4.1 Properties of Waves

Waves transfer energy through matter or space. Amplitude is the height of a wave crest or depth of a wave trough, as measured from its rest position. A wavelength is the distance over which the wave repeats. As the wavelength decreases, the frequency increases. Waves can differ in how much energy they carry and in how fast they travel.

Key Terms

amplitude
crest
energy
frequency
trough
wave
wavelength

A surfer bobs in the ocean waiting for the perfect wave (Figure 4.1), microwaves warm up your leftover pizza, and sound waves from your CD player bring music to your ears. These and other types of waves have many properties in common.

Figure 4.1 Waiting for a wave. A wave transfers energy through matter or space.

4-1 Watching Water Waves

Find Out ACTIVITY

You do not need to visit the ocean to make waves. In this activity, you can make waves right in your classroom.

Materials

- pie plate or wide pan
- water
- pencil

What to Do

1. Fill a pie plate or other wide pan with water about 2 cm deep.
2. Lightly tap the bottom of a pencil once in the middle of the surface of the water. Observe the waves that form.
3. Lightly tap your pencil once per second on the surface of the water. Observe the spacing of the water waves.
4. Increase the rate of your tapping. Observe the spacing of the water waves.
5. Clean up and put away the equipment you have used.

What Did You Find Out?

1. In what direction did the waves travel when you tapped the water lightly with your pencil?
2. How did the spacing of the water waves change when the rate of tapping increased?

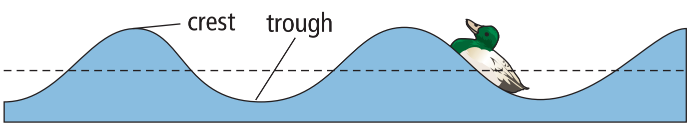
Features of a Wave

A **wave** is a disturbance or movement that transfers energy through matter or space, without causing any permanent displacement. Sound waves disturb the air and transfer energy through it. Ocean waves disturb the water and transfer energy through it. **Energy** is the capacity to apply a force over a distance. A **force** is a push or pull on an object.

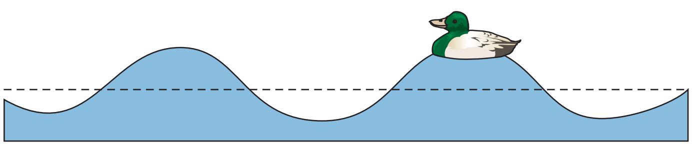
To visualize the features of a wave, examine Figure 4.2. The dotted line shows the equilibrium or rest position. The rest position is the level of the water when there are no waves. Notice the labels in the illustration. A **crest** is the highest point in a wave. A **trough** is the lowest point in a wave.

Did You Know?

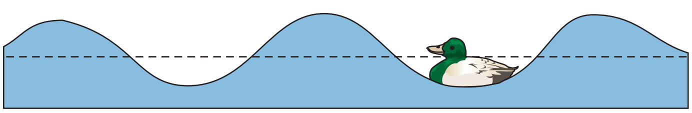
Sound waves can be used to make an image of an unborn child during an ultrasound procedure. Sound waves can also be used for cleaning lenses and other optical equipment, dental instruments, and surgical instruments.



The duck and the water around it do not move forward. They just move up and down as the wave passes.



A crest comes through, and the duck rises.



A trough comes through, and the duck drops.

Figure 4.2 The wave is moving from left to right.

Wavelength

The **wavelength** is the distance from crest to crest or from trough to trough. You can also think of a wavelength as the distance covered by one complete crest plus one complete trough (see Figure 4.3). Wavelength is measured in metres.

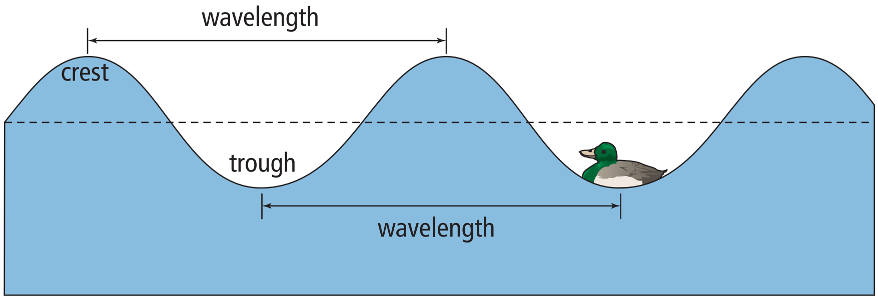


Figure 4.3 A wavelength is the distance over which the wave repeats.

