Name _____ Class _____ Date _____

CHAPTER 20 The Energy of Waves

SECTION 1

The Nature of Waves

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What is a wave, and how does it transmit energy?
- How do waves move?
- What are the different types of waves?

National Science Education Standards

PS 3a

What Is Wave Energy?

A **wave** is any disturbance that transmits energy through matter or empty space. Energy can be carried away from its source by a wave. However, the material through which the wave moves is not transmitted. For example, a ripple caused by a rock thrown into a pond does not move water out of the pond.

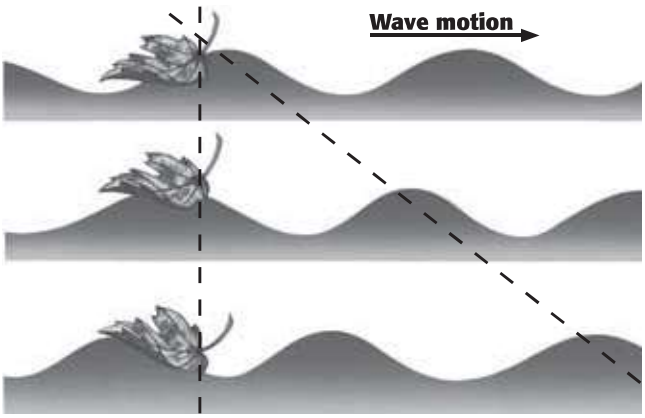
A wave travels through a material or substance called a **medium**. A medium may be a solid, a liquid, or a gas. The plural of medium is *media*. ☑

STUDY TIP

As you read the section, make a table of the types of waves. Have columns for the type of wave, what it moves through, its direction of motion, and how it transmits energy.

READING CHECK

1. Identify What does a wave move through?



A wave travels through the medium, but the medium does not travel. In a pond, lake or ocean, the medium through which a wave travels is the water. The waves in a pond travel towards the shore. However, the water and the leaf floating on the surface only travel up and down.

How Can Waves Do Work?

As a wave travels, it does work on everything in its path. The waves traveling through a pond do work on the water. Anything floating on the surface of the water moves up and down. The fact that any object on the water moves indicates that the waves are transferring energy. Waves can transfer energy through a medium or without a medium. ☑

READING CHECK

2. Describe What indicates that a water wave transfers energy to a floating object?

WAVES CAN TRANSFER ENERGY THROUGH A MEDIUM

When a particle *vibrates* (moves back and forth), it can pass its energy to the particle next to it. The second particle will vibrate like the first particle and may pass the energy on to another particle. In this way, energy is transmitted through a medium.

TAKE A LOOK

3. Describe How did the last ball in the figure on the right gain energy?

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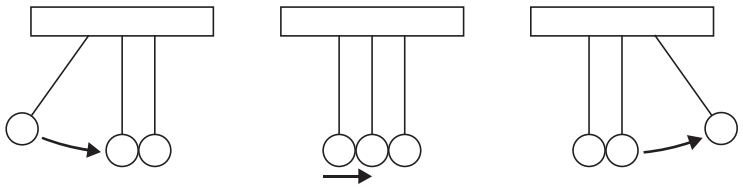

A particle can pass energy to the particle next to it. The particle receiving the energy will vibrate like the first particle. This is shown by the Newton's pendulum above. When the moving steel ball collides with another steel ball, its energy is given to that ball. Notice that the first ball stops, but its energy is passed on to a third ball.

Waves that require a medium are called *mechanical waves*. Mechanical waves include sound waves, ocean waves, and earthquake waves. For example, consider a radio inside a jar. If all of the air from inside the jar is removed to create a vacuum, the radio can not be heard.

WAVES CAN TRANSFER ENERGY WITHOUT A MEDIUM

Waves that transfer energy without a medium are called *electromagnetic waves*. Examples of electromagnetic waves include visible light, microwaves, TV and radio signals, and X-rays used by dentists and doctors.

Electromagnetic waves may also go through matter, such as air, water, or glass. Light waves travel from the sun through space toward Earth. Light waves then travel through the air in the atmosphere to reach the surface of Earth.

