SECTION 2

Properties of Waves

You are in a swimming pool, floating on your air mattress, enjoying a gentle breeze. Your friend does a "cannonball" from the high dive nearby. Suddenly, your mattress is rocking wildly on the waves generated by the huge splash.

What You Will Learn

- Identify and describe four wave properties.
- Explain how frequency and wavelength are related to the speed of a wave.

Vocabulary

amplitude
frequency
wavelength
wave speed

READING STRATEGY

Mnemonics As you read this section, create a mnemonic device to help you remember the wave equation.

The breeze generates waves in the water as well, but they are very different from the waves created by your diving friend. The waves made by the breeze are shallow and close together, while the waves from your friend's splash are tall and widely spaced. Properties of waves, such as the height of the waves and the distance between crests, are useful for comparing and describing waves.

Amplitude

If you tie one end of a rope to the back of a chair, you can create waves by moving the free end up and down. If you shake the rope a little, you will make a shallow wave. If you shake the rope hard, you will make a tall wave.

The **amplitude** of a wave is related to its height. A wave's amplitude is the maximum distance that the particles of a medium vibrate from their rest position. The rest position is the point where the particles of a medium stay when there are no disturbances. The larger the amplitude is, the taller the wave is. **Figure 1** shows how the amplitude of a transverse wave may be measured.

amplitude the maximum distance that the particles of a wave's medium vibrate from their rest position

Larger Amplitude—More Energy

When using a rope to make waves, you have to work harder to create a wave with a large amplitude than to create one with a small amplitude. The reason is that it takes more energy to move the rope farther from its rest position. Therefore, a wave with a large amplitude carries more energy than a wave with a small amplitude does.

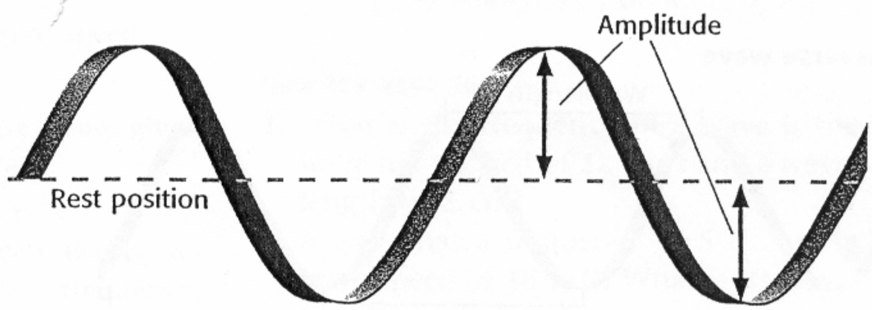


Figure 1 *The amplitude of a transverse wave is measured from the rest position to the crest or to the trough of the wave.*

Wavelength

Another property of waves is wavelength. A **wavelength** is the distance between any two crests or compressions next to each other in a wave. The distance between two troughs or rarefactions next to each other is also a wavelength. In fact, the wavelength can be measured from any point on a wave to the next corresponding point on the wave. Wavelength is measured the same way in both a longitudinal wave and a transverse wave, as shown in **Figure 2.**

wavelength the distance from any point on a wave to an identical point on the next wave

Shorter Wavelength—More Energy

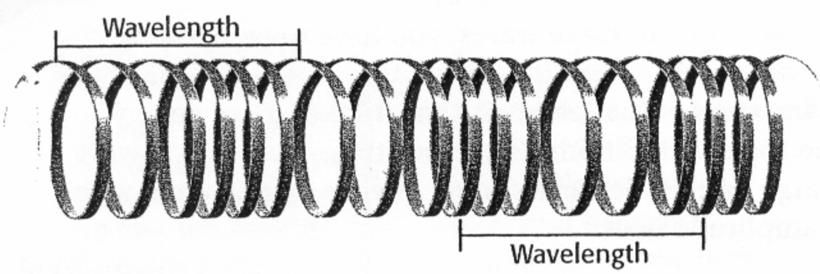
If you are making waves on either a spring or a rope, the rate at which you shake it will determine whether the wavelength is short or long. If you shake it rapidly back and forth, the wavelength will be shorter. If you are shaking it rapidly, you are putting more energy into it than if you were shaking it more slowly. So, a wave with a shorter wavelength carries more energy than a wave with a longer wavelength does.

