Lesson: Waves

In this lesson, you will learn how waves are formed and what determines their size and speed? You will also learn how ocean swells are different from whitecaps, and the difference between a rogue wave and a tsunami. Have you ever wondered how high is the highest wave, and how scientists use their knowledge of wave dispersion to warn us of an approaching hurricane?

When you blow on a cup of hot tea, you see ripples in the liquid. A ripple is a small wave. Nature's "breath," the wind, also produces waves when it blows across the surface of the ocean.

A **wave** is an up-and-down movement of the ocean surface. Most waves are caused by wind. How does the wind produce a wave? When the wind blows, it pushes on the ocean surface, causing the water to lift. A gentle wind produces a small wave; a strong wind produces a bigger wave.

In general, the greater the wind's speed, length of time it blows, and distance over which it blows, the greater are the size and speed of the waves that it generates. The effect of wind speed on wave size: the faster the wind, the larger the wave.

One of the biggest waves ever recorded at sea was observed by someone aboard the U.S. Navy tanker U.S.S. Ramapo during a storm in the South Pacific in February 1933. The wave was calculated to be about 34 meters high.

How is the height of an ocean wave calculated? The **Pythagorean theorem** wave height is the vertical distance between the top of a wave, or crest, and the bottom of the preceding wave, or trough. Wave height can be measured (by use of basic geometry) either when the wave is perpendicular to the ship's direction (when the ship's stern is down in the trough) or when the wave is parallel to the ship.

When the stern of a ship is in the trough, an observer on the deck can line up the crow's nest with the crest of the wave.

When the reference points are connected by straight lines, they form a right triangle, where BC is the height of the crow's nest, AC is the length from the stern to the base of the mast, and AB is the **hypotenuse**. The hypotenuse, which is the side of the right triangle opposite the right angle (AB), would equal the height of the wave.

When a steady wind blows, a wave train is produced. A **wave train** is a series of waves, one followed by the other, moving in the same direction. How fast do the waves move?

You can calculate the speed (velocity) of a wave if you know its wavelength and period. The wavelength is the distance between two successive crests or troughs.

The period is the time it takes for one wave to pass a given point. (The wave frequency is the number of waves that pass a given point in a given amount of time, such as the number of waves per minute.)

Use the following formula to calculate the velocity of a wave:

Velocity (V) = wavelength (W)/period (P)
If W = 10 meters and P = 5 seconds,
V = 10 meters/5 seconds
V = 2 meters/second

After observing waves and calculating their speed, you may be left with the impression that the water, which goes up and down as waves, is also moving horizontally. Although waves look like they are moving along, this is only an illusion.

A floating object such as a boat or the cork on a fishing line does not move forward in a wave train but moves up and down with each passing wave. This is because a wave is a form of energy that moves across the water- not the water itself moving along.

Wave action is like the snapping of a rope. When you snap a rope, the rope itself does not move forward. The movement of your hand produces mechanical energy that is transferred in waves along the length of the rope. Similarly, a wave starts with the energy of the wind pushing on the water.

Mechanical energy is transferred to each successive wave. When waves extend beyond the windy area in which they are generated, they have longer periods and more rounded crests, and are called **swells**. The swells may travel for thousands of kilometers across the ocean, until they reach a distant shore where the energy is released in the form of a crashing wave.

What causes a wave to crash, or break, on the beach? As a wave approaches the shore, it enters shallow waters. As the bottom of the wave makes contact with the sea floor, the wave slows (due to friction), which decreases its wavelength, too. This occurs when the water depth is about one-half the wave's wavelength. When the water depth is less than one-half the wavelength, the top of the wave-which moves faster than its bottom-pitches forward and crashes. This action produces a type of wave known as a breaker

Waves can also break on the open seas. Strong winds produce steep waves with narrow crests. The narrow crests are easily blown off by the winds, creating a mixture of air and water known as a **whitecap**.

When a ship's crew spots whitecaps ahead, they know they are in for rough weather. Every now and then, huge lone waves, with very high crests and low troughs, are encountered at sea. These tall waves, known as **rogue waves**, are formed either when two or more large waves from a storm unite, or when waves meet opposing currents. Rogue waves are dangerous and have caused the loss of many ships at sea.

In some rivers, the energy of the incoming tide can create a solitary wave called a **tidal bore**. This occurs where the sea floor at the mouth of the river slopes gently and the tidal range is greater than 5 meters. A strong tidal bore may reach several meters in height and rapidly advance many kilometers upriver.

In 1976, a wave 6 meters high surged up the Penobscot River in Maine and flooded the town of Bangor, 25 km upriver from the sea.

Tidal bores occur in rivers and estuaries around the world. Dwarfing that of the Penobscot, the tidal bore in the Amazon normally extends hundreds of kilometers upriver.

Tidal bores can also prove fatal. In 1843, the daughter of French novelist and poet Victor Hugo was drowned when a tidal bore in the Seine River capsized her boat; she was memorialized in one of his poems.

Fortunately, tidal bores are limited to the relatively small number of rivers that have the unusual combination of a high intertidal range and a gently sloping river mouth.

On April 24, 1971, a massive wave "attack" struck a chain of islands south of Japan. On one of these islands, a wave 84 meters high was observed-the highest wave ever recorded. One of the waves lifted a massive chunk of coral weighing three-quarters of a million kilograms and tossed it inland a distance of 0.8 km. These giant waves, which are often incorrectly called tidal waves, are in fact not related to tides at all. The Japanese have a more accurate name for this type of wave-they call it **tsunami** (pronounced soo-NAM-e), which means "harbor" (tsu) "wave" (nami).

What causes a tsunami? Tsunamis are generated by a sudden disturbance in Earth's crust, that is, by seismic activity such as an undersea earthquake, a landslide on the ocean floor, or a volcanic eruption. An earthquake on the sea floor was responsible for another tsunami off Japan in 1993.

The point of origin of an earthquake is called the **epicenter**. An underwater earthquake releases a great deal of energy, which is transmitted through the water column. When this energy reaches the ocean surface, it generates high-velocity waves. Some tsunamis have been clocked at more than 800 km per hour. The waves are also characterized by long wavelengths (some being more than 200 km long) and a long period. Contrary to what you might expect, the waves at the epicenter are only a meter or two high. Not until they reach shallow waters do they grow to great heights.

When a tsunami wave train going hundreds of kilometers per hour approaches a shore, its wave speed slows. On slowing, the wave's energy of forward motion is converted into a lifting force that creates a giant wave, as much as 20 to 30 meters high. Just before the wave hits, water along the beach is suddenly sucked away and then the giant wave approaches with a loud noise.

After the tsunami breaks on the shore, there is another tremendous rush of water back to the sea. In years past, many people, thinking that the tsunami was over, would go down to the beach to take advantage of the unexpected harvest of stranded fish. To their horror, they discovered another tsunami ready to crash down on them.

Many people lost their lives because they did not know that these giant waves often come in a succession of three or more high crests that arrive 15 to 60 minutes apart. A tsunami wave train may strike a coast for the better part of a day before it ends.

Since tsunamis are unexpected and can be so destructive, the U.S. Coast and Geodetic Service has placed seismic recorders at various locations in the Pacific Ocean, where most tsunamis occur (because of the frequency of undersea seismic activity).

These recorders can detect disturbances on the sea floor that might cause tsunamis. The information is then relayed to coastal stations and analyzed. Because the Pacific Ocean is so large, this early warning system can give coastal populations enough time to move inland before a tsunami reaches their shores.