STANDARDS CHECK

PS 3a Energy is a property of many substances and is associated with heat, light, electricity, mechanical motion, sound, nuclei, and the nature of a chemical. Energy is transferred in many ways.

4. Identify What kinds of waves need a medium to transfer their energy? What kinds of waves don't need a medium to transfer their energy?

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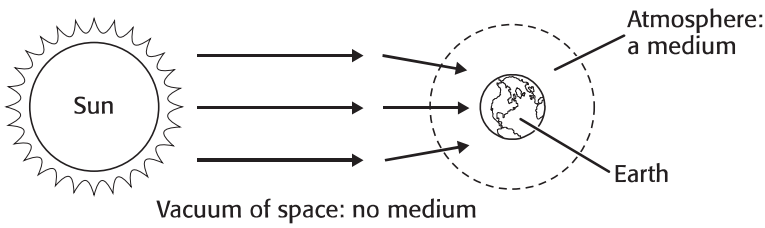

To reach the Earth, light travels from the sun, through the vacuum of space. The light then travels through the particles of the atmosphere before reaching the surface of the earth.

What Are the Different Types of Waves?

Waves transfer energy through vibrations. However, the way particles in a wave vibrate depends on the type of wave. Waves are classified based on the direction in which wave particles vibrate compared with the direction in which waves move. There are two main types of waves, *transverse waves* and *longitudinal waves*. ☑

READING CHECK

5. Identify What are the two main types of waves?

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_____

TRANSVERSE WAVES

Waves in which the particles vibrate in an up-and-down motion are called **transverse waves**. Particles in a transverse wave move at right angles relative to the direction of the wave. See the figure below. The highest point in a transverse wave is a *crest*. The lowest point in a transverse wave is a *trough*. ☑

READING CHECK

6. Identify What is the direction of a transverse wave relative to its direction of motion?

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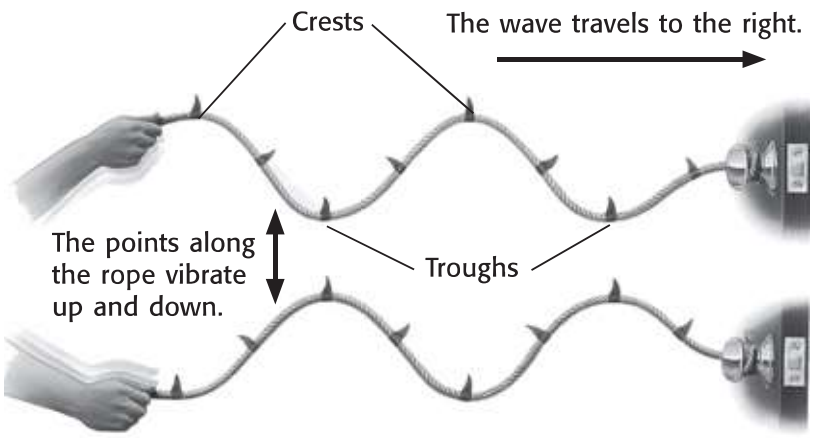
_____

Motion of a Transverse Wave



A wave traveling down a length of rope is an example of a transverse wave. The wave travels to the right. The particles in the medium, the rope, travel up-and-down. The particles in the wave and the medium are moving at right angles to each other.

All electromagnetic waves are transverse waves. Remember, electromagnetic waves can travel through space or through a medium. Electromagnetic waves are transverse waves because the wave vibrations are at right angles to the direction the wave is traveling. ☑

READING CHECK

7. Describe Why is an electromagnetic wave identified as a transverse wave?

_____

_____

_____

_____

LONGITUDINAL WAVES

Waves in which the particles of the medium vibrate back and forth along the path of the wave are called **longitudinal waves**. For example, pushing together two ends of a spring causes the coils to crowd together. When you let go, a longitudinal wave is created in the spring that travels along the length of the spring. ☑

In a longitudinal wave, a *compression* is the location of the crowded particles. A *rarefaction* is where the particles are spread apart.