Reading Check **How does shaking a rope at different rates affect the wavelength of the wave that moves through the rope?** (*See the Appendix for answers to Reading Checks.*)

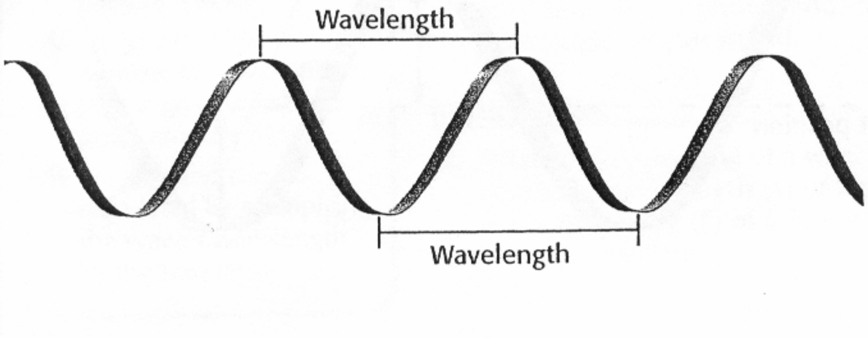
Figure 2 **Measuring Wavelengths**

Wavelength can be measured from any two corresponding points that are adjacent on a wave.

Longitudinal wave



Transverse wave



QUICK LAB

Springy Waves

1. Hold a coiled **spring toy** on the floor between you and a classmate so that the spring is straight. This is the rest position.
2. Move one end of the spring back and forth at a constant rate. Note the wavelength of the wave you create.
3. Increase the amplitude of the waves. What did you have to do? How did the change in amplitude affect the wavelength?
4. Now, shake the spring back and forth about twice as fast as you did before. What happens to the wavelength? Record your observations.

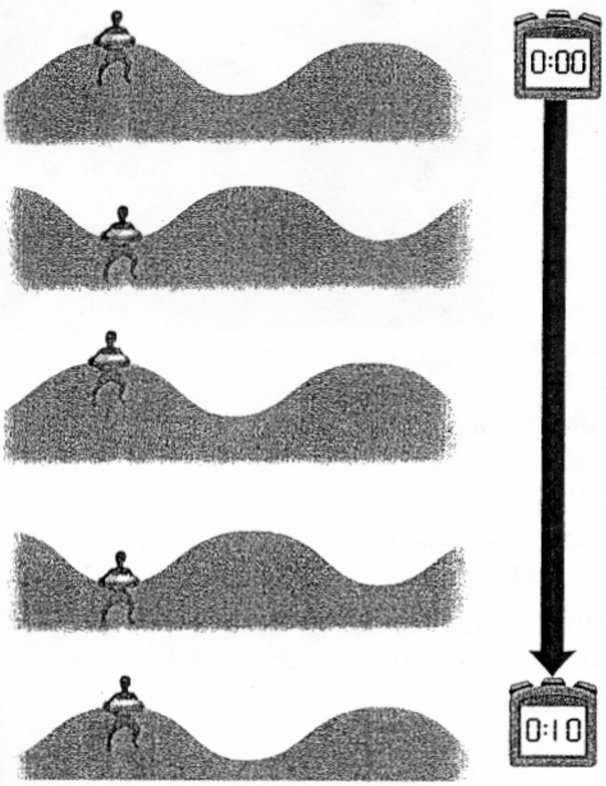


Figure 3 *Frequency can be measured by counting how many waves pass by in a certain amount of time. Here, two waves went by in 10 s, so the frequency is 2/10 s = 0.2 Hz.*

Frequency

Think about making rope waves again. The number of waves that you can make in 1 s depends on how quickly you move the rope. If you move the rope slowly, you make only a small number of waves each second. If you move it quickly, you make a large number of waves. The number of waves produced in a given amount of time is the **frequency** of the wave. Frequency is usually expressed in *hertz* (Hz). For waves, one hertz equals one wave per second (1 Hz = 1/s). **Figure 3** shows a wave with a frequency of 0.2 Hz.

