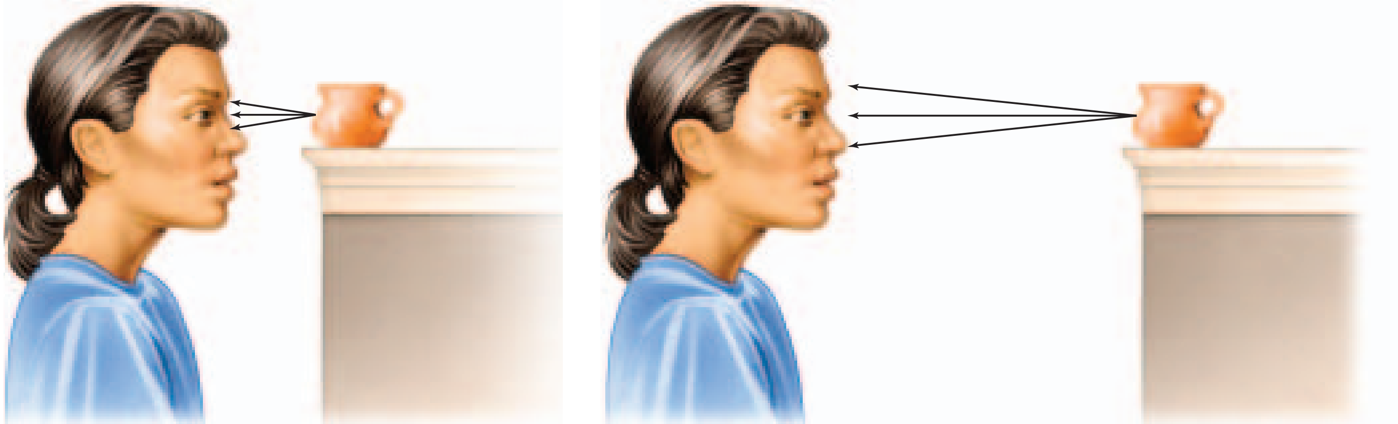
- refracting telescope
- reflecting telescope
- microscope

Telescopes

You know from your experience that it's hard to see faraway objects clearly. When you look at an object, only some of the light reflected from its surface enters your eye. As the object moves farther away, the amount of light entering your eye decreases, as shown in **Figure 17.** As a result, the object appears dimmer and less detailed.

A telescope uses a lens or a concave mirror that is much larger than your eye to gather more of the light from distant objects. The largest telescopes can gather more than a million times more light than the human eye. As a result, objects such as distant galaxies appear much brighter. Because the image formed by a telescope is so much brighter, more detail can be seen when the image is magnified.

Figure 17 As the cup gets farther away, fewer light rays from any point on the cup enter the viewer's eye. The amount of light from an object that enters the eye decreases as the object gets farther away.



Refracting Telescopes One common type of telescope is the refracting telescope. A simple **refracting telescope**, shown in **Figure 18,** uses two convex lenses to gather and focus light from distant objects. Incoming light from distant objects passes through the first lens, called the objective lens. Because they are so far away, light rays from distant objects are nearly parallel to the optical axis of the lens. As a result, the objective lens forms a real image at the focal point of the lens, within the body of the telescope. The second convex lens, called the eyepiece lens, acts like a magnifying glass and magnifies this real image. When you look through the eyepiece lens, you see an enlarged, inverted, virtual image of the real image formed by the objective lens.

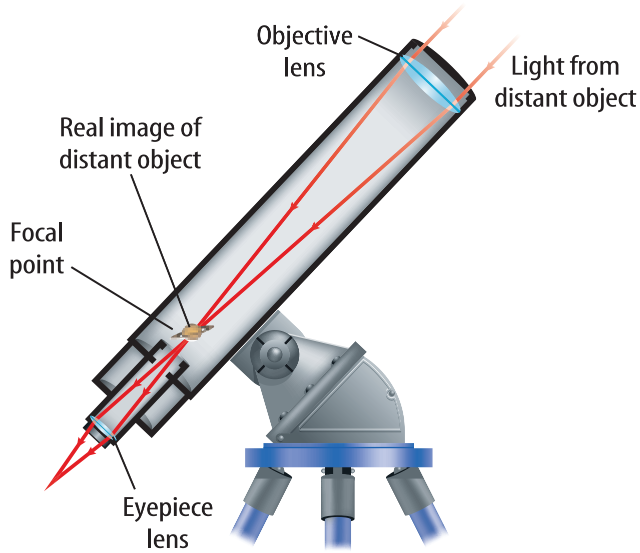


Figure 18 Light from a distant object passes through an objective lens and an eyepiece lens in a refracting telescope. The two lenses produce a large virtual image.

Reading Check ***What type of image is formed by the objective lens in a refracting telescope?***

Several problems are associated with refracting telescopes. In order to form a detailed image of distant objects, such as planets and galaxies, the objective lens must be as large as possible. A large lens is heavy and can be supported in the telescope tube only around its edge. The lens can sag or flex due to its own weight, distorting the image it forms. Also, these heavy glass lenses are costly and difficult to make.

