1 FOCUS

Objectives

17.2.1 **Define** frequency, period, wavelength, and wave speed and **describe** these properties for different kinds of waves.

17.2.2 **Solve equations** relating wave speed to wavelength and frequency or period.

17.2.3 **Describe** how to measure amplitude and **relate** amplitude to the energy of a wave.

Reading Focus

Build Vocabulary

L2

Word Forms The term amplitude contains the root *ampl-,* which comes from the Latin *amplus.* Have students think of other English words that contain *ampl- (amplify, ample).* What do these words have in common? *(All have to do with largeness or fullness.)*

Reading Strategy

L2

a. The time required for one cycle **b.** The number of complete cycles in a given time **c.** The distance between a point on a wave and the same point on the next cycle of the wave **d.** The maximum displacement of a medium from its rest position

2 INSTRUCT

Frequency and Period

Use Visuals

L1

Figure 5 Have students compare the number of complete cycles per second in Figures 5A and 5B. Ask, **What happens to the frequency when the number of cycles per second increases?** *(It increases.)* **If a wave has a frequency of 0.5 Hz, how many cycles per second is it vibrating?** *(It is vibrating at one-half cycle per second.)* **What is the period of a 0.5-Hz wave?** *(2 seconds)*

Logical

17.2 Properties of Mechanical Waves

Reading Focus

Key Concepts

- What determines the frequency of a wave?
- How are frequency, wavelength, and speed related?
- How is the amplitude of a wave related to the wave's energy?

Vocabulary

- periodic motion
- period
- frequency
- hertz
- wavelength
- amplitude

Reading Strategy

Building Vocabulary Copy and expand the table below. As you read, write a definition in your own words for each term.

Vocabulary Term	Definition
Period	a. ?
Frequency	b. ?
Wavelength	c. ?
Amplitude	d. ?

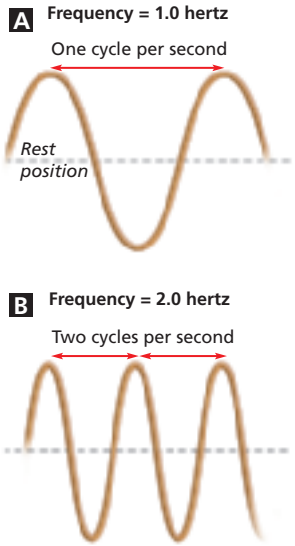

Figure 5 Frequency is the number of complete cycles in a given time. **A** A wave vibrating at one cycle per second has a frequency of 1.0 Hz. **B** A wave vibrating at two cycles per second has a frequency of 2.0 Hz.

Will it be a good day for surfing? You might not think that a surfer would check the Internet to find out. But some Web sites now update ocean wave data every hour. Of course, fishing boats and naval vessels also need this information. Usually, the properties used to describe waves are period, frequency, wavelength, speed, and amplitude.

Frequency and Period

How do surfers know when the next wave is coming? If they count the time between two successive crests, the next crest usually will come after this same time interval. Any motion that repeats at regular time intervals is called **periodic motion.** The time required for one cycle, a complete motion that returns to its starting point, is called the **period.** For an ocean wave, the period is the time between two successive crests.

Any periodic motion has a **frequency,** which is the number of complete cycles in a given time. For a wave, the frequency is the number of wave cycles that pass a point in a given time. Frequency is measured in cycles per second, or **hertz** (Hz).

A wave's frequency equals the frequency of the vibrating source producing the wave. The rope in Figure 5A is shaken with a frequency of one vibration per second, so the wave frequency is one cycle per second, or 1 hertz. In Figure 5B, the vibration is twice as fast, so the frequency is two cycles per second, or 2 hertz.

Section Resources

Print

- ***Reading and Study Workbook With Math Support,*** Section 17.2 and **Math Skill:** Calculating Wave Properties
- ***Math Skills and Problem Solving Workbook,*** Section 17.2
- ***Transparencies,*** Section 17.2

Technology

- ***Interactive Textbook,*** Section 17.2
- ***Presentation Pro CD-ROM,*** Section 17.2
- ***Go Online,*** NSTA SciLinks, Wave properties

Quick Lab

Comparing Frequency and Wave Speed

Materials

3-m rope, tape measure, stopwatch

Procedure

1. Tie one end of the rope to a chair. Shake the other end to send waves down the rope.
2. With a partner, measure the time it takes your hand to move back and forth ten times. Then, measure and record the distance from your hand to the chair and the time it takes a wave crest to travel this distance.
3. Repeat Step 2, but this time shake the rope more rapidly. Record your data.

