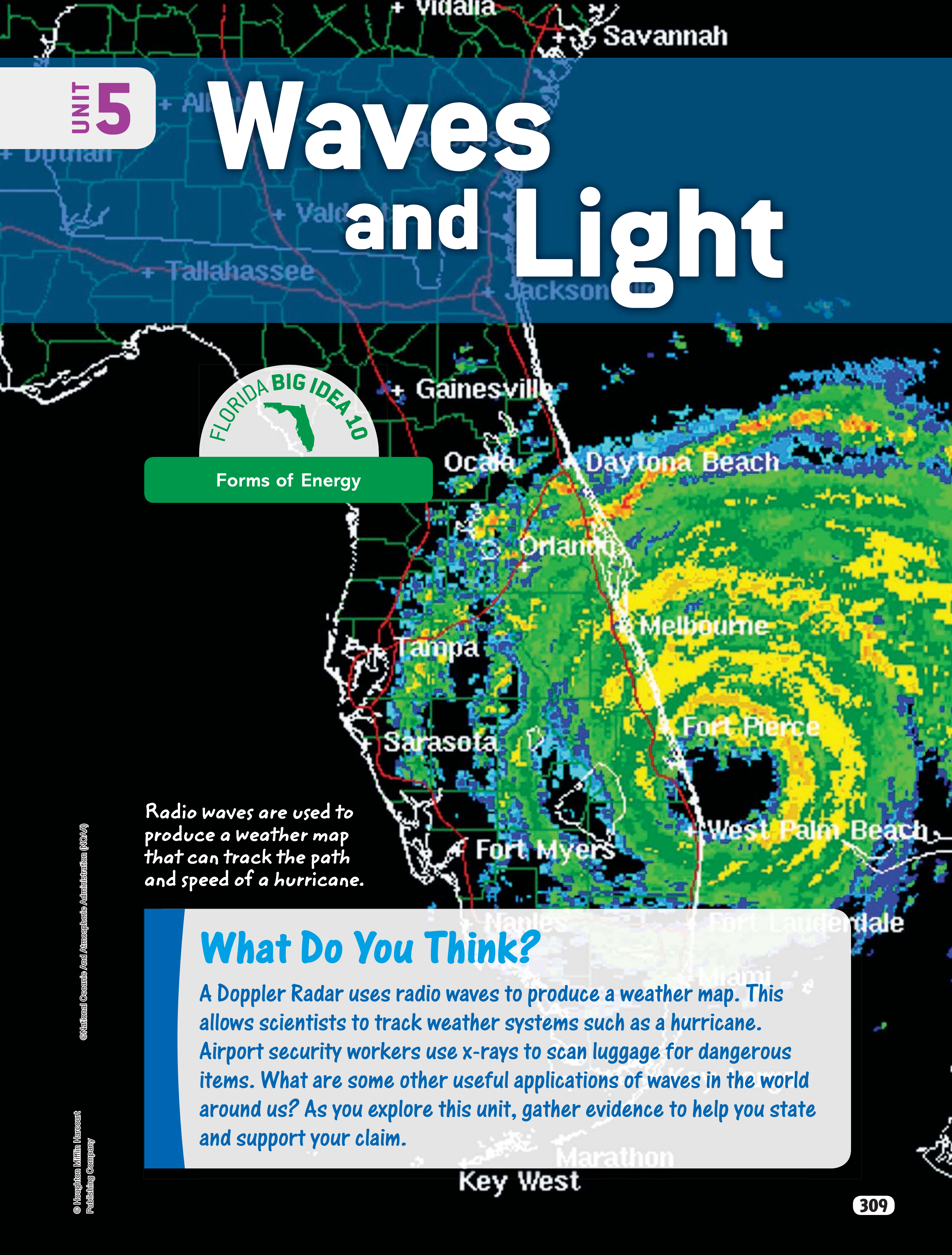
UNIT 5 Waves and Light

FLORIDA BIG IDEA 10

Forms of Energy



Radio waves are used to produce a weather map that can track the path and speed of a hurricane.

What Do You Think?

A Doppler Radar uses radio waves to produce a weather map. This allows scientists to track weather systems such as a hurricane. Airport security workers use x-rays to scan luggage for dangerous items. What are some other useful applications of waves in the world around us? As you explore this unit, gather evidence to help you state and support your claim.

UNIT 5

Waves and Light

CITIZEN SCIENCE

Looking Into Space

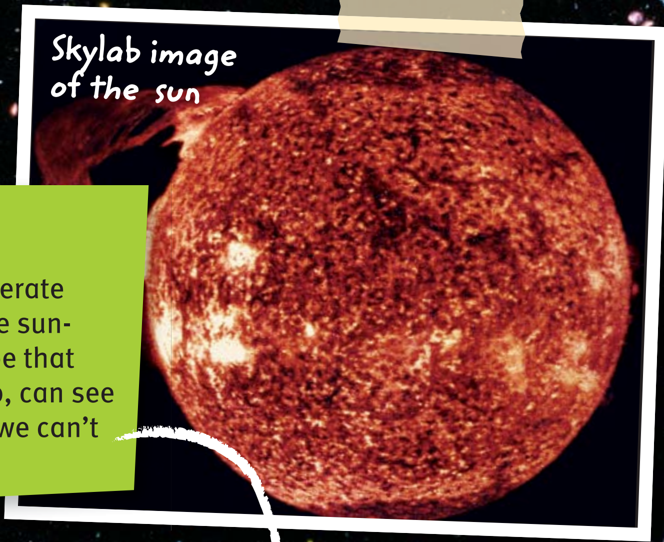
The first telescopes were refracting telescopes, which used a pair of lenses to gather light. Today, astronomers also use reflecting telescopes, which gather light with large mirrors, to observe distant objects.


Galileo observing space

1609
Galileo Galilei used a refracting telescope to observe phases of Venus, the moons of Jupiter, the surface of the moon, sunspots, and a supernova.

List other tools that use lenses and think of a use for each one.


Telescope similar to Isaac Newton's


Skylab image of the sun

1973

Telescopes that operate from space, like the sun-observing telescope that was aboard Skylab, can see all kinds of things we can't see from Earth.

1668

Isaac Newton built a reflecting telescope that used a curved mirror to gather light. Newton's mirror did not split light into colors like the lenses in early refracting telescopes did.

1990

The orbiting Hubble Space Telescope can capture detailed images of objects very far from Earth. The Hubble Space Telescope has taken images of the most distant galaxies astronomers have ever seen.


Hubble Space Telescope

Take It Home!

Eyes to the Sky

Use a pair of binoculars or a telescope to look at the night sky. Compare what you can see with magnification to what you can see when looking at the same part of the sky without magnification. Draw or write your observations in the chart.

Unmagnified Night Sky	Magnified Night Sky

LESSON 1

Waves

ESSENTIAL QUESTION

What are waves?

By the end of this lesson, you should be able to distinguish between types of waves based on medium and direction of motion.

Ocean waves can cause great destruction. This woodblock print illustrates a great wave threatening boats off the coast of Japan.

SC.7.N.1.1 Define a problem from the seventh grade curriculum, use appropriate reference materials to support scientific understanding, plan and carry out scientific investigation of various types, such as systematic observations or experiments, identify variables, collect and organize data, interpret data in charts, tables, and graphics, analyze information, make predictions, and defend conclusions. **SC.7.P.10.3** Recognize that light waves, sound waves, and other waves move at different speeds in different materials.

Lesson Labs

Quick Labs
- Energy in Sound Waves
- Waves on a Spring
- Seeing Vibrations

Exploration Lab
- Sound Idea

S.T.E.M. Lab
- Building a Speaker

Engage Your Brain

1 Predict Check T or F to show whether you think each statement is true or false.

T	F	
☐	☐	The air around you is full of waves.
☐	☐	Ocean waves carry water from hundreds of miles away.
☐	☐	Sound waves can travel across outer space.
☐	☐	Visible light is a wave.

2 Identify Make a list of items in the classroom that are making waves. Next to each item, write what kind of waves you think it is making.

ACTIVE READING

3 Distinguish Which of the following definitions of *medium* do you think is most likely to be used in the context of studying waves? Circle your answer.

A of intermediate size

B the matter in which a physical phenomenon takes place

C between two extremes

Vocabulary Terms

- **wave**
- **medium**
- **longitudinal wave**
- **transverse wave**
- **mechanical wave**
- **electromagnetic wave**

4 Apply As you learn the definition of each vocabulary term in this lesson, write your own definition or sketch to help you remember the meaning of the term.

Riding the Wave

What are waves?

The world is full of waves. Water waves are just one of many kinds of waves. Sound and light are also waves. A **wave** is a disturbance that transfers energy from one place to another.

Waves Are Disturbances

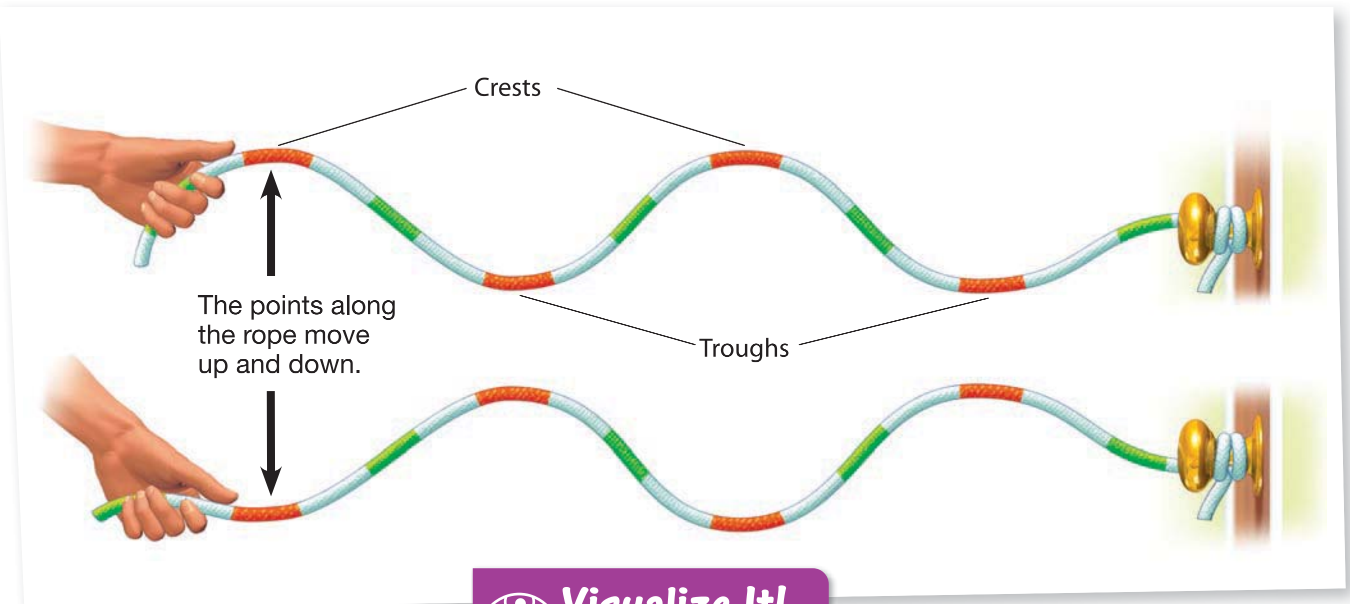
Many waves travel by disturbing a material. The material then returns to its original place. A **medium** is the material through which a wave travels.

You can make waves on a rope by shaking the end up and down. The rope is the medium, and the wave is the up-and-down disturbance. As the part of the rope nearest your hand moves, it causes the part next to it to move up and down too. The motion of this part of the rope causes the next part to move. In this way, the wave moves as a disturbance down the whole length of the rope.

Each piece of the rope moves up and down as a wave goes by. Then the piece of rope returns to where it was before. A wave transfers energy from one place to another. It does not transfer matter. The points where the wave is highest are called crests. The points where the wave is lowest are called troughs.

ACTIVE **READING**

5 Identify Underline the names for the highest and lowest points of a wave.



Visualize It!

6 Claims • Evidence • Reasoning Make a claim about what direction the wave travels. Draw an arrow near the rope to show the direction the wave travels as evidence to support your claim and explain your reasoning.

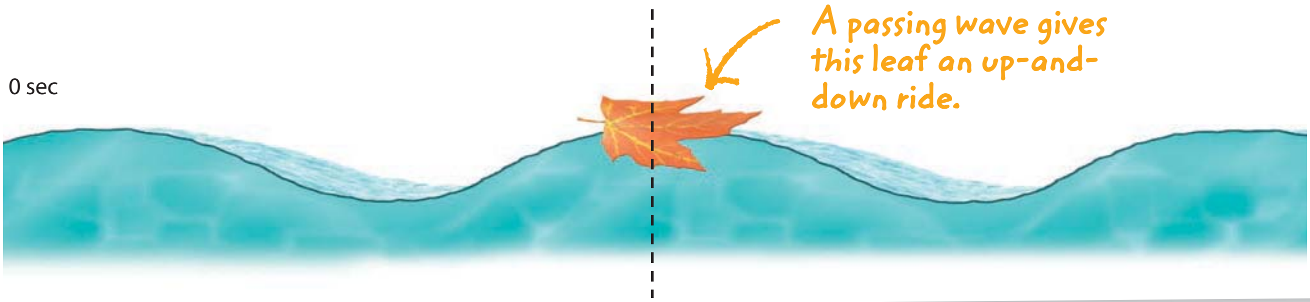
Waves Are a Transfer of Energy

A wave is a disturbance that transfers energy. Some waves need a medium to transfer energy, such as waves in the ocean that move through water and waves that are carried on guitar or cello strings when they vibrate. Some waves can transfer energy without a medium. One example is visible light. Light waves from the sun transfer energy to Earth across empty space.

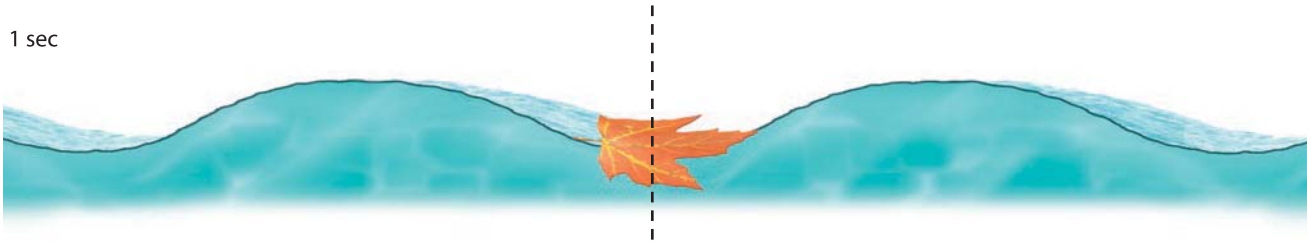
Visualize It!

Each snapshot below shows the passage of a wave. The leaf rises and falls as crests and troughs carry it.

0 sec

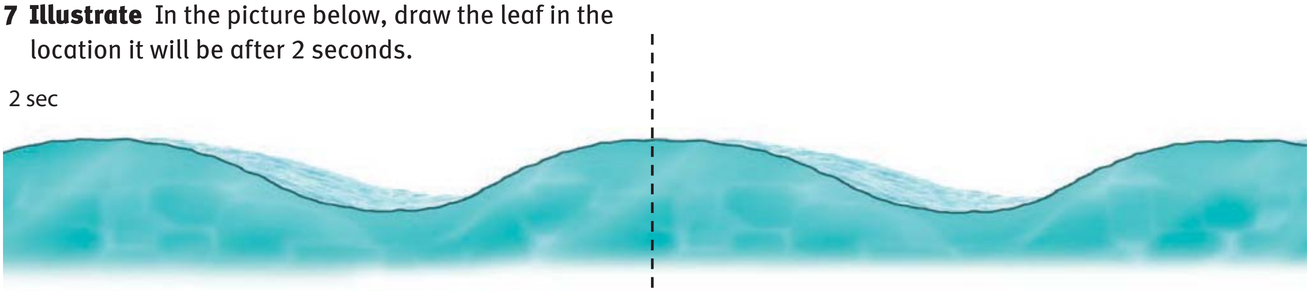


1 sec



7 Illustrate In the picture below, draw the leaf in the location it will be after 2 seconds.

2 sec



8 Model In the space below, draw the leaf and wave as they will appear after 3 seconds.

3 sec

Different Ways

How does a wave transfer energy?

A wave transfers energy in the direction it travels. However, the disturbance may not be in the same direction as the wave. Each wave can be classified by comparing the direction of the disturbance, such as the motion of the medium, with the direction the wave travels.