Compressions and rarefactions are similar to crests and troughs in a transverse wave. See the figure below.

READING CHECK

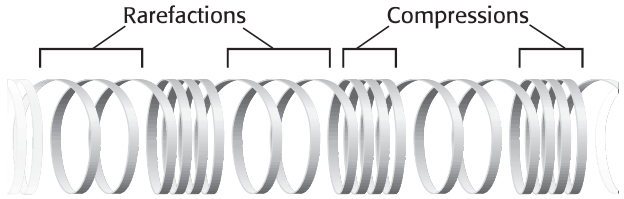
8. Describe How do the particles of a longitudinal wave vibrate?

_____

_____

_____

Comparing Longitudinal and Transverse Waves



A wave traveling along the length of a spring is an example of a longitudinal wave. The wave travels to the right. The particles in the medium, the spring, move back-and-forth. The particles in wave and the medium are moving along the same direction as each other.

The troughs and crests of a transverse wave represent an up-and-down motion around a central point. Similarly, the rarefactions and compressions of a longitudinal wave represent a back-and-forth motion around a central point.

Critical Thinking

9. Describe How could you produce a transverse wave in a spring?

_____

_____

A sound wave is an example of a longitudinal wave. Sound waves travel by compressions and rarefactions of air particles.

When the drumhead moves out after being hit, a compression is created in the air particles.

When the drumhead moves back in, a rarefaction is created.

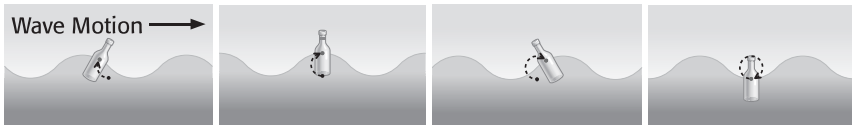
Sound energy is carried away from a drum by a longitudinal wave through the air.

TAKE A LOOK

10. Identify Circle the compression part of the wave in the second figure.

SURFACE WAVE

When waves move at or near the surface between two media a *surface wave* may form. For example, this occurs when an ocean wave comes into shallow water at the shore. Surface waves travel in both transverse and longitudinal motion. A particle in a surface wave will appear to move in a circular motion.



Ocean waves are surface waves. A floating bottle shows the circular motion of particles in a surface wave.

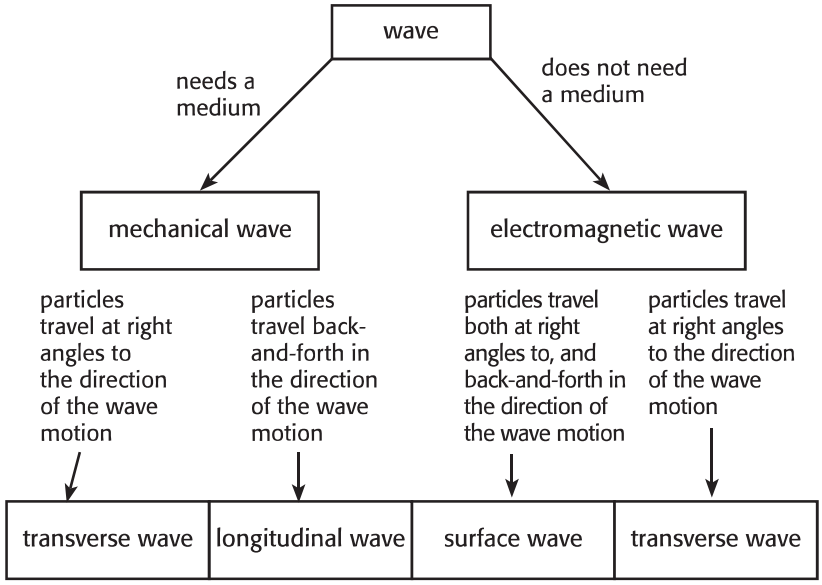
Critical Thinking

11. Identify An ocean wave forms a surface wave as it comes into shallow water. What are the two media involved in forming the surface wave?

