Chapter 2

Using Light

CALIFORNIA Standards Preview

S 7.5 The anatomy and physiology of plants and animals illustrate the complementary nature of structure and function. As a basis for understanding this concept:

g. Students know how to relate the structures of the eye and ear to their functions.

S 7.6 Physical principles underlie biological structures and functions. As a basis for understanding this concept:

a. Students know visible light is a small band within a very broad electromagnetic spectrum.

b. Students know that for an object to be seen, light emitted by or scattered from it must be detected by the eye.

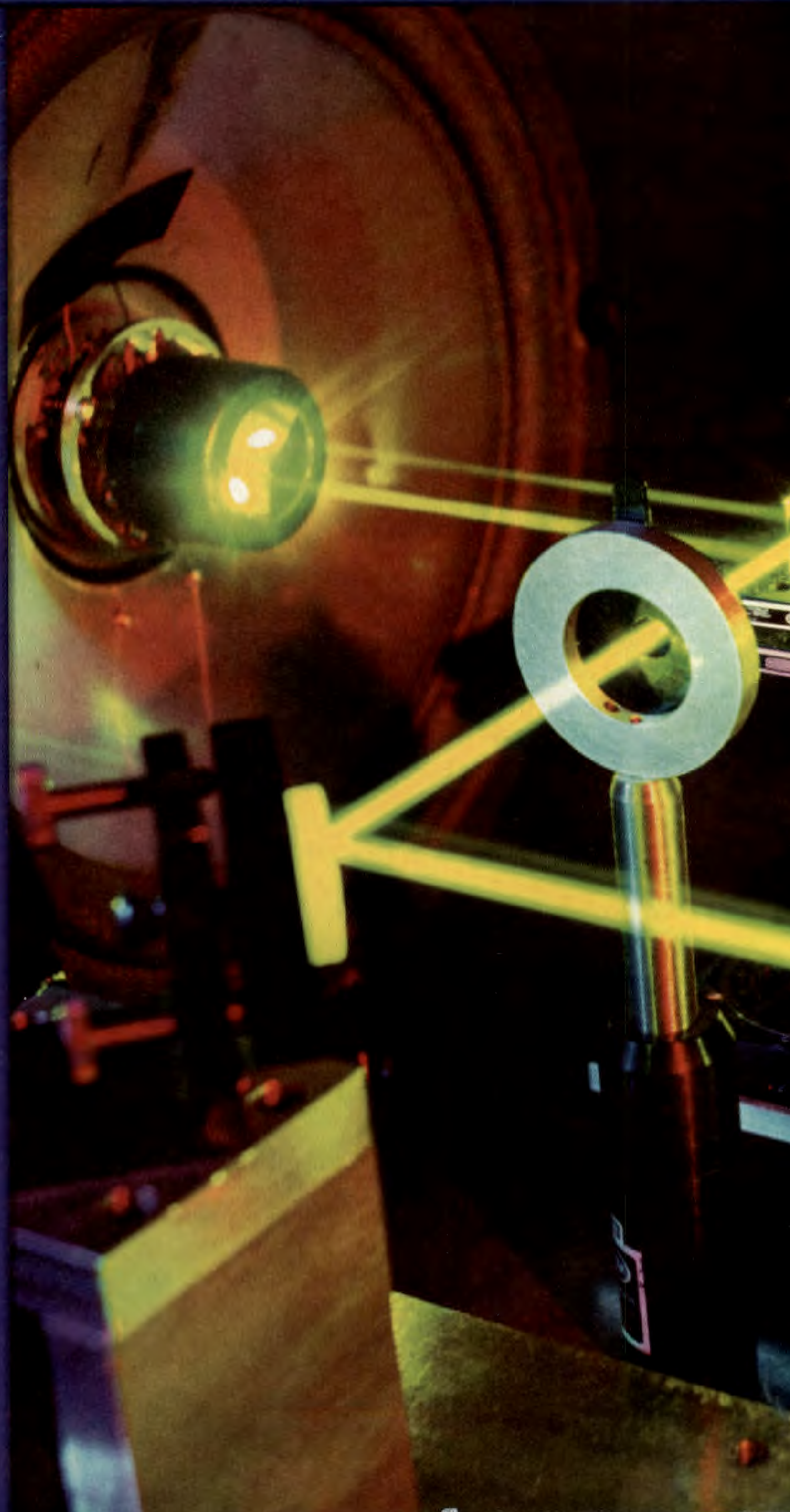
c. Students know light travels in straight lines if the medium it travels through does not change.

d. Students know how simple lenses are used in a magnifying glass, the eye, a camera, a telescope, and a microscope.

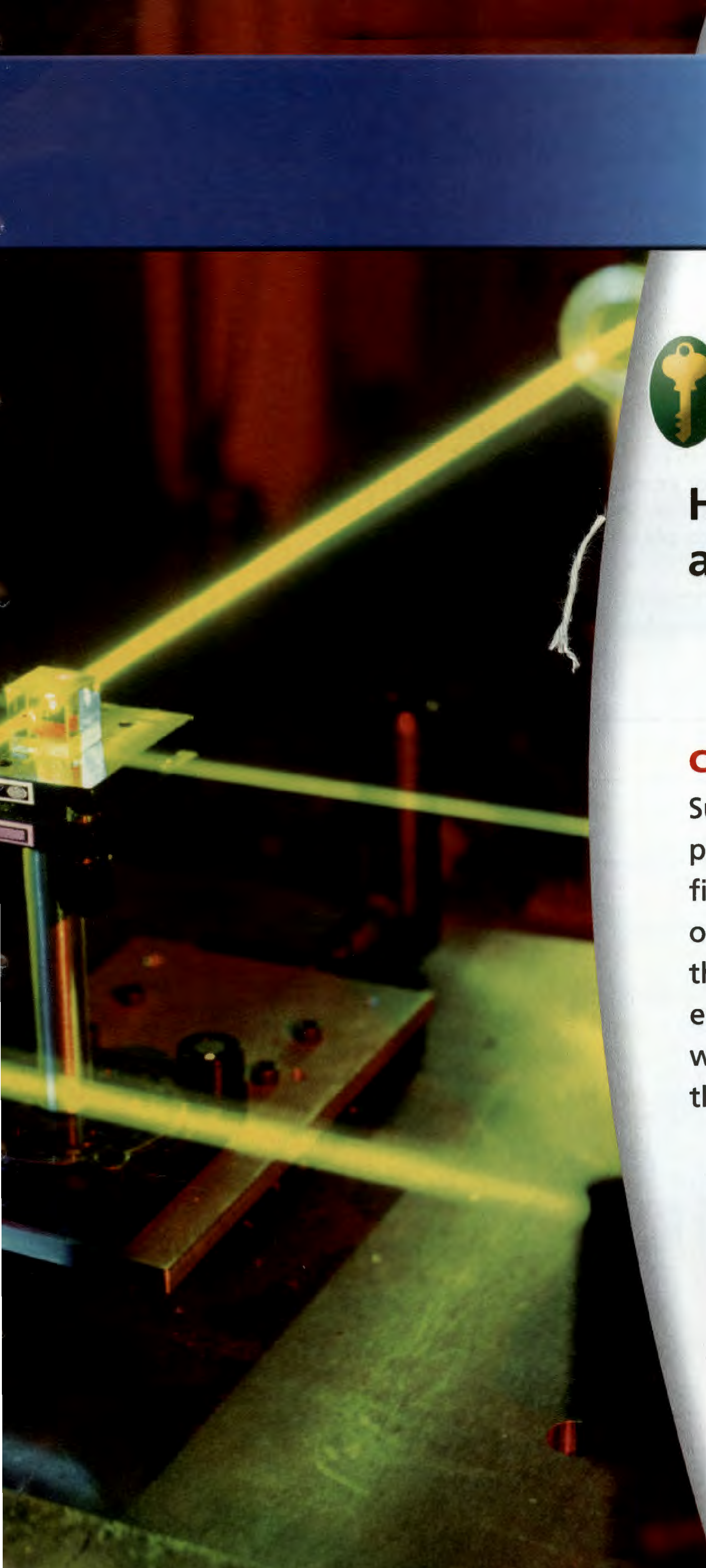
e. Students know that white light is a mixture of many wavelengths (colors) and that retinal cells react differently to different wavelengths.

f. Students know light can be reflected, refracted, transmitted, and absorbed by matter.

g. Students know the angle of reflection of a light beam is equal to the angle of incidence.



A laser produces a narrow beam of light. ▶



Video Preview

Discovery Channel School

Light

S 7.6.b

Focus on the
BIG Idea

How does light allow you to see?

Check What You Know

Suppose you aim a flashlight at a pair of colored light filters. The first filter is blue and the second one is red. When the light passes through the blue filter, it will emerge blue. But what happens when the blue light passes through the red filter?

Build Science Vocabulary

The images shown here represent some of the key terms in this chapter. You can use this vocabulary skill to help you understand the meaning of some key terms in this chapter.

Vocabulary Skill

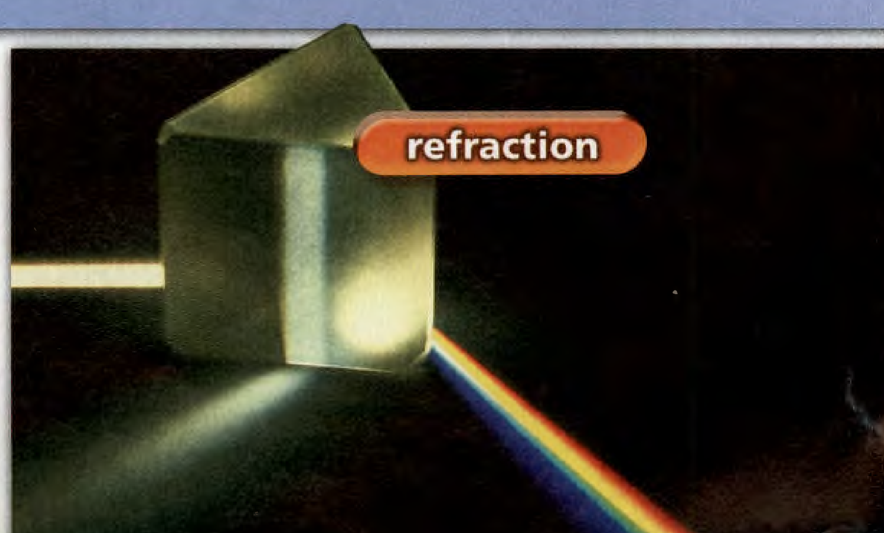
Latin Word Origins

Many English words come from ancient Latin words. One example is the Latin word part *re-*, meaning "back" or "again." When you review for a chapter test, for example, you look back at the chapter or read it again. The table below shows Latin words that are sources for some key terms in this chapter.

Latin Word	Meaning of Latin Word	Key Term
flectere	to bend	**reflection** The bouncing back of something, such as light or sound, when it hits a surface
lux, lucere	to light	**translucent** Scattering light; allowing some, but not all, light to pass through
re-	back; again	**reflection** The bouncing back of something, such as light or sound, when it hits a surface
trans-	through; across	**transparent** Allowing light to pass through

Apply It!

1. Which key term in the chart comes from the two Latin words *flect* and *re*? How does the meaning of this key term involve both those Latin words?
2. What part of the word *translucent* lets you know that the word's meaning has something to do with light?



Chapter 2 Vocabulary

Section 1 (page 38)

wave
energy
medium
crest
trough
amplitude
wavelength
frequency
hertz
electromagnetic radiation
electromagnetic spectrum
visible light

Section 2 (page 46)

transparent
translucent
opaque
pigment
secondary color
complementary colors
primary colors

Section 3 (page 52)

reflection
law of reflection
plane mirror
image
virtual image
concave mirror
optical axis
focal point
real image
convex mirror
refraction
lens
convex lens
concave lens

Section 4 (page 62)

cornea
pupil
iris
retina
rods
cones
nearsighted
farsighted

Section 5 (page 65)

camera
telescope
refracting telescope
objective
eyepiece
reflecting telescope
microscope
electron microscope

Interactive Textbook

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How to Read Science

Reading Skill

Preview Visuals

Before you read each chapter in your textbook, take time to preview the visuals. Visuals are photographs, graphs, tables, and illustrations. Visuals contain important information to help you understand what you read. Follow these steps to preview visuals.

- Look carefully at the visual.
- Read the title, the labels, and the caption.
- Ask yourself questions about the visual.
- Write your questions in a graphic organizer.
- As you read the section, write answers to your questions.

Preview Figure 2 in Section 1. Copy the incomplete graphic organizer below into your notebook.

Amplitude, Wavelength, and Frequency

Q. What is the subject of this illustration?

A. The basic properties of waves—amplitude, wavelength, and frequency

Q. What does the label Amplitude mean?

A.

Apply It!

1. What is the first question in the graphic organizer? Why is it good to ask this question when you preview any visual?
2. Add at least two questions about Figure 2 to your graphic organizer. As you read Section 1, answer the questions.
3. Before you read Section 2, preview Figure 8. Before you read Section 4, preview Figure 22. Before you read Section 5, preview Figure 25. For each of these visuals, make a graphic organizer with your questions. Answer the questions when you read the section.

Lab zone

Standards Investigation

S 7.6.d

Design and Build an Optical Instrument

You see reflections all the time—in shiny surfaces, windows, and mirrors. A camera can capture reflections on film. A telescope can capture reflected light with a curved mirror. Cameras and telescopes are optical instruments, devices that control light with mirrors or lenses. In this investigation, you will design and build your own optical instrument.

Your Goal

To design, build, and test an optical instrument that serves a specific purpose

Your optical instrument must

- be made of materials that are approved by your teacher
- include at least one mirror or one lens
- be built and used following the safety guidelines in Appendix A

Plan It!

Start by deciding on the purpose of your optical instrument and how you will use it. Sketch your design and choose the materials you will need. Then build and test your optical instrument. Finally, make a manual that describes and explains each part of the instrument.

Section 1

Waves and the Electromagnetic Spectrum

CALIFORNIA Standards Focus

S 7.6.a Students know visible light is a small band within a very broad electromagnetic spectrum.

- What causes waves?
- What are the basic properties of waves?
- What does an electromagnetic wave consist of?
- What are the waves of the electromagnetic spectrum?

Key Terms

- wave
- energy
- medium
- vibration
- crest
- trough
- amplitude
- wavelength
- frequency
- hertz
- electromagnetic wave
- electromagnetic radiation
- electromagnetic spectrum
- visible light

Lab zone **Standards Warm-Up**

What Is White Light?

1. Line a cardboard box with white paper. Hold a small triangular prism up to direct sunlight. **CAUTION:** *Do not look directly at the sun.*
2. Rotate the prism until the light coming out of the prism appears on the inside of the box as a wide band of colors. Describe the colors and their order.
3. Using colored pencils, draw a picture of what you see inside the box.