ACTIVE **READING**

9 Identify As you read, underline the type of wave that sound is.

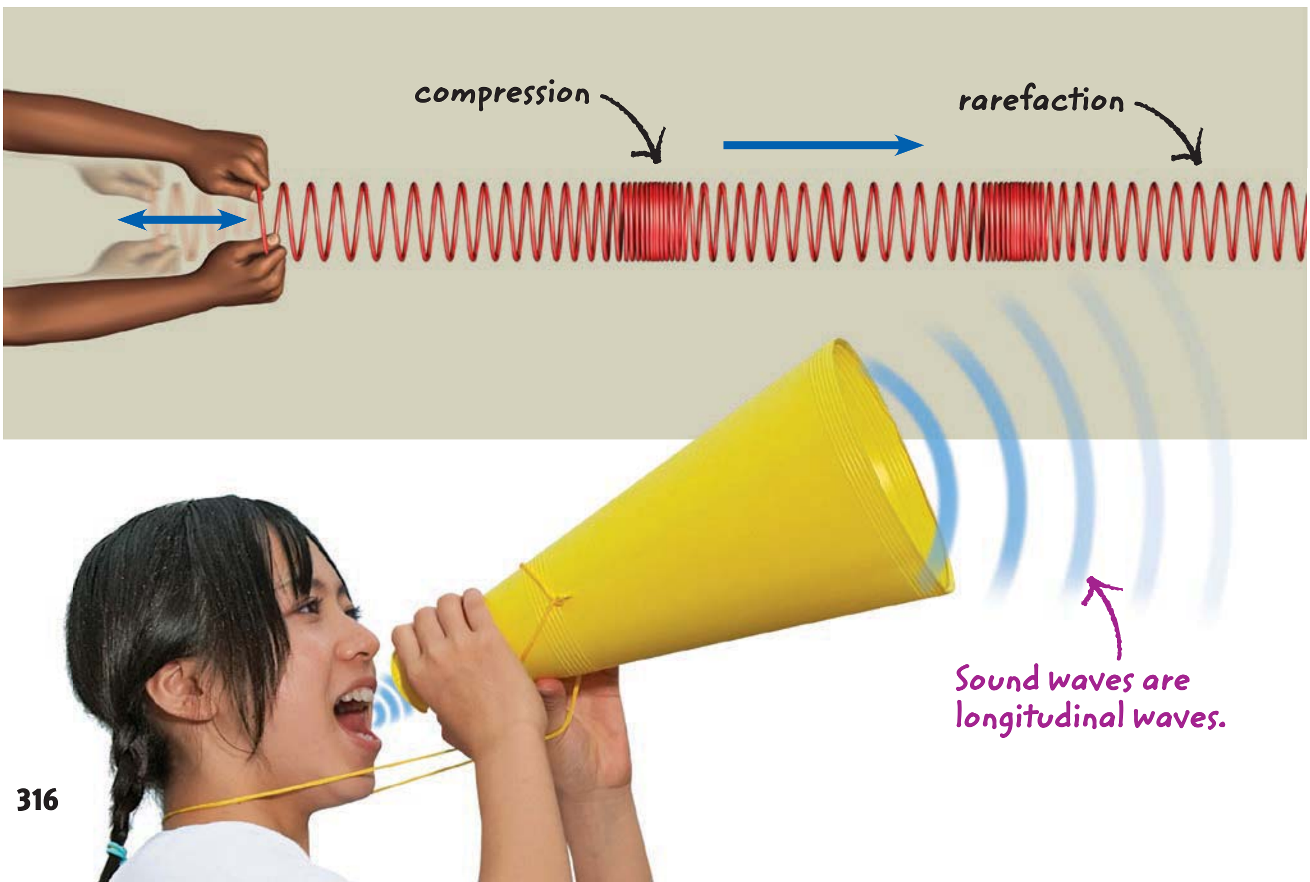
As a Longitudinal Wave

When you pull back on a spring toy like the one below, you spread the coils apart and make a *rarefaction*. When you push forward, you squeeze the coils closer together and make a *compression*. The coils move back and forth as the wave passes along the spring toy. This kind of wave is called a longitudinal wave. In a **longitudinal wave** (lahn•jih•TOOD•n•uhl), particles move back and forth in the same direction that the wave travels, or parallel to the wave.

Sound waves are longitudinal waves. When sound waves pass through the air, particles that make up air move back and forth in the same direction that the sound waves travel.

Visualize It!

10 Label In this longitudinal wave, label the arrow that shows the direction the wave travels with a *T*. Label the arrow that shows how the spring is disturbed with a *D*.



to Transfer Energy

When these fans do "The Wave," they are modeling the way a disturbance travels through a medium.

As a Transverse Wave

The same spring toy can be used to make other kinds of waves. If you move the end of the spring toy up and down, a wave also travels along the spring. In this wave, the spring's coils move up and down as the wave passes. This kind of wave is called a **transverse wave**. In a transverse wave, particles move perpendicularly to the direction the wave travels.

Transverse waves and longitudinal waves often travel at different speeds in a medium. In a spring toy, longitudinal waves are usually faster. An earthquake sends both longitudinal waves (called P waves) and transverse waves (called S waves) through Earth's crust. In this case, the longitudinal waves are also faster. During an earthquake, the faster P waves arrive first. A little while later, the S waves arrive. The S waves are slower but usually more destructive.

A transverse wave and a longitudinal wave can combine to form another kind of wave called a surface wave. Ripples on a pond are an example of a surface wave.

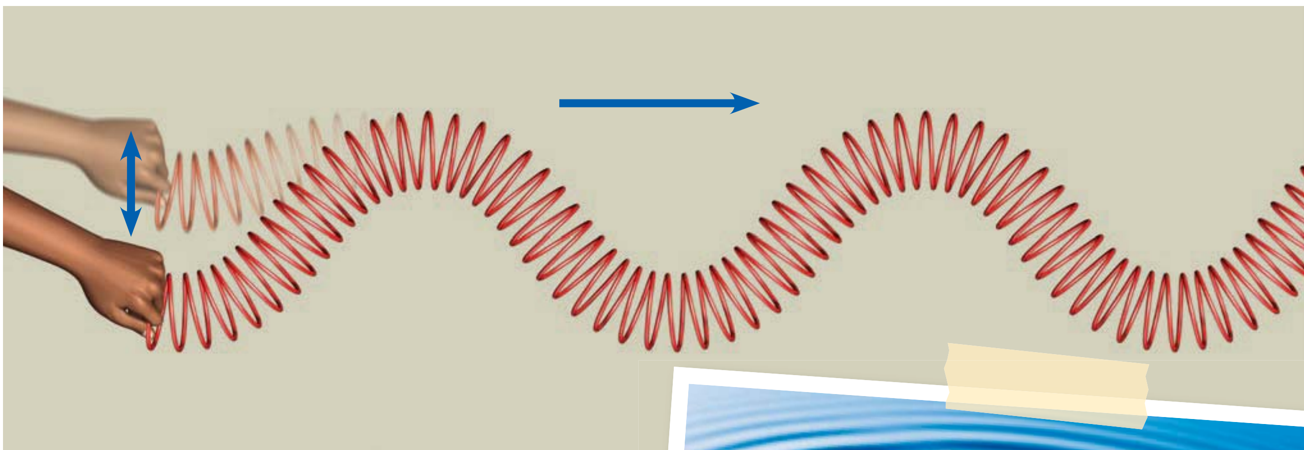
12 State Your Claim Make a claim about what type of wave the stadium wave shown above is.

Visualize It!

11 Label In this transverse wave, label the arrow that shows the direction the wave travels with a *T*. Label the arrow that shows how the spring is disturbed with a *D*.

Think Outside the Book

13 Identify What do the letters *S* in S waves and *P* in P waves stand for? Relate this to earthquakes.



Water waves are surface waves, a combination of transverse and longitudinal waves.

Making Waves

What are some types of waves?

As you have learned, waves are disturbances that transfer energy. Waves can be classified by the direction of disturbance. But they can also be classified by what is disturbed.

Mechanical Waves

Most of the waves we have talked about so far are waves in a medium. For water waves, water is the medium. For earthquake waves, Earth is the medium. A wave that requires a medium through which to travel is called a **mechanical wave**.

Some mechanical waves can travel through more than one medium. For example, sound waves can move through air, through water, or even through a solid wall. The waves travel at different speeds in the different media. Sound waves travel much faster in a liquid or a solid than in air.

Mechanical waves can't travel without a medium. Suppose all the air is removed from beneath a glass dome, or bell jar, as in the photograph below. In a vacuum, there is no air to transmit sound waves. The vibrations made inside the bell jar can't be heard.

Electromagnetic Waves

Are there waves that can travel without a medium? Yes. Sunlight travels from the sun to Earth through empty space. Although light waves can travel through a medium, they can also travel without a medium. Light and similar waves are called electromagnetic (EM) waves. An **electromagnetic wave** is a disturbance in electric and magnetic fields. They are transverse waves. Examples of EM waves include

- visible light
- radio waves
- microwaves
- ultraviolet (UV) light
- x-rays

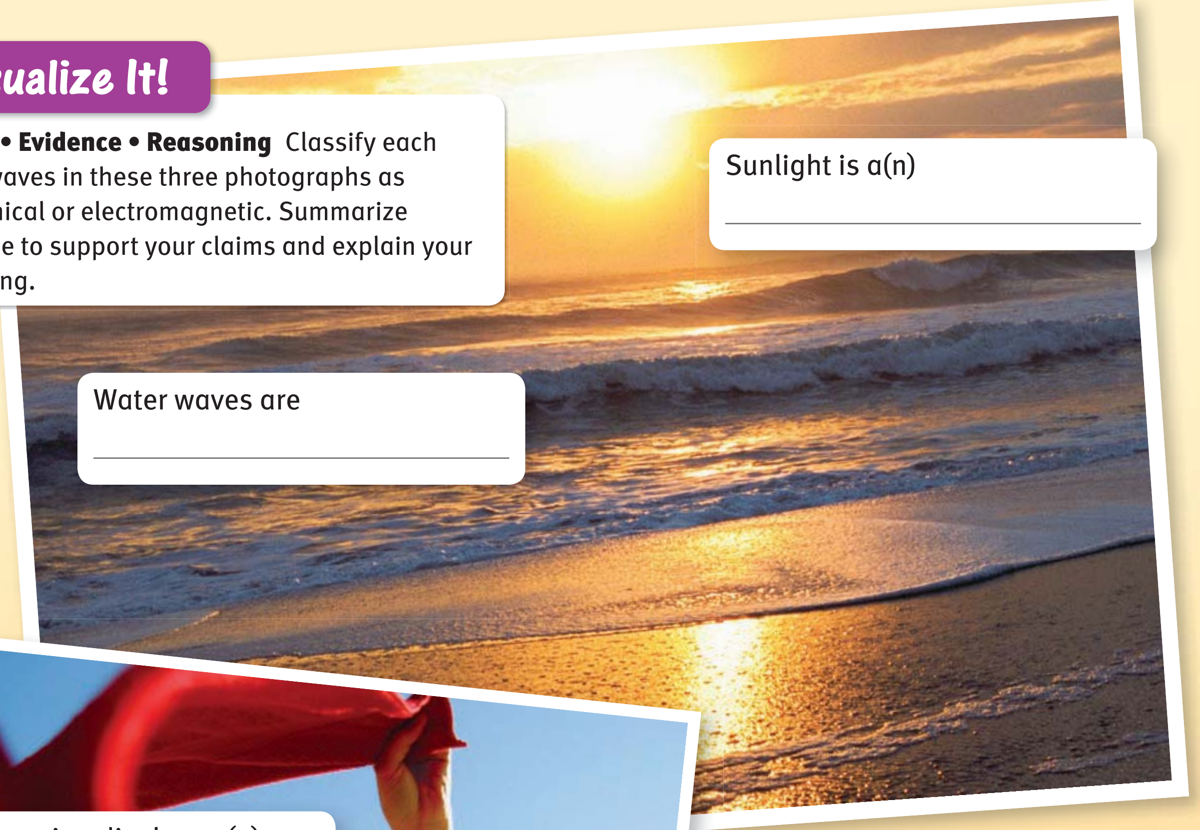
In empty space, all these waves travel at the same speed. This speed, referred to as the speed of light, is about 300 million meters per second!

The sound from the toy cannot be heard because there is no air to transmit the sound.

Visible light is a type of wave called an electromagnetic wave.

Visualize It!

14 Claims • Evidence • Reasoning Classify each of the waves in these three photographs as mechanical or electromagnetic. Summarize evidence to support your claims and explain your reasoning.



Sunlight is a(n) ______________________

Water waves are ______________________

A towel waving displays a(n) ______________________

Vocal sounds are ______________________

Music is a(n) ______________________

Firelight is a(n) ______________________

(t) ©Third Eye Images/Corbis; (c) ©Angela Cameron/Pixtal/age fotostock; (b) ©ClassicStock/Alamy

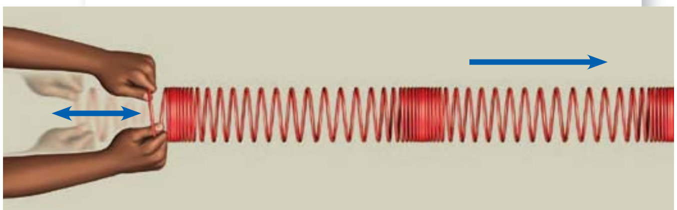
Visual Summary

To complete this summary, fill in the lines below the statement to correct the statement so that it is true. You can use this page to review the main concepts of the lesson.

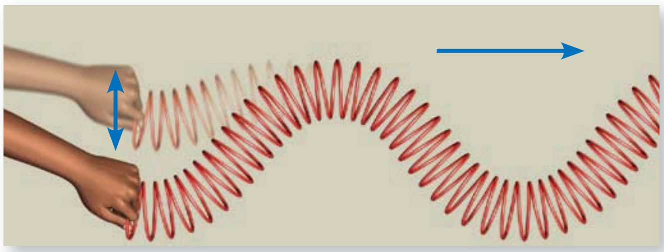
Waves are disturbances that transfer energy.

15 The water particles in the wave move to the right, along with the wave.

Waves can be longitudinal or transverse.



16 The toy above and the toy below both show longitudinal waves.



Waves

Waves can be mechanical or electromagnetic.

17 This picture shows only examples of mechanical waves.

18 Claims • Evidence • Reasoning Consider the following claim: Waves transfer energy but not matter. Do you agree or disagree with this? Summarize evidence to support or refute this claim and explain your reasoning.

Lesson Review

LESSON 1

Vocabulary

Circle the term that best completes the following sentences.

1 A wave is a disturbance that transfers *matter/energy*.

2 In a *longitudinal/transverse* wave, the disturbance moves parallel to the direction the wave travels.

3 *Mechanical/Electromagnetic* waves require a medium in which to travel.

Key Concepts

4–6 Identify Name the medium for each of the following types of waves.

Type of wave	Medium
ocean waves	**4**
earthquake waves	**5**
sound waves from a speaker	**6**

7 Describe Explain how transverse waves can be produced on a rope. Then describe how pieces of the rope move as waves pass.

8 Claims • Evidence • Reasoning Make a claim about whether the sun's rays are mechanical or electromagnetic waves. Summarize evidence to support this claim and explain your reasoning.

Critical Thinking

9 Contrast Mechanical waves travel as disturbances in a physical medium. How do electromagnetic waves travel?

Use this image to answer the following questions.

10 Claims • Evidence • Reasoning Even though the phone is ringing, no sound comes out of the jar. Make a claim about the nature of the space inside the jar. Summarize evidence to support this claim and explain your reasoning.

11 Infer What does this same experiment tell you about light waves? Explain your reasoning.

LESSON 2

Properties of Waves

A heartbeat monitor displays a wave, the characteristics of which contain information about a patient's heartbeat.

ESSENTIAL **QUESTION**

How can we describe a wave?

By the end of this lesson, you should be able to identify characteristics of a wave and describe wave behavior.

SC.7.P.10.3 Recognize that light waves, sound waves, and other waves move at different speeds in different materials.

Lesson Labs

Quick Labs
- Waves in a Bottle
- Different Instrument Sounds
- Waves

Exploration Lab
- Wave Energy and Speed

S.T.E.M. Lab
- Echoes

Engage Your Brain

1 Describe Fill in the blank with the word that you think correctly completes the following sentences.

A guitar amplifier makes a guitar sound

____

FM radio frequencies are measured in mega- ________________________

The farther you are from a sound source, the ____________________ the sound is.

2 Illustrate Draw a diagram of a wave in the space below. How would you describe your wave so that a friend on the phone could duplicate your drawing?

ACTIVE **READING**

3 Predict Many scientific words also have everyday meanings. For each of the following terms, write in your own words what it means in common use. Then try writing a definition of what it might mean when applied to waves.

length:

____

speed:

____

period (of time):

____

Vocabulary Terms

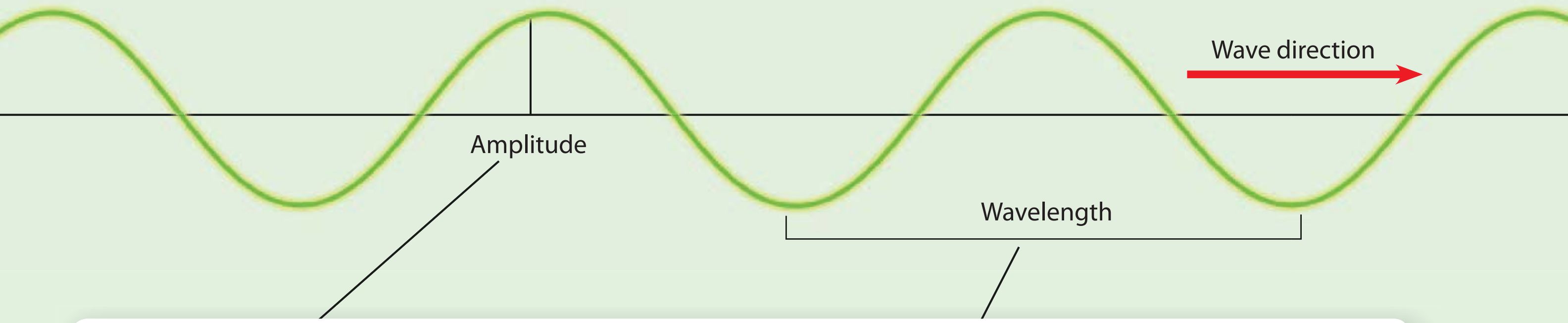
- **wave**
- **amplitude**
- **wavelength**
- **wave period**
- **frequency**
- **hertz**
- **wave speed**

4 Compare This list contains the vocabulary terms you'll learn in this lesson. As you read, circle the definition of each term.