Analyze and Conclude

1. **Calculating** What was the frequency of the waves in Steps 2 and 3? (*Hint:* Divide 10 waves by the time it took to make them.)
2. **Calculating** What was the wave speed in Steps 2 and 3? (*Hint:* Divide distance by time.)
3. **Drawing Conclusions** How was wave speed affected by increasing the frequency?

Wavelength

Wavelength is the distance between a point on one wave and the same point on the next cycle of the wave. For a transverse wave, wavelength is measured between adjacent crests or between adjacent troughs. For a longitudinal wave, wavelength is the distance between adjacent compressions or rarefactions. Notice in Figure 6 that when wavelength is shorter, crests are closer together. They must occur more frequently. **Increasing the frequency of a wave decreases its wavelength.**

Reading Checkpoint *What is wavelength?*

Wave Speed

Recall that the speed of an object equals distance divided by time. To calculate a swimmer's speed, for example, you can measure the length of one lap in a pool and the time it takes to swim one lap. This is like measuring the wavelength (one lap) and period (time to swim one lap) of the swimmer's motion. In much the same way, you can calculate the speed of a wave by dividing its wavelength by its period. You can also calculate wave speed by multiplying wavelength by frequency.

Speed of Waves

$$\text{Speed} = \text{Wavelength} \times \text{Frequency}$$

When the wavelength is in meters and the frequency is in hertz, the units for speed are meters per second. If you know any two of the values in this formula, you can solve for the third value.

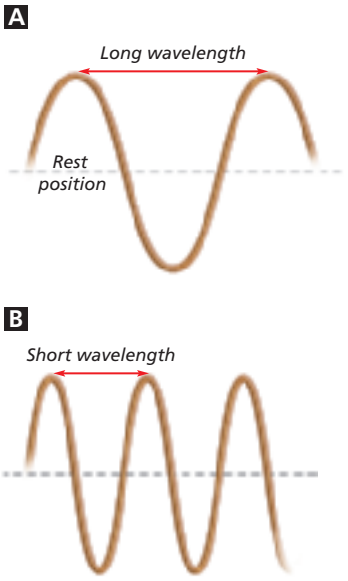

Figure 6 Wavelength can be measured from any point on a wave to the same point on the next cycle of the wave. **A** The wavelength of a transverse wave equals the distance from crest to crest or from trough to trough. **B.** The wavelength of this wave is half the wavelength of the wave in A. **Inferring** ***Which wave has a greater frequency?***

Customize for Inclusion Students

Visually Impaired

Tie a weight (such as a washer or fishing weight) to a string, and attach the string to a pendulum clamp on a ring stand so that it hangs vertically and is free to swing. Allow students to touch the pendulum and make it swing. By holding their hand in the right place, they can feel the weight touch their hand as it completes each cycle. Students can compare the periods and frequencies of pendulums with different lengths (lengths of 1 m, 25 cm, and 6.25 cm should produce frequencies of about 0.5 Hz, 1 Hz, and 2 Hz, respectively).

Wavelength

Build Science Skills L2

Measuring Have students use a small ruler to measure the wavelength of each wave in Figure 6 and verify that the wavelength measured does not depend on which two corresponding points are used. **Visual, Logical**

Wave Speed

Quick Lab

Comparing Frequency and Wave Speed L2

Objective

After completing this activity, students will be able to

- distinguish between wave frequency and wave speed.

Skills Focus **Measuring, Comparing and Contrasting**

Time Saver **Prep Time** 10 minutes

Class Time 20 minutes

Teaching Tips

- Have students practice before doing timed trials.
- Using a longer rope gives more clear-cut results.

Expected Outcome Neither the amplitude nor the frequency affects the speed of propagation of a wave.

Analyze and Conclude

1. Answers will depend on student data. Answers of one to five waves per second are reasonable.
2. Answers will depend on student data but should be expressed in units of m/s.
3. The wave frequency had no effect on the wave speed. **Logical**

For Enrichment L3

Students can time the speed of waves in various other solid media, such as wires and monofilament fishing line, and attempt to determine the properties of materials that affect the speed of wave transmission. **Kinesthetic**

Answer to . . .

