Name: ______________________________________ Date: ________________________

Guided Learning: Water Waves

Learning goals
After completing this activity, you will be able to …

- Identify the parts of a wave.
- Describe how a floating particle will move as a water wave passes.
- Describe how the energy of a water wave is transmitted to other materials.
  - Explain how barrier beaches form.
  - Describe the origin and effects of tsunamis.
  - Explain how wave power can be harnessed as a source of renewable energy.

Vocabulary: amplitude, barrier island, compression, crest, current, hurricane, light wave, longitudinal, rarefaction, seismic wave, sound wave, storm surge, transverse, trough, tsunami, water wave, wavelength

Warm-up questions

1. Have you ever floated in the ocean a short distance from the beach? _________________

2. How does your body move as an ocean swell passes by? ___________________________

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3. What happens if you stand in the waves close to the beach? _________________________

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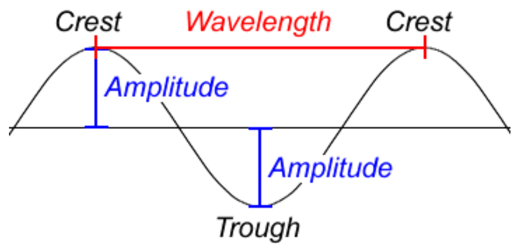
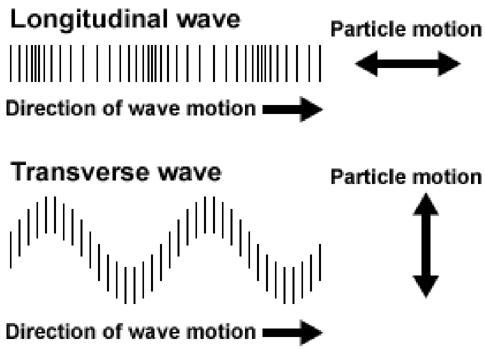
Wave motion
Waves can be defined as periodic disturbances that transfer energy through space and/or through matter. There are many types of waves. **Light waves** are composed of perpendicular pulsating electric and magnetic fields that can travel through empty space at blinding speeds. **Sound waves** travel through the air as a series of **compressions** (where air molecules are pushed together) and **rarefactions** (where air molecules are spread apart). **Seismic waves** travel through Earth's crust and are caused by earthquakes or explosions. **Water waves** may be caused by any disturbance of a body of water, from the delicate ripples surrounding a dropped pebble to a massive **tsunami** caused by an undersea earthquake. The most common source of water waves is the wind.

Seen from the side, a water wave resembles a sine wave. The high points are called **crests**, while the low points are **troughs**. The height of the crest above the midpoint—which is equal to the depth of the trough below the midpoint—is the **amplitude** of the wave. The **wavelength** is equal to the distance between two successive crests (or troughs).

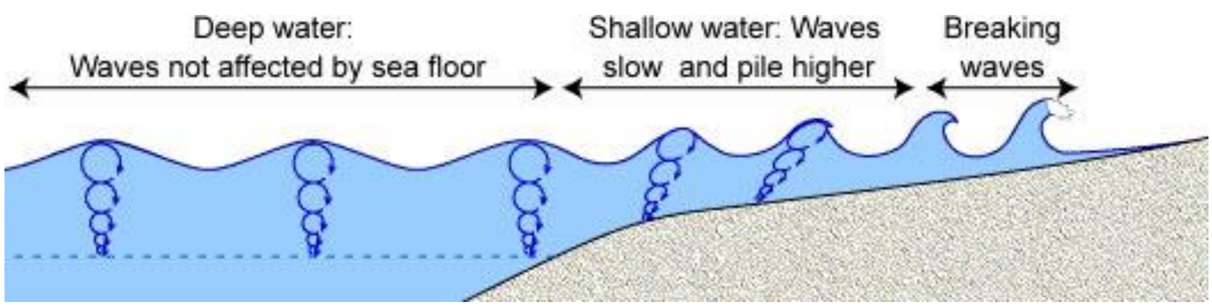




Wave motion is classified as **longitudinal** or **transverse**. In a longitudinal wave, particles move back and forth parallel to the direction of the wave as it passes. Sound waves and seismic P-waves are longitudinal. In a transverse wave, particles move up and down perpendicular to the direction of the wave. Light waves and seismic S-waves are examples of transverse waves. In both types of motion, the particles return to their original positions after the wave has passed.

Water waves combine longitudinal and transverse motion. For example, when an ocean wave passes a floating object such as a corked bottle, the bottle's motion will be circular. Although the wave travels from one location to another, each unit of water ends up close to its starting position after the wave has passed. The radius of the circle is greatest at the surface and decreases steadily with depth.

