Section 3
Waves and Tides

Key Concept Energy is carried through the ocean by tides, which are caused by gravitational attraction between Earth, the moon, and the sun, and by waves.

What You Will Learn
- Ocean waves transfer energy through water and to the shore when the wave breaks.
- Tides are the periodic rise and fall of the water level in the oceans.

Why It Matters
Waves and tides carry energy from one place to another, and they influence coastlines.

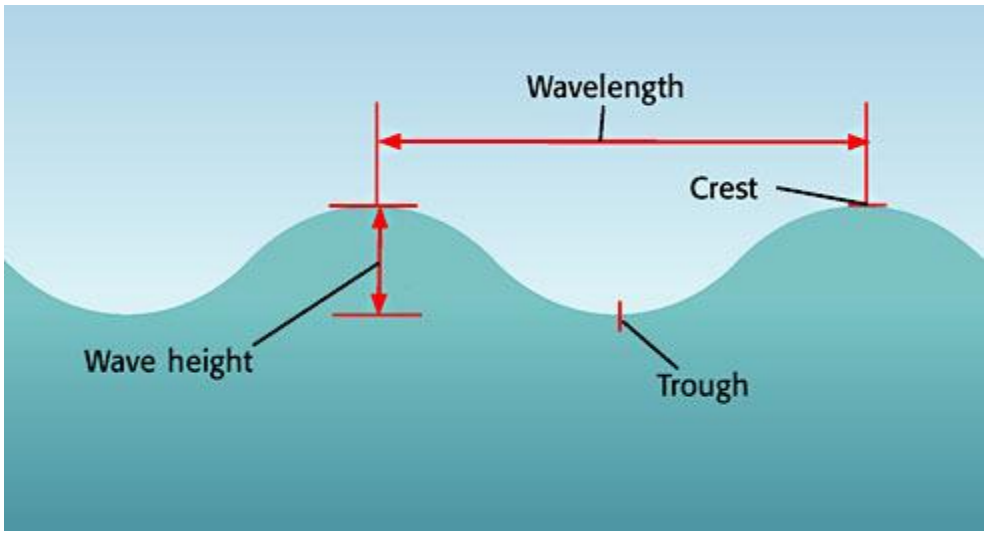
Have you ever seen a surfer riding waves? Did you ever wonder where the waves come from? A **wave** is any disturbance that transmits energy through matter or empty space. Waves in the ocean carry energy through water.

Standards Check What is a wave, and what do waves in the ocean carry through water?

Waves
Ocean waves are affected by a number of different factors. They can be formed by something as simple as wind or by something as violent as an earthquake. Ocean waves can travel through water slowly or incredibly quickly. The size of an ocean wave depends on the energy the wave carries.

Parts of a Wave
Waves are made up of two main parts—crests and troughs. A *crest* is the highest point of a wave. A *trough* is the lowest point of a wave. Imagine a roller coaster designed with many rises and dips. The top of a rise on a roller-coaster track is similar to the crest of a wave. The bottom of a dip in the track resembles the trough of a wave. The distance between two adjacent wave crests or wave troughs is a *wavelength.* The vertical distance between the crest and trough of a wave is called the *wave height.* **Figure 1** shows the parts of a wave.

Figure 1 Parts of a Wave



Wave Formation

Ocean waves form when energy is transferred from a source to the ocean water. Most ocean waves form as wind blows across the water's surface and transfers energy to the water. The energy is then carried by the wave, usually the entire distance to the ocean shore. Waves can also form from other sources of energy. Underwater earthquakes and landslides, as well as impacts by asteroids or meteorites, can form waves in the ocean.

Standards Check List four sources of energy for ocean waves.

Wave Movement

If you have watched ocean waves, you may have noticed that water appears to move across the ocean's sur face. However, this movement is only an illusion. As the energy moves through the water, so do the waves. But the water itself does not travel significantly with the energy. Notice in **Figure 2** that the floating bottle remains in the same spot as the waves travel from left to right. The water only rises and falls in circular movements. This circular movement of water is generally greatest at the ocean surface. Wave energy decreases as the water depth increases.