Think It Over

Forming Operational Definitions The term *spectrum* describes a range. How is this term related to what you just observed?

It was a long swim, but now you're resting on the swimming raft in the lake. You hear the water lapping gently against the raft as the sun warms your skin. Suddenly a motorboat zooms by. A few seconds later you're bobbing wildly up and down as the boat's waves hit the raft. Although the speedboat didn't touch the raft, its energy caused waves in the water. Then the waves moved the raft—and you!

You can see and feel the water waves when you're on a swimming raft. But did you know that many other kinds of waves affect you every day? Sound is a wave. Sunlight is a different kind of wave. Light, sound, and water waves may seem very different, but they all are waves. What is a wave?

▼ A motorboat making waves

FIGURE 1
Waves
You are being "showered" all the time by many types of waves.

Waves and Energy

A **wave** is a disturbance that transfers energy from place to place. In science, **energy** is defined as the ability to do work. To understand waves, think about the swimming raft. A wave that disturbs the surface of the water also will disturb the raft. The wave's energy lifts the heavy raft as the wave passes under it. But the disturbance caused by the wave is temporary. After the wave passes, the water is calm again and the raft stops bobbing.

What Carries Waves? Most kinds of waves need something to travel through. Water waves, for example, travel along the surface of the water. A wave can even travel along a rope. The material through which a wave travels is called a **medium.** Gases (such as air), liquids (such as water), and solids (such as rope), all act as mediums. Waves that require a medium through which to travel are called mechanical waves.

Some waves do not require a medium to travel through. Light can travel and carry energy through empty space. Waves that can travel without a medium are called electromagnetic waves.

How Do Waves Transfer Energy? Energy is required to make a wave. **Mechanical waves are produced when a source of energy causes a medium to vibrate.** A **vibration** is a repeated back-and-forth or up-and-down motion. When a vibration moves through a medium, a wave results. When waves travel through a medium, they do not carry the medium with them. Why doesn't the medium travel along with the wave? All mediums are made of tiny particles. When a wave enters a medium, it transfers energy to the medium's particles. The particles bump into each other, passing the wave's energy along.

Reading Checkpoint What is a vibration?

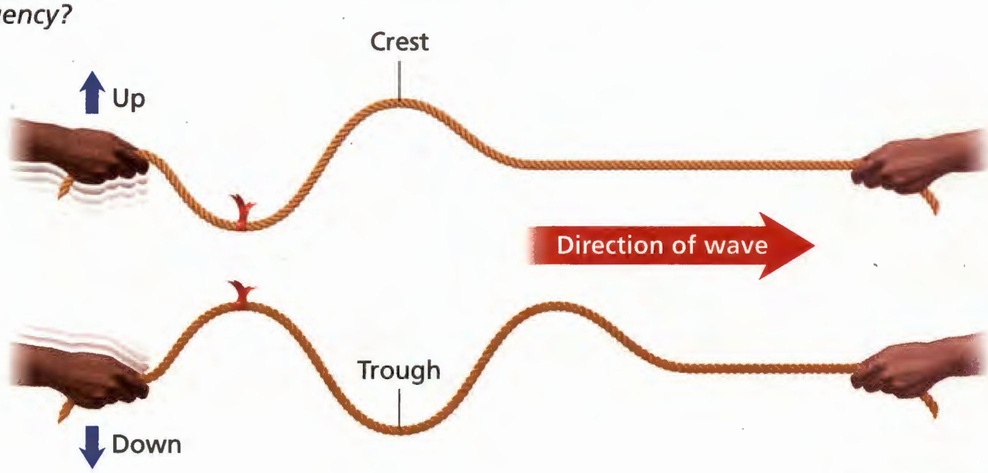
Properties of Waves

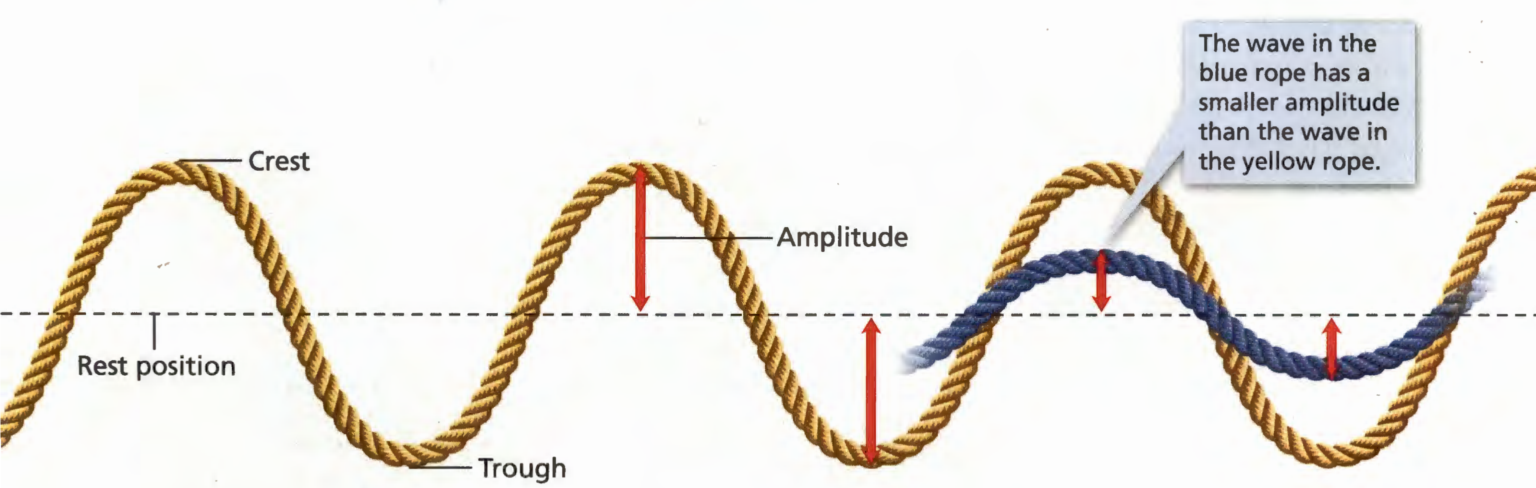
Waves can carry a little energy or a lot. They can be short or long. All waves, however, share certain properties. **The basic properties of waves are amplitude, wavelength, frequency, and speed.**

Amplitude When you make a wave on a rope, the rope itself moves up and down or from side to side, perpendicular (at a 90° angle) to the direction in which the wave travels. The high point of a wave is called a **crest**, and the low point is called a **trough** (trawf). The distance the medium rises depends on the amplitude of the wave. **Amplitude** is the maximum distance that the particles of the medium carrying the wave move away from their rest positions. For example, the amplitude of a water wave is the maximum distance a water particle moves above or below the surface level of calm water. You can increase the amplitude of a wave in a rope by moving your hand up and down a greater distance. To do this, you have to use more energy. This energy is transferred to the rope. Thus, the more energy a wave has, the greater its amplitude.

FIGURE 2
Amplitude, Wavelength, and Frequency

The basic properties of all waves include amplitude, wavelength, and frequency. A wave moves the rope up and down in a direction perpendicular to the direction in which the wave travels.
Developing Hypotheses *How could you increase the amplitude of a wave in a rope? How could you increase the frequency?*





Wavelength A wave travels a certain distance before it starts to repeat. The distance between two corresponding parts of a wave is its **wavelength.** You can find the wavelength of a wave by measuring the distance from crest to crest, as shown on Figure 2. Or you can measure from trough to trough.

Frequency Wave **frequency** is the number of complete waves that pass a given point in a certain amount of time. For example, if you make waves on a rope so that one wave passes by every second, the frequency is 1 wave per second. How can you increase the frequency? Simply move your hand up and down more quickly, perhaps two or three times per second. To decrease the frequency, move your hand up and down more slowly.

Frequency is measured in units called **hertz** (Hz). A wave that occurs every second has a frequency of 1 Hz. If two waves pass you every second, then the frequency of the wave is 2 per second, or 2 hertz. The hertz was named after Heinrich Hertz, the German scientist who discovered radio waves.

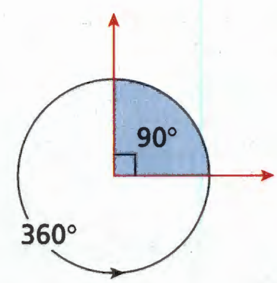
Speed Different waves can travel at different speeds. The speed of a wave is how far the wave travels in a given amount of time. If the medium that a wave travels through does not change, the speed of the wave is constant. The speed of a wave can be found by multiplying its frequency by its wavelength. Thus, you can increase the speed of a wave by increasing either the wavelength or the frequency.

Reading Checkpoint **In what unit is the frequency of a wave measured?**

Math Skills

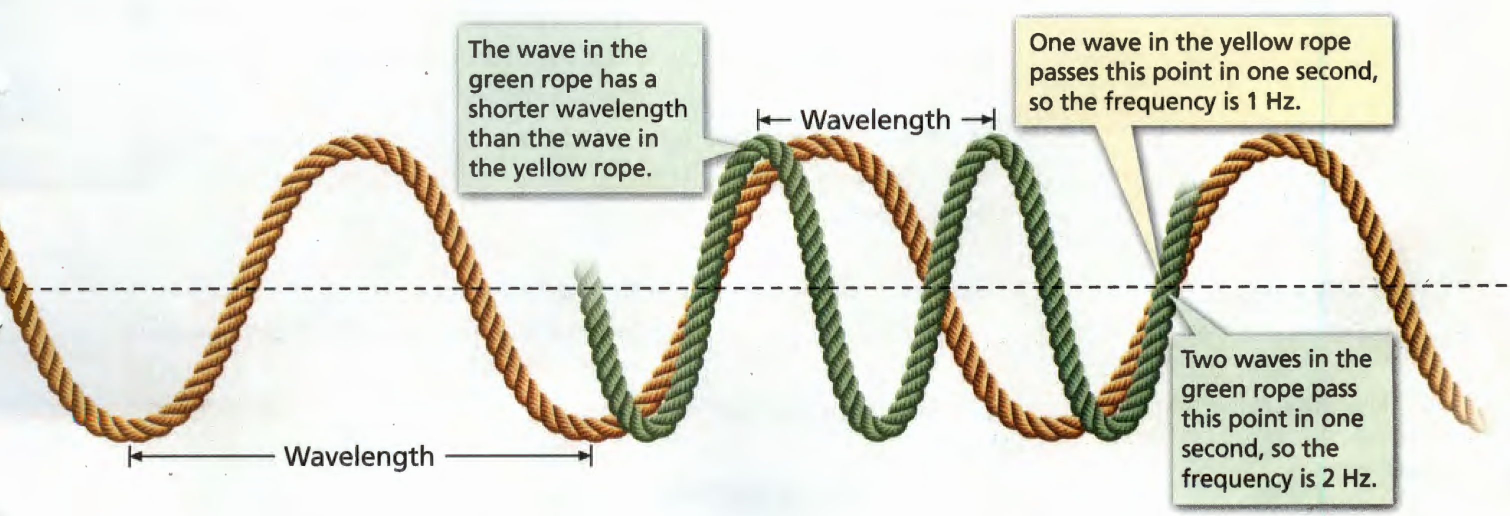
Angles

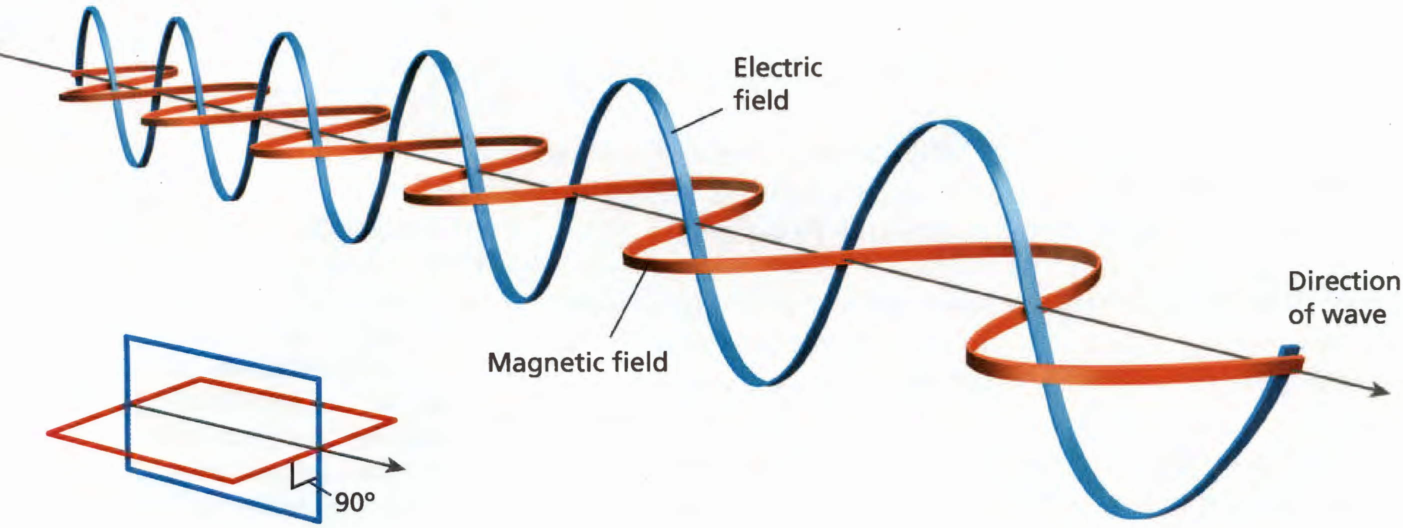
An angle is formed when two lines meet at a point. Angles are measured in degrees, indicated by the symbol °. A circle has 360 degrees. A right angle is an angle that contains 90 degrees. Two lines that meet at a point to form a 90° angle are said to be perpendicular to each other.



Practice Problems

1. Draw a circle on a piece of paper. How many right angles can you fit in the circle?
2. How many degrees do two right angles contain?





Fields are at right angles.

FIGURE 3
Electromagnetic Wave
In an electromagnetic wave, electric and magnetic fields vibrate at right angles to each other. **Interpreting Diagrams** *What is the angle between the fields?*

What Is an Electromagnetic Wave?