Reflecting Telescopes Due to the problems with making large lenses, most large telescopes today are reflecting telescopes. A **reflecting telescope** uses a concave mirror, a plane mirror, and a convex lens to collect and focus light from distant objects. **Figure 19** shows a reflecting telescope. Light from a distant object enters one end of the telescope and strikes a concave mirror at the opposite end. The light reflects off of this mirror and converges. Before it converges at a focal point, the light hits a plane mirror that is placed at an angle within the telescope tube. The light is reflected from the plane mirror toward the telescope's eyepiece. The light rays converge at the focal point, creating a real image of the distant object. Just as in a refracting telescope, a convex lens in the eyepiece then magnifies this image.

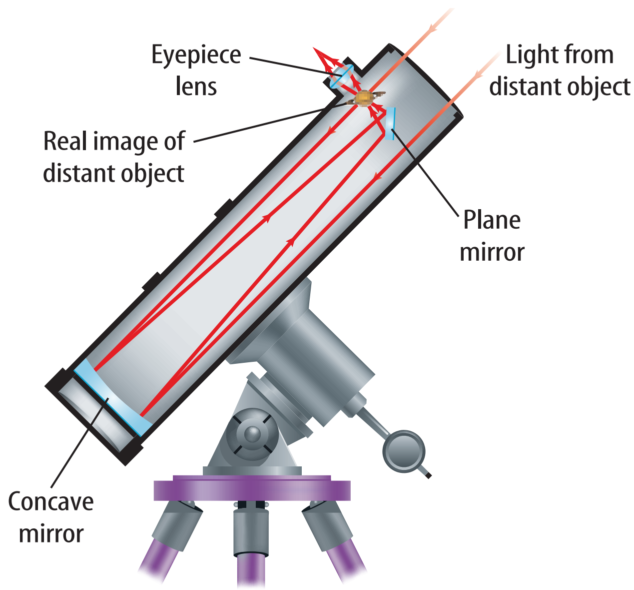


Figure 19 Reflecting telescopes use two mirrors to create a real image, which then is magnified by a convex lens.
Infer *whether the image produced by the eyepiece lens is real or virtual.*

Figure 20 The view from telescopes on Earth is different from the view from telescopes in space.

The distorting effects of Earth's atmosphere can cause telescopes on Earth to form blurry images.

The *Hubble Space Telescope* is above Earth's atmosphere and forms clearer images of objects in space.

Telescopes In Space Imagine being at the bottom of a swimming pool and trying to read a sign by the pool's edge. The water in the pool would distort your view of any object beyond the water's surface. In a similar way, Earth's atmosphere blurs the view of objects in space. To overcome the blurriness of humans' view into space, the National Aeronautics and Space Administration (NASA) built a telescope called the *Hubble Space Telescope* to be placed into space high above Earth's atmosphere. On April 25, 1990, NASA used the space shuttle Discovery to launch this telescope into an orbit about 600 km above Earth. The *Hubble Space Telescope* has produced images much sharper and more detailed than the largest telescopes on Earth can. **Figure 20** shows the difference in the images produced by telescopes on Earth and the *Hubble* telescope. With the *Hubble Space Telescope,* scientists can detect visible light—as well as other types of radiation—that is affected by Earth's atmosphere from the planets, stars, and distant galaxies.

Science Online

Topic: *Hubble Space Telescope*

Visit gpscience.com for Web links to information and data about the *Hubble Space Telescope.*

Activity Prepare a speech to defend your opinion on whether or not the *Hubble Space Telescope* is useful and important. Hold a class debate.

Reading Check ***Why is the* Hubble Space Telescope *able to produce clearer images than telescopes on Earth?***

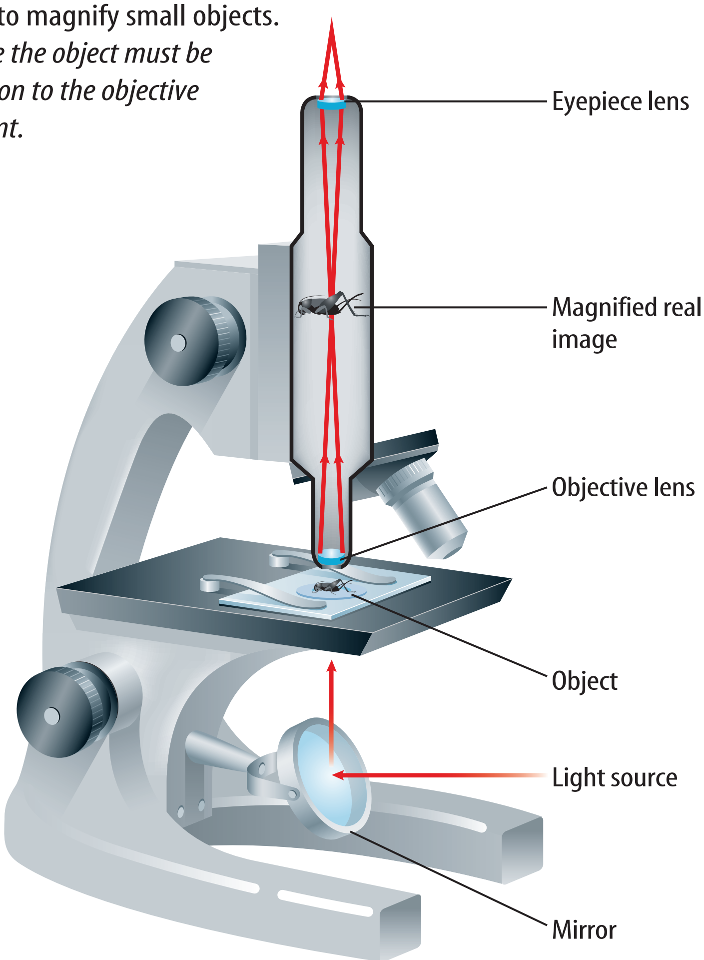
The *Hubble* telescope is a type of reflecting telescope that uses two mirrors to collect and focus light to form an image. The primary mirror in the telescope is 2.4 m across. When the *Hubble* was first launched, a defect in this primary mirror caused the telescope to create blurry images. The telescope was repaired by astronauts in December 1993.