Below a depth of about half a wavelength, water is not affected by the energy of surface waves.

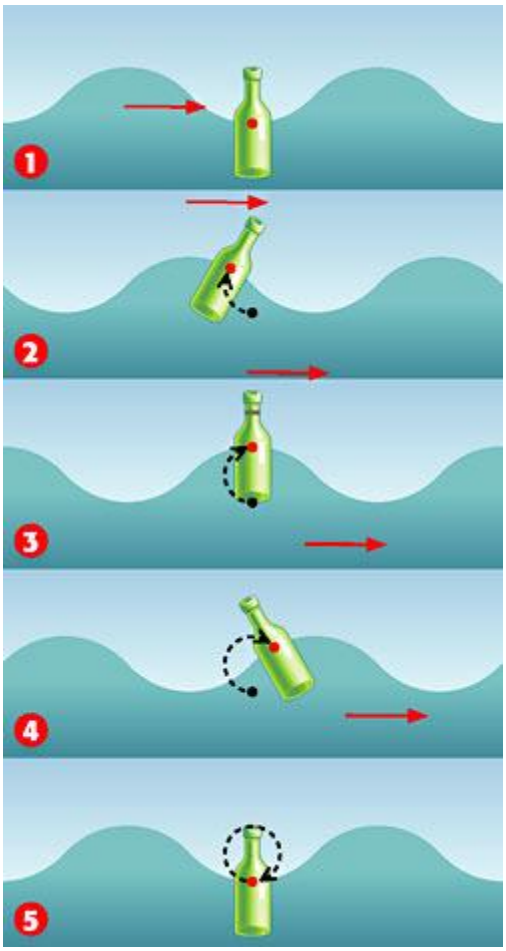


Figure 2 Like the bottle in this figure, water remains in the same place as waves travel through it.

Wave Energy

You have learned that most ocean waves are formed by the wind. Have you ever wondered why these waves are different sizes? When wind begins to blow over water, small waves, or ripples, form. If the wind keeps blowing, the ripples receive more

energy and grow into larger waves. The longer the wind blows in the same direction across the water, the more energy is transferred from the wind to the water and the larger the waves become.

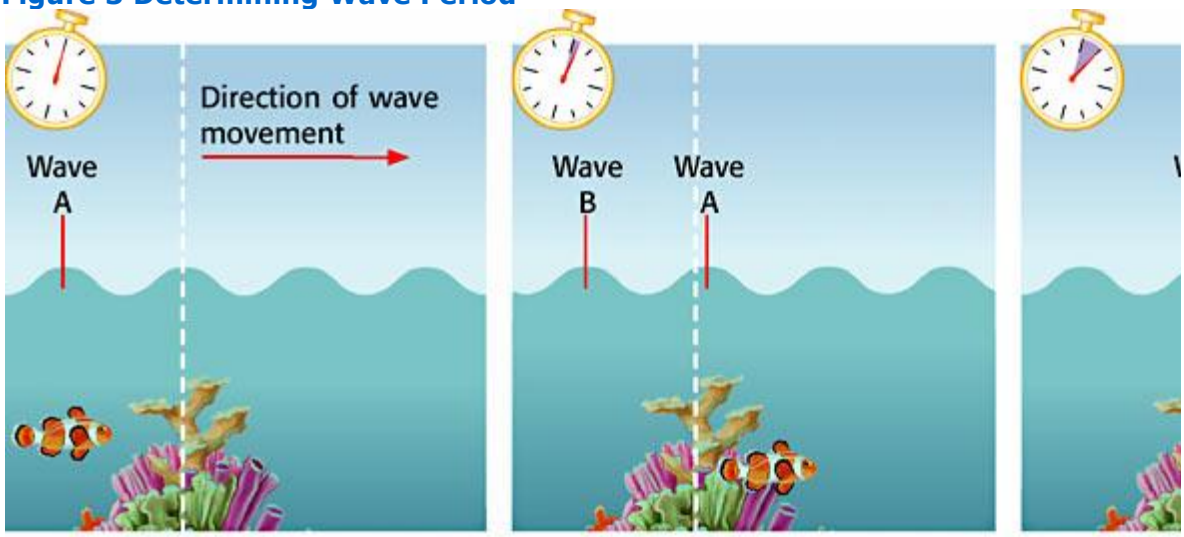
Standards Check How does the length of time that wind blows over water affect the amount of energy in a wave?