Waves in water and ropes have two things in common—they transfer energy and they also require a medium through which to travel. But electromagnetic waves can transfer energy without a medium. An **electromagnetic wave** transfers electrical and magnetic energy. **An electromagnetic wave consists of vibrating electric and magnetic fields that move through space at the speed of light.**

Producing Electromagnetic Waves Light and all other electromagnetic waves are produced by charged particles. Every charged particle has an electric field surrounding it. When a charged particle moves, it produces a magnetic field. When a charged particle changes its motion, its magnetic field changes. The changing magnetic field causes the electric field to change. When one field vibrates, so does the other. In this way, the two fields constantly cause each other to change. The result is an electromagnetic wave, as shown in Figure 3. Notice that the two fields vibrate at right angles to each other.

Energy The energy that is transfered through space by electromagnetic waves is called **electromagnetic radiation.** Electromagnetic waves do not require a medium, so they can transfer energy through a vacuum, or empty space. This is why you can see the sun and stars—their light reaches Earth through the vacuum of space.

Speed All electromagnetic waves travel at the same speed in a vacuum—about 300,000 kilometers per second. This speed is called the speed of light. At this speed, light from the sun takes about 8 minutes to travel the 150 million kilometers to Earth. When light waves travel through a medium such as air or water, however, they travel more slowly.

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What Is the Electromagnetic Spectrum?

All electromagnetic waves travel at the same speed in a vacuum, but they have different wavelengths and different frequencies. As the wavelength decreases, the frequency increases. Waves with the longest wavelengths have the lowest frequencies. Waves with the shortest wavelengths have the highest frequencies. The amount of energy carried by an electromagnetic wave increases with frequency. The higher the frequency of a wave, the higher its energy.

The **electromagnetic spectrum** is the complete range of electromagnetic waves placed in order of increasing frequency. The full spectrum is shown in Figure 5. **The electromagnetic spectrum is made up of radio waves, infrared rays, visible light, ultraviolet rays, X-rays, and gamma rays.** Electromagnetic waves that you can see are called **visible light.**

Radio Waves The electromagnetic waves with the longest wavelengths and lowest frequencies are radio waves. The very long wavelengths are used for broadcasting AM and FM radio and television signals.

Microwaves The radio waves with the shortest wavelengths and highest frequencies are microwaves. These waves are used in microwave ovens to heat your food, but they are also used in cellular phone communication and in radar systems.

Infrared Rays If you turn on a burner on an electric stove, you can feel it warm up before the heating element starts to glow. The invisible heat you feel is infrared radiation. Infrared rays are used in heat lamps.

Reading Checkpoint What is the electromagnetic spectrum?

FIGURE 4
Radar Gun
Radio waves are used to find the speeds of moving vehicles.

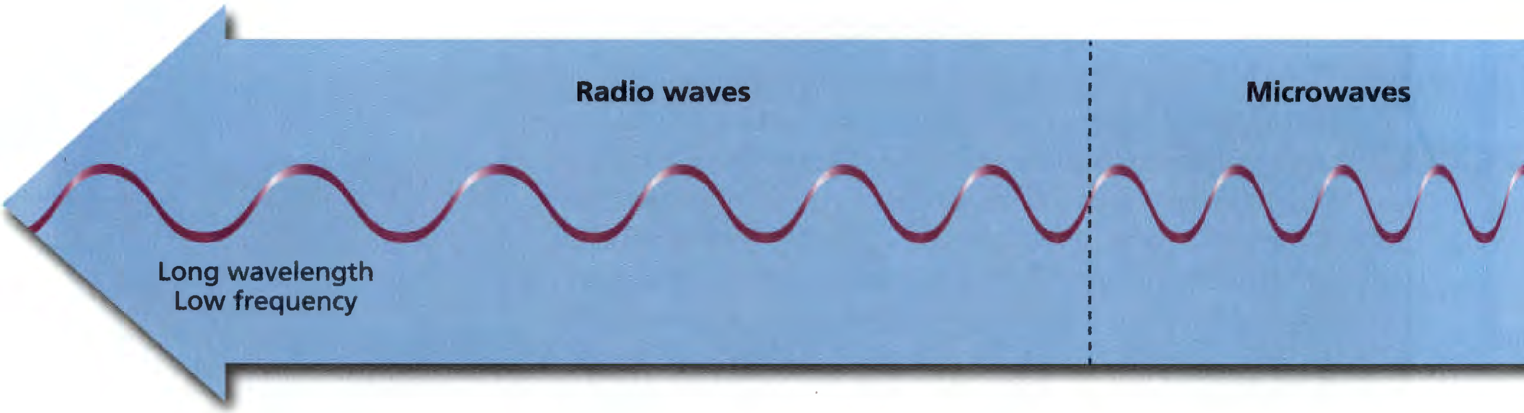


FIGURE 5

The Electromagnetic Spectrum

The electromagnetic spectrum shows the range of different electromagnetic waves in order of increasing frequency and decreasing wavelength.
Interpreting Diagrams *Which electromagnetic waves have the longest wavelengths?*

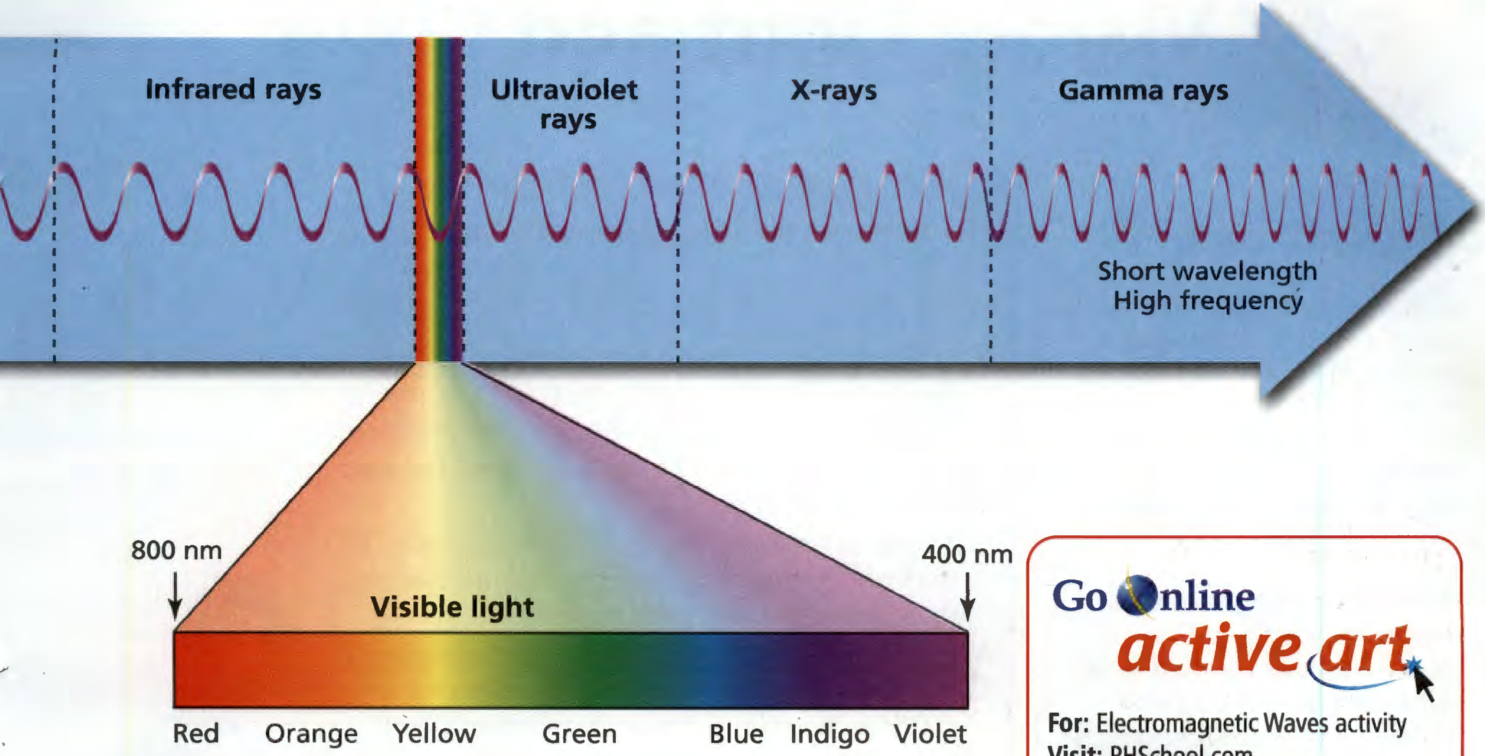
Visible Light Visible light is a small band within a very broad electromagnetic spectrum. The wavelengths of visible light vary from 800 nanometers, or 0.0000008 m(red light) to 400 nanometers, or 0.0000004 m(violet light). The main colors of visible light in order from largest to smallest wavelength are red, orange, yellow, green, blue, indigo, and violet. They form a continuous spectrum.

Ultraviolet Rays Electromagnetic waves with wavelengths just shorter than those of visible light are called ultraviolet rays. They carry more energy than visible light. Small doses of ultraviolet rays are useful. For example, ultraviolet rays cause skin cells to produce vitamin D, which is needed for healthy bones and teeth. However, too much exposure to ultraviolet rays is dangerous. They can cause skin cancer and damage your eyes. If you apply sunblock and wear sunglasses that block ultraviolet rays, you can limit the damage caused by ultraviolet rays.

X-Rays Electromagnetic waves with wavelengths just shorter than those of ultraviolet rays are called X-rays. Because they have more energy than ultraviolet rays, they can penetrate most matter. But dense matter, such as bone or lead, absorbs them and does not allow them to pass through. Therefore, X-rays are used to make images of teeth and of bones inside the body. Too much exposure to X-rays, however, can lead to cancer.

Gamma Rays The electromagnetic waves with the shortest wavelengths and the greatest amount of energy are gamma rays. Gamma rays are the most penetrating of all the electromagnetic waves. They can be used to kill cancer cells inside the body.

Reading Checkpoint **What are the colors of visible light?**



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Section 1 Assessment

S 7.6.a E-LA: Reading 7.2.0, Writing 7.2.1

Target Reading Skill **Preview Visuals** Use your graphic organizer to help answer Question 2 below.

Reviewing Key Concepts

1. a. **Identifying** What is a wave?
   b. **Explaining** How are mechanical waves produced?
   c. **Comparing and Contrasting** What is an example of a wave that requires a medium? What kind of wave can travel without a medium?
2. a. **Listing** What are four basic properties of waves?
   b. **Describing** Use a wave diagram to label the amplitude and wavelength of a wave. In a light wave, which of these properties tells you the color of the light?
   c. **Identifying** Which wave properties are distances? Which properties are measured relative to time?
3. a. **Identifying** What is an electromagnetic wave?
   b. **Explaining** Why can electromagnetic radiation travel through empty space?
4. a. **Listing** List the waves in the electromagnetic spectrum in order from longest wavelength to shortest wavelength. Make sure to include all the colors of visible light.
   b. **Explaining** Why are some electromagnetic waves harmful to you while others are not?
   c. **Classifying** List one or more types of electromagnetic waves that are useful for each of these purposes: cooking food, communication, seeing inside the body, curing diseases, reading a book, warming your hands.

Writing in Science

Firsthand Narrative Suppose you are a particle of water in a lake. Describe what happens to you when a motorboat passes by. Be sure to use words like *amplitude* and *crest* in your description.

Section 2

Visible Light and Color

CALIFORNIA Standards Focus

S 7.6.e Students know that white light is a mixture of many wavelengths (colors) and that retinal cells react differently to different wavelengths.

S 7.6.f Students know light can be reflected, refracted, transmitted, and absorbed by matter.

- How does visible light interact with an object?
- What determines the color of an opaque object?
- How is mixing pigments different from mixing colors of light?

Key Terms

- transparent
- translucent
- opaque
- primary colors
- secondary color
- complementary colors
- pigment

Lab zone Standards Warm-Up

How Do Colors Mix?

1. Cut a disk with a diameter of 10 cm out of white cardboard. Divide the disk into three equal-sized segments. Color one segment red, the next green, and the third blue.
2. Carefully punch two holes, 2 cm apart, on opposite sides of the center of the disk.
3. Thread a 1-m long string through the holes. Tie the ends of the string together to make a loop that passes through both holes.
4. With equal lengths of string on each side of the disk, tape the string in place. Turn the disk to wind up the string. Predict what color(s) you will see if the disk spins fast.
5. Spin the disk by pulling the loops to unwind the string.

Think It Over

Observing What color do you see as the wheel spins fast? Was your prediction correct?

It was hard work, but you are finally finished. You stand back to admire your work. Color is everywhere! The bright green grass rolls right up to the flower garden you just weeded. In the bright sunlight, you see patches of yellow daffodils, purple hyacinths, and red tulips. The sun's light allows you to see each color. But sunlight is white light. What makes each flower appear to be a different color?

Flowers in sunlight ▼

Visible Light

For you to see an object, light from the object has to reach your eye. An object can either be a primary source of light, meaning it emits, or gives off, its own light, or it can be a secondary source of light, meaning it reflects light from a primary source.

When light strikes an object, the light can be reflected, transmitted, or absorbed. Think about a pair of sunglasses. If you hold the sunglasses in your hand, you can see light that reflects off the lenses. If you put the sunglasses on, you see light that is transmitted by the lenses. The lenses also absorb some light. That is why objects appear darker when seen through the lenses. Most materials can be classified as transparent, translucent, or opaque based on what happens to light that strikes the material.

Transparent Materials A **transparent** material transmits most of the light that strikes it. When light hits the particles of a transparent material, the particles absorb it but then reemit it, or send it back out, until the light finally passes through to the other side. However, if a transparent medium has impurities or imperfections in it, it can scatter some of the light so it doesn't reach your eye, similar to translucent materials.

Translucent Materials A **translucent** (trans LOO sunt) material scatters light as it passes through, just as smoke, fog, and clouds scatter light as it passes through the air. You can usually see something behind a translucent object, but the details are blurred. Wax paper and frosted glass like the middle glass in Figure 6 are translucent materials.

Opaque Materials An **opaque** (oh PAYK) material reflects or absorbs all of the light that strikes it. You cannot see through opaque materials because light cannot pass through them. You cannot see the straw through the white glass in Figure 6 because the glass is opaque.