Amp It UP!

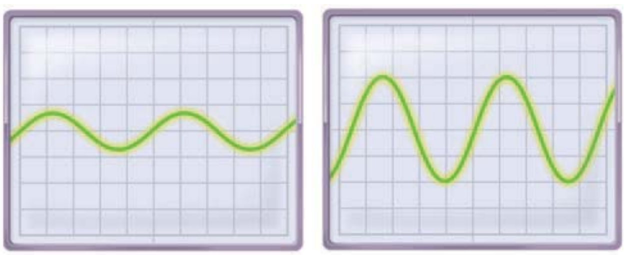
How can we describe a wave?

Suppose you are talking to a friend who had been to the beach. You want to know what the waves were like. Were they big or small? How often did they come? How far apart were they? Were they moving fast? Each of these is a basic property that can be used to describe waves.



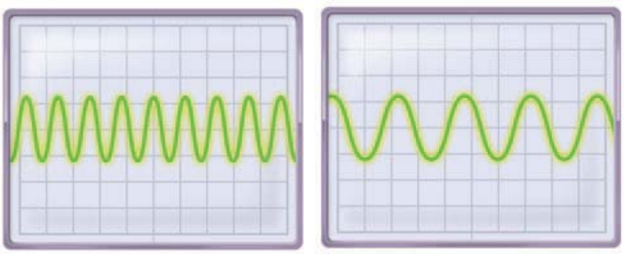
By Its Amplitude

A **wave** is a disturbance that transfers energy from one place to another. As a wave passes, particles in the medium move up and down or back and forth. A wave's **amplitude** is a measure of how far the particles in the medium move away from their normal rest position. The graph above shows a transverse wave. Notice that the amplitude of a wave is also half of the difference between the highest and lowest values.



By Its Wavelength

You can use amplitude to describe the height of an ocean wave, for example. But to describe how long the wave is, you need to know its wavelength. The **wavelength** is the distance from any point on a wave to an identical point on the next wave. For example, wavelength is the distance from one crest to the next, from one trough to the next, or between any other two corresponding points. Wavelength measures the length of one cycle, or repetition.



Visualize It!

5 Label Mark the amplitude in the two graphs above. Which wave has the greater amplitude?

____

6 Label Mark the wavelength in the two graphs above. Which wave has the greater wavelength?

____

By Its Frequency

Wavelength and amplitude tell you about the size of a wave. Another property tells you how much time a wave takes to repeat. The **wave period** (usually "period") is the time required for one cycle. You can measure the period by finding the time for one full cycle of a wave to pass a given point. For example, you could start timing when one crest passes you and stop when the next crest passes. The time between two crests is the period.

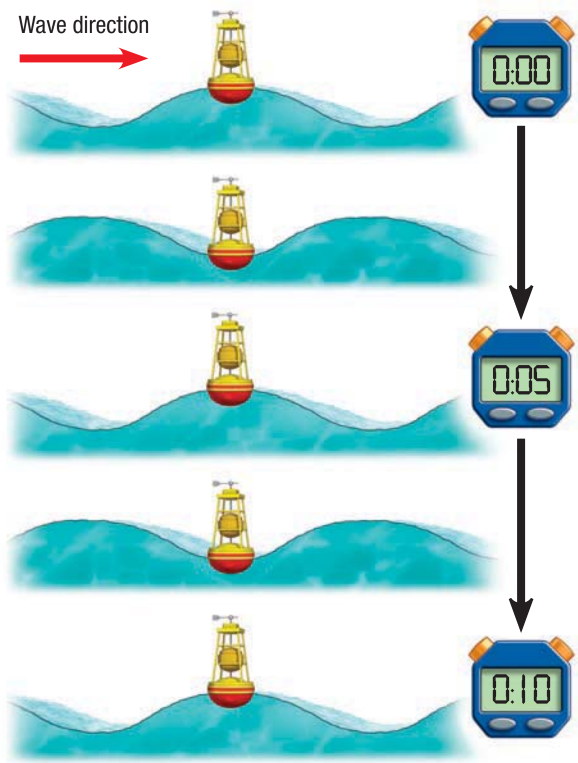
Another way to express the time of a wave's cycle is frequency. The **frequency** of a wave tells how many cycles occur in an amount of time, usually 1 s. Frequency is expressed in **hertz** (Hz). One hertz is equal to one cycle per second. If ten crests pass each second, the frequency is 10 Hz.

Frequency and period are closely related. Frequency is the inverse of period:

$$\text{frequency} = \frac{1}{\text{period}}$$

Suppose the time from one crest to another—the period—is 5 s. The frequency is then $\frac{1}{5}$ Hz, or 0.2 Hz. In other words, one-fifth (0.2) of a wave passes each second.

The buoy moves down and back up every five seconds as waves pass.



Frequency is equal to the number of cycles per unit of time:

$$\text{frequency} = \frac{\text{number of cycles}}{\text{time}}$$

Visualize It!

7 Illustrate On the grid below, draw a wave, and then draw another wave with twice the amplitude.

8 Illustrate On the grid below, draw a wave, and then draw another wave with half the wavelength.

Amp It Down

What affects the energy of a wave?

All waves carry energy from one place to another, but some waves carry more energy than others. A leaf falling on water produces waves so small they are hard to see. An earthquake under the ocean can produce huge waves that cause great destruction.

ACTIVE READING

9 Identify As you read, underline the kind of wave whose energy depends mostly on frequency.

The Amplitude or The Frequency

For a mechanical wave, amplitude is related to the amount of energy the wave carries. For two similar waves, the wave with greater amplitude carries more energy. For example, sound waves with greater amplitude transfer more energy to your eardrum, so they sound louder.

Greater frequency can also mean greater energy in a given amount of time. If waves hit a barrier three times in a minute, they transfer a certain amount of energy to the barrier. If waves of the same amplitude hit nine times in a minute, they transfer more energy in that minute.

For most electromagnetic (EM) waves, energy is most strongly related to frequency. Very high-frequency EM waves, such as x-rays and gamma rays, carry enough energy to damage human tissue. Lower-frequency EM waves, such as visible light waves, can be absorbed safely by your body.

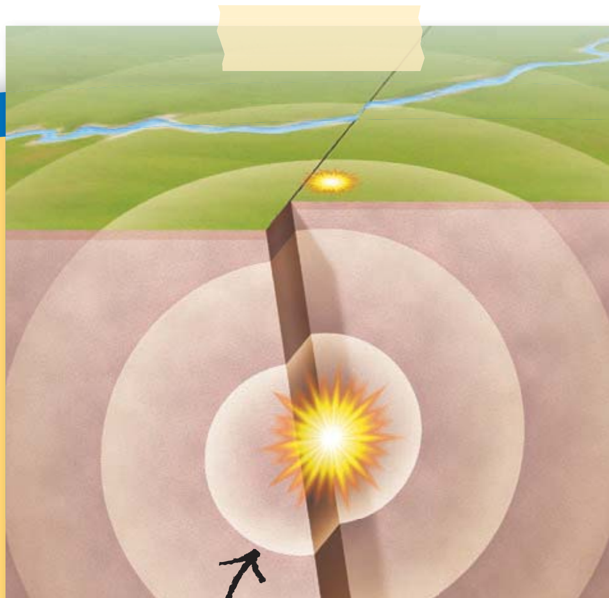
Think Outside the Book

10 Claims • Evidence • Reasoning An echo is the reflection of sound waves as they bounce back after hitting a barrier. Make a claim about how the design of a building, such as a concert hall, can reduce unwanted noises and echoes. Summarize evidence to support this claim and explain your reasoning.

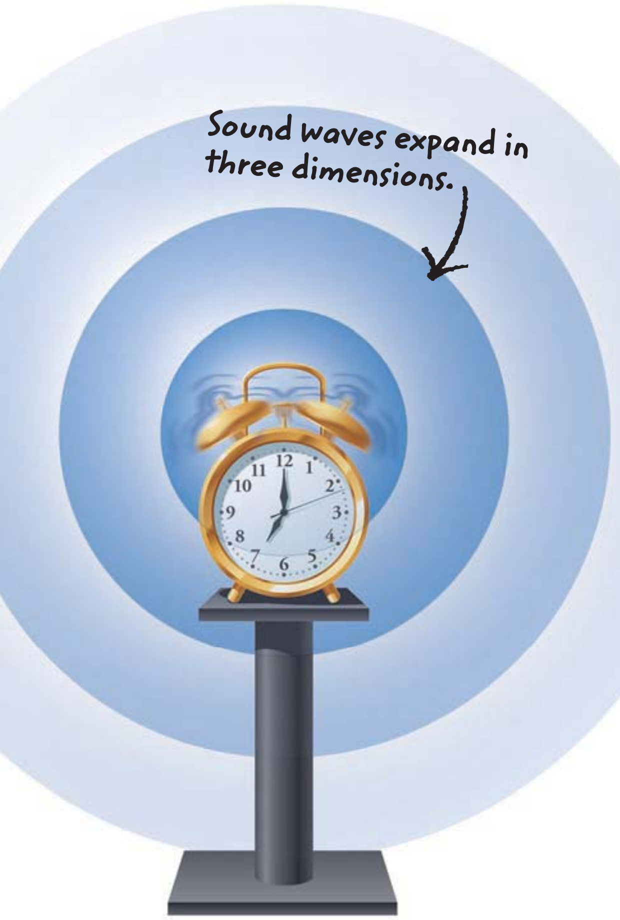
Energy Loss to a Medium

A medium transmits a wave. However, a medium may not transmit all of the wave's energy. As a wave moves through a medium, particles may move in different directions or come to rest in different places. The medium may warm up, shift, or change in other ways. Some of the wave's energy produces these changes. As the wave travels through more of the medium, more energy is lost to the medium.

Often, higher-frequency waves lose energy more readily than lower-frequency waves. For example, when you stand far from a concert, you might hear only the low-frequency (bass) sounds.



Some of the energy of these earthquake waves is lost to the medium when the ground shifts.



Energy Loss Due to Spreading

So far, we have mostly talked about waves moving in straight lines. But waves usually spread out in more than one dimension. The crests can be drawn as shapes, such as circles or spheres, called *wavefronts*. As each wavefront moves farther from the source, the energy is spread over a greater area. Less energy is available at any one point on the wavefront. If you measure a wave at a point farther from the source, you measure less energy. But the total energy of the wavefront stays the same.

Ripples on a water surface expand in two dimensions.

11 Predict Which type of wave spreading do you think causes faster energy loss—two-dimensional or three-dimensional? Explain your reasoning.

____

____

____

As the student on the left knocks on the table, the students farther away feel the resulting waves less strongly.

Visualize It!

12 **Claims • Evidence • Reasoning** Make a claim about what differences the students would observe if they were to repeat their experiment using a longer table. Summarize evidence to support this claim and explain your reasoning.

____

____

____

A Happy Medium

What determines the speed of a wave?

Waves travel at different speeds in different media. For example, sound waves travel at about 340 m/s in air at room temperature, but they travel at nearly 1,500 m/s in water. In a solid, sound waves travel even faster.

The Medium in Which It Travels

The speed at which a wave travels—called **wave speed**—depends on the properties of the medium. Specifically, wave speed depends on the interactions of the atomic particles of the medium. In general, waves travel faster in solids than in liquids and faster in liquids than in gases. Interactions, or collisions, between particles happen faster in solids because the medium is more rigid.

How fast the wave travels between particles within the medium depends on many factors. For example, wave speed depends on the density of the medium. Waves usually travel slower in the denser of two solids or the denser of two liquids. The more densely packed the particles are, the more they resist motion, so they transfer waves more slowly.

In a gas, wave speed depends on temperature as well as density. Particles in hot air move faster than particles in cold air, so particles in hot air collide more often. This faster interaction allows waves to pass through hot air more quickly than through the denser cold air. The speed of sound in air at 20 °C is about 340 m/s. The speed of sound in air at 0 °C is slower, about 330 m/s.

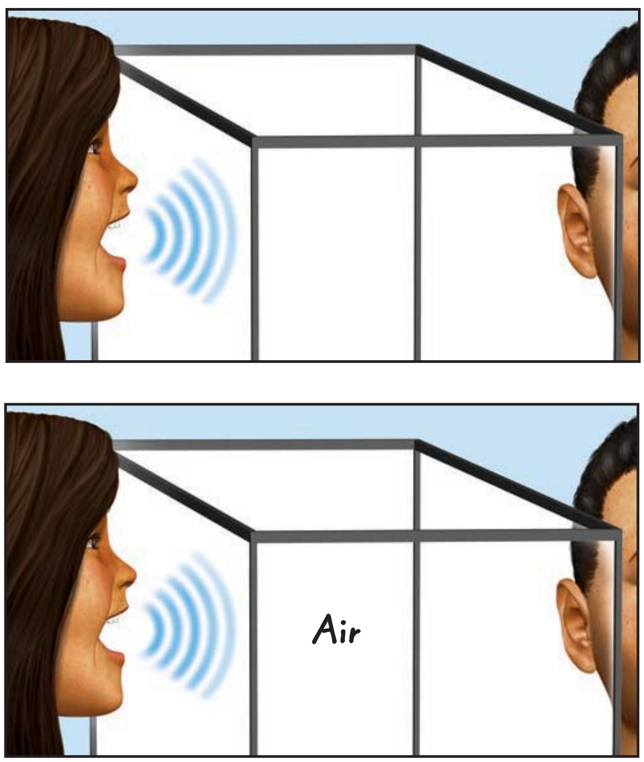
Electromagnetic waves don't require a medium, so they can travel in a vacuum. All electromagnetic waves travel at the same speed in empty space. This speed, called the speed of light, is about 300,000,000 m/s. While passing through a medium such as air or glass, EM waves travel more slowly than they do in a vacuum.

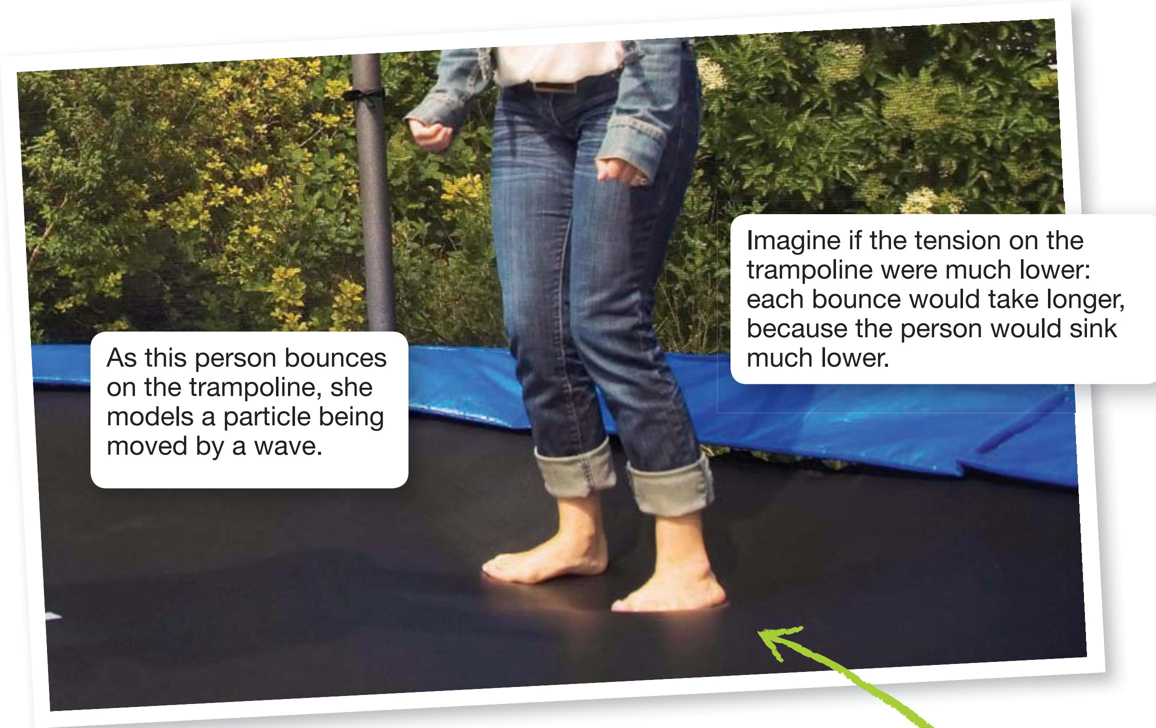
ACTIVE **READING**

13 Identify Does sound travel faster or slower when the air gets warmer?

Visualize It!

14 Claims • Evidence • Reasoning One diagram shows sound traveling through an air-filled tank. Draw a medium in the second tank in which sound will travel faster than in the air-filled tank. Make a claim about why the medium you have drawn will transmit sound waves faster than air. Summarize evidence to support this claim and explain your reasoning.