Microscopes

A telescope would be useless if you were trying to study the cells in a butterfly wing, a sample of pond scum, or the differences between a human hair and a horse hair. You would need a microscope to look at such small objects. A **microscope** uses two convex lenses with relatively short focal lengths to magnify small, close objects. A microscope, like a telescope, has an objective lens and an eyepiece lens. However, it is designed differently because the objects viewed are close to the lens.

Figure 21 shows a simple microscope. The object to be viewed is placed on a transparent slide and illuminated from below. The light passes by or through the object on the slide and then travels through the objective lens. The objective lens is a convex lens. It forms a real, enlarged image of the object, because the distance from the object to the lens is between one and two focal lengths. The real image is then magnified again by the eyepiece lens (another convex lens) to create a virtual, enlarged image. This final image can be hundreds of times larger than the actual object, depending on the focal lengths of the two lenses.

Figure 21 A microscope uses two convex lenses to magnify small objects. **Explain** *where the object must be placed in relation to the objective lens's focal point.*



Mini LAB

Experimenting with Focal Lengths

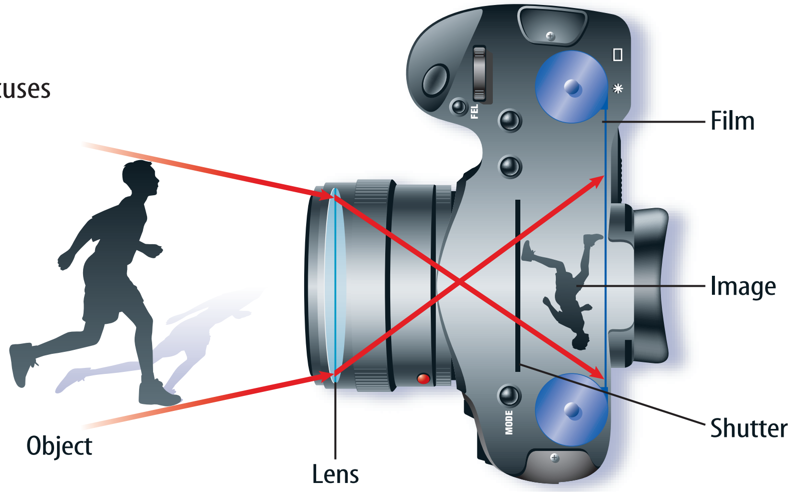
Procedure

1. Fill a glass **test tube** with **water** and seal it with a **lid or stopper.**
2. Type or print the compound name *SULFUR DIOXIDE* in capital letters on a piece of **paper or a note card.**
3. Set the test tube horizontally over the words and observe them. What do you notice?
4. Hold the tube 1 cm over the words and observe them again. Record your observations. Repeat, holding the tube at several other heights above the words.

Analysis

1. What were your observations of the words at the different distances? How do you explain your observations?
2. Is the image you see at each height real or virtual?

Figure 22 A camera's lens focuses an image on photographic film.