As a wave approaches the shore, the water below the wave is slowed by friction with the seafloor. The water behind the wave catches up and the water begins to pile higher and higher at the wave crest. Because the crest of the wave is farther from the sea floor, it travels faster than the trough and eventually tumbles over as the wave breaks. This process is shown below.



1. What is the only type of wave that can travel through empty space? ____________________

2. As waves pass through a medium such as air, rock, or water, what is true about the net displacement of particles in the medium? ____

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3. Suppose you are standing on the beach and you see waves breaking about 200 meters offshore. What does this indicate, and why? ______________________________________

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Wave energy

As waves crash upon the shore, they transmit their energy to the sediments found there. Rocks, shells, chunks of coral and other materials are tossed around by the breaking waves and deposited on the beach. Over time, these materials grind against one another and are gradually rounded and broken up into smaller pieces to form cobbles, pebbles, and sand. The image at right shows cobbles on a beach in Maine.

While wave energy causes sediments to change their size and shape, most transport of materials are caused by **currents**–net movements of water from one region to another. (Recall that waves alone do not cause net displacements of materials.) Currents moving along shorelines can pick up materials such as sand from one location and deposit them in another. This can result in the formation of long sand bars and **barrier islands** such as those that line much of the mid-Atlantic coast of North America. Barrier islands are temporary structures that are in constant danger of reforming and repositioning themselves, which can be a major problem for the people who build ocean-view mansions close to the beach.

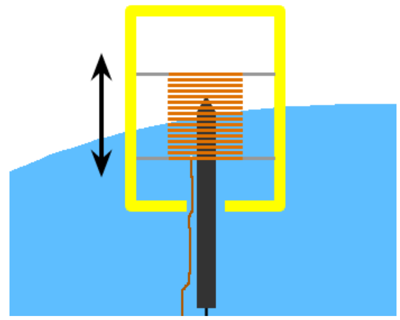
The transformation of coastlines by waves and currents is generally a slow process that operates on the scale of thousands and even millions of years. However, some catastrophic events can cause major changes to coastlines in a matter of hours or even minutes. **Hurricanes** are powerful storms that are common in tropical regions. When a hurricane approaches the coast, water pushed by the wind may pile up near the shoreline, a phenomenon called **storm surge**. In 2005, the storm surge from Hurricane Katrina destroyed properties on the Gulf Coast and breached levees surrounding the city of New Orleans. The resulting flooding caused the deaths of nearly 2,000 people and over $80 billion in property damage.

An even greater danger is posed by tsunamis, which are destructive waves caused by undersea earthquakes. Tsunamis carry enormous energy and travel through the ocean much faster than normal waves. In the open ocean, tsunamis have a small amplitude (~30 cm) and may pass by unnoticed. But when they approach the shore, tsunamis slow down and may reach heights of 10 to 20 meters before surging onto the shore. Tsunamis can travel for miles across flat coastal land, wiping out everything in their path.

On December 26, 2004, a magnitude 9.3 earthquake struck off the coast of Sumatra. The quake triggered a tsunami that spread around the rim of the Indian Ocean. Lacking a warning system, low-lying coastal communities throughout the Indian Ocean basin were wiped out and over 200,000 people were killed.

A second deadly tsunami occurred on March 11, 2011 in northeast Japan. Also caused by an enormous (magnitude 9.0) earthquake, the Tohoku tsunami devastated the coastal lowlands in this region, killing over 15,000 people, causing around $300 billion in property damage, and crippling the Fukushima Nuclear Power Plant. Because the flat land did not offer much resistance, the wave in some places traveled over 10 km (6 miles) inland! Luckily, a sophisticated tsunami warning system throughout the Pacific prevented many deaths from occurring beyond Japan, which was too close to the epicenter to receive much warning.

While the energy of ocean waves is often destructive, it is also a potential source for clean renewable energy. Although wave energy has not been harvested yet, a variety of designs for "wave farms" are being developed and tested. A design developed at Oregon State University (shown at right) utilizes a magnetic shaft that is tethered to the ocean floor. Surrounding the shaft is an electric coil that is attached to a floating buoy. As waves pass, the buoy (and coil) moves up and down relative to the magnetic shaft, inducing an alternating current in the coil.



1. How do waves transform rocks over long periods of time? ___________________________

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2. Why does the height of a tsunami wave increase as it approaches the shore? ___________

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3. What are some of the hazards of living in a low-elevation coastal area? ________________

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On your own: Do an Internet search on "wave power" to find information on ways of converting wave energy to electricity. Study one design in depth, and prepare a presentation for your class. If you like, create a model to demonstrate how the technology works.