As a medium becomes more flexible, it carries waves more slowly.

Its Frequency and Wavelength

Wave speed can be calculated from frequency and wavelength. To understand how, it helps to remember that speed is defined as distance divided by time:

$$\text{speed} = \frac{\text{distance}}{\text{time}}$$

So if a runner runs 8 m in 2 s, then the runner's speed is 8 m ÷ 2 s = 4 m/s. For a wave, a crest moves a distance of one wavelength in one cycle. The time for the cycle to occur is one period. Using wavelength and period as the distance and time:

$$\text{wave speed} = \frac{\text{wavelength}}{\text{wave period}}$$

So if a crest moves one wavelength of 8 m in one period of 2 s, the wave speed is calculated just like the runner's speed: 8 m ÷ 2 s = 4 m/s.

Frequency is the inverse of the wave period. So the relationship can be rewritten like this:

$$\text{wave speed} = \text{frequency} \times \text{wavelength}$$

or

$$\text{wavelength} = \frac{\text{wave speed}}{\text{frequency}}$$

If you already know the wave speed, you can use this equation to solve for frequency or wavelength.

Do the Math

You Try It

15 Calculate Complete this table relating wave speed, frequency, and wavelength.

Wave speed (m/s)	Frequency (Hz)	Wavelength (m)
20		5
75	15	
	23	16
625		25
	38	20

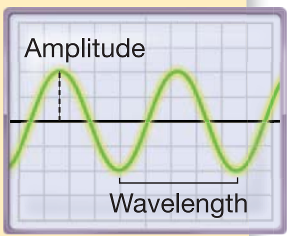
Visual Summary

To complete this summary, fill in the blanks with the correct word or phrase. You can use this page to review the main concepts of the lesson.

Amplitude tells the amount of displacement of a wave.

Wavelength tells how long a wave is.

Wave period is the time required for one cycle.



16 ______________ $= \dfrac{1}{\text{wave period}}$

17 Hertz is used to express ______________

18 One hertz is equal to ______________

Wave energy depends on amplitude and frequency.

Most waves lose energy over time as they travel and spread.

20 Some of the wave's energy stays in the ______________

Wave Properties

Wave speed depends on the properties of the medium.

In a vacuum, electromagnetic waves all move at the speed of light.

19 wave speed = frequency × ______________

21 Claims • Evidence • Reasoning Make a claim about how the properties of sound waves change as they spread out in a spherical pattern. Summarize evidence to support this claim and explain your reasoning.

Lesson Review

LESSON 2

Vocabulary

Fill in the blank with the correct letter.

1 frequency ____

2 wavelength ____

3 wave speed ____

4 wave period ____

5 amplitude ____

A the distance over which a wave's shape repeats

B the maximum distance that particles in a wave's medium vibrate from their rest position

C the time required for one wavelength to pass a point

D the number of wavelengths that pass a point in a given amount of time

E the speed at which a wave travels through a medium

Key Concepts

6 Describe What measures the amount of displacement in a transverse wave?

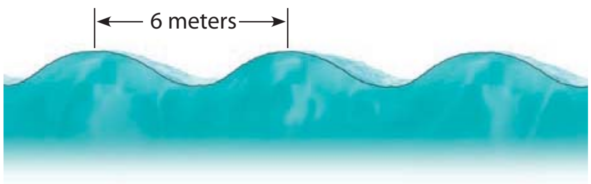
7 Relate How are frequency and wave period related?

8 Provide What does the energy of an electromagnetic wave depend on?

9 Infer Sound travels slower in colder air than it does in warmer air. Why does the speed of sound depend on air temperature? Explain your reasoning.

Critical Thinking

Use this diagram to answer the following questions. The frequency of the wave is 0.5 Hz.



10 Analyze What is the wavelength of these waves?

11 Calculate What is the speed of these waves?

12 Solve If you were sitting in a boat as these waves passed by, how many seconds would pass between wave crests?

13 Claims • Evidence • Reasoning Make a claim about how the energy of the sound wave changes as it moves farther away from its source. Summarize evidence to support this claim and explain your reasoning.

14 Claims • Evidence • Reasoning A wave has a low speed but a high frequency. Make a claim about the wavelength of this wave. Summarize evidence to support this claim and explain your reasoning.

15 Predict How do you know the speed of an electromagnetic wave in a vacuum?

SC.7.N.1.5 Describe the methods used in the pursuit of a scientific explanation as seen in different fields of science such as biology, geology, and physics.

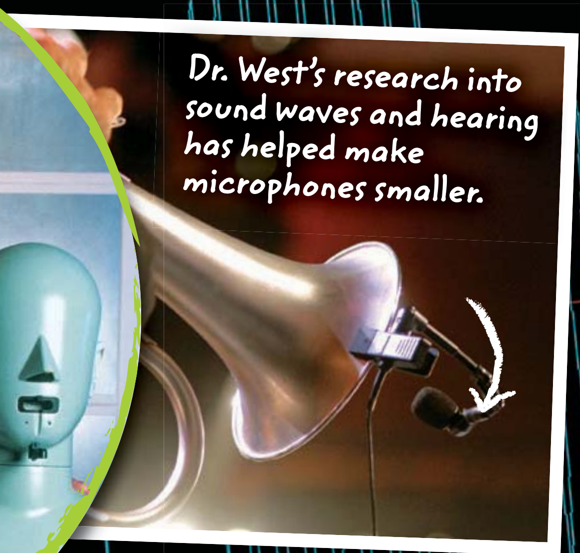
James West

RESEARCH SCIENTIST

James West's parents wanted him to be a medical doctor, but he wanted to study physics. His father was sure he'd never find a job that way. But Dr. West wanted to study what he loved. He did study physics, and he did find a job. He worked for Bell Laboratories and developed a microphone called the electret microphone. Today, Dr. West's microphone is in almost all telephones, cell phones, and other equipment that records sound.

Dr. West's interest in the microphone started with a question about hearing. A group of scientists wanted to know how close together two sounds could be before the ear would not be able to tell them apart. At the time, there was no earphone sensitive enough for their tests. Dr. West and fellow scientist Dr. Gerhard Sessler found that they could make a more sensitive microphone by using materials called *electrets*. Electrets are the electrical counterparts of permanent magnets. Electrets can store electric charge. This eliminates the need for a battery. The new microphones were cheaper, more reliable, smaller, and lighter than any microphone before them.

Dr. West enjoys the thrill of discovery. He should know. To date, he holds more than 250 U.S. and foreign patents. In 1999 he was inducted into the National Inventors Hall of Fame. Dr. West retired from Bell Laboratories in 2001 and is now on the faculty at Johns Hopkins University. He has won many awards for his work, including both the Silver and Gold Medals from the Acoustical Society of America, The National Medal of Technology and Innovation, and the Benjamin Franklin Medal in Electrical Engineering.



Dr. West's research into sound waves and hearing has helped make microphones smaller.

JOB BOARD

Dispensing Optician

What You'll Do: Help select and then fit eyeglasses and contact lenses.

Where You Might Work: Medical offices, or optical, department, or club stores

Education: Most training is on the job or through apprenticeships that last two years or longer. Some employers prefer graduates of postsecondary training programs in opticianry.

Other Job Requirements: A good eye for fashion, face shape, and color is a plus, as opticians help people find glasses they like.

Lighting Designer

What You'll Do: Work in theater, television, or film to make what happens on stage or on set visible to audiences. Lighting designers also use lighting and shadow to create the right tone or mood.

Where You Might Work: Theaters, television and film studios and sets, concerts and other special events

Education: A diploma or certificate in lighting design or technical stage management from a college or performing arts institute

Other Job Requirements: Experience lighting stage productions, the ability to work in a team

PEOPLE IN SCIENCE NEWS

ELY Silk

A New Light on Microscopy

Doctors and medical researchers use fluorescent microscopes to see colored or fluorescent dyes in medical research. These microscopes use expensive and dangerous mercury light bulbs to illuminate the dyes. But Ely Silk, a retired computer programmer and inventor in Florida, found a less expensive source of light.

When the mercury bulb on his microscope died, Silk replaced it with many differently colored light-emitting diodes (LEDs). Each inexpensive LED emits light of a different wavelength. The LEDs cost only a couple of dollars each and are much safer than mercury bulbs. Yet they still provide the light needed to view the fluorescent dyes. Now, researchers can use the LED microscopes to really light up their dyes!

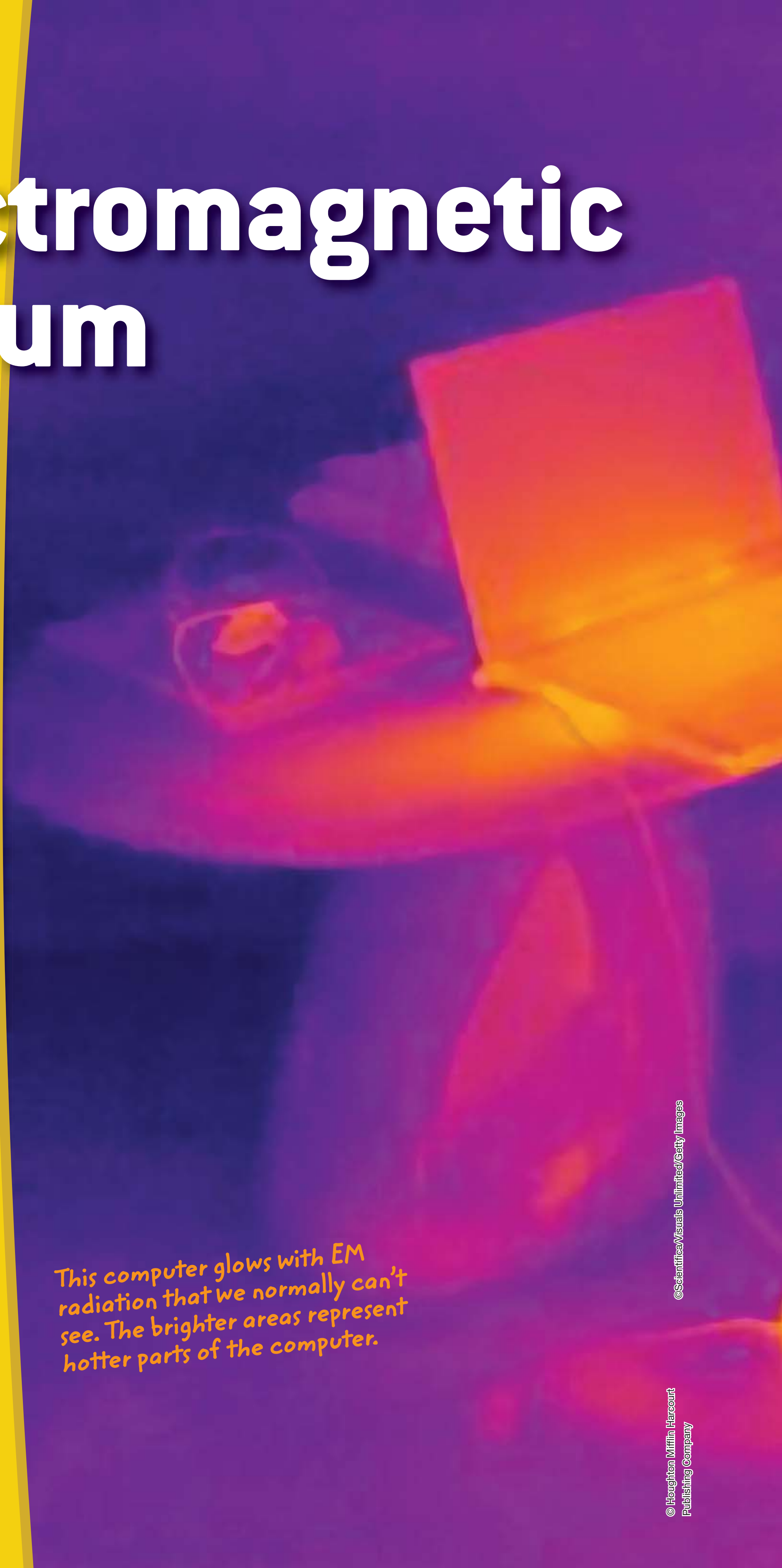
LESSON 3

The Electromagnetic Spectrum

ESSENTIAL **QUESTION**

What is the relationship between various EM waves?

By the end of this lesson, you should be able to distinguish between the parts of the electromagnetic spectrum.



This computer glows with EM radiation that we normally can't see. The brighter areas represent hotter parts of the computer.

SC.7.P.10.1 Illustrate that the sun's energy arrives as radiation with a wide range of wavelengths, including infrared, visible, and ultraviolet, and that white light is made up of a spectrum of many different colors.

Lesson Labs

Quick Lab

- White Light
- Modeling Earth's Magnetic Field

Engage Your Brain

1 **Select** Circle the word or phrase that best completes each of the following sentences:

Radio stations transmit (*radio waves*/*gamma rays*).

The dentist uses (*infrared light*/*x-rays*) to examine your teeth.

Intense (*visible light*/*ultraviolet light*) from the sun can damage your skin.

2 **Predict** Imagine that humans had not realized there are other parts of the electromagnetic spectrum besides visible light. How would your day today be different without technology based on other parts of the EM spectrum?

ACTIVE **READING**

3 **Synthesize** You can often define an unknown word if you know the meaning of its word parts. Use this table of word parts to make an educated guess about the meanings given.

Word part	Meaning
ultra-	beyond
infra-	below
electro-	related to electricty
-magnetic	related to magnetism

What word means "beyond violet"?

What word means "below red"?

What word means "related to electricity and magnetism"?

Vocabulary Terms

- **radiation**
- **electromagnetic spectrum**
- **infrared**
- **ultraviolet**

4 **Apply** As you learn the definition of each vocabulary term in this lesson, think of an example of a real-world use. Practice writing the term and its definition, and then writing or drawing a sketch of the example next to the definition.

Electromagnetic Light Show

What is the nature of light?

Light is a type of energy that travels as waves, but light waves are not disturbances in a medium. Light waves are disturbances in electric and magnetic fields. If you have felt the static cling of fabric and the pull of a magnet, then you have experienced electric and magnetic fields. Because these fields can exist in empty space, light does not need a medium in which to travel.

When an electrically charged particle vibrates, it disturbs the electric and magnetic fields around it. These disturbances, called electromagnetic (EM) waves, carry energy away from the charged particle. The disturbances are perpendicular to each other and to the direction the wave travels. **Radiation** (ray•dee•AY•shuhn) is the transfer of energy as EM waves.

In a vacuum, all EM waves move at the same speed: 300,000,000 m/s, called the speed of light. That's fast enough to circle Earth more than seven times in one second!

Although light and other EM waves do not need a medium, they can travel through many materials. EM waves travel more slowly in a medium such as air or glass than in a vacuum.

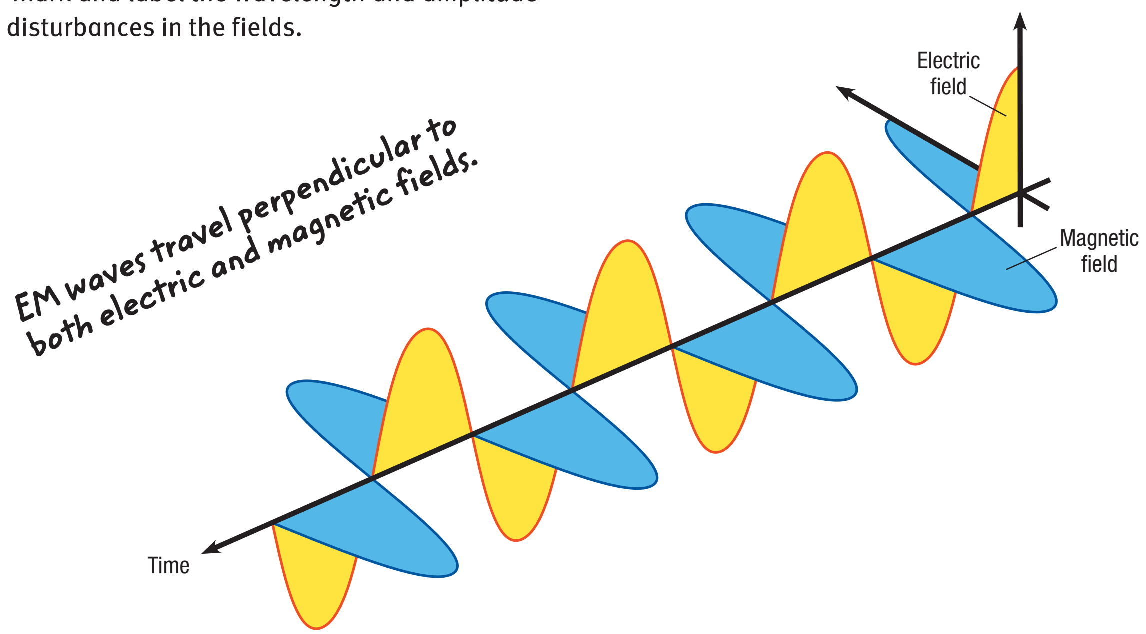
ACTIVE READING

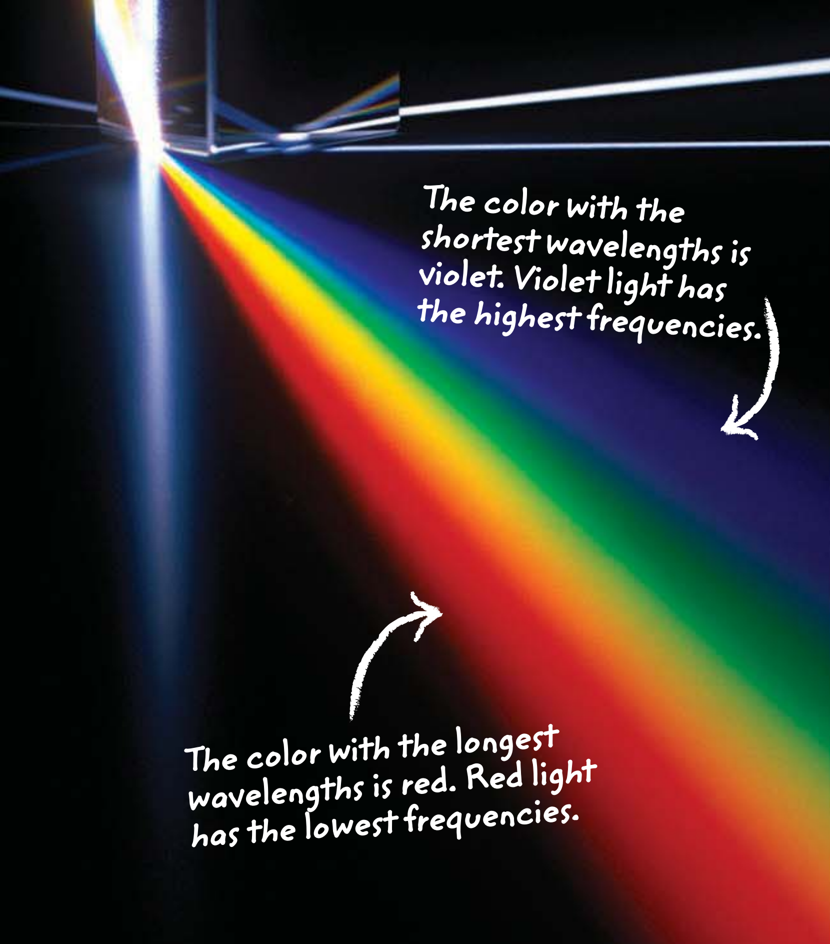
5 Identify Underline what produces EM waves.