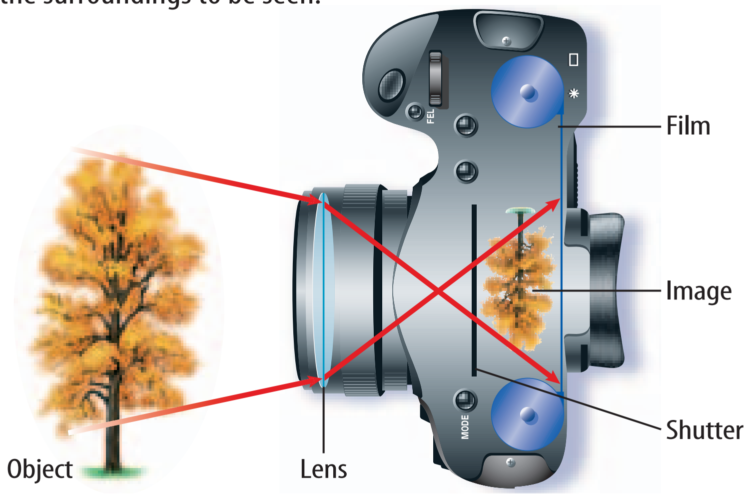


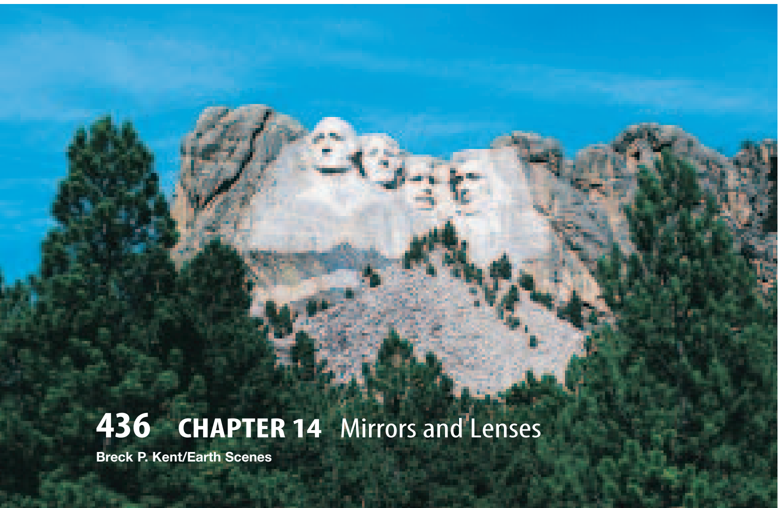
Cameras

Imagine swirls of lavender, gold, and magenta clouds sweeping across the sky at sunset. With the click of a button, you can capture the beautiful scene in a photo. How does a camera make a reduced image of a life-sized scene on film? A camera works by gathering and bending light with a lens. This lens then projects an image onto light-sensitive film to record a scene.

When you take a picture with a camera, a shutter opens to allow light to enter the camera for a specific length of time. The light reflected off your subject enters the camera through an opening called the aperture. It passes through the camera lens, which focuses the image on the film, as in **Figure 22.** The image is real, inverted, and smaller than the actual object. The size of the image depends upon the focal length of the lens and how close the lens is to the film.

Figure 23 Each object in the image produced by a wide-angle lens is small. This allows more of the surroundings to be seen.

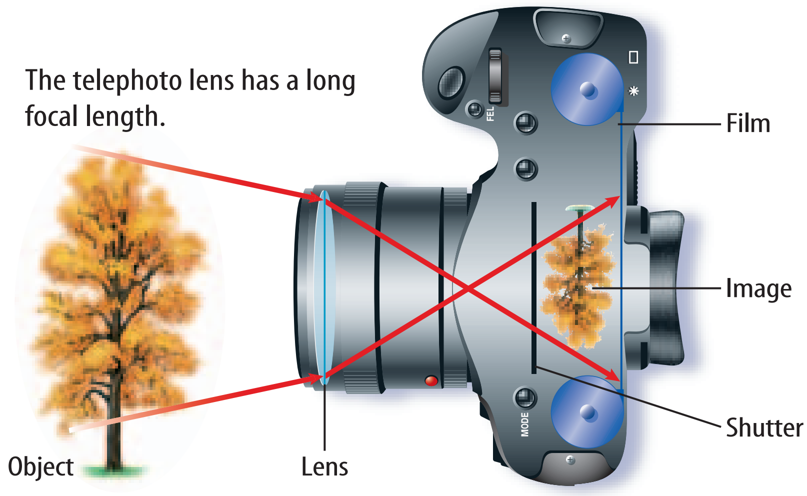




Wide-Angle Lenses Suppose you and a friend use two different cameras to photograph the same object at the same distance. If the cameras have different lenses, your pictures might look different. For example, some lenses have short focal lengths that produce a relatively small image of the object but have a wide field of view. These lenses are called wide-angle lenses, and they must be placed close to the film to form a sharp image with their short focal length. **Figure 23** shows how a wide-angle lens works. The photo in **Figure 23** was taken with a wide-angle lens.

Breck P. Kent/Earth Scenes

Figure 24 A telephoto lens creates a larger image of an object than a wide-angle lens does.



Less of the surroundings can be seen, though a close-up of one of the objects can be photographed.

Telephoto Lenses Telephoto lenses have longer focal lengths. **Figure 24** shows how a telephoto lens forms an image. The image through a telephoto lens seems enlarged and closer than it actually is. Telephoto lenses are easy to recognize because they usually protrude from the camera to increase the distance between the lens and the film.

section 3 review

Summary

Telescopes

- Refracting telescopes use two convex lenses to gather and focus light.
- Reflecting telescopes use a concave mirror, a plane mirror, and a convex lens to collect, reflect, and focus light.
- Placing a telescope in orbit avoids the distorting effects of Earth's atmosphere.

Microscopes

- A microscope uses two convex lenses with short focal lengths to magnify small, close objects.

Cameras

- A wide-angle lens has a short focal length that produces a wide field of view.
- Telephoto lenses have longer focal lengths and are located farther from the film than wide-angle lenses are.

Self Check

1. **Describe** the image formed by the objective lens in a microscope.
2. **Infer** how the amount of light that enters the eye from an object changes as the object moves closer.
3. **Identify** the advantage to making the objective lens larger in a refracting telescope.
4. **Explain** why the largest telescopes are reflecting telescopes instead of refracting telescopes.
5. **Think Critically** Which optical instrument—a telescope, a microscope, or a camera—forms images in a way most like your eye? Explain.