_____

_____

Summary of Wave Types and Their Motion Through Space



TAKE A LOOK

12. Identify Which type of wave must have a medium in order to travel?

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Section 1 Review

NSES PS 3a

SECTION VOCABULARY

medium a physical environment in which phenomena occur **longitudinal wave** a wave in which the particles of the medium vibrate parallel to the direction of wave motion	**transverse wave** a wave in which the particles of the medium move perpendicularly to the direction the wave is traveling **wave** a periodic disturbance in a solid, liquid, or gas as energy is transmitted through a medium

1. **Describe** How does energy travel through a wave in a medium?

_____

_____

_____

2. **Identify** Determine the method of energy transfer, and the wave type for each wave source.

Wave source	Wave energy transfer (electromagnetic wave or mechanical wave)	Wave type (transverse wave, longitudinal wave, or surface wave)
Light emitted from a light bulb		
Sound coming from a violin		
Rock dropped in a pond		

3. **Apply Concepts** A ribbon is tied to the first loop of a spring as a marker. The spring is pulled and then released to create a longitudinal wave. Where is the ribbon after three complete vibrations?

_____

4. **Recall** Label each wave part as a crest, trough, compression, or rarefaction according to its description.

Wave Part	Description
	particles are crowded toward each other
	particles are at their highest point
	particles are at their lowest point
	particles are spread away from each other

Name _____ Class _____ Date _____

CHAPTER 20 The Energy of Waves

SECTION 2

Properties of Waves

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What are ways to describe a wave?
- What determines the energy of a wave?

National Science Education Standards

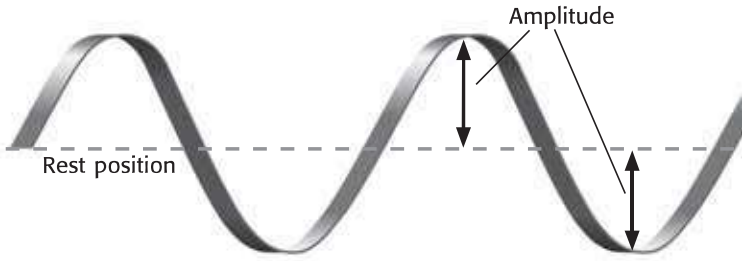
PS 3a

What Is the Amplitude of a Wave?

An earthquake in the ocean can make a transverse wave called a *tsunami*. The waves can get very tall as they reach land. The *amplitude* of a transverse wave is related to the height of the wave. **Amplitude** is the maximum distance the particles of the wave vibrate away from their rest position. The rest position, shown in the figure below, is the location of the particles of the medium before the wave gets there. ☑

STUDY TIP

With a partner, discuss the properties of a wave and how they affect the energy of a wave.



The amplitude of a transverse wave is measured from the rest position to the crest or the trough of the wave.

READING CHECK

1. Describe What is the amplitude of a wave?

_____

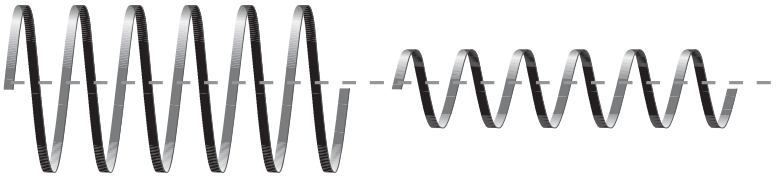
_____

_____

_____

RELATIONSHIP BETWEEN AMPLITUDE AND ENERGY

Taller waves have larger amplitudes, and shorter waves have smaller amplitudes. It takes more energy to create a wave with a large amplitude. Therefore, it carries more energy. ☑



A wave with a larger amplitude carries more energy.

A wave with a smaller amplitude carries less energy.