6 Claims • Evidence • Reasoning Make a claim about why we see lightning before we hear the accompanying thunder during a storm. Summarize evidence to support this claim and explain your reasoning.

Visualize It!

7 Label Mark and label the wavelength and amplitude of the disturbances in the fields.





What determines the color of light?

Light comes in many colors, from red to violet. But what is different about each color of light? Like all waves, light has wavelengths. Different wavelengths of light are interpreted by our eyes as different colors. The shortest wavelengths are seen as violet. The longest wavelengths are seen as red. Even the longest wavelengths we can see are still very small—less than one ten-thousandth of a centimeter.

White light is what we perceive when we see all the wavelengths of light at once, in equal proportions. A prism can split white light into its component colors, separating the colors by wavelength. The various wavelengths of light can also be combined to produce white light.

Our eyes only register three color ranges of light, called the primary colors—red, green, and blue. All other colors we see are a mixture of these three colors. A television or computer screen works by sending signals to make small dots, called pixels, give off red, green, and blue light.

Visualize It!

8 Arrange List the colors of the spectrum in order of increasing wavelength.

____

____

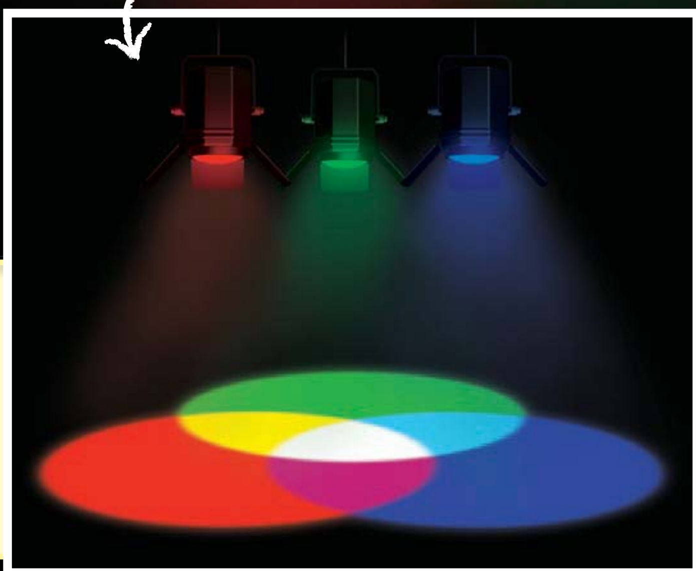
____

____

____

____

Red, green, and blue light combine to appear white.



9 Select What combination of primary colors do we perceive as yellow?

____

____

Invisible Colors

What are the parts of the EM spectrum?

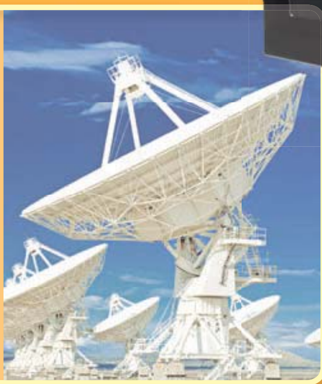
EM waves are measured by frequency or by wavelength. The light waves we see are EM waves. However, visible light represents only a very small part of the range of frequencies (or wavelengths) that an EM wave can have. This range is called the **electromagnetic (EM) spectrum**. These other EM waves are the same type of wave as the light we're used to. They're just different frequencies.

Two parts of the spectrum are close to visible light. **Infrared**, or IR, light has slightly longer wavelengths than red light. **Ultraviolet**, or UV, light has slightly shorter wavelengths than violet light.

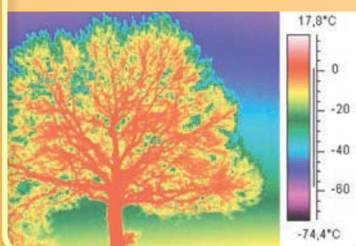
The Electromagnetic Spectrum

Microwaves
Despite their name, microwaves are not the shortest EM waves. Besides heating food, microwaves are used by cellular phones.

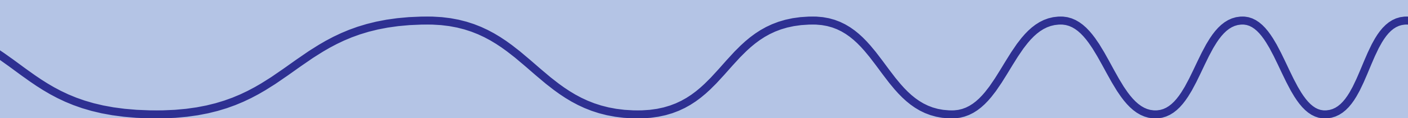
Radio Waves
Radio waves have the longest wavelengths. They are used to broadcast signals for radios, televisions, alarm systems, and other devices.



Infrared Light
Infrared means "below red." The amount of infrared light an object gives off depends on its temperature. Below, colors indicate different amounts of infrared light.



Frequency in hertz (1 hertz = 1 cycle/second)



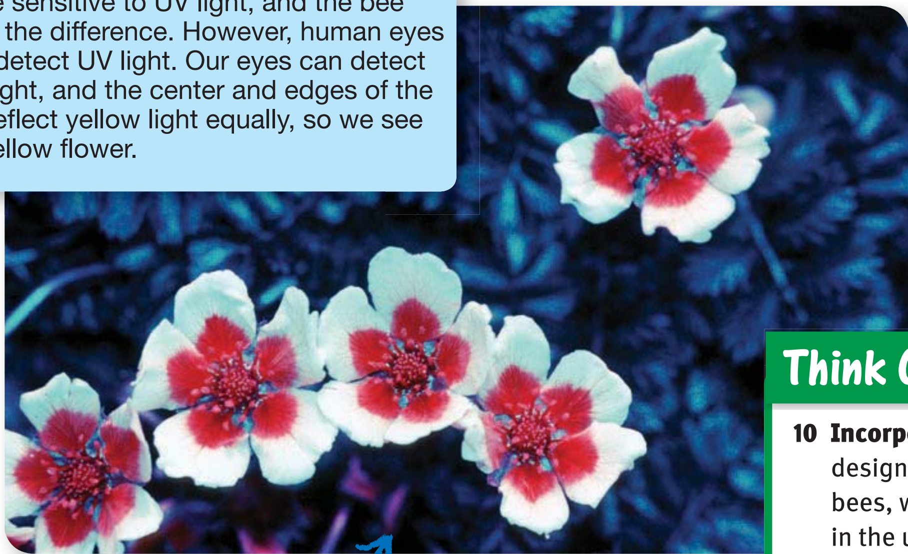
10^2 10^3 10^4 10^5 10^6 10^7 10^8 10^9 10^{10} 10^{11}

Radio Waves

Microwaves

The inner part of these flowers reflects UV light differently than the outer part. A bee's eyes are sensitive to UV light, and the bee can see the difference. However, human eyes cannot detect UV light. Our eyes can detect yellow light, and the center and edges of the flower reflect yellow light equally, so we see an all-yellow flower.

Human eyes see the flowers as entirely yellow.



A bee's eyes see a pattern in UV light.

Think Outside the Book

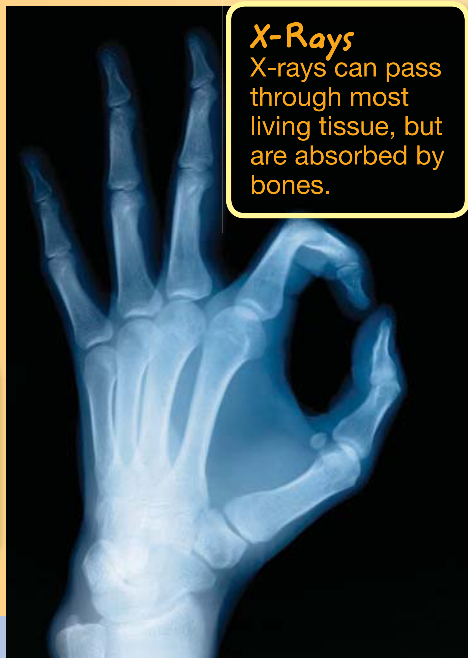
10 Incorporate The flower shows designs that are visible to bees, which can see light in the ultraviolet range. Research and explain how this adaptation leads to a symbiotic relationship between the flowers and bees.

Visible Light

Visible light is all the colors of the EM spectrum we can see. It is the narrowest part of the EM spectrum.

Ultraviolet Light

Ultraviolet means "beyond violet." Some animals can see ultraviolet light.

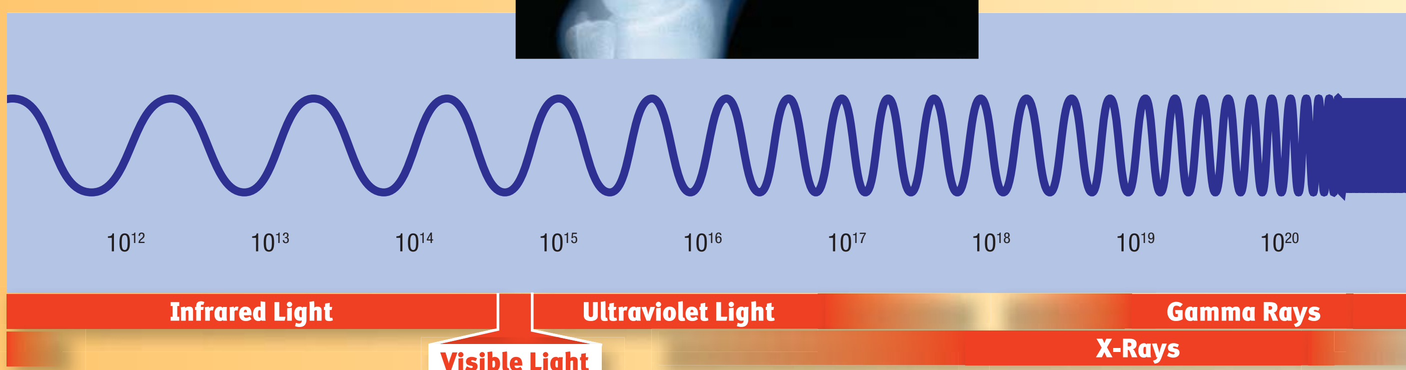


X-Rays

X-rays can pass through most living tissue, but are absorbed by bones.

Gamma Rays

Gamma rays can be used to treat illnesses and in making medical images.



Star Light,

How much of the sun's energy reaches us?

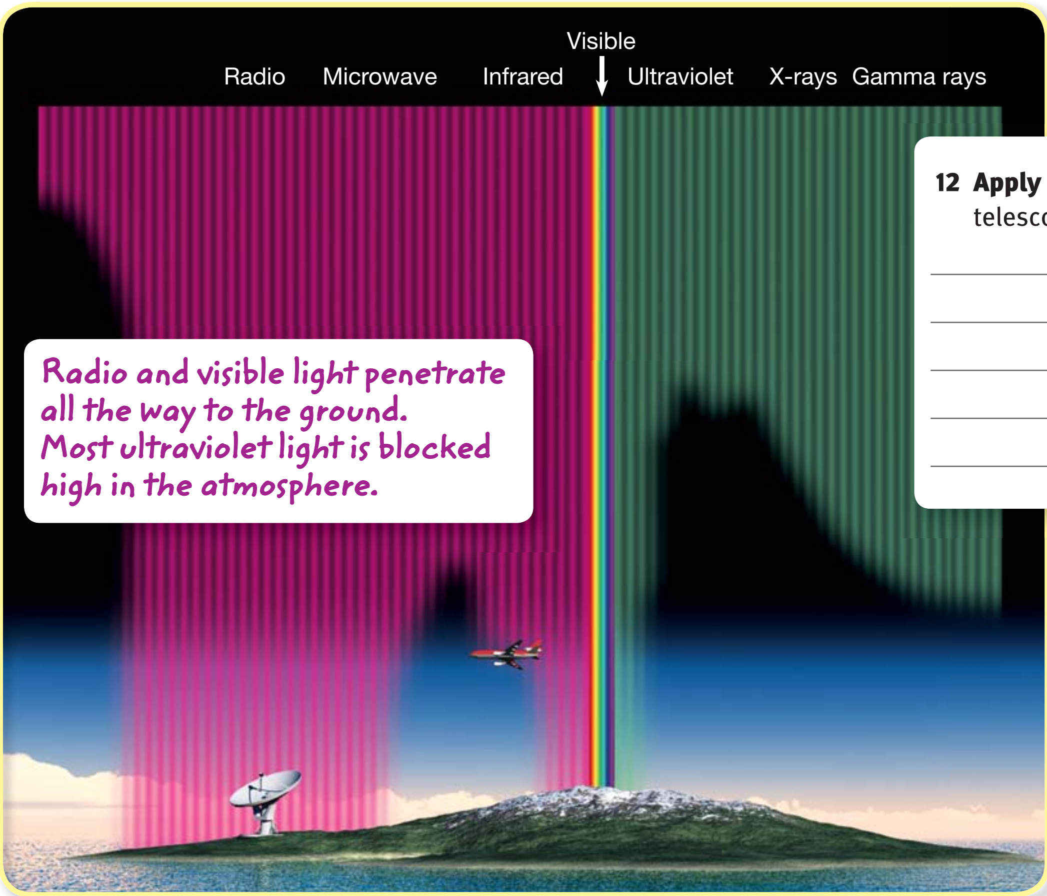
The sun gives off huge amounts of energy in the form of EM radiation. More of this energy is in the narrow visible light range than any other part of the spectrum, but the sun gives off some radiation in every part of the spectrum.

ACTIVE READING

11 Identify What prevents most of the sun's gamma rays from reaching us?

Visualize It!

The illustration shows how far down each part of the EM spectrum penetrates Earth's atmosphere.



Radio and visible light penetrate all the way to the ground. Most ultraviolet light is blocked high in the atmosphere.

12 Apply Why do we keep some telescopes in space?

Earth Shields Us from Some EM Radiation

Between the sun and us lies Earth's atmosphere. In order for us to see anything, some of the sun's light must make it through the atmosphere. However, not all wavelengths of light penetrate the atmosphere equally. The atmosphere blocks most of the higher-frequency radiation like x-rays and gamma rays from reaching us at the ground level, while allowing most of the visible light to reach us. There is a "window" of radio frequencies that are barely blocked at all, and this is why the most powerful ground-based telescopes are radio telescopes.

Star Bright

Astronauts need extra protection from EM radiation in space.

13 Gather Evidence A student claims that it might be less dangerous to wear no sunglasses than to wear sunglasses that do not block UV light. Summarize evidence to support the claim.

____

____

____

We Shield Ourselves from Some Radiation

The atmosphere blocks much of the sun's radiation, but not all. Some EM radiation can be dangerous to humans, so we take extra steps to protect ourselves. Receiving too much ultraviolet (UV) radiation can cause sunburn, skin cancer, or damage to the eyes, so we use sunscreen and wear UV-blocking sunglasses to protect ourselves from the UV light that passes through the atmosphere. Hats, long-sleeved shirts, and long pants can protect us, too.

We need this protection even on overcast days because UV light can travel through clouds. Even scientists in Antarctica, one of the coldest places on Earth, need to wear sunglasses, because fresh snow reflects about 80% of UV light back up to where it might strike their eyes.