Reading Checkpoint **What happens when light strikes an opaque material?**

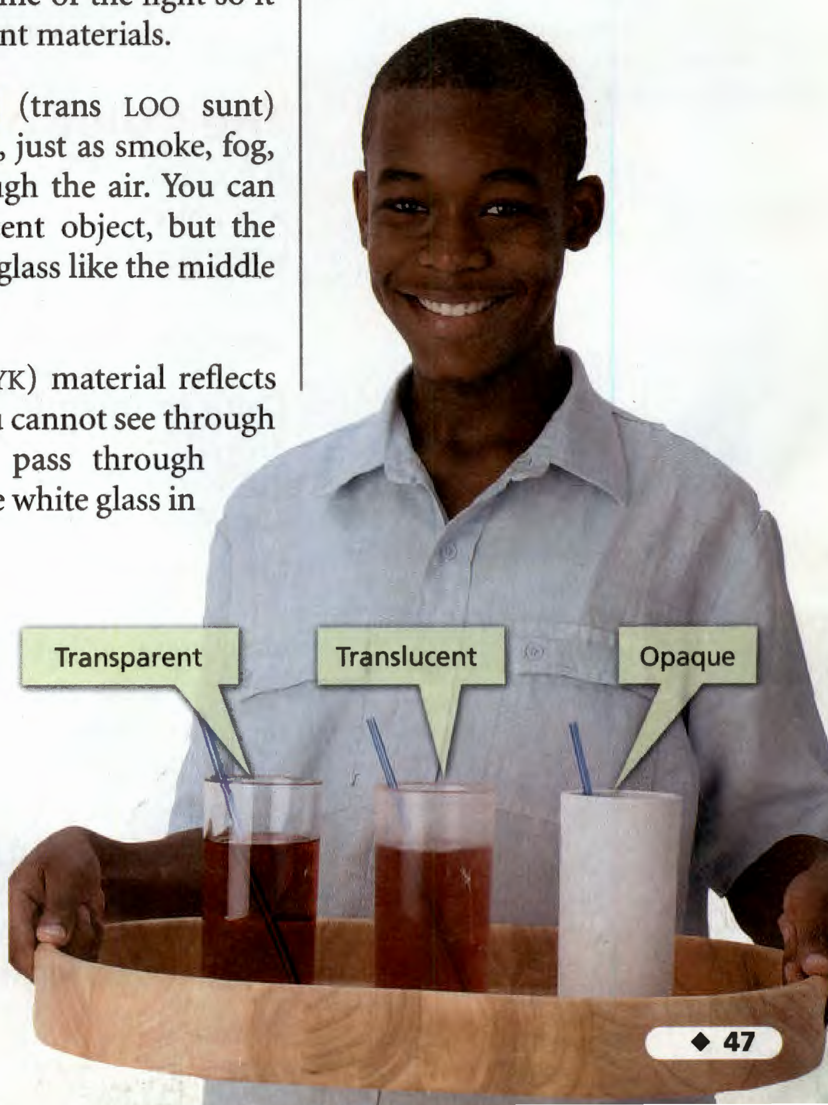
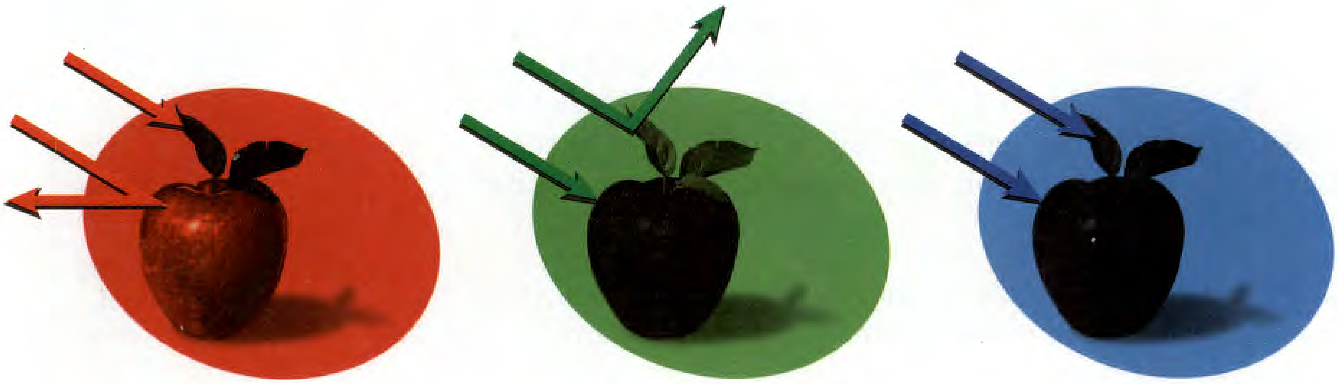


FIGURE 6
Types of Materials
Different types of materials reflect, transmit, and absorb different amounts of light.
Comparing and Contrasting *How does a straw seen through transparent glass compare with a straw seen through translucent glass?*

FIGURE 7

Colored Light

The color an apple appears to be depends on the color of the light that strikes it.
Applying Concepts *What color of light is reflected by a red apple?*



In red light, the apple appears red because it reflects the red light. But the leaves look black.

In green light, the apple appears black because no red light strikes it. But the leaves look green.

In blue light, both the apple and the leaves appear black.

The Color of Objects

If you know how light interacts with objects, you can explain why objects such as flowers have different colors. The color and brightness of any object depends on the material the object is made of. The color and brightness of the light striking the object also affect the color of the object.

Color of Opaque Objects The color of an opaque object depends on the wavelengths of light that the object reflects. Every opaque object absorbs some wavelengths of light and reflects others. **The color of an opaque object is the color of the light it reflects.** For example, look at the apple shown at the top of Figure 7. The apple appears red because it reflects red wavelengths of light. The apple absorbs the other colors of light. The leaf looks green because it reflects green light and absorbs the other colors.

Objects can appear to be a different color if you view them in a different color of light. In red light, the apple appears red because there is red light for it to reflect. But the leaf appears black because there is no green light to reflect. In green light, the leaf looks green but the apple looks black. And in blue light, both the apple and the leaf look black.

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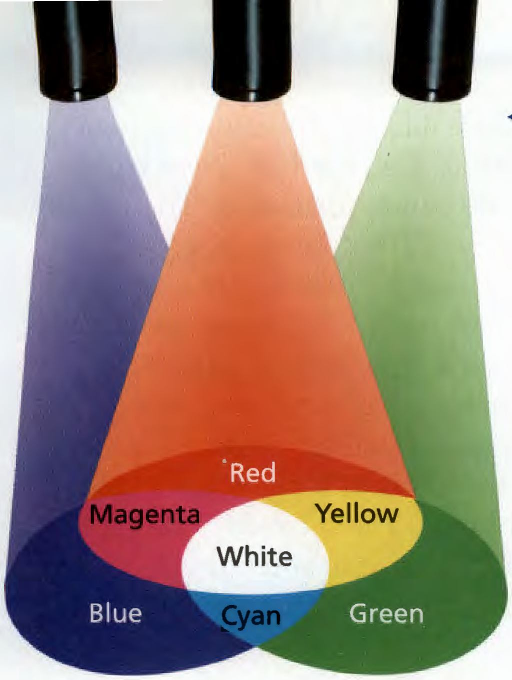
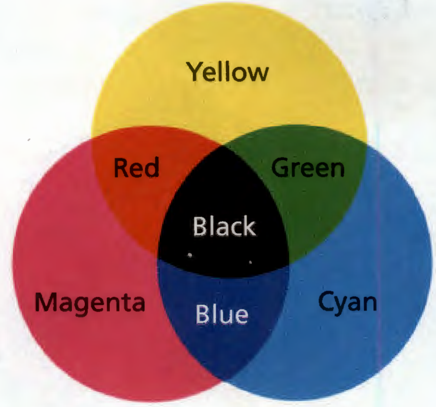


◀ **FIGURE 8**
Primary Colors of Light
The primary colors of light combine in equal amounts to form white light.



▲ **FIGURE 9**
Primary Colors of Pigments
Unlike the primary colors of light, the primary colors of pigments combine in equal amounts to form black.

Combining Colors

Color is used in painting, photography, theater lighting, and printing. People who work with color must learn how to produce a wide range of colors using just a few basic colors. Three colors that can combine to make any other color are called **primary colors.** Two primary colors combine in equal amounts to produce a **secondary color.**

Mixing Colors of Light The primary colors of light are red, green, and blue. **When combined in equal amounts, the three primary colors of light produce white light.** If they are combined in different amounts, the primary colors can produce other colors. For example, red and green combine to form yellow light. Yellow is a secondary color of light because two primary colors produce it. The secondary colors of light are yellow (red + green), cyan (green + blue), and magenta (red + blue). Figure 8 shows the primary and secondary colors of light.

A primary and a secondary color can combine to make white light. Any two colors that combine to form white light are called **complementary colors.** Yellow and blue are complementary colors, as are cyan and red, and magenta and green.

Mixing Pigments How does a printer produce the many shades of colors you see in this textbook? Inks, paints, and dyes contain **pigments**, or colored substances that are used to color other materials. Pigments absorb some colors and reflect others. The color you see is the result of the colors that particular pigment reflects, as shown in Figure 9 .

FIGURE 10
The photograph shows a printed image, and the round insert shows an enlargement of it. Four-color printing uses the three primary colors of pigment, plus a very dark purple or black.

Mixing colors of pigments is different from mixing colors of light. **As pigments are added together, fewer colors of light are reflected and more are absorbed.** The more pigments that are combined, the darker the mixture looks.

Cyan, yellow, and magenta are the primary colors of pigments. These colors combine in equal amounts to produce black. By combining pigments in varying amounts, you can produce many other colors. If you combine two primary colors of pigments, you get a secondary color. The secondary colors of pigments are red, green, and blue.

Look at the pictures in this book with a magnifying glass. You can see tiny dots of different colors of ink. The colors used are cyan, yellow, and magenta. Black ink is also used, so the printing process is called four-color printing.

Reading Checkpoint **What colors are used in printing?**

Section 2 Assessment

S 7.6.e, 7.6.f, E-LA: Reading 7.1.2

Vocabulary Skill **Latin Word Origins** What does the Latin word part *trans* mean? What does *luc* mean? How do these Latin words help you understand what *translucent* means?

Reviewing Key Concepts

1. a. **Identifying** What three things may happen to the light that strikes an object?
   b. **Applying Concepts** What happens to light that strikes the following materials: clear plastic, aluminum foil, and tissue paper?
   c. **Problem Solving** Room-darkening window shades are used to keep sunlight out of a theater. What type of material should the shades be made of? Explain.
2. a. **Reviewing** What determines the color of an opaque object?
   b. **Drawing Conclusions** An actor's red shirt and blue pants both appear black. What color is the stage light shining on the actor?
3. a. **Describing** What are the primary colors of light? The primary colors of pigments?
   b. **Comparing and Contrasting** How does the result of mixing the primary colors of pigments compare to the result of mixing the primary colors of light?
   c. **Interpreting Diagrams** In Figure 9, which pair of colors combine to make blue?

Lab zone **At-Home Activity**

Color Mix See how many different shades of green you can make by mixing blue and yellow paint in different proportions. On white paper, paint a "spectrum" from yellow to green to blue. Show the results to your family. Then explain how magazine photos reproduce thousands of colors.

Lab zone **Skills Lab**

Changing Colors

S 7.6.e, 7.7.c

Problem

How do color filters affect the appearance of objects in white light?

Skills Focus

observing, inferring, predicting

Materials

- shoe box
- scissors
- flashlight
- removable tape
- red object (such as a ripe tomato)
- yellow object (such as a ripe lemon)
- blue object (such as blue construction paper)
- red, green, and blue cellophane, enough to cover the top of the shoe box

Procedure

1. Carefully cut a large rectangular hole in the lid of the shoe box.
2. Carefully cut a small, round hole in the center of one of the ends of the shoe box.
3. Tape the red cellophane under the lid of the shoe box, covering the hole in the lid.
4. Place the objects in the box and put the lid on.
5. In a darkened room, shine the flashlight into the shoe box through the side hole. Note the apparent color of each object in the box.
6. Repeat Steps 3–5 using the other colors of cellophane.

Analyze and Conclude

1. **Observing** What did you see when you looked through the red cellophane? Explain why each object appeared as it did.
2. **Observing** What did you see when you looked through the blue cellophane? Explain.
3. **Inferring** What color(s) of light does each piece of cellophane allow through?
4. **Predicting** Predict what you would see under each piece of cellophane if you put a white object in the box. Test your prediction.
5. **Predicting** What do you think would happen if you viewed a red object through yellow cellophane? Draw a diagram to support your prediction. Then test your prediction.
6. **Communicating** Summarize your conclusions by drawing diagrams to show how each color filter affects white light. Write captions to explain your diagrams.

Design an Experiment

Do color filters work like pigments or like colors of light? Design an experiment to find out what happens if you shine a light through both a red and a green filter. *Obtain your teacher's permission before carrying out your investigation.*

Section 3

Reflection and Refraction

CALIFORNIA Standards Focus

S 7.6.c Students know light travels in straight lines if the medium it travels through does not change.

S 7.6.g Students know the angle of reflection of a light beam is equal to the angle of incidence.

- What does the law of reflection state?
- Why do light rays bend when they enter a new medium at an angle?
- What determines the types of images formed by convex and concave lenses?

Key Terms

- reflection
- law of reflection
- plane mirror
- image
- virtual image
- concave mirror
- optical axis
- focal point
- real image
- convex mirror
- refraction
- lens
- convex lens
- concave lens

Lab zone Standards Warm-Up

How Does a Ball Bounce?

1. Choose a spot at the base of a wall. From a distance of 1 m, roll a wet ball along the floor straight at the spot you choose. Watch the angle at which the ball bounces by looking at the path of moisture on the floor.
2. Wet the ball again. From a different position, roll the ball at the same spot, but at an angle to the wall. Again, observe the angle at which the ball bounces back.

Think It Over

Developing Hypotheses How do you think the angle at which the ball hits the wall is related to the angle at which the ball bounces back? Test your hypothesis.

You laugh as you and a friend move toward the curved mirror. First your reflections look tall and skinny. Then they become short and wide. At one point, your reflections disappear even though you are still in front of the mirror. Imagine what it would be like if this happened every time you tried to comb your hair in front of a mirror!

Funhouse Mirror ▶

Reflection

The reflection you see in a mirror depends on the surface. Light travels in straight lines if the medium it travels through does not change. But when a light beam encounters a shiny reflecting surface, it will bounce back.

If you did the Standards Warm-Up, you saw that the ball hit the wall and bounced back, or was reflected. When you look in a mirror, you use reflected light to see yourself. **Reflection** occurs when an object or wave bounces back off a surface through which it cannot pass.