READING CHECK

2. Explain Why do waves of large amplitude carry more energy?

_____

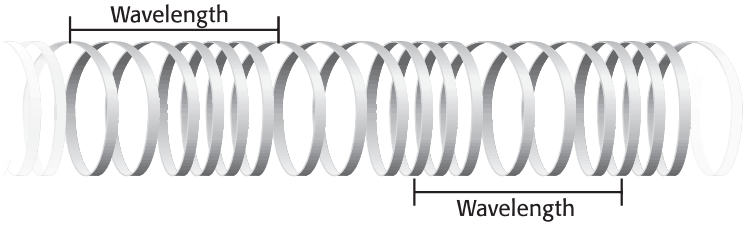
_____

What Is the Wavelength of a Wave?

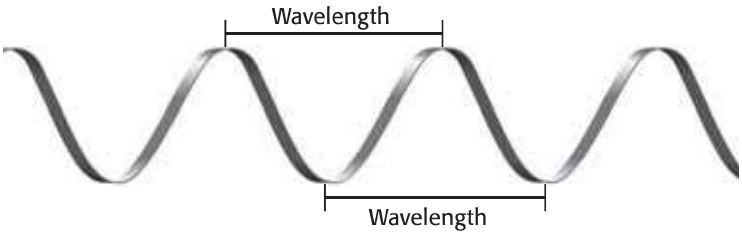
The **wavelength** is the distance between any point on a wave and the identical point on the next wave. A wavelength is the distance between two neighboring crests or two compressions. The distance between two troughs or two rarefactions next to each other is also a wavelength. See the figure below.

Measuring Wavelengths

Longitudinal wave



Transverse wave



A wavelength can be measured between any two identical points on neighboring waves.

Math Focus

3. Infer What is the distance between a crest and a trough next to a crest? Hint: use the figure for help.

_____

STANDARDS CHECK

PS 3a Energy is a property of many substances and is associated with heat, light, electricity, mechanical motion, sound, nuclei, and the nature of a chemical. Energy is transferred in many ways.

4. Identify There are two groups of waves with the same amplitude. One contains waves of short wavelength and the other has waves of long wavelength. Which waves have the most energy?

_____

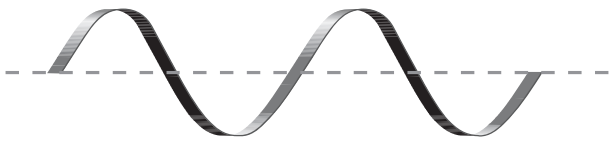
_____

_____

RELATIONSHIP BETWEEN WAVELENGTH AND ENERGY

Suppose you have two waves of the same amplitude. The wave with a shorter wavelength carries more energy than the wave with a longer wavelength.

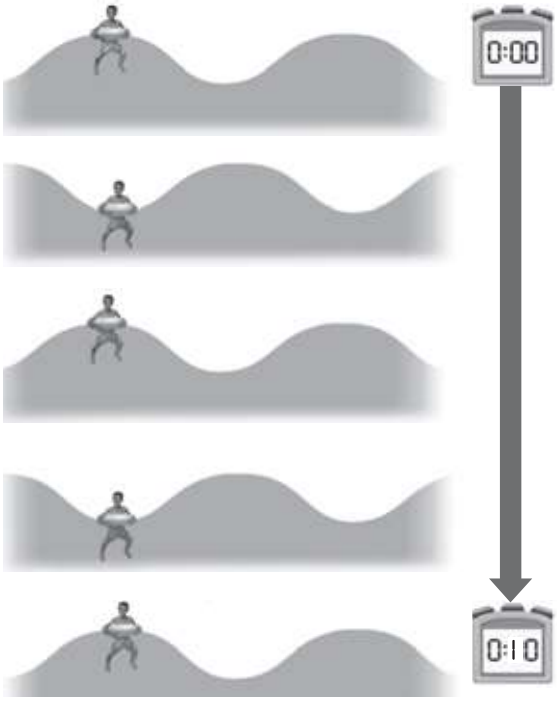
A wave with a short wavelength carries more energy.



A wave with a long wavelength carries less energy.

What Is the Frequency of a Wave?

The **frequency** of a wave is the number of waves produced in a given amount of time. Frequency is often expressed in *hertz* (Hz). One hertz equals one wave per second (1 Hz = 1/s).