Figure 6 *The frequency of B is greater than the frequency of A.*

Reading Checkpoint *Wavelength is the distance between one point on a wave and the same point on the next cycle of the wave.*

Math Practice

Solutions L2

1. The speed is 2.0 m × 2.0 Hz = 4.0 m/s.
2. The speed is 0.1 m × 4 Hz = 0.4 m/s.
3. The speed is 10 cm/0.2 s = 50 cm/s.
4. The wavelength is (5 km/s)/10 Hz = 0.5 km.
Logical

For Extra Help L1

Have students write the equation required to solve each problem first. Then, check that they recognize what they know and don't know in the equation. **Logical**

Direct students to the **Math Skills** in the **Skills and Reference Handbook** at the end of the student text for additional help.

Additional Problems

1. The waves in a pool have a wavelength of 0.20 m and a frequency of 2.8 Hz. What is the speed of these waves? *(0.56 m/s)*
2. A student moves the end of a soft spring back and forth to make waves. The waves travel at 1.8 m/s and have a wavelength of 1.2 m. What is the frequency of these waves? *(1.5 Hz)*
Logical, Portfolio

Build Science Skills L2

Inferring Physics includes many relationships similar to the wave equation. Students need to develop a sense of how each variable relates to the others. Ask, **If the speed of a wave decreases, but the frequency stays the same, what happens to the wavelength?** *(The wavelength must decrease.)*
Logical

Address Misconceptions L2

Students are sometimes unable to distinguish between the transverse motion of the medium and motion of the wave and think that waves with a higher frequency will move faster. In many mediums, mechanical waves move at approximately the same speed for a wide range of frequencies. To reinforce this idea, have students shake the end of the rope at several frequencies. They can confirm that this doesn't affect the wave speed. **Logical**

Math Skills

Speed of Mechanical Waves

One end of a rope is vibrated to produce a wave with a wavelength of 0.25 meters. The frequency of the wave is 3.0 hertz. What is the speed of the wave?

1 Read and Understand

What information are you given?

Wavelength = 0.25 m

Frequency = 3.0 Hz

2 Plan and Solve

What unknown are you trying to calculate?

Speed = ?

What formula contains the given quantities and the unknown?

Speed = Wavelength × Frequency

Replace each variable with its known value.
(Hint: $1\text{Hz} = \frac{1}{\text{s}}$)

$$\text{Speed} = 0.25\ \text{m} \times 3.0\ \text{Hz}$$

$$= 0.25\ \text{m} \times 3.0\ \frac{1}{\text{s}}$$

$$\text{Speed} = 0.75\ \text{m/s}$$

3 Look Back and Check

Is your answer reasonable?

Because the frequency is 3.0 hertz, the wave should travel a distance of 3 wavelengths in 1 second. This distance is 0.75 meters, which agrees with the calculated speed of 0.75 m/s.

Math Practice

1. A wave on a rope has a wavelength of 2.0 m and a frequency of 2.0 Hz. What is the speed of the wave?
2. A motorboat is tied to a dock with its motor running. The spinning propeller makes a surface wave in the water with a frequency of 4 Hz and a wavelength of 0.1 m. What is the speed of the wave?
3. What is the speed of a wave in a spring if it has a wavelength of 10 cm and a period of 0.2 s? (*Hint:* Use the equation $\text{Speed} = \frac{\text{Wavelength}}{\text{Period}}$.)
4. What is the wavelength of an earthquake wave if it has a speed of 5 km/s and a frequency of 10 Hz?

Go Online NSTA SCILINKS

For: Links on wave properties
Visit: www.SciLinks.org
Web Code: ccn-2172

The speed of a wave can change if it enters a new medium or if variables such as pressure and temperature change. However, for many kinds of waves, the speed of the waves is roughly constant for a range of different frequencies. **If you assume that waves are traveling at a constant speed, then wavelength is inversely proportional to frequency.** What does this mean for two waves with different frequencies? The wave with the lower frequency has a longer wavelength.

Go Online NSTA SCILINKS

Download a worksheet on wave properties for students to complete, and find additional teacher support from NSTA SciLinks.