All waves obey the **law of reflection.** To help you understand this law, look at Figure 11. In the photo, you see light reflected off the surface of the sunglasses. The diagram shows how the light waves travel to make the reflection. The arrow labeled *Incoming wave* represents a wave moving toward the surface at an angle. The arrow labeled *Reflected wave* represents the wave that bounces off the surface at an angle. The dashed line labeled *Normal* is drawn perpendicular to the surface at the point where the incoming wave strikes the surface. The angle of incidence is the angle between the incoming wave and the normal. The angle of reflection is the angle between the reflected wave and the normal line. **The law of reflection states that the angle of incidence equals the angle of reflection.**

Reading Checkpoint **What is reflection?**

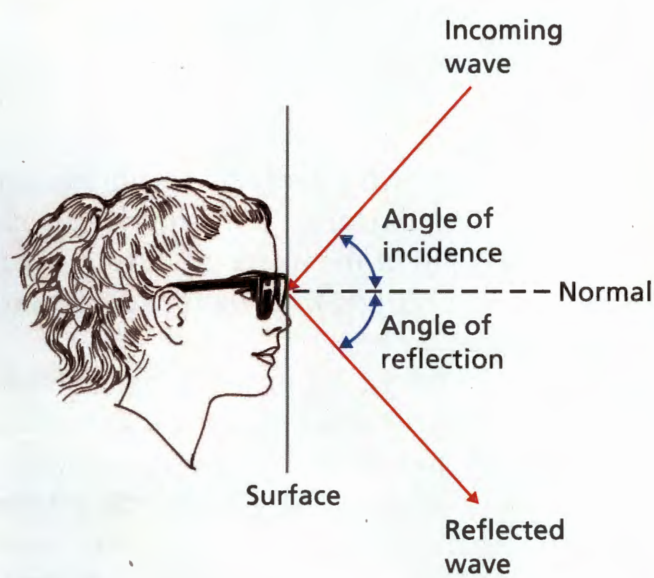


FIGURE 11
Law of Reflection
The angle of incidence equals the angle of reflection. All waves obey this law, including the light waves reflected from these sunglasses.
Predicting *What happens to the angle of reflection if the angle of incidence increases?*

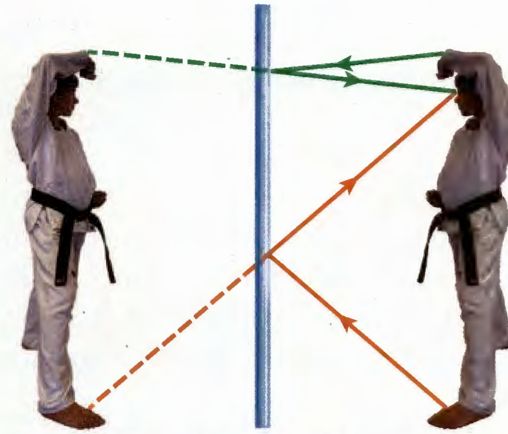


FIGURE 12
Image in a Plane Mirror
A plane mirror forms a virtual image. The reflected light rays appear to come from behind the mirror, where the image forms. **Observing** *Is the raised hand in the image a left hand or a right hand?*

Mirrors

Did you look into a mirror this morning to comb your hair or brush your teeth? If you did, you probably used a plane mirror. The law of reflection explains the kind of images you see in different types of mirrors such as plane, concave, and convex mirrors.

Plane Mirrors A **plane mirror** is a flat sheet of glass that has a smooth, silver-colored coating on one side. When light strikes a mirror, the coating reflects the light. Because the coating is smooth, reflection occurs and a clear image forms. An **image** is a copy of an object formed by reflected or refracted rays of light.

The image you see in a plane mirror is a **virtual image**—an upright image that forms where light seems to come from. "Virtual" describes something that does not really exist. Your image appears to be behind the mirror, but you can't reach behind the mirror and touch it.

A plane mirror produces a virtual image that is upright and the same size as the object. But the image is not quite the same as the object. The left and right of the image are reversed. For example, when you look in a mirror, your right hand appears to be a left hand in the image.

Figure 12 shows how a plane mirror forms an image. Some light rays from the karate student strike the mirror and reflect toward his eye. Even though the rays are reflected, the student's brain treats them as if they had come from behind the mirror. The dashed lines show where the light rays appear to come from. Because the light appears to come from behind the mirror, this is where the student's image appears to be located.

Reading Checkpoint **Where does an image in a plane mirror appear to be located?**

Concave Mirrors A mirror with a surface that curves inward like the inside of a bowl is a **concave mirror**. Figure 13 shows how a concave mirror can reflect parallel rays of light so that they meet at a point. Notice that the rays of light shown are parallel to the optical axis. The **optical axis** is an imaginary line that divides a mirror in half. The point at which rays parallel to the optical axis meet or converge is called the **focal point**. The location of the focal point depends on the shape of the mirror. The more curved the mirror is, the closer the focal point is to the mirror.

Concave mirrors can form either virtual images or real images. If an object is farther away from the mirror than the focal point, the reflected rays form a real image as shown in Figure 14. A **real image** forms when rays actually meet. But if the object is between the mirror and the focal point, the reflected rays form a virtual image behind the mirror. Virtual images formed by a concave mirror are always larger than the object.

FIGURE 13
Focal Point of a Concave Mirror
A concave mirror reflects rays of light parallel to the optical axis back through the focal point.

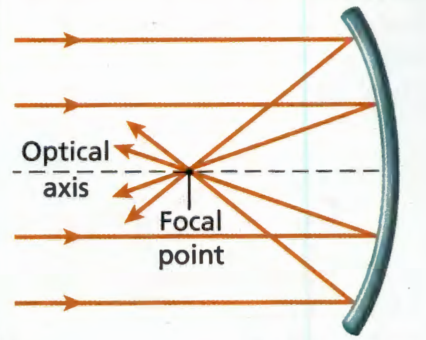
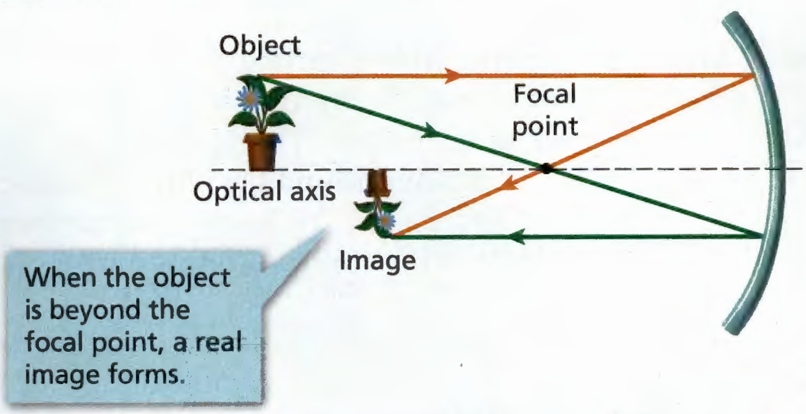


FIGURE 14
Images in Concave Mirrors
The type of image formed depends on the location of the object.
Interpreting Diagrams *When light rays actually meet, what kind of image is formed?*



▲ Looking into a concave mirror

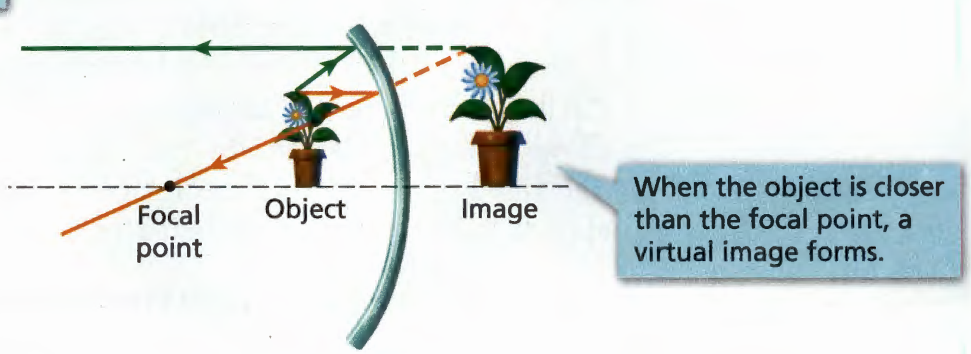


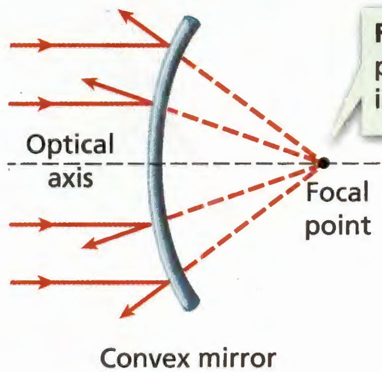
FIGURE 15

Images in Convex Mirrors

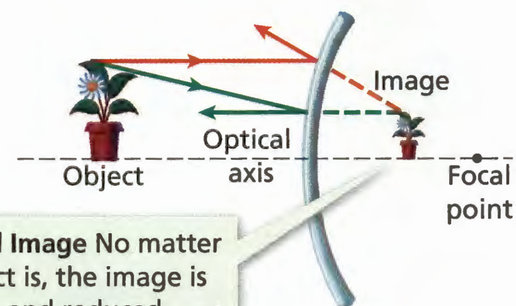
Light rays parallel to the optical axis reflect as if they came from the focal point behind the mirror. The image formed by a convex mirror is always virtual.

Making Generalizations *Describe the directions of the parallel rays reflected by a convex mirror.*

Looking into ▶ a convex mirror



Focal Point The focal point of a convex mirror is behind the mirror.



Virtual Reduced Image No matter where the object is, the image is virtual, upright, and reduced.

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Convex Mirrors A mirror with a surface that curves outward is called a **convex mirror.** Figure 15 shows how convex mirrors reflect parallel rays of light. The rays diverge but appear to come from a focal point behind the mirror. Because the rays never meet, images formed by convex mirrors are always virtual and smaller than the object. A convex mirror can never create a real image.

Perhaps you have seen this warning on a car mirror: "Objects in mirror are closer than they appear." Convex mirrors are used in cars as passenger-side mirrors. They are also used as security mirrors and safety mirrors in banks, grocery stores, parking garages, and offices. The advantage of a convex mirror is that it allows you to see a larger area than you can with a plane mirror. The disadvantage is that the image is reduced in size, so it appears to be farther away than it actually is.

Reading Checkpoint **Where are convex mirrors typically used?**

Refraction

Light travels in straight lines if the medium it travels through does not change. If light enters a new medium, it might slow down or speed up, because the speed of light is different for different mediums. If light enters the new medium perpendicular to the boundary, it will keep moving in the same direction. But if it hits the boundary at an angle, it will also bend. This bending of light waves due to a change in speed is known as **refraction.**

Refraction in Different Mediums Some mediums cause light to bend more than others, as shown in Figure 16. **When light rays enter a medium at an angle, the change in speed causes the rays to bend, or change direction.** When light passes from air into water, the light slows down. Light slows down even more when it passes from water into glass. When light passes from glass back into air, the light speeds up. Light travels fastest in air, a little slower in water, and slower still in glass. Notice that the ray that leaves the glass is traveling in the same direction as it was before it entered the water.

Different densities within the same medium can cause refraction as well. For example, the air heated by a campfire can cause objects to appear to shimmer because the path of the light is not a straight line. Also, stars appear to twinkle because of variations in the density of Earth's atmosphere.

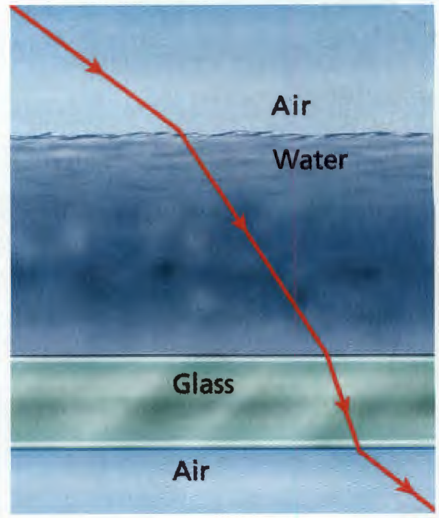


FIGURE 16
Refraction of Light
As light passes from a less dense medium into a more dense medium, it slows down and is refracted.

Math: Mathematical Reasoning 7.2.5

Math Analyzing Data

Bending Light

The index of refraction of a medium is a measure of how much light bends as it travels from air into the medium. The table shows the index of refraction of some common mediums.

1. **Interpreting Data** Which medium causes the greatest change in the direction of a light ray?
2. **Interpreting Data** Which tends to bend light more: solids or liquids?
3. **Predicting** Would light bend if it entered corn oil at an angle from glycerol? Explain.

Index of Refraction

Medium	Index of Refraction
Air (gas)	1.00
Water (liquid)	1.33
Corn oil (liquid)	1.47
Glycerol (liquid)	1.47
Glass, crown (solid)	1.52
Sodium chloride (solid)	1.54
Diamond (solid)	2.42

FIGURE 17
Rainbows
A rainbow forms when sunlight is refracted and reflected by tiny water droplets. **Observing** *What is the order of colors in a rainbow?*

Effects of Refraction One pretty effect of refraction is the separation of visible light into its component colors by a prism. A prism does this because the angle of refraction is different for each color or wavelength of light. The longer the wavelength, the less the wave is bent by a prism. Red light, with the longest wavelength, is refracted the least. Violet light, with the shortest wavelength, is refracted the most. This difference in refraction causes white light to spread out into the colors of the spectrum—red, orange, yellow, green, blue, indigo, and violet.

The same process occurs in water droplets suspended in the air. When white light from the sun shines through the droplets, a rainbow may appear. The water droplets act like tiny prisms, refracting and reflecting the light and separating the colors.

You can also see the effects of refraction if you place a pencil in a glass of water, as shown in Figure 18. As you look at a pencil in a glass of water, the light coming from the pencil to your eye bends as it passes through three different mediums. The mediums are water, glass, and air. As the light passes from one medium to the next, it refracts.

FIGURE 18
Pencil in a Glass
The pencil appears broken because the light bends. As light from the pencil passes from water into glass, it slows down and is refracted. When the light passes from the glass into the air, it speeds up and is refracted again.

Reading Checkpoint **What causes a rainbow?**

Lenses

When you look through a camera, a telescope, or a microscope, you use lenses. A **lens** is a curved piece of glass or other transparent material that refracts light. A lens forms an image by refracting light rays that pass through it. The type of image formed by a lens depends on the shape of the lens and the position of the object.

Convex Lenses A convex lens or magnifying glass is thicker in the center than at the edges. As light rays parallel to the optical axis pass through a convex lens, they converge. The rays meet at the focal point of the lens and continue to travel beyond. The distance from the lens to the focal point is called the focal length. The more curved the lens, the more it refracts light. A convex lens focuses rays of light.

An object's position relative to the focal point determines whether a convex lens forms a real image or a virtual image. Figure 19 shows that if the object is farther away than the focal point, the refracted rays form a real image on the other side of the lens. If the object is between the lens and the focal point, a virtual image forms on the same side of the lens as the object.