Outer space is often thought of as being cold, but despite this, one of the biggest dangers to astronauts is from overheating! Outside of Earth's protective atmosphere, the level of dangerous EM radiation is much higher. And, in the vacuum of space, it's much harder to dispose of any energy, because there's no surrounding matter (like air) to absorb the extra energy. This is one reason why astronauts' helmets have a thin layer of pure gold. This highly reflective gold layer reflects unwanted EM radiation away.

Frequency Asked Questions

How much energy does EM radiation have?

What makes some EM waves safe, and some dangerous? The answer is that different frequencies of EM waves carry different amounts of energy.

Higher Frequency Means More Energy

The energy of an EM wave depends on its frequency. High-frequency, short-wavelength EM waves have more energy than low-frequency, long-wavelength waves.

More Energy Means More Dangerous

A high-frequency EM wave carries a lot of energy, so it has the possibility of damaging living tissue. But a low-frequency wave carries much less energy, and is safer. This is why radio waves (which have the lowest frequencies) are used so often, such as in walkie-talkies and baby monitors. In contrast, UV light causes sunburn unless you have protection, and when working with even higher-energy waves like x-rays, special precautions must be taken, such as wearing a lead apron to block most of the rays.

Think Outside the Book

15 Apply On a separate sheet of paper, write a short story where the main character needs protection from two different kinds of EM radiation.

ACTIVE **READING**

14 Claims • Evidence • Reasoning Make a claim about what kinds of EM waves are most dangerous to humans. Summarize evidence that would support this claim and explain your reasoning.

Radio waves pass through humans safely.

UV waves can cause damage to living tissue.

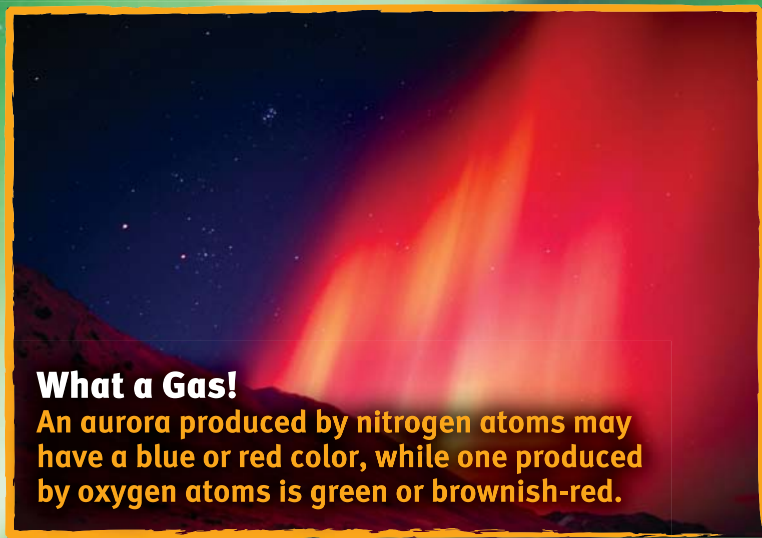
X-rays require extra safety.

WHY IT **MATTERS**

WEIRD SCIENCE

Fire in the Sky

The sun constantly streams out charged particles. Earth has a strong magnetic field. When particles from the sun strike Earth, the magnetic field funnels them together, accelerating them. When these particles collide with the atmosphere, they give off electromagnetic radiation in the form of light, and near the poles where they usually come together, a beautiful display called an *aurora* (uh•RAWR•uh) sometimes lights up the sky.



What a Gas!
An aurora produced by nitrogen atoms may have a blue or red color, while one produced by oxygen atoms is green or brownish-red.

Winds of Change
The stream of electrically charged particles from the sun is called the *solar wind.*

Pole Position
At the North Pole, this phenomenon is called the *aurora borealis* (uh•RAWR•uh bawr•ee•AL•is), or northern lights. At the south pole, it is called the *aurora australis* (uh•RAWR•uh aw•STRAY•lis), or southern lights.

Extend

16 Relate Which color of aurora gives off higher-energy light, green or red?

17 Explain Why don't we see auroras on the moon? Explain your reasoning

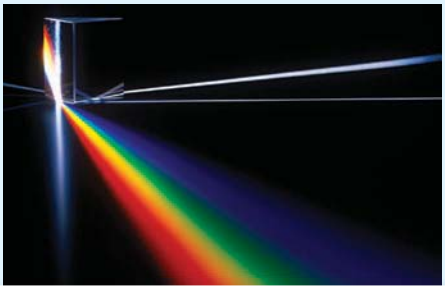
18 Claims • Evidence • Reasoning Make a claim about whether auroras occur on other planets. Summarize evidence that would support this claim and explain your reasoning.

Visual Summary

To complete this summary, fill in the blanks with the correct word or phrase. You can use this page to review the main concepts of the lesson.

The **Electromagnetic Spectrum**

Different wavelengths of light appear as different colors.



19 The color of the longest visible wavelength is ____________

20 The color of the shortest visible wavelength is ____________

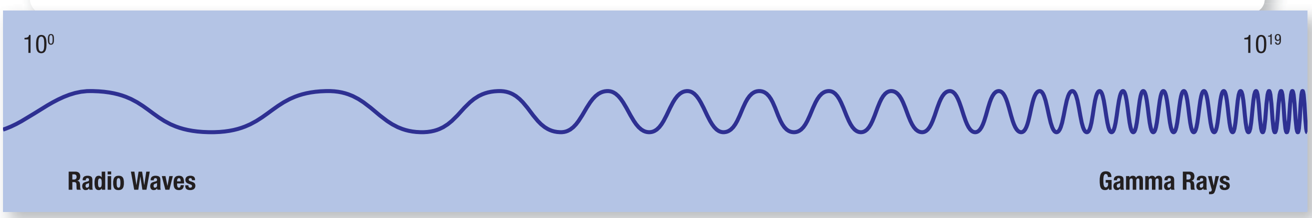
Higher-frequency waves carry more energy. This makes them more dangerous.

21 The energy of an electromagnetic (EM) wave is proportional to its ____________

EM waves exist along a spectrum.

22 The waves with the longest wavelengths are ____________ waves.

23 The waves with the shortest wavelengths are ____________



24 **Claims • Evidence • Reasoning** Suppose you are designing a device to transmit information without wires. Make a claim about which part of the EM spectrum would be best for this device. Summarize evidence that would support this claim and explain your reasoning.

Lesson Review

Vocabulary

Fill in the blanks with the terms that best complete the following sentences.

1 The transfer of energy as electromagnetic waves is called ______________________

2 The full range of wavelengths of EM waves is called the ______________ ______________

3 ______________ radiation lies at frequencies just below the frequencies of visible light.

Key Concepts

4 **Describe** What is an electromagnetic wave?

5 **Organize** What are the highest-frequency and lowest-frequency parts of the EM spectrum?

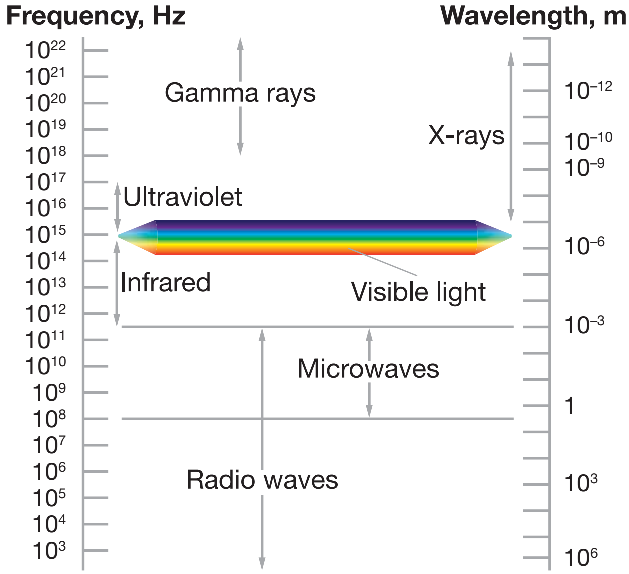
6 **Compare** How fast do different parts of the EM spectrum travel in a vacuum?

Suppose you like to listen to two different radio stations. The opera station broadcasts at 90.5 MHz and the rock and roll station broadcasts at 107.1 MHz.

7 **Support Your Claim** Which station's signal has waves with longer wavelengths? Provide evidence to support your claim.

8 **Support Your Claim** Which station's signal has waves with higher energy? Provide evidence to support your claim.

Use the graph to answer the following questions.



9 **State Your Claim** How would you classify an EM wave with a frequency of 10^7 Hz?

10 **State Your Claim** How would you classify an EM wave with a wavelength of 10^{-12} m?

11 **Apply** What is white light?

Critical Thinking

12 **Claims • Evidence • Reasoning** Suppose you want to detect x-rays coming from the sun. Make a claim about the best location to place the detector. Summarize evidence that would support this claim and explain your reasoning.

THINK SCIENCE

SC.7.N.1.1 Define a problem from the seventh grade curriculum, use appropriate reference materials to support scientific understanding, plan and carry out scientific investigation of various types, such as systematic observations or experiments, identify variables, collect and organize data, interpret data in charts, tables, and graphics, analyze information, make predictions, and defend conclusions.

Mean, Median, Mode, and Range

You can analyze both the measures of central tendency and the variability of data using mean, median, mode, and range.

Tutorial

Imagine that a group of students records the light levels at various places within a classroom.

Classroom Light Levels

Area	Illuminance (lux)
1	800
2	300
3	150
4	300
5	200

Mean The mean is the sum of all of the values in a data set divided by the total number of values in the data set. The mean is also called the *average*.	$\frac{800 + 300 + 150 + 300 + 200}{5}$ **mean** = 350 lux
Median The median is the value of the middle item when data are arranged in order by size. In a range that has an odd number of values, the median is the middle value. In a range that has an even number of values, the median is the average of the two middle values.	If necessary, reorder the values from least to greatest: 150, 200, **300**, 300, 800 **median** = 300 lux
Mode The mode is the value or values that occur most frequently in a data set. If all values occur with the same frequency, the data set is said to have no mode. Values should be put in order to find the mode.	If necessary, reorder the values from least to greatest: 150, 200, 300, 300, 800 The value 300 occurs most frequently. **mode** = 300 lux
Range The range is the difference between the greatest value and the least value of a data set.	800 − 150 **range** = 650 lux

You Try It!

The data table below shows the data collected for rooms in three halls in the school.

Illuminance (lux)				
	Room 1	**Room 2**	**Room 3**	**Room 4**
Science Hall	150	250	500	400
Art Hall	300	275	550	350
Math Hall	200	225	600	600

1

Using Formulas Find the mean, median, mode, and range of the data for the school.

2

Claims • Evidence • Reasoning The school board is considering replacing the lights because some people claim that parts of the school are too poorly lit. However, others claim that the lighting in the school is acceptable. Summarize evidence from the school's data that would support each of these claims and explain your reasoning.

Language Arts Connection

On flashcards, write sentences that use the keywords *mean, median, mode,* and *range*. Cover the keywords with small sticky notes. Review each sentence, and determine if it provides enough context clues to determine the covered word. If necessary, work with a partner to improve your sentences.

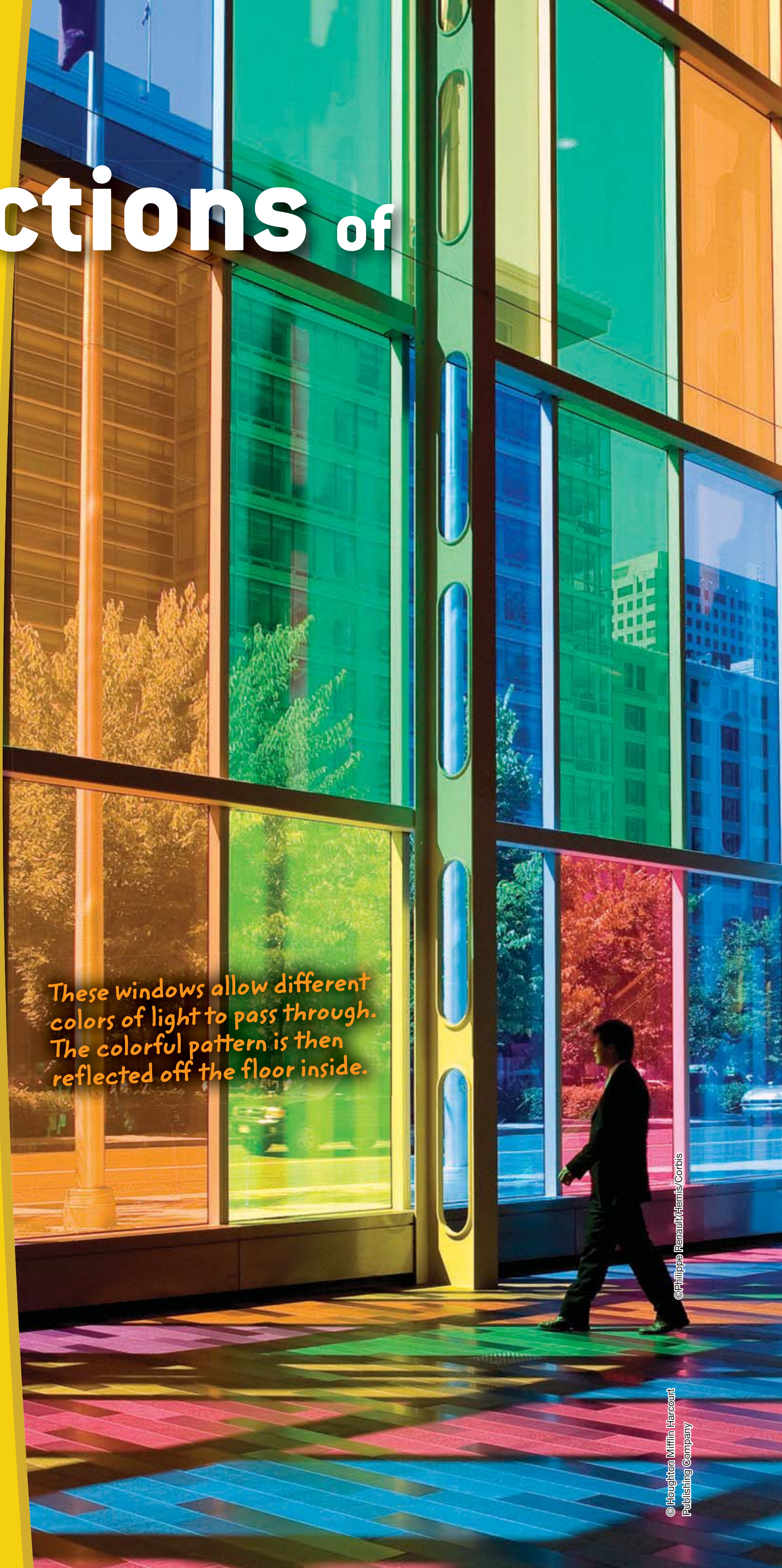
LESSON 4

Interactions of Light

ESSENTIAL **QUESTION**

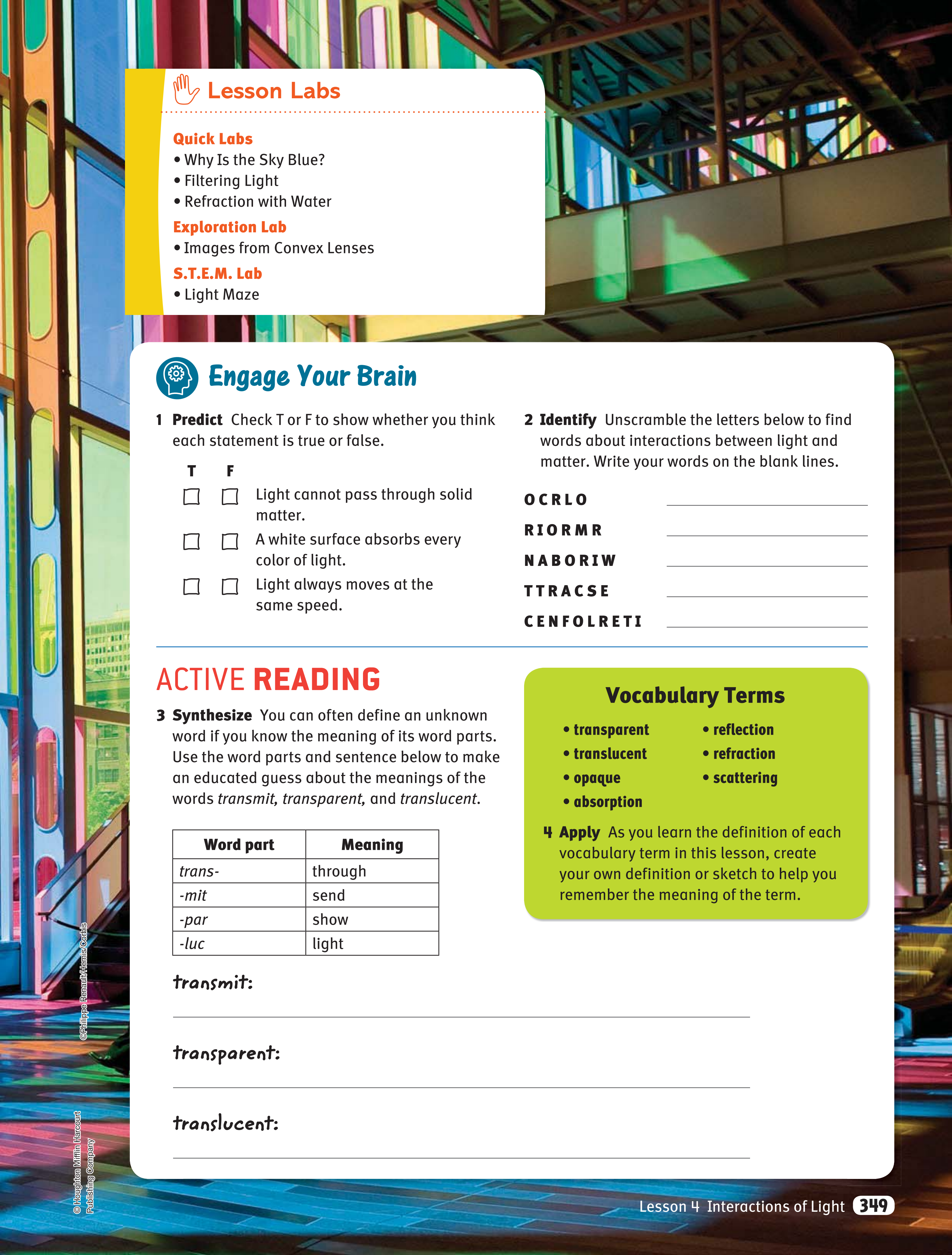
How does light interact with matter?