Wave Speed

Waves not only are different sizes but also travel at different speeds. To calculate wave speed, scientists must know the wavelength and the wave period. *Wave period* is the time between the passage of two wave crests (or troughs) at a fixed point, as **Figure 3** shows. Dividing wavelength by wave period gives you wave speed, as shown below.

$$\frac{\text{wavelength (m)}}{\text{wave period (s)}} = \text{wave speed (m/s)}$$

Figure 3 Determining Wave Period



For any given wavelength, an increase in the wave period will decrease the wave speed. For a given wavelength, a decrease in the wave period will increase the wave speed.

Waves Reaching the Shore

No matter how waves form, most waves reach the shore. When waves reach the shore, energy from the wave is transferred to the beach environment. The energy of the wave and the angle at which the wave hits the shore determine how much energy is transferred. Some waves, such as tsunamis, transfer large amounts of energy. Tsunamis are huge ocean waves that form as a result of underwater earthquakes or underwater landslides. These events release large amounts of energy. This energy can be carried by tsunamis that may become very big near land. Tsunamis can cause a great deal of damage when they reach the shore and can be dangerous to humans.

Why Waves Break

Have you ever wondered why waves increase in height and crash as they reach the shore? The answer has to do with the depth of the water, as **Figure 4** shows. When waves reach water shallower than one-half their wavelength, they begin to interact with the ocean floor. As waves begin to touch the ocean floor, the waves transfer energy to the ocean floor. As a result, the water particles at the bottom of the wave slow down and the wave height increases. The water at the top of the wave is not slowed as much. So, the top of the wave continues to travel at the original speed. The top of the wave travels faster than the bottom of the wave. Eventually, the high wave crest crashes down onto the ocean floor as a *breaker.*

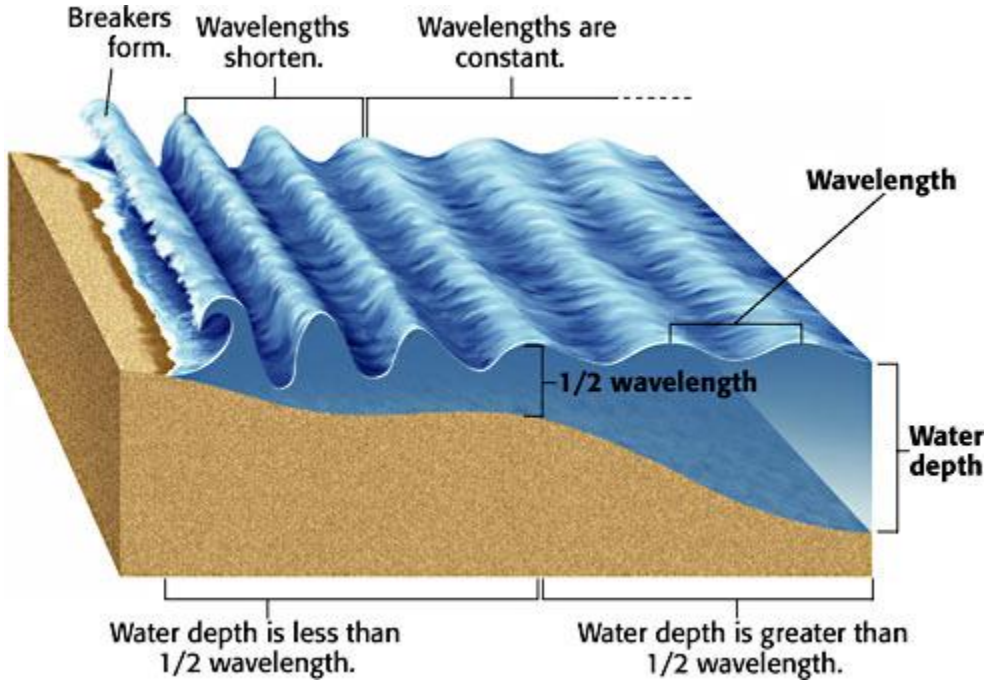


Figure 4 Breakers begin to form as a wave approaches the coastline. As water depth becomes shallower, wave height increases. **At what depth do wavelengths shorten?**

Standards Check How do waves transfer energy to the ocean floor and to the shore?