Lab zone Try This Activity

Making an Image

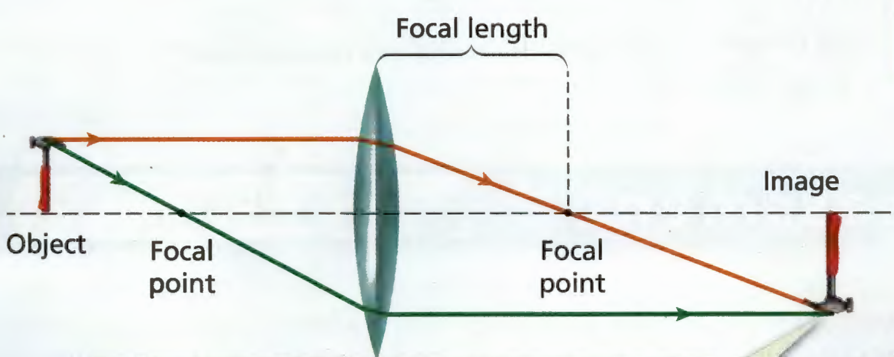
1. Hold a hand lens above a table that sits directly under a ceiling light. Lift the lens up until the sharpest image of the light is formed on the table. How high above the table are you holding the lens? That distance is called the focal length.
2. Now look through a lens above a printed page at a distance of less than the focal length. What do you see?
3. Move the lens until it is farther away from the printed page than the focal length. How does the print appear now?

Classifying What type of image do you see in each step?

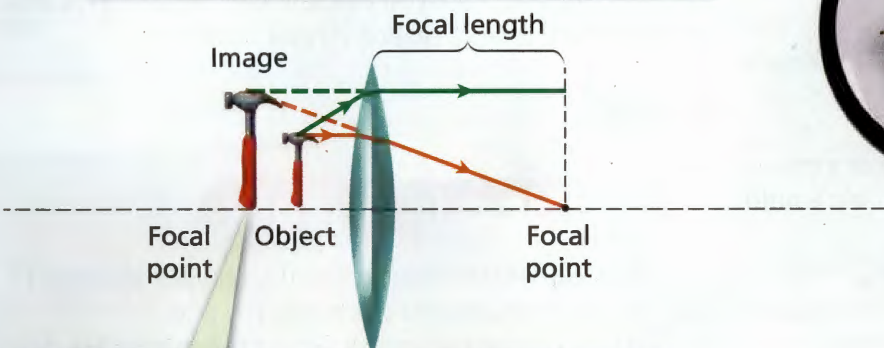
FIGURE 19

Images in Convex Lenses

The type of image formed by a convex lens depends on the object's position.



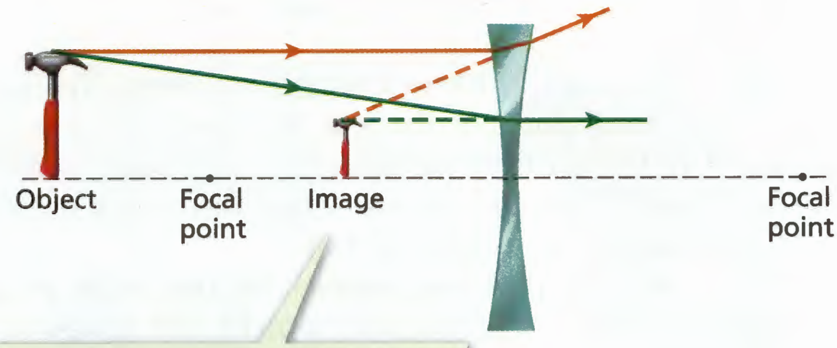
Real Image If the object is farther from the lens than the focal point, a real image forms.



Virtual Image If the object is closer to the lens than the focal point, a virtual image forms.

FIGURE 20
Images in Concave Lenses

A concave lens produces virtual images that are upright and smaller than the object. **Interpreting Diagrams** *Why can a concave lens only form a virtual image?*



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Concave Lenses A **concave lens** is thinner in the center than at the edges. When light rays traveling parallel to the optical axis pass through a concave lens, they bend away, or diverge, from the optical axis and never meet. **A concave lens can produce only virtual images because parallel light rays passing through the lens never meet.**

Figure 20 shows how an image forms in a concave lens. The virtual image is located where the light rays appear to come from. The image is always upright and smaller than the object.

Reading Checkpoint: What is the shape of a concave lens?

Section 3 Assessment

S 7.6.c, 7.6.g E-LA: Reading 7.1.2, Writing 7.2.1

Vocabulary Skill Latin Word Origins The Latin word *planus* means "flat." How does this Latin meaning help you remember what a plane mirror is?

Reviewing Key Concepts

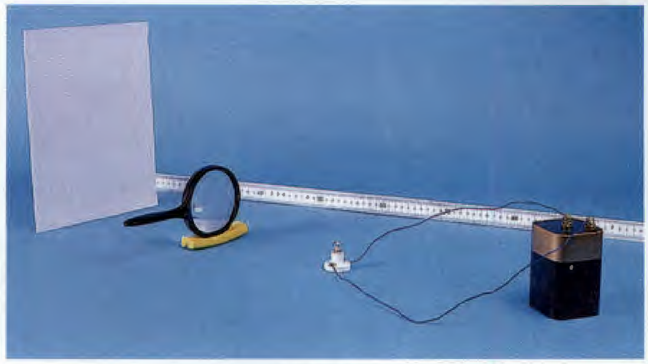
1. a. **Defining** What is reflection?
   b. **Identifying** What does the law of reflection state?
   c. **Predicting** If a beam of light hits a plane mirror at a 30° angle, at what angle would it be reflected?
2. a. **Identifying** What is refraction?
   b. **Relating Cause and Effect** What causes light rays to bend when they enter a new medium at an angle?
   c. **Predicting** If a glass prism were placed in a medium such as water, would it separate white light into different colors? Explain.
3. a. **Defining** What is a lens?
   b. **Comparing and Contrasting** Describe the shapes of a concave lens and a convex lens.
   c. **Interpreting Diagrams** Use Figure 19 to explain how you can tell whether a convex lens will form a real or virtual image.

Writing in Science

Dialogue At a funhouse mirror, your younger brother notices he can make his image disappear as he walks toward the mirror. He asks you to explain, but your answer leads to more questions. Write the dialogue that might take place between you and your brother.

Looking at Images

S 7.6.d, 7.7.c



Problem

How does the distance between an object and a convex lens affect the image formed?

Skills Focus

controlling variables, interpreting data

Materials

- tape
- convex lens
- cardboard stand
- blank sheet of paper
- light bulb and socket
- clay, for holding the lens
- battery and wires
- meter stick
- centimeter ruler

Procedure

1. Tape the paper onto the cardboard stand.
2. Place a lit bulb more than 2 m from the paper. Use the lens to focus light from the bulb onto the paper. Measure the distance from the lens to the paper. This is the approximate focal length of the lens you are using.
3. Copy the data table into your notebook.
4. Now place the bulb more than twice the focal length away from the lens. Adjust the cardboard until the image is focused. Record the size of the image on the paper and note the orientation of the image. Record the distance from the bulb to the lens and from the lens to the cardboard.
5. Now, move the bulb so that it is just over one focal length away from the lens. Record the position and size of the image.

Analyze and Conclude

1. **Controlling Variables** Make a list of the variables in this experiment. Which variables did you keep constant? Which was the manipulated variable? Which were the responding variables?
2. **Observing** What happened to the position of the image as the bulb moved toward the lens?
3. **Interpreting Data** Was the image formed by the convex lens always enlarged? If not, under what conditions was the image reduced?
4. **Predicting** What would happen if you look through the lens at the bulb when it is closer to the lens than the focal point? Explain your prediction.
5. **Communicating** Write a paragraph explaining how the distance between an object and a convex lens affects the image formed. Use ray diagrams to help you summarize your results.

Design an Experiment

Design an experiment to study images formed by convex lenses with different thicknesses. How does the lens thickness affect the position and size of the images? *Obtain your teacher's permission before carrying out your investigation.*

Data Table			
Focal Length of Lens: ____ cm		Height of Bulb: ____ cm	
Distance From Bulb to Lens (cm)	Distance From Lens to Cardboard (cm)	Image Orientation (upright or upside down)	Image Size (height in cm)

Section 4

Seeing Light

CALIFORNIA Standards Focus

S 7.5.g Students know how to relate the structures of the eye and ear to their functions.

S 7.6.b Students know that for an object to be seen, light emitted by or scattered from it must be detected by the eye.

S 7.6.e Students know light is a mixture of many wavelengths (colors) and that retinal cells react differently to different wavelengths.

- How do you see objects?
- What types of lenses are used to correct vision problems?

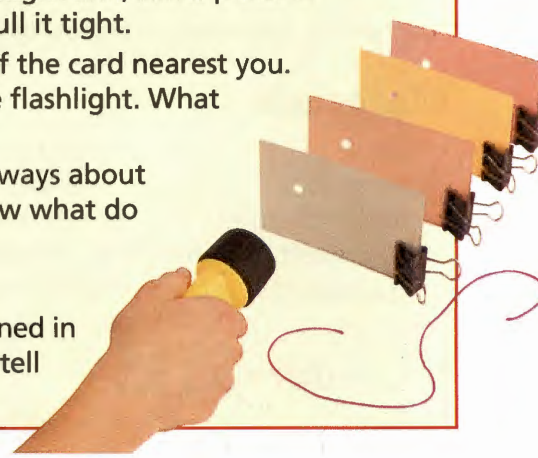
Key Terms

- cornea
- pupil
- iris
- retina
- rods
- cones
- nearsighted
- farsighted

Lab zone **Standards Warm-Up**

How Does a Beam of Light Travel?

1. Punch a hole (about 0.5 cm in diameter) through four large index cards.
2. Use binder clips or modeling clay to stand each card upright so that the long side of the index card is on the tabletop. Space the cards about 10 cm apart, as shown in the photo. To line the holes up in a straight line, run a piece of string through them and pull it tight.
3. Place a flashlight in front of the card nearest you. Shut off all light except the flashlight. What do you see on the wall?
4. Move one of the cards sideways about 3 cm and repeat Step 3. Now what do you see on the wall?



Think It Over

Inferring Explain what happened in Step 4. What does this activity tell you about the path of light?

You return from a field trip to a nearby pond, carrying a bottle of water you collected. Carefully, you place a drop of water onto a slide and look through it using a microscope. At first, the image appears fuzzy. You turn the focus adjustment knobs. Suddenly the image becomes sharp. You are amazed to see a world of tiny creatures living in the drop of water!

In the next lesson, you will learn about optical tools that help scientists see things that are very small. Some of the tools are complex, with many parts that have to work together to produce a clear image. Just as you have to focus a microscope, your eye has to focus light for you to see clearly. In this lesson, you will learn how the many parts of your eye work together so you can see.

◀ **Focusing light**

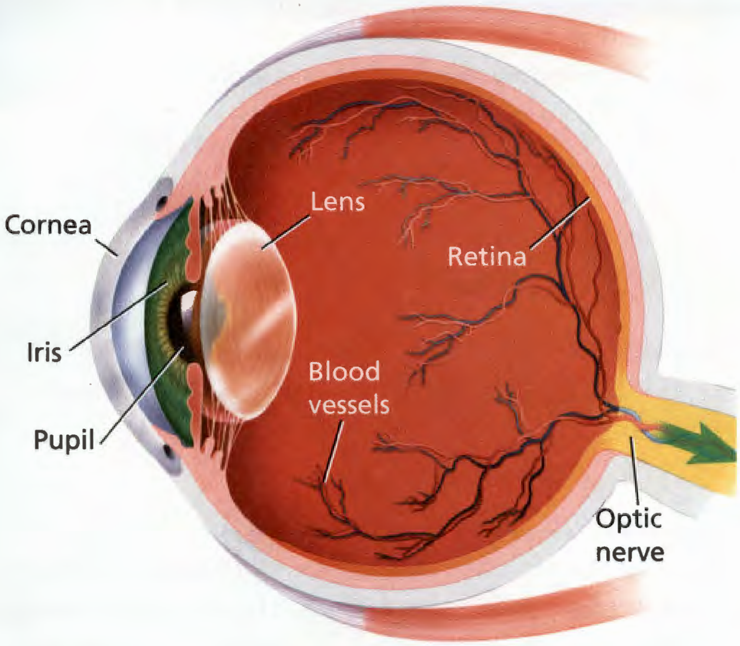
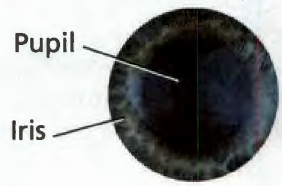


FIGURE 21
The Eye
Your eyes allow you to sense light. The pupil is the opening through which light enters the eye. In bright light, the pupil becomes smaller. In dim light, the pupil enlarges and allows more light to enter the eye. **Interpreting Diagrams** *What structure adjusts the size of the pupil?*

Pupil and Iris
The iris controls the size of the pupil, which determines how much light enters the eye.



Dim Light The iris contracts, making the pupil large.

Bright Light The iris expands, making the pupil small.

Vision
Your eyes sense light. The eye is a complex structure with many parts, as you can see in Figure 21. Each part plays a role in vision. **When light from an object enters your eye, your eye sends a signal to your brain and you see the object.**

Light Enters the Eye Light enters the eye through the transparent front surface called the **cornea** (KAWR nee uh). The cornea protects the eye. It also acts as a lens to help focus light rays. Then, light enters the pupil, the part of the eye that looks black. The **pupil** is an opening through which light enters the inside of the eye. In dim light, the pupil becomes larger to allow in more light. In bright light, the pupil becomes smaller to allow in less light. The **iris** is a ring of muscle that contracts and expands to change the size of the pupil. The iris gives the eye its color. In most people the iris is brown; in others it is blue, green, or hazel.

An Image Forms After entering the pupil, the light passes through the lens. The lens bends light to form an upside-down image on the retina. The **retina** is a layer of cells that lines the inside of the eyeball.

The retina is made up of tiny, light-sensitive cells called rods and cones. **Rods** contain a pigment that responds to small amounts of light. **Cones** respond to color. They detect red light, green, or blue light. Cones respond best in bright light. Rods and cones help change images on the retina into signals that travel to the brain along the optic nerve.

Reading Checkpoint Where does an image form in the eye?