Applying Math

6. **Calculate Magnification** Suppose the objective lens in a microscope forms an image that is 100 times the size of an object. The eyepiece lens magnifies this image ten times. What is the total magnification?

LAB Model & Invent

Make a Refracting Telescope

Goals

- **Build** a simple telescope.
- **Estimate** the magnification of the telescope.
- **Compare** convex and concave eyepieces.

Possible Materials

objective lens—convex, 25 cm to 30 cm focal length, about 4 cm diameter

eyepiece lenses—one each convex and concave, 2 cm to 3 cm focal length, about 2.5 cm to 3 cm diameter

cardboard tubes—one with inside diameter of about 4 cm; one with inside diameter of about 3 cm. (The smaller tube should slide inside the larger one with a snug fit.)

clay to hold the lenses in place

**cellophane tape or duct tape*

scissors

**Alternate materials*

Safety Precautions

WARNING: *Do not look directly at the Sun through a telescope. Permanent eye damage can result.*

Real-World Question

Galileo used the telescope to enhance his eyesight. It enabled him to see planets and stars beyond the range of his eyes alone. By combining two lenses, distant objects can be magnified. A simple refracting telescope uses a small convex eyepiece lens and a larger convex objective lens at the other end. How do the lenses in a simple telescope form an image?

Procedure

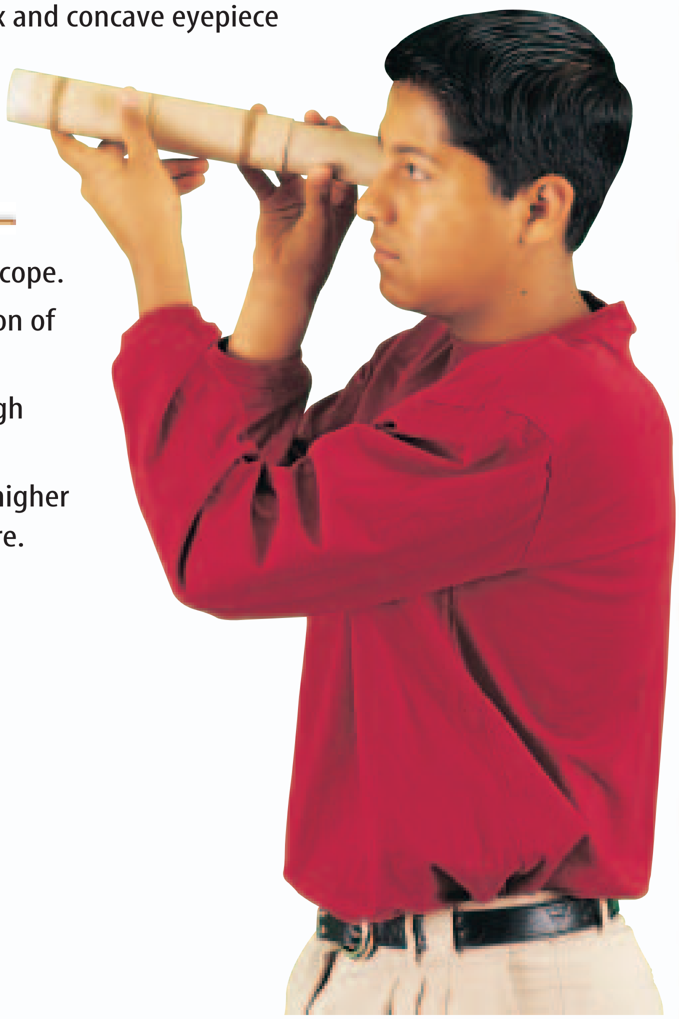
1. Check that the smaller-diameter tube can slide in and out of the larger-diameter tube.
2. Hold the small concave eyepiece lens near your eye. Hold the objective lens in front of the eyepiece lens and move the objective lens away from you until a distant object is in focus. Estimate the distance between the two lenses.
3. Subtract half the length of the larger-diameter tube from the distance you estimated in step 2 to get the length needed for the smaller tube.
4. Cut the smaller-diameter tube to the length determined in step 3. Make two pieces this length.

Dominic Oldershaw

5. Attach the objective lens with clay or tape to the end of the larger tube. Make sure that the lens is perpendicular to the sides of the tube.
6. Attach the convex eyepiece lens with clay or tape to the end of one of the smaller tubes. Make sure the lens is perpendicular to the sides of the tube.
7. Slide the smaller tube into the larger one and look through the eyepiece.
8. Move the smaller tube in and out of the larger tube until a distant object is focused clearly.

Analyze Your Data

1. Estimate how much larger the image seen through the eyepiece is than the image you see with your unaided eye. Describe the appearance of the image.
2. Attach the concave eyepiece to the second smaller tube that you cut.
3. Repeat your observations using the concave eyepiece. Describe the appearance of an object seen through the concave eyepiece.
4. How does the image produced using the convex and concave eyepiece lenses change when you look through the objective lens instead of the eyepiece lens?