Amplitude

If a breeze picks up on the lake where the duck is sitting, the height of the waves can increase. This means that the duck floats higher and lower as the crests rise and the troughs deepen. When the crests are high and the troughs are low, we say the wave has a larger amplitude. The **amplitude** is the height of a wave crest or depth of a wave trough, as measured from its rest position (see Figure 4.4).

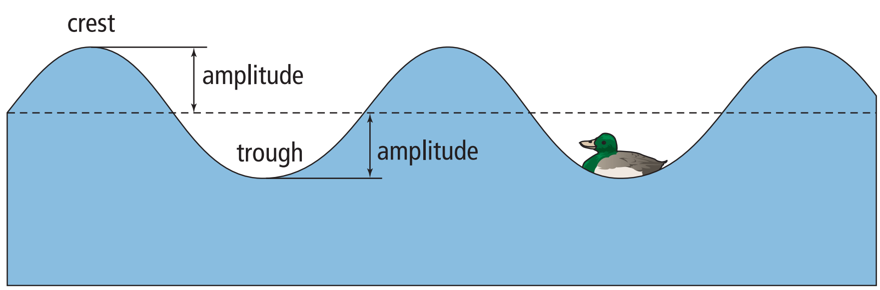


Figure 4.4 The amplitude of the wave crest equals the amplitude of the wave trough.

The amplitude is related to the amount of energy carried by the wave. The larger the amplitude, the greater the energy transported. A light wave that has a large amplitude carries more energy and is very bright. A dim light has a lower amplitude and carries less energy. The next time you lower the brightness of a light using a dimmer switch, think of the switch as a light wave amplitude adjuster.

Frequency

As the wavelength decreases, the duck and the water move up and down more frequently. Every cycle of bobbing up and down is called an oscillation or a vibration. **Frequency** is the number of repetitive motions, or oscillations, that occur in a given time. Frequency is usually measured in **hertz** (Hz), or cycles per second. In our example, it is the number of times per second the duck bobs from crest to crest. For example, if two wave crests were to pass under the duck every second, then the duck is said to be vibrating or oscillating at a frequency of 2 Hz.

When the duck is sitting in water waves with short wavelengths, it will bob up and down frequently. When the duck is sitting in waves with long wavelengths, it will bob up and down less frequently. The shorter the wavelength, the greater the frequency (see Figure 4.5). When one value increases as the other decreases, scientists call this an *inverse relationship*.

internet connect

With sound waves, frequency is related to musical pitch. Find out more about the frequencies of musical notes. Start your search at **www.bcscience8.ca**.

Suggested Activities

Find Out Activity 4-2 on page 138
Find Out Activity 4-3 on page 139

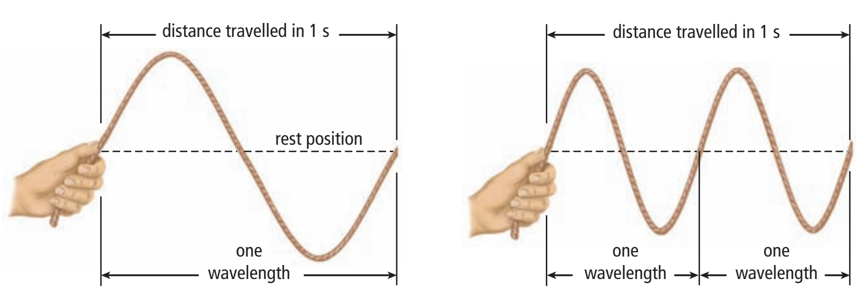


Figure 4.5 The wavelength of a wave decreases as the frequency increases. All waves share this property.

A Water Wave Moves Energy, Not Water

A water wave does not carry water along with it. Only the energy carried by the water wave moves forward (see Figure 4.6). Many important types of waves share this property—they carry energy without transporting matter. Think of being out in the middle of a lake and bobbing straight up and down as the wave passes underneath. Only the energy in the wave moves forward toward the shore. You do not move forward and neither does the water. Once the waves have passed, the water returns to its original, or rest, position.

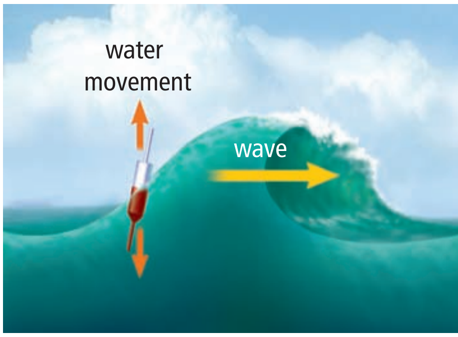


Figure 4.6 The energy carried by the wave moves forward. The water moves up and down.

Two Types of Waves

Waves can differ in how much energy they carry and in how fast they travel. Waves also have other characteristics that make them different from each other.