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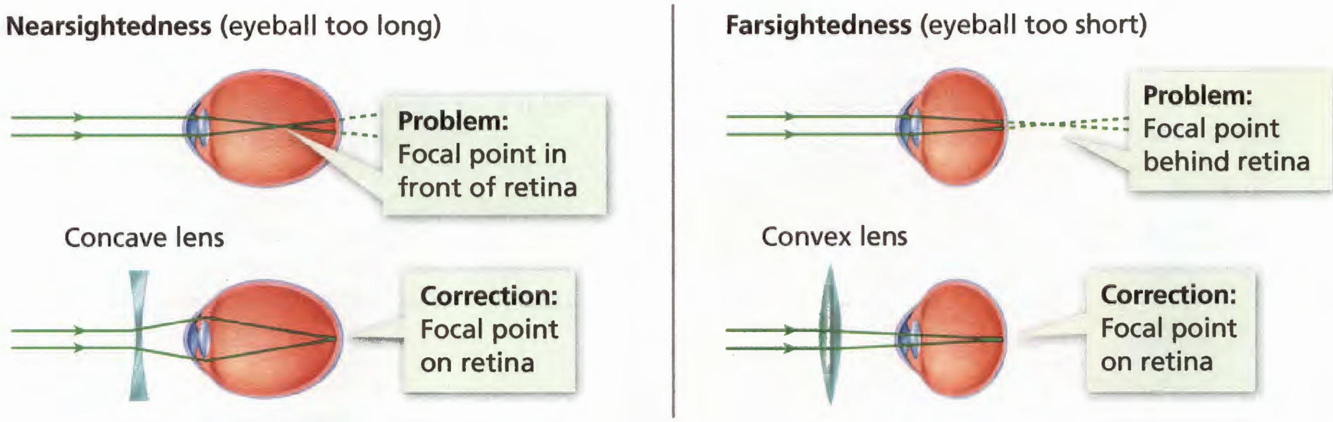


FIGURE 22
Correcting Vision
Nearsightedness and farsightedness are caused when the eyeball is too long or too short. Both can be corrected with lenses.

Correcting Vision If the eyeball is slightly too long or too short, the image on the retina is out of focus. Fortunately, wearing glasses or contact lenses can correct this type of vision problem. **Concave lenses are used to correct nearsightedness. Convex lenses are used to correct farsightedness.**

A **nearsighted** person can see nearby things clearly, but objects at a distance are blurred. The eyeball is too long, so the lens focuses the image in front of the retina. To correct this, a concave lens in front of the eye spreads out light rays before they enter the eye. As a result, the image forms on the retina.

A **farsighted** person can see distant objects clearly, but nearby objects appear blurry. The eyeball is too short, so the image that falls on the retina is out of focus. A convex lens corrects this by bending light rays toward each other before they enter the eye. An image then focuses on the retina.

Section 4 Assessment

S 7.5.g, 7.6.b, 7.6.e, E-LA: Reading 7.2.0, Writing 7.2.1

Target Reading Skill **Preview Visuals**
Use a graphic organizer to answer Question 2.

Reviewing Key Concepts

1. a. **Listing** List the parts of the eye in the order in which light interacts with them.
   b. **Explaining** How is an image formed on the retina?
   c. **Sequencing Events** What happens to light after it strikes the retina?
2. a. **Reviewing** What types of lenses help correct vision problems?
   b. **Describing** Describe a nearsighted person's eye.
   c. **Comparing and Contrasting** With uncorrected vision, where does an image form in a nearsighted person's eye? In a farsighted person's eye?

Writing in Science

Fictional Narrative Imagine that you meet an alien whose eyes work by seeing infrared light rather than visible light. Write a dialogue in which you explain to the alien the colors of light that you see.

Section 5

Optical Tools

CALIFORNIA **Standards Focus**

S 7.6.d Students know how simple lenses are used in a magnifying glass, the eye, a camera, a telescope, and a microscope.

How are lenses used in cameras, telescopes, and microscopes?

Key Terms

- camera
- telescope
- refracting telescope
- objective
- eyepiece
- reflecting telescope
- microscope
- electron microscope

Lab zone **Standards Warm-Up**

How Does a Pinhole Viewer Work?

1. Carefully use a pin to make a tiny hole in the center of the bottom of a paper cup.
2. Place a piece of wax paper over the open end of the cup. Hold the paper in place with a rubber band.
3. Turn off the room lights. Point the end of the cup with the hole in it at a bright window. **CAUTION:** *Do not look directly at the sun.*
4. Look at the image on the wax paper.

Think It Over

Classifying Describe the image you see. Is is upside down or right-side up? Is it smaller or larger than the actual object? What type of image is it?

As you walk through your neighborhood, you can see evidence of life all around you. People, dogs, cats, squirrels, and trees are all types of living beings that you may interact with every day. But there is also life you can't see: tiny creatures that are not visible to the eye without help.

Since the 1600s, scientists have built many optical tools using lenses. Cameras allow them to record photographs of the objects they see. Telescopes help them see objects that are very far away. And microscopes help them see tiny nearby objects by magnifying them many times. Without a microscope, you couldn't see the detail in the water flea at the left. The water flea is only about 1 millimeter in size, not much bigger than the period at the end of this sentence.

◀ **Image of a water flea taken with a microscope**

Video Field Trip
Discovery Channel School
Light

Cameras

A **camera** uses one or more lenses to focus light, and film to record an image. Figure 23 shows the structure of a camera. Light from an object travels to the camera and passes through the lens. **The lens of the camera focuses light to form a real, upside-down image on film in the back of the camera.** In many cameras, the lens automatically moves closer to or away from the film until the image is focused.

To take a photo, you press a button that briefly opens the shutter, a screen in front of the film. Opening the shutter allows light passing through the lens to hit the film. The diaphragm is a device with a hole called an aperture that can be made smaller or larger. The aperture can be adjusted in size to control the amount of light hitting the film, similar to how the iris controls the size of the pupil in your eye.

Reading Checkpoint **What part of a camera controls the amount of light that enters the camera?**

FIGURE 23
Camera
A camera uses a lens to project an image onto film. **Interpreting Diagrams** *What happens to each light ray as it passes through the lens?*

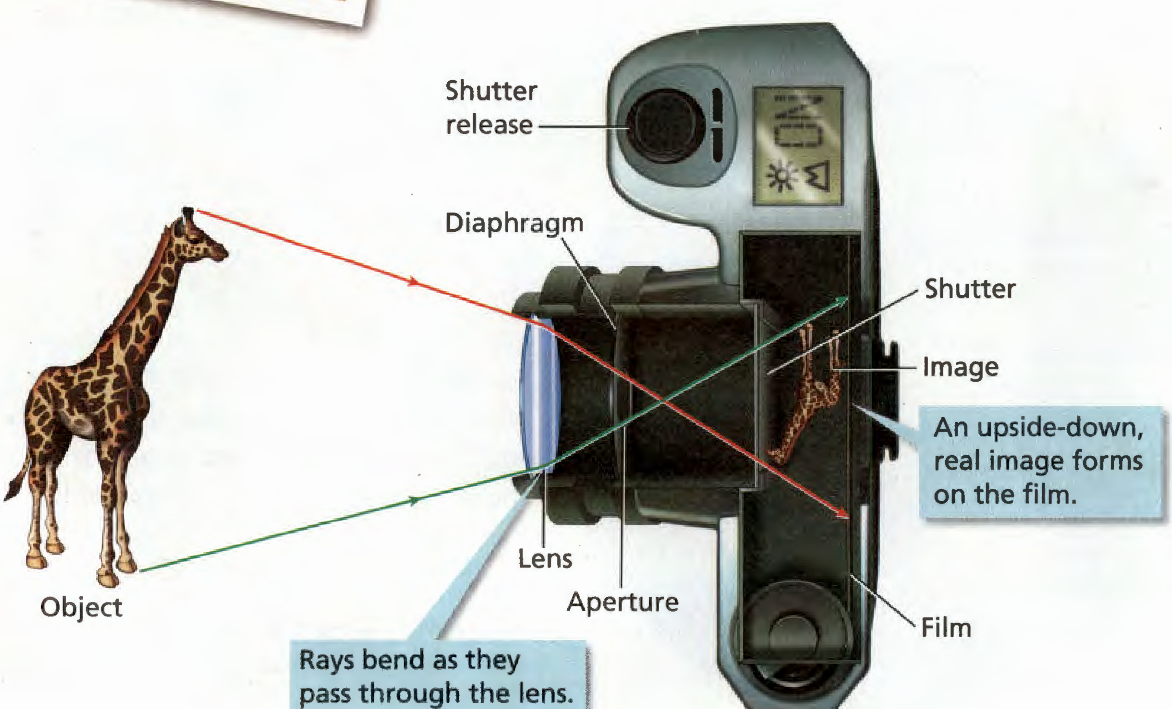
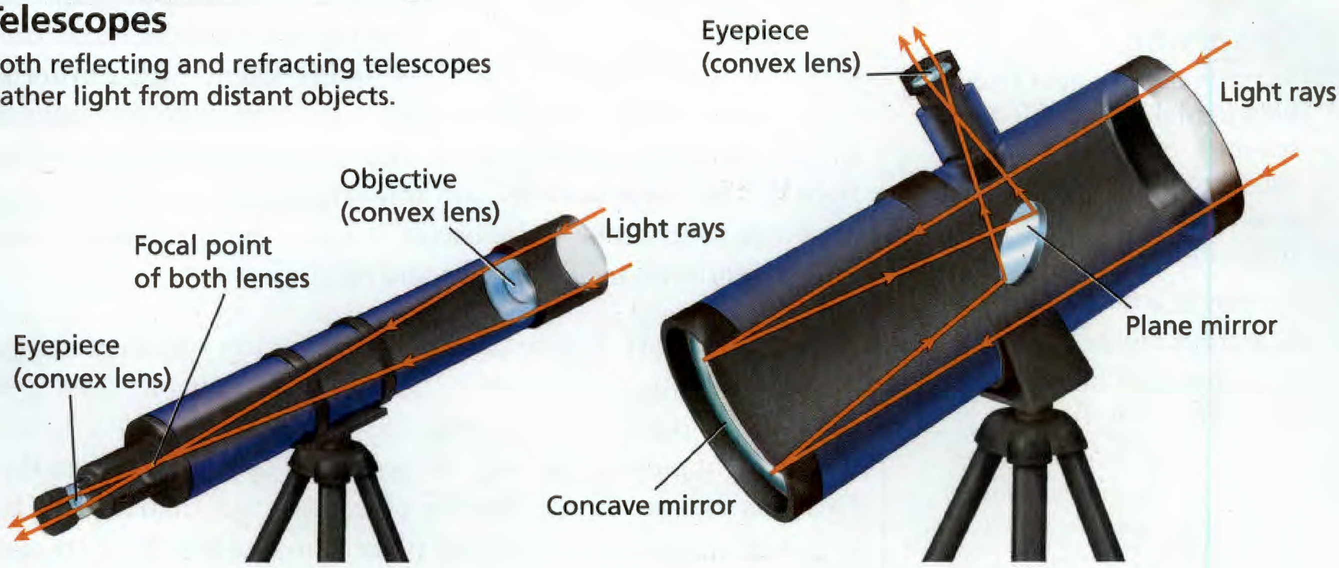


FIGURE 24
Refracting and Reflecting Telescopes

Both reflecting and refracting telescopes gather light from distant objects.



Telescopes

Distant objects are difficult to see because light from them has spread out by the time it reaches your eyes. Your eyes are too small to gather much light. A **telescope** forms enlarged images of distant objects. **Telescopes use combinations of lenses or mirrors to collect and focus light from distant objects.** The most common use of telescopes is to study objects in space. Binoculars, too, enable people to see distant objects. Unlike telescopes, binoculars have two eyepieces.

Figure 24 shows the two main types of telescopes: refracting telescopes and reflecting telescopes. A **refracting telescope** consists of two convex lenses, one at each end of a tube. The larger lens is called the objective. The **objective** gathers the light coming from an object and focuses the rays to form a real image. The lens close to your eye is called the eyepiece. The **eyepiece** magnifies the image so you can see it clearly. The image seen through the refracting telescope in Figure 24 is upside down.

A **reflecting telescope** uses a large concave mirror to gather light. The mirror collects light from distant objects and focuses the rays to form a real image. A small mirror inside the telescope reflects the image to the eyepiece. The images you see through a reflecting telescope are upside down, just like the images seen through a refracting telescope.

Reading Checkpoint What are the objective and the eyepiece?

Lab zone Try This Activity

What a View!

You can use two hand lenses of different strengths to form an image.

1. Hold the stronger lens close to your eye.
2. Hold the other lens at arm's length.
3. Use your lens combination to view a distant object. **CAUTION:** *Do not look at the sun.* Adjust the distance of the farther lens until the image is clear.

Classifying What type of image do you see? What type of telescope is similar to this lens combination?

Lab zone Skills Activity

Observing

Sometimes your eyes need help in making detailed scientific observations. What is the correct optical tool to observe each of the following?

1. Birds at a bird feeder
2. Stars at night.
3. A sample of blood

Microscopes

To look at small, nearby objects you can use a microscope. A **microscope** is an optical tool that makes small objects look larger. You will use it when studying life science. **A microscope uses a combination of lenses to form enlarged images of tiny objects.** Scientists today use two kinds of microscopes: light microscopes and electron microscopes.

For a microscope to be useful, it must combine two important properties—magnification and resolution.

Magnification Magnification is the ability to make things look larger than they are. The lenses in light microscopes magnify an object by bending the light that passes through them. Light passing through a convex lens converges. When this light hits the eye, the eye sees the object as larger than it really is.

Since light microscopes have more than one lens, they are also called compound microscopes. Light passes through a specimen and then through two lenses. The first lens, the objective, magnifies the object. Then a second lens, the eyepiece, further magnifies the enlarged image. The total magnification of the microscope is equal to the magnifications of the two lenses multiplied together. Figure 25 shows a hair follicle at two different magnifications, 18 times and 63 times its real size. You can learn more about using microscopes in Appendix B.

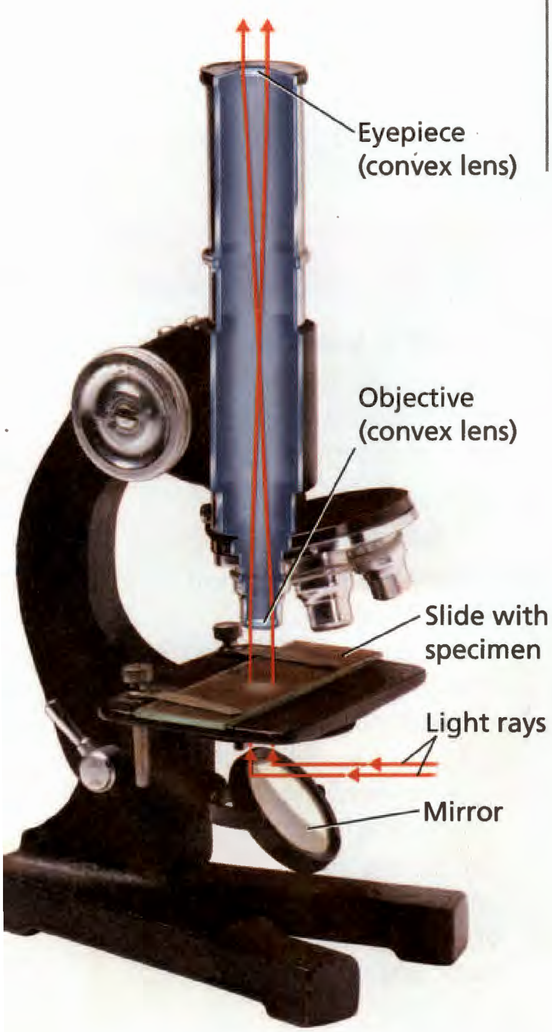


FIGURE 25
Light Microscope
A compound microscope can change magnification. The two pictures of hair follicles were taken at different magnifications. **Inferring** *What is an advantage of higher magnification?*

▲ 18 times actual size

▲ 63 times actual size

Resolution To create a useful image, a microscope must help you see individual parts clearly. The ability to clearly distinguish the individual parts of an object is called resolution. Resolution is another term for the sharpness of an image. For example, a newspaper photograph is really made up of a collection of small dots. If you put the photo under a microscope, you can see the separate dots because the microscope improves resolution.