Conclude and Apply

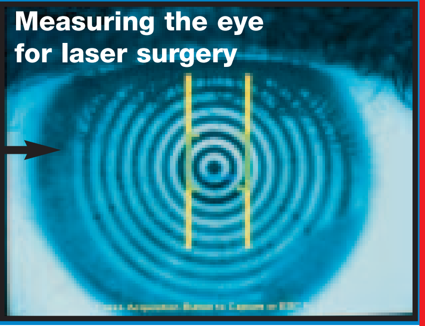
1. **Infer** the estimated magnification of your telescope.
2. **Discuss** how you could change the magnification of your telescope.
3. **Diagram** the path of light rays that pass through the telescope and then into your eye.
4. **Explain** how you could build a telescope with higher magnification than the one you constructed here.

Communicating Your Data

Compare your telescope and its operation with those of other members of your class. Try reading numbers or letters on a distant sign. Which telescope helps you see more detail?

Dominic Oldershaw

Sight Lines



Measuring the eye for laser surgery

Lasers make it possible to throw away eyeglasses

Back in the 1970s, scientists developed a special kind of laser to make microscopic notches in computer chips. This laser is also perfect for eye surgery. It does not generate much heat, so it doesn't damage the delicate tissues of the eye. With this technology, most of the 160 million Americans who wear eyeglasses or contact lenses can kiss them goodbye forever.

The most common type of laser surgery used to correct poor vision is LASIK. This painless procedure takes only about five minutes per eye. The patient is awake the entire time and usually sees well immediately after the surgery.

A microscope mounted on the laser gives the doctor a detailed view during the surgery. The screen allows others to view the surgery.

The Cornea and Vision

The eyeball has two structures, the cornea and a flexible lens, that cause light to be focused on the retina. The cornea is a transparent structure at the front of the eye. Most of the bending of light rays occurs when they pass through the cornea. The lens fine-tunes the focus of light from objects by adjusting its shape so that a sharp image is formed on the retina. Unlike the lens, the shape of the cornea doesn't change.

How It Works:

The LASIK procedure fixes vision problems by reshaping the cornea. For farsighted eyes, the laser vaporizes a ring of tissue from the cornea. This makes the cornea more curved so that light rays are bent more. For nearsighted eyes, the laser vaporizes tissue from the center of the cornea, making it flatter.

Interview Ophthalmologists are medical doctors who specialize in healing eyes. Optometrists are doctors who specialize in correcting poor vision by prescribing glasses and contact lenses. Interview an optometrist or ophthalmologist to find out how he or she detects eye problems and how these problems can be corrected.

Science Online

For more information, visit gpscience.com/time

Reviewing Main Ideas

Section 1 Mirrors

1. Plane mirrors reflect light to form upright, virtual images.

2. Concave mirrors can form various types of images, depending on where an object is relative to the focal point of the mirror. Concave mirrors can be used to magnify objects or create beams of light.
3. Convex mirrors spread out reflected light to form a reduced image. Convex mirrors allow you to see large areas.

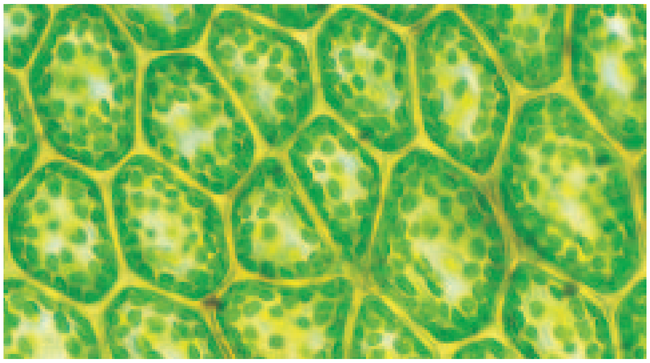
Section 2 Lenses

1. Convex lenses converge light rays. Convex lenses can form real or virtual images, depending on the distance from the object to the lens.
2. Concave lenses diverge light rays to form virtual smaller, upright images. They often are used in combination with other lenses.

3. The human eye has a flexible lens that changes shape to focus an image on the retina.
4. People with imperfect vision can use corrective lenses to improve their vision. Farsighted people wear convex lenses, and nearsighted people wear concave lenses.

Section 3 Optical Instruments

1. A refracting telescope uses convex lenses to magnify distant objects.
2. A reflecting telescope uses concave and plane mirrors and a convex lens to magnify distant objects.
3. By avoiding atmospheric distortion, the *Hubble Space Telescope* produces sharper images than telescopes on Earth are able to produce.
4. A simple microscope uses a convex objective lens and eyepiece lens with short focal lengths to magnify small objects.



5. Light passing through the lens of a camera is focused on light-sensitive film inside the camera. The image on the film is inverted and reduced.

FOLDABLES™ Use the Foldable that you made at the beginning of the chapter to help you review image formation by mirrors.

Science Online gpscience.com/interactive_tutor

chapter 14 Review

Using Vocabulary

concave lens p. 426	optical axis p. 418
concave mirror p. 418	plane mirror p. 417
convex lens p. 424	real image p. 419
convex mirror p. 421	reflecting telescope p. 433
cornea p. 427	refracting telescope p. 433
focal length p. 418	retina p. 427
focal point p. 418	virtual image p. 418
microscope p. 435	

Complete each sentence with the correct vocabulary word.