Frequency is the number of waves that pass a certain point in a given amount of time. Frequency can be measured by counting the waves that pass a certain point in a certain amount of time. In the image shown here, two waves passed by in 10 s. The frequency is 2/10 s = 0.2 1/s = 0.2 Hz.

RELATIONSHIP BETWEEN FREQUENCY AND ENERGY

When the amplitudes of two waves are equal, the wave with the higher frequency has more energy. Lower-frequency waves carry less energy. ☑

What Is Wave Speed?

Wave speed is the speed at which a wave travels through a medium. Wave speed is symbolized by v. The speed of a wave is a property of the medium. Changing the medium of a wave changes its speed. For example, light travels faster in air than in water.

The equation for calculating speed is $v = \lambda \times f$. λ is the Greek letter *lambda* and means the wavelength. f is the frequency of the wave.

Let's do a problem. What is the speed of a wave whose wavelength is 5 m and frequency is 4 Hz (or 4 1/s)?

Step 1: write the equation $v = \lambda \times f$

Step 2: replace λ and f with their values

$v = 5 \text{ m} \times 4 \text{ 1/s} = 20 \text{ m/s}$

Math Focus

5. Determine If a source of waves produces 30 waves per second, what is the frequency in hertz?

_____

Critical Thinking

6. Applying Concepts What would the time of the lower clock read if the frequency of the wave were 0.1 Hz?

_____

READING CHECK

6. Identify When the amplitudes of waves are equal, which frequency waves have the most energy?

_____

_____

Math Focus

7. Calculate What is the speed of a wave whose wavelength is 30 m and frequency is 20 Hz? Show your work.

Name _____ Class _____ Date _____

Section 2 Review

NSES PS 3a

SECTION VOCABULARY

amplitude the maximum distance that the particles of a wave's medium vibrate from their rest position **frequency** the number of waves produced in a given amount of time	**wavelength** the distance from any point on a wave to an identical point on the next wave **wave speed** the speed at which a wave travels through a medium

1. **Apply Concepts** The distance between the crest and trough of an ocean wave is 1 meter. What is the amplitude of the wave?

_____

2. **Identify** Indicate whether the wave description should result in higher-energy wave, or a lower-energy wave.

Wave description	Wave energy
high amplitude	
low frequency	
low wavelength	

3. **Apply Concepts** Explain how to produce a longitudinal wave on a spring that has large energy. There are two answers; one involves wavelength and the other frequency.

_____

_____

4. **Math Concepts** What is the speed of a wave that has a wave length of 100 m and a frequency of 25 Hz? Show your work.

5. **Apply Concepts** A sound wave has a frequency of 125 Hz and a speed of 5000 m/s. What is the wavelength of the wave? Show your work.

Name _____ Class _____ Date _____

CHAPTER 20 The Energy of Waves

SECTION 3

Wave Interactions

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- How do waves interact with objects?
- How do waves behave when they move between two media?
- How do waves interact with other waves?

National Science Education Standards

PS 3a

Why Do Waves Reflect?

A **reflection** occurs when a wave bounces back after hitting a barrier. All waves can be reflected. Light waves reflecting off an object allow you to see that object. For example, light waves from the sun reflecting off the moon allow you to see the moon. Sound wave can also reflect. Sound waves reflecting off a barrier are called an *echo*.

STUDY TIP

In your science notebook, define each new vocabulary word. Include sketches illustrating reflection, refraction, diffraction, and both kinds of interference.

The waves in this photograph were formed by drops of water that fell into a container of water. When the waves caused by the drops of water hit one side of the container, they reflect off. The shape of the reflected waves is opposite that of the waves that struck the side of the tank.

Waves are not always reflected when they hit a barrier. Sometimes they pass through a substance. When a wave passes through a substance, it is *transmitted*. Light waves transmitted through a glass window allow light to enter a room. Light waves transmitted through eyeglasses allow the wearer to see through them.

Critical Thinking

1. Infer How does your reflection in a bathroom mirror look when you raise you right arm?