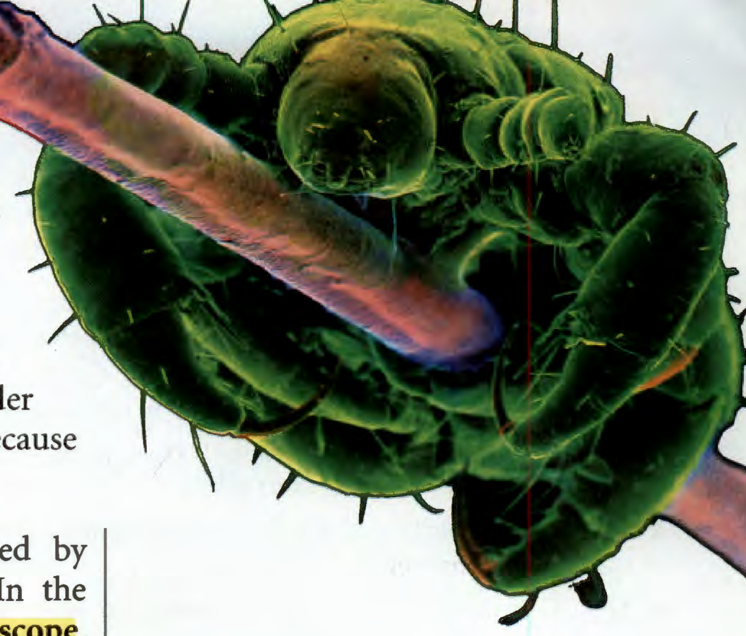


FIGURE 26
Electron Microscope Picture
A head louse clings to a human hair. This picture was taken with a scanning electron microscope. The louse has been magnified to more than 100 times its actual size.

Electron Microscopes The microscopes used by early researchers were all light microscopes. In the 1930s, scientists developed the **electron microscope**. Electron microscopes use a beam of tiny particles called electrons instead of light to produce a magnified image. Electron microscopes can take pictures of extremely small objects—much smaller than those that can be seen with light microscopes. The resolution of electron microscopes is much better than the resolution of light microscopes.

Section 5 Assessment

S 7.6.d E-LA: Reading 7.2.0, Writing 7.2.4

Target Reading Skill **Preview Visuals** List three questions and answers that you wrote about Figure 25.

Reviewing Key Concepts

1. a. **Reviewing** How are lenses used in telescopes, microscopes, and cameras?
   b. **Comparing and Contrasting** Compare and contrast how images form in a refracting telescope, a reflecting telescope, and a microscope.
   c. **Classifying** A pair of binoculars has two lenses in each tube. Which type of optical instrument are the binoculars most similar to?
2. a. **Reviewing** What are the parts of a camera?
   b. **Comparing and Contrasting** How is the aperture of the camera like the pupil?
   c. **Explaining** Why does a camera need an aperture to control the amount of light hitting the film?
3. a. **Reviewing** What does a microscope enable people to do?
   b. **Defining** What is magnification?
   c. **Calculating** If one lens has a magnification of 10, and the other lens has a magnification of 50, what is the total magnification?
   d. **Comparing and Contrasting** Contrast the way light microscopes and electron microscopes magnify objects.

Writing in Science

Advertisement A company has asked you to write an advertisement for its new, easy-to-use camera. In the ad, the company wants you to describe the camera's features so that buyers will understand how the camera works. Be sure to mention the shutter, lens, diaphragm, and aperture.

Chapter 2

Study Guide

The BIG Idea Light entering the eye is bent by the cornea and lens to form an image on the retina.

1 Waves and the Electromagnetic Spectrum

Key Concepts — S 7.6.a

- Mechanical waves are produced when a source of energy causes a medium to vibrate.
- The basic properties of waves are amplitude, wavelength, frequency, and speed.
- The electromagnetic spectrum is made up of radio waves, infrared rays, visible light, ultraviolet rays, X-rays, and gamma rays.

Key Terms

• wave • energy • medium • crest • trough
• amplitude • wavelength • frequency
• hertz • electromagnetic radiation
• electromagnetic spectrum • visible light

2 Visible Light and Color

Key Concepts — S 7.6.e, 7.6.f

- When light strikes an object, the light can be reflected, transmitted, or absorbed.
- The color of an opaque object is the color of the light it reflects.
- When combined in equal amounts, the three primary colors of light produce white light.
- As pigments are added together, fewer colors of light are reflected and more are absorbed.

Key Terms

• transparent • translucent • opaque
• primary colors • secondary color
• complementary colors • pigments

3 Reflection and Refraction

Key Concepts — S 7.6.c, 7.6g

- The law of reflection states that the angle of incidence equals the angle of reflection.
- When light rays enter a medium at an angle, the change in speed causes the rays to bend, or change direction.
- An object's position relative to the focal point determines whether a convex lens forms a real image or a virtual image.
- A concave lens can produce only virtual images because parallel light rays passing through the lens never meet.

Key Terms

• reflection • law of reflection • plane mirror
• image • virtual image • concave mirror
• optical axis • focal point • real image
• convex mirror • refraction • lens
• convex lens • concave lens

4 Seeing Light

Key Concepts — S 7.5.g, 7.6.b, 7.6.e

- When light from an object enters your eye, your eye sends a signal to your brain and you see the object.
- Concave lenses correct nearsightedness. Convex lenses correct farsightedness.

Key Terms

• cornea • pupil • iris • retina • rods
• cones • nearsighted • farsighted

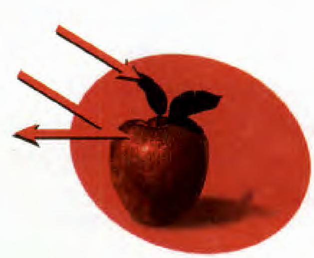
5 Optical Tools

Key Concepts — S 7.6.d

- The camera lens camera focuses light to form a real, upside-down image on film in the back of the camera.
- Telescopes use combinations of lenses or mirrors to collect and focus light from distant objects.
- A microscope uses a combination of lenses to form enlarged images of tiny objects.

Key Terms

• camera • telescope • refracting telescope
• objective • eyepiece • reflecting telescope
• microscope • electron microscope



Review and Assessment

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Target Reading Skill

Previewing Visuals Complete a graphic organizer for the illustration on Law of Reflection, Figure 11. Add more questions and answers to show that you understand the law of reflection.

Law of Reflection

Q.	In your own words, what is the subject of this illustration?
A.	**a.** ___?___
Q.	What is the incoming wave?
A.	**b.** ___?___
Q.	How is the incoming wave different from the reflected wave?
A.	**c.** ___?___

Reviewing Key Terms

Choose the letter of the best answer.

1. A wave transfers
a. energy. **b.** particles.
c. water. **d.** air.

2. Two complementary colors of light that can combine to form white light are
a. red and green.
b. green and cyan.
c. cyan and yellow.
d. yellow and blue.

3. A curved piece of glass or other transparent material that is used to refract light is a
a. plane mirror. **b.** concave mirror.
c. convex mirror. **d.** concave lens.

4. The opening through which light enters the inside of your eye is the
a. cornea. **b.** iris.
c. pupil. **d.** retina.

5. A device used to make objects that are far away appear closer is a(n)
a. camera.
b. telescope.
c. microscope.
d. electron microscope.

Complete the following sentences so that your answers clearly explain the key terms.

6. Visible light is a tiny part of the whole **electromagnetic spectrum,** which also includes _______ .

7. The colors in this textbook come from **pigments,** which are _______ .

8. If you look into a plane mirror, you see a **virtual image,** which is _______ .

9. The lens of the eye forms an image on the **retina,** which is _______ .

10. A **microscope** allows you to see something very small, because _______ .

Writing in Science

Persuasive Letter Write a short letter to your representative in Congress asking him or her to continue supporting telescopes in space. Include at least two advantages of space telescopes in your letter.

Video Assessment
Discovery Channel School
Light

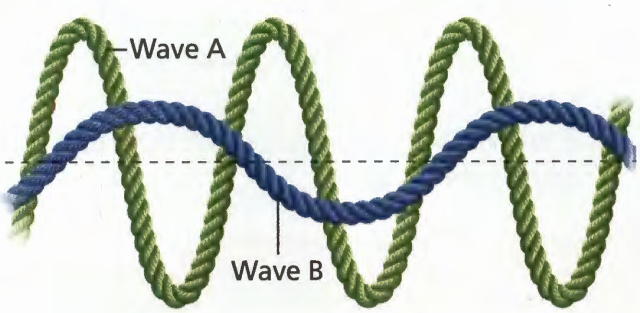
Review and Assessment

Checking Concepts

11. How can you measure the amplitude of a wave?
12. How do you know that electromagnetic waves can travel through a vacuum?
13. Explain why the energy of infrared waves is greater than the energy of radio waves.
14. Which color of light has the longest wavelength? The shortest wavelength?
15. Describe transparent, translucent, and opaque materials. Give an example of each.
16. Why do you see the petals of a rose as red and the leaves as green?
17. Sketch the optical axis and focal point(s) of a concave lens and a convex lens.
18. Describe real and virtual images. How can each type of image be formed by mirrors?
19. Which parts of the eye help you see colors?
20. How are lenses used in a microscope?

Thinking Critically

Use the illustration to answer Question 21.



21. **Comparing and Contrasting** The waves shown travel at the same speed.
    a. Which wave has the higher frequency?
    b. Which has the longer wavelength?
    c. Which has the greater amplitude?
22. **Applying Concepts** Suppose ripples move from one side of a lake to the other. Does the water move across the lake? Explain.
23. **Applying Concepts** Why is it hard to see on a foggy day?
24. **Applying Concepts** Can a plane mirror produce a real image? Explain.
25. **Comparing and Contrasting** How are convex and concave mirrors alike? How are they different?
26. **Comparing and Contrasting** How is a nearsighted person's sight similar to a farsighted person's? How is it different?
27. **Problem Solving** A telescope produces an upside-down image. How could you modify the telescope so the image is upright?
28. **Comparing and Contrasting** How is a microscope similar to a convex lens used as a magnifying lens? How is it different?

Applying Skills

Use the illustration to answer Questions 29–31.

29. **Explaining** What colors of visible light are absorbed by the red apple?
30. **Predicting** In green light, what color would the red apple appear?
31. **Drawing Conclusions** Why do we use ceiling lights that give off white light?

Lab zone Standards Investigation

Performance Assessment Demonstrate your optical instrument to your class. Explain how your instrument works and how it can be used. Use diagrams that show how the mirrors or lenses in your instrument reflect or refract light.

CALIFORNIA Standards Practice

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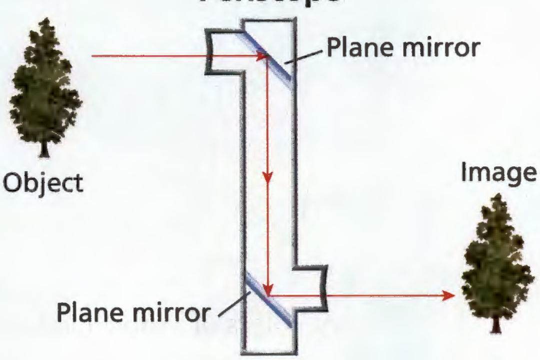
Choose the letter of the best answer.

1. If you shine a green light on a red apple, the apple's color appears
   A red.
   B green.
   C blue.
   D black. **S 7.6.b**

2. A prism disperses white light into many colors because the prism
   A obeys the law of reflection.
   B bends the different colors of light by different angles.
   C is opaque.
   D acts like the retina's cone cells. **S 7.6.e**

Use the diagram to answer Question 3.

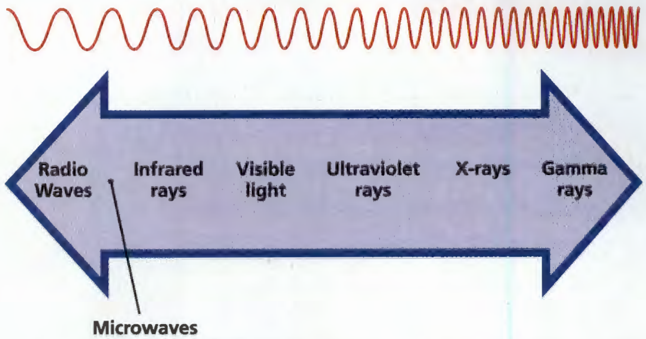
Periscope



3. If you want to build a periscope, what measurement is most important?
   A the angle between the two mirrors
   B the distance between the mirrors
   C the width of the mirrors
   D the width of the tube **S 7.6.g**

4. A wave enters a new medium. The wave
   A slows down and bends.
   B speeds up and bends.
   C may slow down or speed up.
   D must always bend. **S 7:6.c**

Use the diagram to answer Question 5.



5. The amount of energy carried by an electromagnetic wave increases with frequency. Which of the following groups of waves is listed correctly in order of increasing energy?
   A X-rays, visible light, radio waves
   B radio waves, visible light, X-rays
   C infrared rays, visible light, radio waves
   D visible light, gamma rays, X-rays **S 7.6.a**

6. In dim light, which part of the eye gets larger to let in more light?
   A pupil
   B iris
   C lens
   D cornea **S 7.5.g**

7. If light passes through a medium without being scattered, the medium is classified as
   A reflective.
   B opaque.
   C translucent.
   D transparent. **S 7.6.f**

Apply the BIG Idea

8. How is a human eye like a camera? Describe the function of each part of the eye and identify the part of a camera that has the same function. Use the following terms in your answer: *lens, diaphragm, aperture, film, pupil,* and *retina.* **S 7.5.g, 7.6.d**