Tides

If you stand at some ocean shores for an hour or so, you will see the edge of the ocean shrink away from you. If you wait longer, you will see it return to its original place on the shore. Would you believe the moon causes this movement?

You have learned how winds and earthquakes can move ocean water. But other forces also move ocean water in regular patterns. **Tides** are daily changes in the level of

ocean water. Tides are influenced by the sun and the moon, as **Figure 5** shows, and tides occur in a variety of cycles.

Figure 5 Although gravitational forces from both the sun and moon continuously pull on Earth, the moon's gravity is the dominant force on Earth's tides.

Why Tides Happen

The gravity of the moon pulls on every particle of Earth. However, the moon's gravitational pull on Earth decreases with distance from the moon. As a result, different parts of Earth are pulled more strongly toward the moon than other parts are. In addition, the pull on liquids is much more noticeable than the pull on solids, because liquids move more easily. Even the liquid in a carton of milk is slightly pulled by the moon's gravity.

Where Tides Happen

The part of the ocean that directly faces the moon is pulled toward the moon with the greatest force. As a result, the water on the side of Earth that faces the moon bulges toward the moon. The solid center of Earth is also pulled toward the moon. However, because it is farther from the moon, the solid Earth is not pulled as strongly as the ocean facing the moon is. The ocean on Earth's far side is pulled with even less force than the solid Earth is. So, the water on the side of Earth that is farthest from the moon bulges away from Earth's center.

High Tides and Low Tides

The bulges that form in Earth's oceans as a result of the moon's gravitational pull are called *high tides.* In high-tide areas, shown in **Figure 6,** the water level is higher than the average sea level. In the areas between the high tides, *low tides* form. In low tide areas, the water levels are lower because the water is pulled toward high-tide areas. As the moon moves around Earth, the tidal bulges sweep around the planet in a regular pattern. As a result, many places on Earth experience two high tides and two low tides every day.

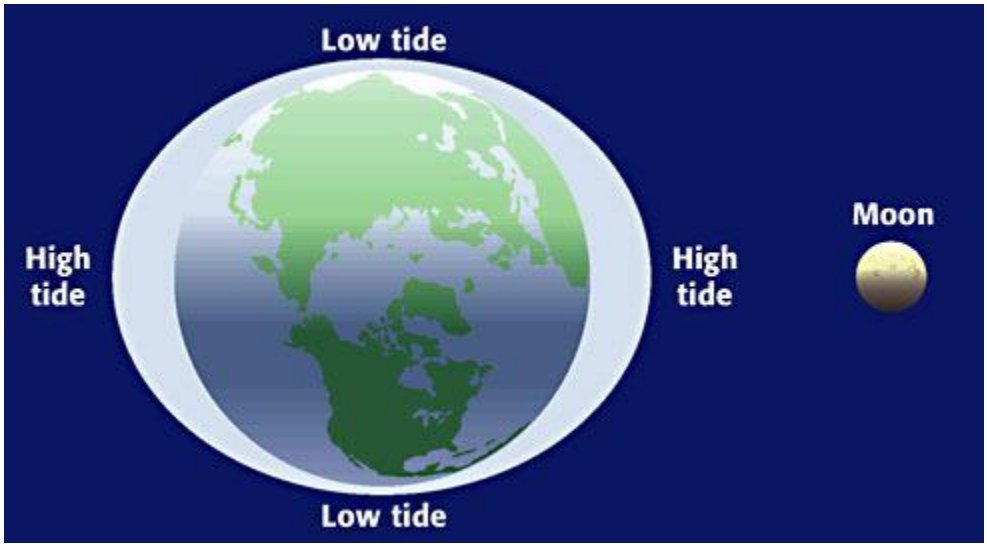


Figure 6 High tide occurs on the part of Earth that is closest to the moon and on the opposite side of Earth. Low tides occur in the areas between the high tides.