By the end of this lesson, you should be able to explain how light and matter can interact.



These windows allow different colors of light to pass through. The colorful pattern is then reflected off the floor inside.

SC.7.N.1.1 Define a problem from the seventh grade curriculum, use appropriate reference materials to support scientific understanding, plan and carry out scientific investigation of various types, such as systematic observations or experiments, identify variables, collect and organize data, interpret data in charts, tables, and graphics, analyze information, make predictions, and defend conclusions. **SC.7.P.10.2** Observe and explain that light can be reflected, refracted, and/or absorbed. **SC.7.P.10.3** Recognize that light waves, sound waves, and other waves move at different speeds in different materials.



Lesson Labs

Quick Labs
- Why Is the Sky Blue?
- Filtering Light
- Refraction with Water

Exploration Lab
- Images from Convex Lenses

S.T.E.M. Lab
- Light Maze

Engage Your Brain

1 **Predict** Check T or F to show whether you think each statement is true or false.

T	F	
☐	☐	Light cannot pass through solid matter.
☐	☐	A white surface absorbs every color of light.
☐	☐	Light always moves at the same speed.

2 **Identify** Unscramble the letters below to find words about interactions between light and matter. Write your words on the blank lines.

OCRLO ______________________

RIORMR ______________________

NABORIW ______________________

TTRACSE ______________________

CENFOLRETI ______________________

ACTIVE **READING**

3 **Synthesize** You can often define an unknown word if you know the meaning of its word parts. Use the word parts and sentence below to make an educated guess about the meanings of the words *transmit, transparent,* and *translucent*.

Word part	Meaning
trans-	through
-mit	send
-par	show
-luc	light

transmit:

____

transparent:

____

translucent:

____

Vocabulary Terms

- **transparent**
- **translucent**
- **opaque**
- **absorption**
- **reflection**
- **refraction**
- **scattering**

4 **Apply** As you learn the definition of each vocabulary term in this lesson, create your own definition or sketch to help you remember the meaning of the term.

Shedding Light

How can matter interact with light?

Interactions between light and matter produce many common but spectacular effects, such as color, reflections, and rainbows. Three forms of interaction play an especially important role in how people see light.

ACTIVE **READING**

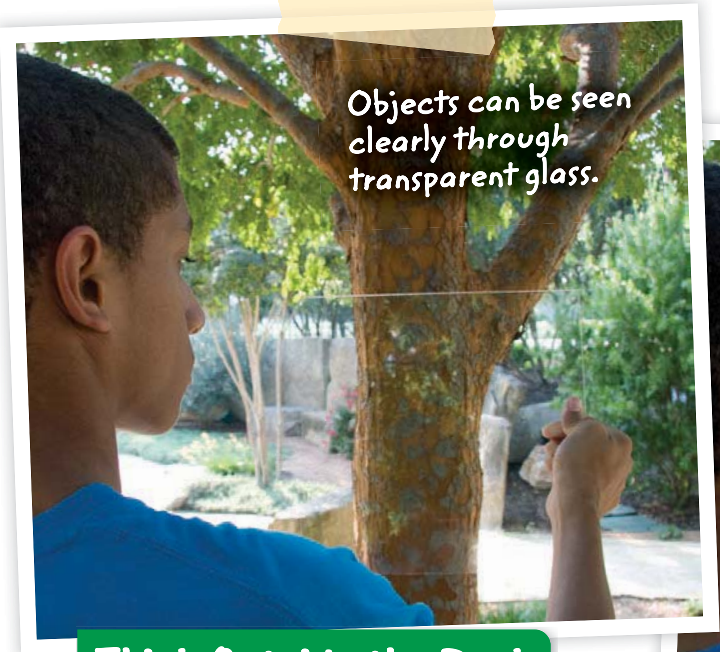
5 Identify As you read, underline three words that describe how well matter transmits light.

Matter Can Transmit Light

Recall that light and other electromagnetic waves can travel through empty space. When light encounters a material, it can be passed through the material, or transmitted. The medium can transmit all, some, or none of the light.

Matter that transmits light is **transparent** (tranz•PAHR•uhnt). Air, water, and some types of glass are transparent materials. Objects can be seen clearly through transparent materials.

Translucent (tranz•LOO•suhnt) materials transmit light but do not let the light travel straight through. The light is scattered into many different directions. As a result, you can see light through translucent materials, but objects seen through a translucent material look distorted or fuzzy. Frosted glass, some lamp shades, and tissue paper are examples of translucent materials.



Objects can be seen clearly through transparent glass.

Objects look distorted when seen through translucent glass.

Think Outside the Book

6 Discuss Write a short story in which it is important that a piece of glass is translucent or transparent.

on the Matter

Matter Can Absorb Light

Opaque (oh•PAYK) materials do not let any light pass through them. Instead, they reflect light, absorb light, or both. Many materials, such as wood, brick, or metal, are opaque. When light enters a material but does not leave it, the light is absorbed. **Absorption** is the transfer of light energy to matter.

The shirt at right absorbs the light that falls on it, and so the shirt is opaque. However, absorption is not the only way an object can be opaque.

The shirt is opaque, because light does not pass through it. We can't see the table underneath.

Visualize It!

7 Claims • Evidence • Reasoning Make a claim about whether the table in the photo at the right is transparent, translucent, or opaque. Summarize evidence to support the claim and explain your reasoning.

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Matter Can Reflect Light

You see an object only when light from the object enters your eye. However, most objects do not give off, or emit, light. Instead, light bounces off the object's surface. The bouncing of light off a surface is called **reflection**.

Most objects have a surface that is at least slightly rough. When light strikes a rough surface, such as wood or cloth, the light reflects in many different directions. Some of the reflected light reaches your eyes, and you see the object.

Light bounces at an angle equal to the angle at which it hit the surface. When light strikes a smooth or shiny surface such as a mirror, it reflects in a uniform way. As a result, a mirror produces an image. Light from a lamp might be reflected by your skin, then be reflected by a mirror, and then enter your eye. You look at the mirror and see yourself.

Light is reflected by the girl's face and by the mirror.

Visualize It!

8 Identify What is the difference between the way light interacts with the shirt above and the way light interacts with the mirror at right?

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Color Me Impressed!

What determines the color of objects we see?

Visible light includes a range of colors. Light that includes all colors is called white light. When white light strikes an object, the object can transmit some or all of the colors of light, reflect some or all of the colors, and absorb some or all of the colors.

The frog's body is green because it reflects green light while absorbing other colors of light.

The Light Reflected or Absorbed

The perceived color of an object is determined by the colors of light reflected by the object. For example, a frog's skin absorbs most colors of light, but reflects most of the green light. When you look in the direction of the frog, the green light enters your eyes, so the frog appears green.

An object that reflects every color appears white. An object that absorbs every color appears black.

The Light Transmitted

The color of a transparent or translucent object works differently than it does for opaque objects. Some materials may absorb some colors but let other colors pass through. Green plastic, for example, does not appear green because it reflects green light, but rather, because it transmits green light while absorbing other colors of light. When you look toward a bottle made of green plastic, the transmitted green light reaches your eyes. Therefore, the bottle looks green.

Some matter can absorb visible light but let other kinds of electromagnetic waves pass through. For example, radio waves can easily pass through walls that are opaque to visible light. X-rays pass through skin and muscle, but are stopped by denser bone.

The bottle is green because it allows green light to pass through while absorbing other colors of light.

Think Outside the Book

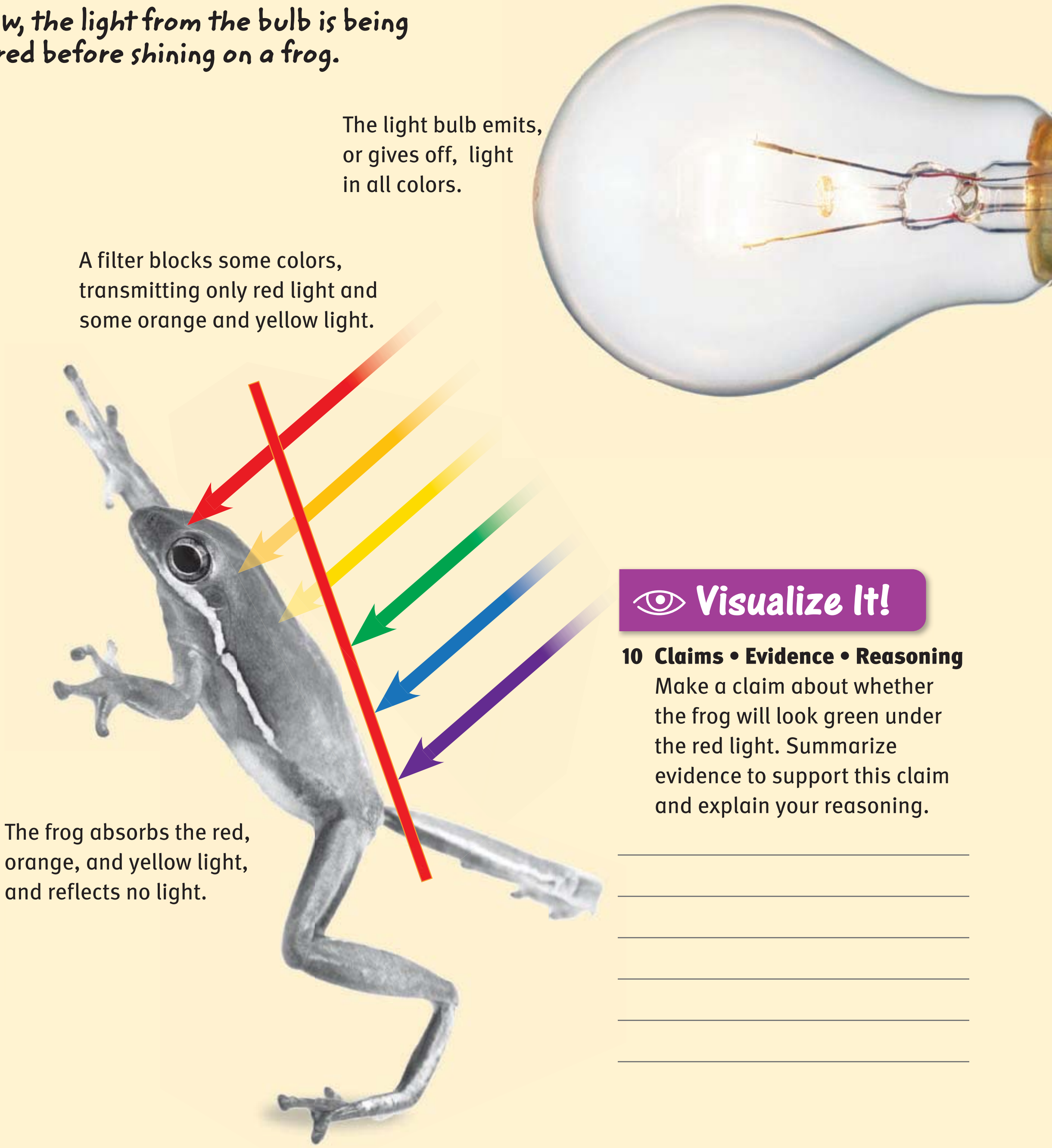
9 **Diagram** Use colored pencils, crayons, or markers to draw light shining on an object. Draw arrows showing the colors of incoming light and which colors are reflected.

The Available Light

Sometimes the perceived color of an object depends on the light available in the area. You may have been in a room with a red light bulb. The glass around the bulb filters out all colors except red, plus some orange and yellow. An object that reflects red light would still appear red under such a light bulb. But an object that absorbed all red, orange, and yellow light would appear gray or black. We can't see colors of light that aren't there to be reflected to our eyes!

Filtered Light

Below, the light from the bulb is being filtered before shining on a frog.



Visualize It!

10 Claims • Evidence • Reasoning Make a claim about whether the frog will look green under the red light. Summarize evidence to support this claim and explain your reasoning.

Matter Scatter

Light changes direction when it leaves the water, making the straw look broken.

What happens when light waves interact with matter?

You have already learned that light can pass through a transparent medium. But when light waves pass through a medium, the medium can change properties of the light.

Light Slows When It Passes Through Matter

You may have learned that light always travels at the same speed in a vacuum. This speed, about 300,000,000 m/s, is called the *speed of light*. However, light travels slower in a medium. Light travels only about three-fourths as fast in water as in a vacuum, and only about two-thirds as fast in glass as in a vacuum.

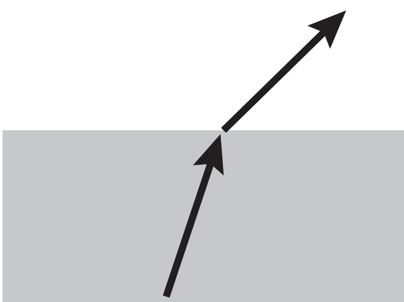
Although light of all wavelengths travels at the same speed in a vacuum, the same is not true in a medium. When light enters a medium from a vacuum, shorter wavelengths are slowed more than longer wavelengths. In a medium, the speed of violet light is less than the speed of red light.

Light Changes Direction

A straight object, such as the straw in the picture above, looks bent or broken when part of it is underwater. Light from the straw changes direction when it passes from water to glass and from glass to air. **Refraction** (ri•FRAK•shuhn) is the change in direction of a wave as it passes from one medium into another at an angle.

Your brain always interprets light as traveling in a straight line. You perceive the straw where it would be if light traveled in a straight line. The light reflected by the straw in air does travel in a straight line to your eye. But the light from the lower part of the straw changes direction when it passes into air. It refracts, causing the illusion that the bottom part of the straw in a water glass is disconnected from the top part.

Refraction is due to the change in speed as a wave enters a new medium. In glass, light's speed depends on wavelength. When light passes through a glass prism, the light waves with shorter wavelengths change direction more than waves with longer wavelengths. So, a prism separates light into a spectrum of colors.



Think Outside the Book

11 Apply When a bird tries to catch a fish, it must account for refraction. Draw a picture like the one above to show the path of light from the fish to the bird. Then trace the path backward to show where the fish appears to be to the bird.

12 Claims • Evidence • Reasoning Make a claim about which color of light will bend the least when passing through a prism. Summarize evidence to support this claim and explain your reasoning.

Light Scatters

You don't see a beam of light shining through clear air. But if the beam of light shines through fog, some of the light is sent in many different directions. Some enters your eye, and you see the beam. **Scattering** occurs when light is sent in many directions as it passes through a medium. Dust and other small particles can scatter light.

The color of the sky is due to scattered light. Particles of air scatter short wavelengths—blue and violet light—more than long wavelengths. As sunlight passes through air, blue light is scattered first. The blue light appears to come from all directions, and so the sky appears blue. When the sun is near the horizon in the sky, sunlight passes through more of the atmosphere. As the light passes through more and more air, almost all light of short wavelengths is scattered. Only the longest wavelengths are left. The sun and the sky appear yellow, orange, or red.

We can see the light beam coming out of the lighthouse because the fog scatters the light.

ACTIVE READING

13 Identify What color of light is scattered most easily by the atmosphere?

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In the diagram below, the red lines represent paths of light from the sun. The black brackets show the amount of atmosphere the light must pass through to reach our eyes.

In the evening, sunlight travels through a lot of air. The blue light scatters, leaving only redder light.

The daytime sky appears blue because air scatters blue light more than it does other colors.

Visual Summary

To complete this summary, circle the correct word to complete each statement. You can use this page to review the main concepts of the lesson.

Interactions of Light

Matter can transmit, reflect, or absorb light.

14 Matter that transmits no light is (transparent/translucent/opaque).

The color of an object depends on what colors of light it reflects or transmits.

15 A frog in white light appears green because it (reflects/absorbs/transmits) green light and (reflects/absorbs/transmits) other colors of light.

A transparent medium can bend, scatter, or change the speed of light.