1. A flat, smooth surface that reflects light and forms an image is a(n) _________.
2. A(n) _________ uses two convex lenses to magnify small, close objects.
3. Every light ray that travels parallel to the optical axis before hitting a concave mirror is reflected such that it passes through the _________.
4. A(n) _________ is thicker in the middle than at the edges.
5. The inner lining of the eye that converts light images into electrical signals is called the _________.

Checking Concepts

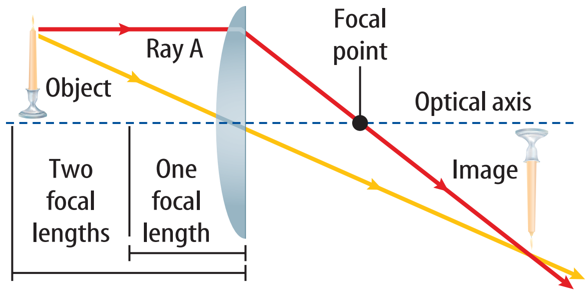
Choose the word or phrase that best answers the question.

6. Which of the following best describes image formation by a plane mirror?
   - **A)** A real image is formed in front of the mirror.
   - **B)** A real image is formed behind the mirror.
   - **C)** A virtual image is formed in front of the mirror.
   - **D)** A virtual image is formed behind the mirror.
7. Which mirror can form an enlarged image?
   - **A)** convex
   - **B)** plane
   - **C)** concave
   - **D)** transparent
8. Which of the following is used in a headlight or a flashlight to create a beam of light?
   - **A)** concave lens
   - **B)** convex lens
   - **C)** concave mirror
   - **D)** convex mirror
9. What do lenses do?
   - **A)** reflect light
   - **B)** refract light
   - **C)** diffract light
   - **D)** interfere with light
10. Which way does a concave lens bend light?
    - **A)** toward its optical axis
    - **B)** toward its center
    - **C)** toward its edges
    - **D)** toward its focal point
11. What type of lens is used to correct farsightedness?
    - **A)** flat lens
    - **B)** convex lens
    - **C)** concave lens
    - **D)** plane lens
12. Which of the following is NOT part of a reflecting telescope?
    - **A)** plane mirror
    - **B)** concave mirror
    - **C)** convex lens
    - **D)** concave lens
13. Which of the following images do light rays never pass through?
    - **A)** real
    - **B)** virtual
    - **C)** enlarged
    - **D)** reduced
14. The image formed by a camera lens must always be which of the following?
    - **A)** real
    - **B)** upright
    - **C)** virtual
    - **D)** enlarged
15. What happens to a light ray traveling parallel to the optical axis of a convex lens that passes through the lens?
    - **A)** It travels parallel to the optical axis.
    - **B)** It passes through the focal point.
    - **C)** It is bent away from the optical axis.
    - **D)** It forms a virtual image.

Science Online gpscience.com/vocabulary_puzzlemaker

Interpreting Graphics

Use the illustration below to answer question 16.



16. Suppose the image of the candle moves away from the focal point. How did the position of the candle change?

17. Copy and complete the following table on the image formation by lenses and mirrors.

Image Formation by Lenses and Mirrors

Type of Lens or Mirror	Position of Object	Type of Image
Concave lens	All positions of object	virtual, upright, reduced
Convex lens	closer than one focal length	
	between one and two focal lengths	
	farther than two focal lengths	real, inverted reduced
Concave mirror	closer than one focal length	
	object placed at focal point	
	farther than two focal lengths	
Convex mirror	All positions of object	

Thinking Critically

18. Describe how the shape of the lens in your eye changes when you look at a nearby object, and then a distant object.

19. Compare and contrast a refracting telescope and a microscope.

20. Infer why a convex mirror and a conccave lens can never produce a real image.

21. Explain why people often become far-sighted as they grow older.

22. Infer why it would be easier to make a concave mirror for a reflecting telescope than an objective lens of the same size for a refracting telescope.

23. Determine whether a convex lens could form an image that is enlarged, real, and upright.

24. Compare A concave lens made of plastic is placed in a liquid. Light rays traveling in the liquid are not refracted when they pass through the lens. Comare the speed of light in the plastic and in the liquid.

Applying Math

25. Calculate Magnification The magnification of a refracting telescope can be calculated by dividing the focal length of the objective lens by the focal length of the eyepiece lens. If an objective lens has a focal length of 1 m and the eyepiece has a focal length of 1 cm, what is the magnification of the telescope?

26. Determine Object Distance You hold an object in front of a concave mirror with a focal length of 30 cm. If you do not see a reflected image, how far from the mirror is the object?