Reading Check **If you make three rope waves per second, what is the frequency of the wave?**

Higher Frequency–More Energy

To make high-frequency waves in a rope, you must shake the rope quickly back and forth. To shake a rope quickly takes more energy than to shake it slowly. Therefore, if the amplitudes are equal, high-frequency waves carry more energy than low-frequency waves.

Wave Speed

Wave speed is the speed at which a wave travels. Wave speed (v) can be calculated using wavelength (λ, the Greek letter *lambda*) and frequency (f), by using the *wave equation*, which is shown below:

$$v = \lambda \times f$$

MATH FOCUS

Wave Calculations Determine the wave speed of a wave that has a wavelength of 5 m and a frequency of 4 Hz.

Step 1: Write the equation for wave speed.

$$v = \lambda \times f$$

Step 2: Replace the λ and f with the values given in the problem, and solve.

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

The equation for wave speed can also be rearranged to determine wavelength or frequency, as shown at top right.

$$\lambda = \frac{v}{f} \text{ (Rearranged by dividing by } f.)$$

$$f = \frac{v}{\lambda} \text{ (Rearranged by dividing by } \lambda.)$$

Now It's Your Turn

1. What is the frequency of a wave if the wave has a speed of 12 cm/s and a wavelength of 3 cm?
2. A wave has a frequency of 5 Hz and a wave speed of 18 m/s. What is its wavelength?

Frequency and Wavelength Relationship

Three of the basic properties of a wave are related to one another in the wave equation—wave speed, frequency, and wavelength. If you know any two of these properties of a wave, you can use the wave equation to find the third.

One of the things the wave equation tells you is the relationship between frequency and wavelength. If a wave is traveling a certain speed and you double its frequency, its wavelength will be cut in half. Or if you were to cut its frequency in half, the wavelength would be double what it was before. So, you can say that frequency and wavelength are *inversely* related. Think of a sound wave, traveling underwater at 1,440 m/s, given off by the sonar of a submarine like the one shown in **Figure 4.** If the sound wave has a frequency of 360 Hz, it will have a wavelength of 4.0 m. If the sound wave has twice that frequency, the wavelength will be 2.0 m, half as big.

The wave speed of a wave in a certain medium is the same no matter what the wavelength is. So, the wavelength and frequency of a wave depend on the wave speed, not the other way around.

Figure 4 *Submarines use sonar, sound waves in water, to locate underwater objects.*

frequency the number of waves produced in a given amount of time

wave speed the speed at which a wave travels through a medium

SECTION Review

Summary

- Amplitude is the maximum distance the particles of a medium vibrate from their rest position.
- Wavelength is the distance between two adjacent corresponding parts of a wave.
- Frequency is the number of waves that pass a given point in a given amount of time.
- Wave speed can be calculated by multiplying the wave's wavelength by the frequency.

Using Key Terms

1. In your own words, write a definition for each of the following terms: *amplitude, frequency,* and *wavelength.*

Understanding Key Ideas

2. Which of the following results in more energy in a wave?
   a. a smaller wavelength
   b. a lower frequency
   c. a shallower amplitude
   d. a lower speed
3. Draw a transverse wave, and label how the amplitude and wavelength are measured.

Math Skills

4. What is the speed (v) of a wave that has a wavelength (λ) of 2 m and a frequency (f) of 6 Hz?

Critical Thinking

5. **Making Inferences** A wave has a low speed but a high frequency. What can you infer about its wavelength?
6. **Analyzing Processes** Two friends blow two whistles at the same time. The first whistle makes a sound whose frequency is twice that of the sound made by the other whistle. Which sound will reach you first?

SCILINKS — NSTA — Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: Properties of Waves
SciLinks code: HSM1236