16 The bending of light is called (reflection/refraction/scattering).

17 Claims • Evidence • Reasoning Suppose you are looking at a yellow fish in a fish tank. The tank is next to a window. Make a claim about the path that light takes in order for you to see the fish, starting at the sun and ending at your eyes. Summarize evidence to support the claim and explain your reasoning.

Lesson Review

Vocabulary

Fill in the blank with the term that best completes the following sentences.

1 An object appears fuzzy when seen through a(n) __________________ material.

2 A(n) __________________ material lets light pass through freely.

3 The bouncing of light off a surface is called __________________

4 The bending of light when it changes media is called __________________

5 __________________ occurs when light changes direction after colliding with particles of matter.

Key Concepts

6 Identify For each picture below, identify the material enclosing the sandwich as transparent, translucent, or opaque.

a. ______________

b. ______________

c. ______________

d. ______________

7 State Your Claim Which material in the pictures above reflects the most light?

8 State Your Claim Which material in the pictures above absorbs the most light?

Critical Thinking

9 Claims • Evidence • Reasoning Make a claim about whether a mirror's surface is transparent, translucent, or opaque. Summarize evidence to support the claim and explain your reasoning.

10 Apply Why does a black asphalt road become hotter than a white cement sidewalk in the same amount of sunlight? Explain your reasoning.

11 Explain Why is the sky blue?

12 Explain Red, green, and blue light rays each enter a drop of water from the same direction. Make a claim about which light ray's path will bend the most and which will bend the least as it passes through the drop. Summarize evidence to support each claim and explain your reasoning.

SC.7.N.1.1 Define a problem from the seventh grade curriculum, use appropriate reference materials to support scientific understanding, plan and carry out scientific investigation of various types, such as systematic observations or experiments, identify variables, collect and organize data, interpret data in charts, tables, and graphics, analyze information, make predictions, and defend conclusions.

S.T.E.M. ENGINEERING & TECHNOLOGY

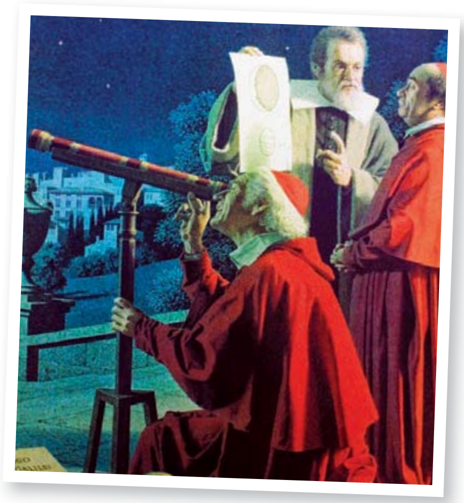
Engineering Design Process

Skills
Identify a need
Conduct research
✔ Brainstorm solutions
✔ Select a solution
Design a prototype
✔ Build a prototype
✔ Test and evaluate
✔ Redesign to improve
✔ Communicate results

Objectives
Identify different uses of mirrors and lenses.
Use mirrors and lenses to design and build a periscope.
Test and evaluate the periscope you built.

Building a Periscope

A *periscope* is a device that uses mirrors and lenses to help people see around obstacles. You might be surprised to learn how many other important technologies benefit from mirrors and lenses.



In 1610, Italian astronomer Galileo used a two-lens telescope to discover Jupiter's moons.

Early Uses of Mirrors and Lenses

For many centuries, people have used mirrors and lenses to bend light. In ancient times, people used shiny metal to see their reflections and pieces of curved glass to start fires. In the 17th century, scientists began using lenses and mirrors to make telescopes, microscopes, and other devices that helped them make new discoveries.

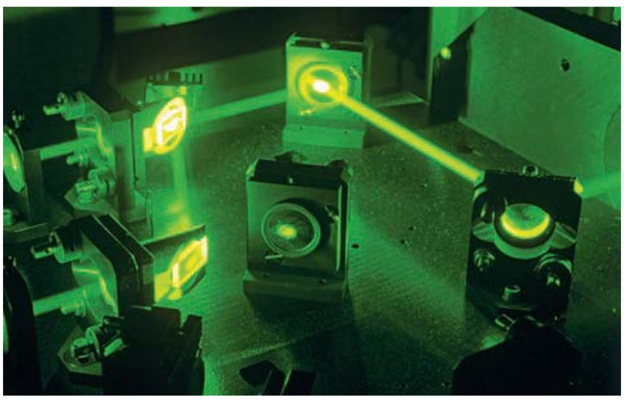
1 **Identify** List devices that use mirrors, lenses, or a combination of both. Then describe the purpose of each device, and identify whether it uses mirrors, lenses, or both.

Device	Purpose	Mirrors, Lenses, or Both
telescope	magnifies far away objects	both

Lasers

Mirrors bend light by reflecting it in a different direction. Lenses bend light by slowing it as it passes through the lens material. Many modern technologies also take advantage of mirrors and lenses. Devices such as DVD players and barcode scanners operate by using laser light. A *laser* is a device that produces a coherent beam of light of a specific wavelength, or color. Laser light is created in a chamber that has mirrors on each end. A single color of light is produced by reflecting light back and forth between the two mirrors. The distance between the mirrors determines the wavelength of light that is amplified. When the light is of the proper wavelength, it can exit the transparent center of one of the mirrors. Lenses are often found in devices that use laser light. Lenses can focus the laser light in devices such as DVD players.

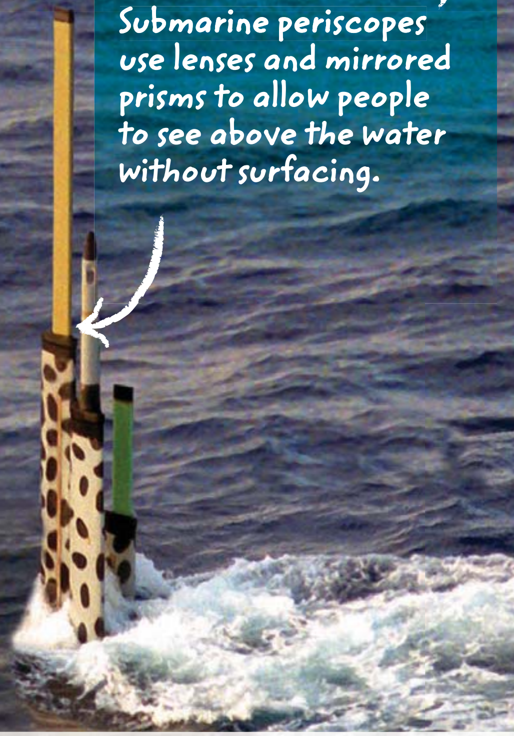
2 Claims • Evidence • Reasoning Conduct research and make a claim about how laser light functions in a device that you use every day. Summarize evidence to support your claim and explain your reasoning.



This device uses mirrors and lasers to measure the wind speed during an aircraft test. Wind speed is measured as the laser interacts with dust in the wind.

Periscopes

A periscope is another type of device that uses mirrors and lenses. The mirrors in a periscope bend light in order to allow a person to see around obstacles or above water. Most people think of periscopes in submarines, but periscopes are also used to see over walls or around corners, to see out of parade floats, and to see inside pipes or machinery.



Submarine periscopes use lenses and mirrored prisms to allow people to see above the water without surfacing.

You Try It!

Now it's your turn to use mirrors and lenses to design and build a periscope.

You Try It!

Mirrors are used to bend light, and lenses are used to focus light. Now it's your turn to use mirrors and lenses to design and build a periscope that can see at least six inches above eye level.

You Will Need

- ✓ cardboard boxes or poster board
- ✓ cardboard or plastic tubes
- ✓ lenses
- ✓ mirrors
- ✓ scissors
- ✓ tape

1 Brainstorm Solutions

A You will build a periscope to see things at least six inches above eye level. Brainstorm some ideas about how your periscope will work. Check a box in each row below to get started.

Length of periscope:	☐ 6 inches	☐ 12 inches	☐ other ________	
Shape of periscope:	☐ tube	☐ box	☐ other ________	
User will look with:	☐ one eye	☐ both eyes		
Your periscope:	☐ will	☐ will not	magnify objects	

B Once you have decided what your periscope needs to do, look at the materials available to you, and brainstorm how you can build your periscope. Write down the materials you will use and how you will use them.

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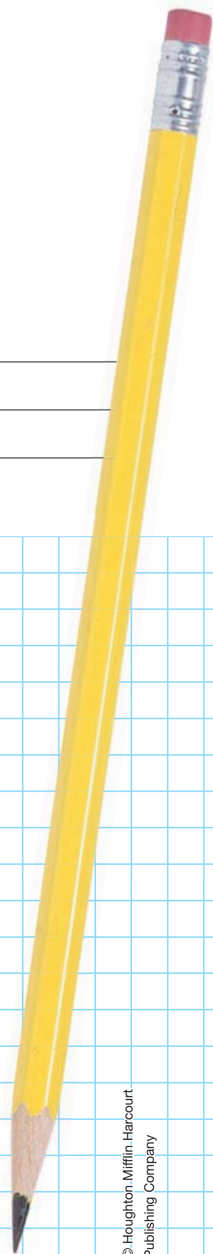
2 Select a Solution

Choose one of the ideas that you brainstormed. In the space below, draw a sketch of how your prototype periscope will be constructed. Include arrows to show the path of light through your periscope.



3 Build a Prototype

Use your materials to assemble the periscope according to your design. Write down the steps you took to assemble the parts.

4 Test, Evaluate, and Redesign to Improve

Test your periscope, and fill in the first row of the table below. Make any improvements, and test your periscope again, filling in an additional row of the table for each revised prototype.

Prototype	What I saw through the periscope	Improvements to be made
1		
2		
3		

5 Communicate Results

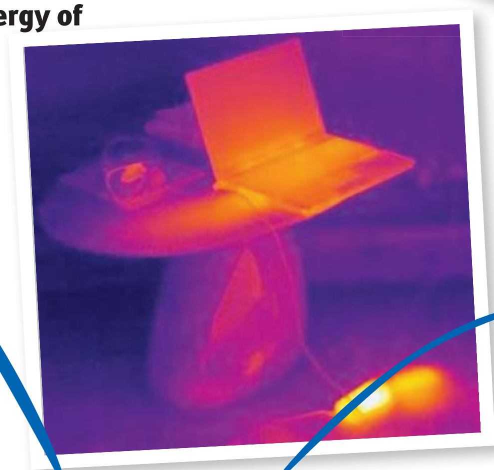
Write a paragraph summarizing what you wanted the periscope to do, how you designed and built it, whether the finished periscope worked as planned, and how you made improvements.

UNIT **5**

Summary

The Electromagnetic Spectrum

is arranged based on the energy of



Waves

are influenced by

Interactions of Light

are influenced by

Properties of Waves

1 **Interpret** The Graphic Organizer above shows that the properties of waves are influenced by the energy of waves. Name two properties of waves that affect the energy of waves.

2 **Predict** When you look in a mirror, you see the reflection of visible light. Would you expect that ultraviolet light would be reflected by a mirror? Explain your reasoning.

3 **Claims • Evidence • Reasoning** Make a claim about how the energy of a microwave compares to the energy of a gamma ray. Summarize evidence to support your claim and explain your reasoning.

4 **Synthesize** Is a radio wave a longitudinal wave or a transverse wave?

Benchmark Review

Name ______________________________

Vocabulary

Fill in each blank with the term that best completes the following sentences.

1 Light travels as a(n) ______________________ wave.

2 The distance from the crest of one wave to the crest of the next wave is the ____________

3 ____________, the number of waves produced in a given amount of time, is expressed in hertz.

4 Sound is a(n) ________________ wave because it cannot travel without a medium.

5 The maximum distance that the particles of a medium move away from their rest position is a measure of a wave's ______________

Key Concepts

Identify the choice that best completes the statement or answers the question.

6 Heather puts a straw into a glass of water. She notices that when she looks through the glass and the water from the side, the straw appears to be broken. Which term **best** explains why the straw looks like it is broken?

A absorption

B refraction

C scattering

D transmission

7 The energy generated by the sun travels to Earth as electromagnetic waves. Because the radiation from the sun travels to Earth in varying wavelengths, scientists consider them to be a spectrum. Which statement describes an electromagnetic wave with a long wavelength?

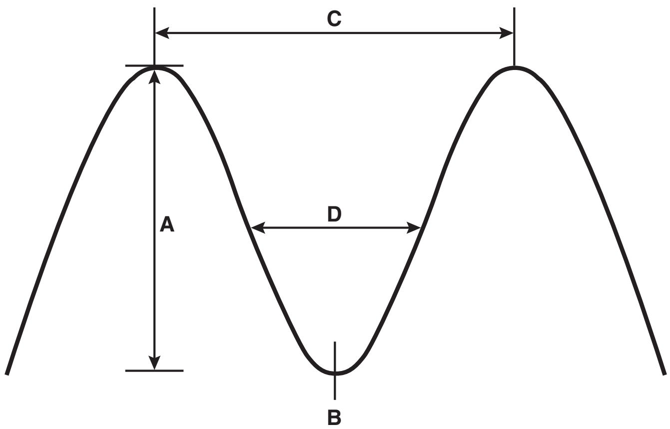
F It has a high frequency and low energy.

G It has a high frequency and high energy.

H It has a low frequency and can travel through a vacuum.

I It has a low frequency and needs a medium to travel through.

8 The diagram below shows a wave. The features of the wave are labeled A, B, C, and D.



Which label identifies the wavelength?

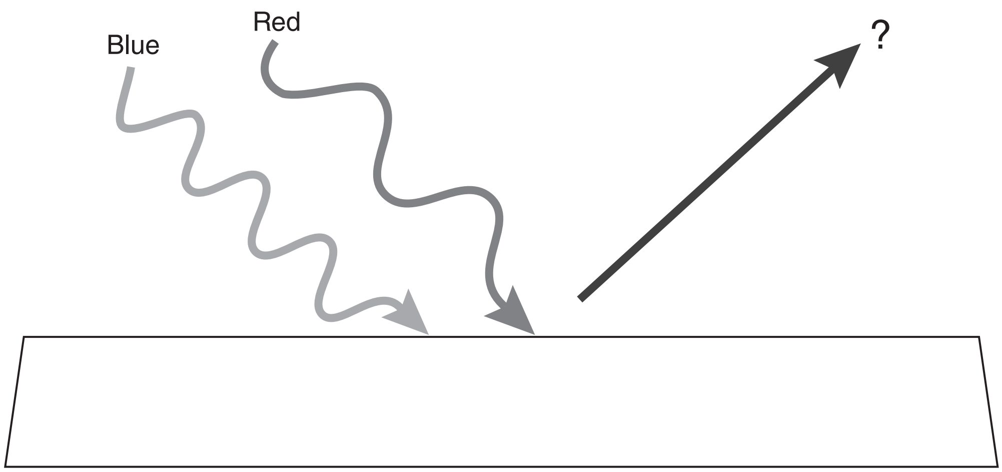
A A

B B

C C

D D

9 Kana shines a light onto paper as shown in the figure below. The light contains both blue and red wavelengths of light.



If the paper is blue, what color (or colors) of light bounces off the paper?

F only red

G only blue

H both red and blue

I neither red nor blue

Name ____________________

10 Habib looks around his classroom at different objects. Which object reflects almost all of the light that strikes it?

A white poster board

B clear window glass

C bright overhead light

D black construction paper

11 Electromagnetic energy travels through space as waves. The electromagnetic spectrum includes all electromagnetic waves, arranged according to frequency and wavelength. Which of these is an example of an electromagnetic wave?

F radio wave

G sound wave

H ocean wave

I gravitational pull

12 Emma measured the maximum displacement of a wave that she made by moving the end of a string up and down. What property of a wave was she measuring?

A period

B frequency

C amplitude

D wavelength

13 Ava covers a flashlight with a piece of thick, black paper. Why doesn't she see the light when she turns on the flashlight?

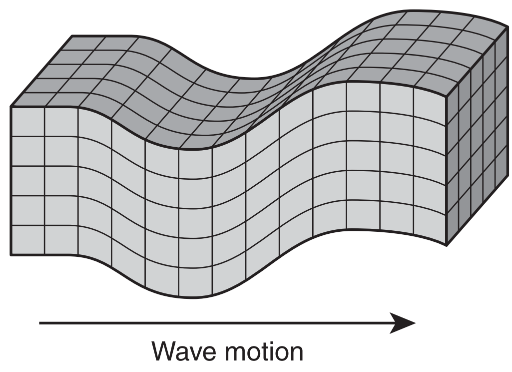
F The paper absorbs most of the light.

G The paper refracts most of the light.

H The paper reflects most of the light.

I The paper transmits most of the light.

14 Isabella researched how waves travel through the ground during an earthquake. She drew a diagram of one, called an S wave, moving through Earth's crust.



Based on her diagram, what kind of wave is an S wave?

A light

B sound

C longitudinal

D transverse

Critical Thinking

Answer the following questions in the space provided.

15 Some waves carry more energy than others. Which wave has more energy, a loud sound or a quiet sound? Why? Use evidence to support your claim and explain your reasoning.

16 Tafari worked one summer on a ship that set weather buoys in the ocean. He watched how the buoys moved in the water.

Which wave property describes why the buoys bobbed up and down?

Which wave property determines how fast the buoys bobbed in the water?

He observed that when the wind blew harder, the ocean waves were larger, and the buoys moved away from the ship. Did the buoys move as a result of the ocean waves? Summarize evidence to support your claim and explain your reasoning.