Physical Science EOCT Practice

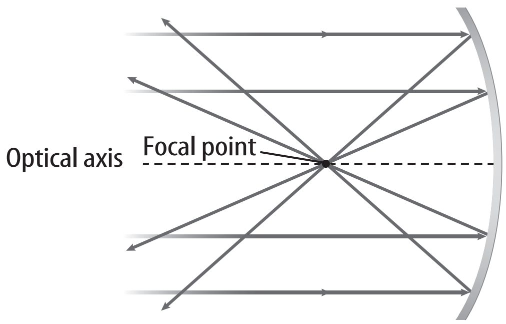
Part 1 Multiple Choice

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

1. Which of the following describes the image formed by a convex mirror? SPS9d

A. real
B. enlarged
C. inverted
D. virtual

Use the illustration below to answer questions 2 and 3.



2. Which of the following describes a light ray that passes through the focal point and then is reflected by the mirror? SPS9d

A. It travels parallel to the optical axis.
B. It forms a real image.
C. It is reflected back through the focal point.
D. It forms a virtual image

3. If the mirror becomes flatter and the focal point moves farther from the mirror, which of the following best describes the reflection of the parallel rays shown in the figure?

A. They pass through the old focal point.
B. They do not pass through either the old or the new focal point.
C. They pass through the new focal point.
D. They reverse direction. SPS9d

Test-Taking Tip

Be Prepared Bring at least two sharpened No. 2 pencils and a good eraser to the test. Make sure the eraser erases completely.

4. How far is an object from a concave mirror if the image formed is upright? SPS9d

A. one focal length
B. less than one focal length
C. more than two focal lengths
D. two focal lengths

5. What is an advantage to increasing the diameter of the concave mirror in a reflecting telescope? SPS9d

A. Brighter images are formed.
B. The mirror forms larger images.
C. The mirror forms sharper images.
D. The focal length increases.

Use the table below to answer questions 6–8.

Image Magnification by a Convex Lens

Object Distance (cm)	Image Distance (cm)	Magnification
250.0	62.5	0.25
200.0	66.7	0.33
150.0	75.0	0.50
100.0	100.0	1.00
75.0	150.0	2.00

6. How does the image change as the object gets closer to the lens? SCSh3d

A. It gets larger.
B. It gets smaller
C. It gets closer.
D. It becomes real.

7. Which of the following is the best estimate of the magnification if the image is 225 cm from the lens? SCSh3d

A. 0.40
B. 1.25
C. 1.5
D. 0.3

8. What should the object distance be if the lens is to be used as a magnifying glass? SCSh3d

A. 150 cm
B. 100 cm
C. greater than 250 cm
D. less than 100 cm

Part 2 Short Response/Grid In

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

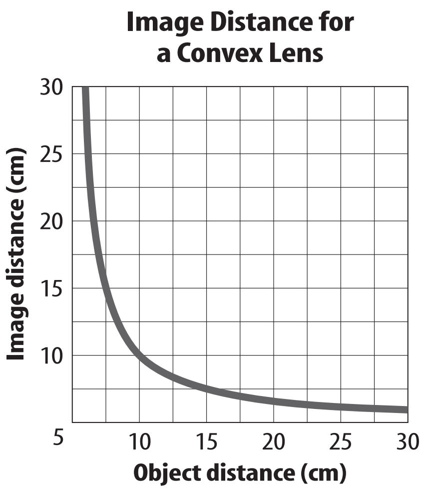
9. Describe how you could determine whether the image formed by a lens or mirror is a real image or a virtual image.

10. The largest refracting telescope has an objective lens with a diameter of 1.0 m. Calculate the area of this lens.

11. The objective lens in a microscope has a magnification of 30. What is the magnification of the microscope if the eyepiece lens has a magnification of 20?

12. Describe how the focal length of a convex lens changes as the lens becomes more curved.

Use the graph below to answer questions 13 and 14.



13. Determine how far the image is from the lens when the object is 15 cm from the lens.

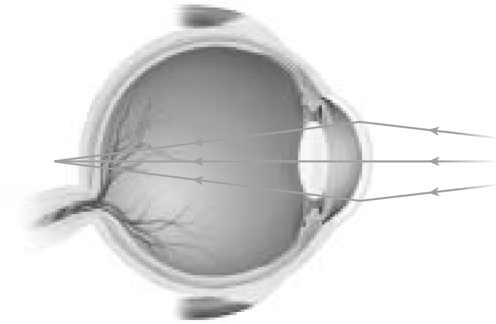
14. At what object distance are the image distance and object distance equal?

15. Explain why the largest telescopes are reflecting telescopes instead of refracting telescopes.

Part 3 Open Ended

Record your answers on a sheet of paper.

Use the illustration below to answer questions 16 and 17.



16. Describe the vision problem shown by the illustration. Why does this vision problem become more prevalent as people age?

17. Explain how the vision problem shown by the illustration can be corrected.

18. A convex lens is formed out of a transparent substance. Light travels with the same speed in this substance as in air. Explain why this lens would not cause light rays to converge.

19. Some cameras have zoom lenses that have a focal length that varies between 35 mm and 155 mm. Determine which focal length would correspond to a wide-angle lens and which would correspond to a telephoto lens.

20. Explain why side-view convex mirrors on the right side of cars have the printed warning "Objects in mirror are closer than they appear."

21. Describe the change in the lens in each of your eyes when you look at this book and then look out the window at a distant object.

22. Explain why objects become dimmer and less detailed as they move farther away.