Timing the Tides

The moon revolves around Earth much more slowly than Earth rotates. As **Figure 7** shows, a place on Earth that is facing the moon takes 24 h and 50 min to rotate to face the moon again. So, the high tides and low tides at that place happen 50 minutes later each day. If Earth rotated at the same speed that the moon revolved around Earth, the tides would not alternate between high and low.

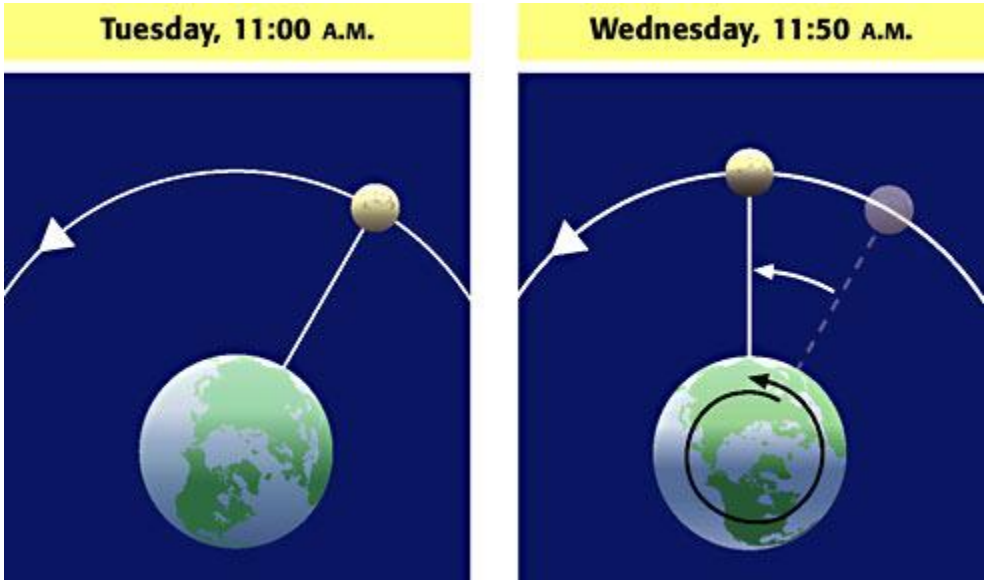


Figure 7 High and low tides occur about 50 minutes later each day at a given place. This happens because the moon moves only a fraction of its orbit in the time that Earth rotates once.