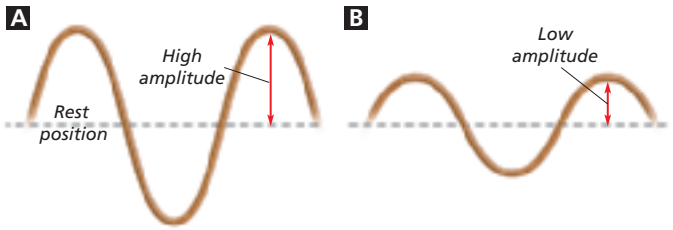

Figure 7 The more energy a wave has, the greater is its amplitude. **A** The amplitude of a transverse wave equals the distance to the highest point above the rest position. **B** This wave's amplitude is one half the amplitude of the wave in A. **Applying Concepts** ***Which wave has more energy?***

Amplitude

If you drop a pebble into a pond, the wave is not very high. If you do a "cannonball" jump into the water, you know the wave will be much higher. These two waves have different amplitudes. The **amplitude** (AM pluh tood) of a wave is the maximum displacement of the medium from its rest position.

Figure 7 shows the amplitudes of two transverse waves in a rope. The amplitude of a transverse wave is the distance from the rest position to a crest or a trough. It takes more energy to produce a wave with higher crests and deeper troughs. **The more energy a wave has, the greater is its amplitude.**

How do you measure the amplitude of a longitudinal wave? In this case, the amplitude is the maximum displacement of a point from its rest position. The more energy the wave has, the more the medium will be compressed or displaced.

Go Online PLANETDIARY

For: Activity on tsunamis
Visit: PHSchool.com
Web Code: ccc-2172

Section 17.2 Assessment

Reviewing Concepts

1. How is the vibration of the source related to a wave's frequency?
2. How is wavelength related to frequency for waves moving at a constant speed?
3. How is the energy of a wave related to its amplitude?
4. Describe two ways you could measure the wavelength of a longitudinal wave.
5. Describe how you measure the amplitude of a transverse wave.

Critical Thinking

6. **Applying Concepts** If a wave's period doubles, how does the wave's frequency change? (*Hint:* Period = $\frac{1}{\text{Frequency}}$)
7. **Designing Experiments** Describe an experiment to measure the frequency of a longitudinal wave in a spring.
8. **Predicting** If you double the frequency of a wave, what is the effect on its wavelength (assuming speed does not change)?

Math Practice

9. A wave on a rope has a frequency of 3.3 Hz and a wavelength of 1.2 m. What is the speed of the wave?
10. A spring toy vibrates at 2 Hz to produce a wave. What is the period of the wave?

Section 17.2 Assessment

1. A wave's frequency equals the frequency of the vibrating source.
2. Wavelength is inversely proportional to frequency for waves moving at a given speed.
3. The more energy a wave has, the greater is its amplitude.
4. The wavelength could be found by measuring the distance between adjacent compressions or adjacent rarefactions. The wavelength also could be calculated by measuring the wave speed and frequency.
5. The amplitude equals the distance from the rest position to a crest or trough.
6. The frequency is one half as great.
7. Put a ribbon on the spring. Set up a mechanical device to vibrate the spring back and forth in periodic motion. Measure the time it takes for the ribbon to vibrate back and forth 20 times. Divide the measured time into 20 cycles to calculate the frequency in Hz. Repeat the procedure for several trials and average the results.
8. Doubling the frequency will halve the wavelength.

Amplitude

Use Visuals L1

Figure 7 The two waves shown have different amplitudes, but the same wavelength and frequency. Ask, **If you were shaking the ropes, how would what you would feel in Figure 7A differ from what you feel in Figure 7B?** *("My hand would shake harder in A than B.")* Explain that wave A delivers more energy than wave B. **Visual, Logical**

Build Reading Literacy L1

Outline Refer to page **156D** in **Chapter 6**, which provides the guidelines for an outline.

Have students outline the section, leaving room for notes. Then, they should scan through each heading and try to find the main idea. **Logical**

3 ASSESS

Evaluate Understanding L2

Have students create cards of vocabulary terms and definitions, and then work in pairs to match them.

Reteach L1

Use Figure 7 to review the section's key concepts. Ask students to describe the frequency and wavelength of the waves.

Math Practice

Solutions
9. The speed is 1.2 m × 3.3 Hz = 4.0 m/s.
10. The period is 1/2 Hz = 0.5 s.

Interactive Textbook If your class subscribes to the Interactive Textbook, use it to review key concepts in Section 17.2.

Go Online PLANETDIARY

Find links to additional activities and have students monitor phenomena that affect Earth and its residents.

Answer to . . .

Figure 7 *The wave in A*