Sound waves travel through the air to reach your ears. Ocean waves move through water to reach the shore. In both cases, the matter the waves travel through is called a **medium**. The medium can be a solid, liquid, or gas, or a combination of these. For sound waves, the medium is air, and for ocean waves the medium is water. The two types of waves that travel through a medium are transverse waves and compression waves.

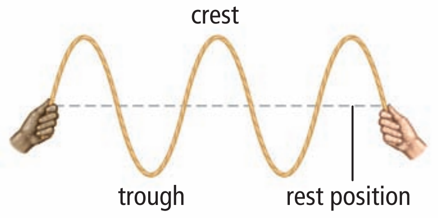


Figure 4.7 A transverse wave travels horizontally along the rope, and the rope moves up and down.

Transverse waves

In a **transverse wave**, matter in the medium moves up and down perpendicular to the direction that the wave travels (see Figure 4.7). When you shake one end of a rope while your friend holds the other end, you are making transverse waves. The wave and its energy travel from you to your friend as the rope moves up and down.

Compression waves

Sound waves are compression waves. In a **compression wave**, matter in the medium moves back and forth along the same direction that the wave travels. You can model compression waves with a coiled spring with a piece of string tied on a coil (see Figure 4.8). Squeeze several coils together at one end of the spring. Then let go of the coils, still holding onto the other end of the spring. A wave will travel along the spring. As the wave moves, it looks as if the whole coil spring is moving toward one end. The string moves back and forth as the wave passes, and then stops moving after the wave has passed. The wave carries energy, but not matter, forward along the spring.

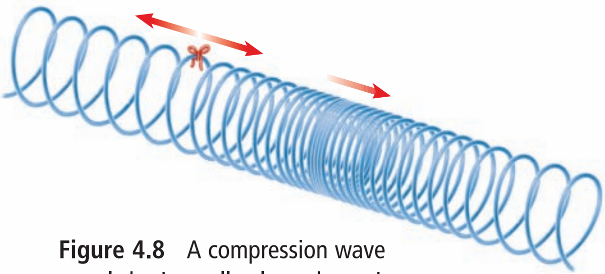


Figure 4.8 A compression wave travels horizontally along the spring, and the coils in the spring move back and forth horizontally.

Water waves and seismic (earthquake) waves are a combination of transverse and compression waves. Seismic waves can travel through Earth and along Earth's surface. When objects on Earth's surface absorb some of the energy carried by seismic waves, the objects move and shake.

Not all waves need a medium to travel through. Some waves, such as visible light waves and radio waves, can travel through space where there is no material.

Explore More

Traffic waves are a form of traffic jam on highways that can occur when cars are more densely packed in some places and less densely packed in others. A traffic wave can move through a lane of cars causing the whole lane to slow down. Find out what causes these waves and what can be done to prevent them. Start your search at **www.bcscience8.ca**.

Suggested Activity

Conduct an Investigation 4-4 on page 140

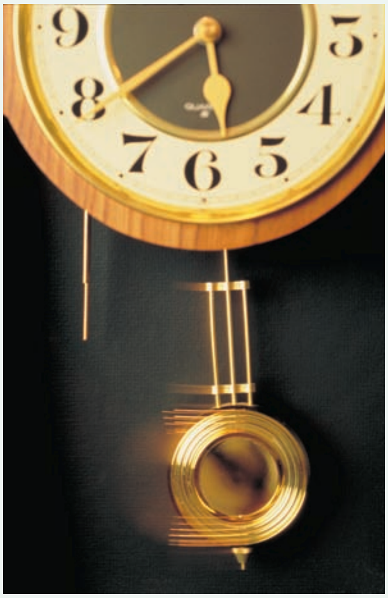
Reading Check

1. What is the difference between a crest and a trough?
2. What are three ways to measure wavelength?
3. What property of a wave is measured in hertz?
4. How are the wavelength and frequency of a wave related?
5. What is the difference between a transverse wave and a compression wave?

4-2 Frequency Formula

Think About It

Examples of frequency exist all around you. In this activity, you can calculate frequency by using the number of cycles, the time, and an equation.



The pendulum on a grandfather clock

What to Do

1. Use the following equation to calculate frequency (in hertz) for each of the examples below. The first example is done for you.

   frequency = cycles ÷ seconds

   (a) pendulum: 24 swings in 6 s
   frequency = cycles/s
   = 24 swings/6 s
   = 4 Hz

   (b) merry-go-round: 12 revolutions per 2 min

   (c) flashing red light at an intersection: 30 flashes in 0.5 min

   (d) heart rate: 18 beats per 20 s

   (e) car drive shaft: 2000 rpm (revolutions per min)

What Did You Find Out?

1. In order to calculate frequency measured in hertz, what must be done with the time unit before dividing?