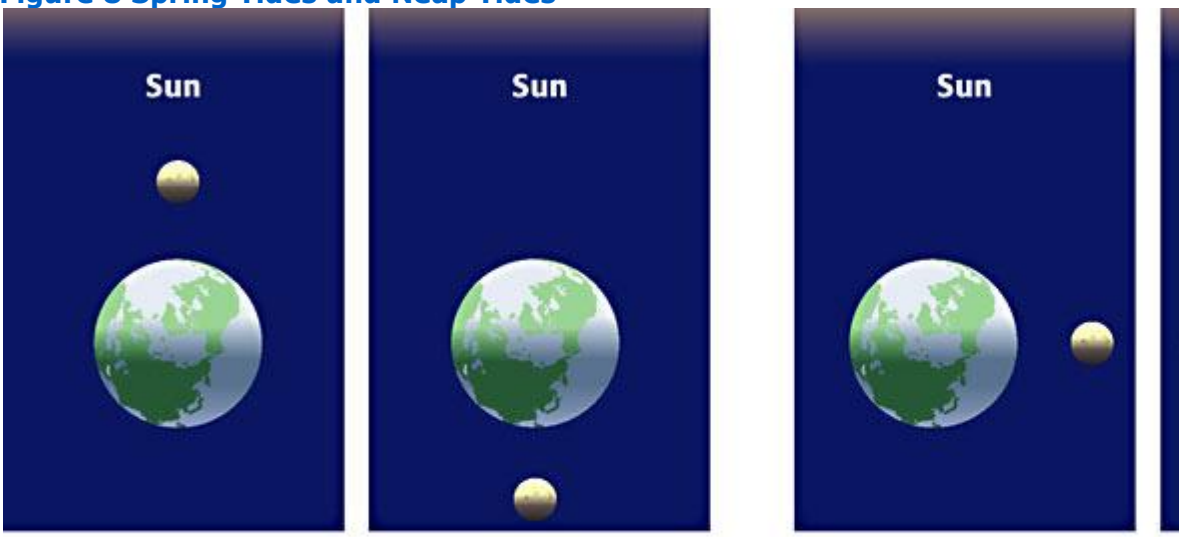
Tidal Variations

The sun is much larger than the moon, but the sun is much farther away from Earth than the moon is. So, the sun's pull on tides is weaker than the moon's pull. The combined forces of the sun and the moon on Earth result in different tidal ranges. A *tidal range* is the difference between levels of ocean water at high tide and low tide. Tidal range depends on the positions of the sun, Earth, and the moon.

Spring Tides

Tides that have the largest daily tidal range are **spring tides.** Spring tides happen when the sun, Earth, and the moon are aligned. In other words, spring tides happen when the moon is between the sun and Earth or when the moon and the sun are on opposite sides of Earth. **Figure 8** shows the positions of the sun, Earth, and the moon during spring tides. Spring tides happen during the new-moon and full-moon phases, or every 14 days. During these times, the sun and moon cause one pair of very large tidal bulges.

Figure 8 Spring Tides and Neap Tides



Spring Tides When the sun, Earth, and the moon form a line, the gravitational force of the sun increases the tidal range that results from the gravitational force of the moon.

Neap Tides When the su at right angles to each othe gravitational force of the su range that results from the the moon.

Neap Tides

Tides that have the smallest daily tidal range are **neap tides.** Neap tides happen when the sun, Earth, and the moon form a 90° angle. **Figure 8** shows the positions of the sun, Earth, and moon during neap tides. Neap tides occur halfway between the occurrence of spring tides, during the first-quarter and third-quarter phases of the moon. During these times, the sun and moon cause two pairs of smaller tidal bulges.

Section Summary

- Waves form when the wind's energy is transferred to the surface of the ocean.
- Wave energy travels through water near the water's surface, while the water itself rises and falls in circular movements.
- Waves break when the water depth becomes so shallow that the bottom of the wave transfers energy to the ocean bottom and the shore.
- Tides are caused by the gravitational forces of the moon and the sun on Earth. The moon's gravity is the main force behind the tides.
- The positions of the sun and moon relative to the position of Earth cause tidal ranges.

Chapter Summary

The Big Idea

The movement of ocean water is a major factor in energy transfer on Earth's surface.

Section 1

Currents

Key Concept The circulation of ocean water distributes water, heat, dissolved gases, and dissolved solids around Earth's surface.

- The sun is the major source of energy that drives wind and ocean currents.

- Surface currents and deep currents form convection currents that move ocean water.

Warm and cold surface currents in the ocean transfer energy around Earth's surface.

Section 2
Currents and Climate

Key Concept Ocean currents transport energy, affect climate and weather, and distribute nutrients.

- Surface currents affect climate by distributing energy around Earth.
- Changes in surface currents, such as El Niño, can cause changes in weather patterns.

Warm and cold currents affect the climates of nearby landmasses.

Section 3

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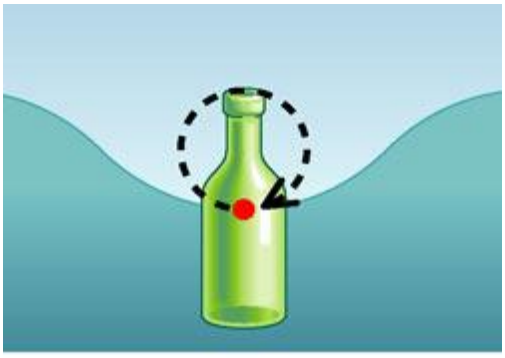

A wave carries energy from one place to another with no net movement of matter.