Water Waves

Waves are the forward movement of the ocean's water due to the oscillation of water particles by the frictional drag of wind over the water's surface.

Waves have crests (the peak of the wave) and troughs (the lowest point on the wave). The wavelength, or horizontal size of the wave, is determined by the horizontal distance between two crests or two troughs. The vertical size of the wave is determined by the vertical distance between the two. Waves travel in groups called wave trains.

Waves can vary in size and strength based on wind speed and friction on the water's surface or outside factors such as boats. The small wave trains created by a boat's movement on the water are called wake. By contrast, high winds and storms can generate large groups of wave trains with enormous energy.

In addition, undersea earthquakes or other sharp motions in the seafloor can sometimes generate enormous waves, called tsunamis (inappropriately known as tidal waves) that can devastate entire coastlines.

Finally, regular patterns of smooth, rounded waves in the open ocean are called swells. Swells are defined as mature undulations of water in the open ocean after wave energy has left the wave generating region. Like other waves, swells can range in size from small ripples to large, flat-crested waves.

Wave Energy and Movement

When studying waves, it is important to note that while it appears the water is moving forward, only a small amount of water is actually moving. Instead, it is the wave's energy that is moving and since water is a flexible medium for energy transfer, it looks like the water itself is moving. In the open ocean, the friction moving the waves generates energy within the water. This energy is then passed between water molecules in ripples called waves of transition. When the water molecules receive the energy, they move forward slightly and form a circular pattern.

As the water's energy moves forward toward the shore and the depth decreases, the diameter of these circular patterns also decreases. When the diameter decreases, the patterns become elliptical and the entire wave's speed slows. Because waves move in groups, they continue arriving behind the first and all of the waves are forced closer together since they are now moving slower. They then grow in height and steepness. When the waves become too high relative to the water's depth, the wave's stability is undermined and the entire wave topples onto the beach forming a breaker.

Breakers come in different types - all of which are determined by the slope of the shoreline. Plunging breakers are caused by a steep bottom; and spilling breakers signify that the shoreline has a gentle, gradual slope.

The exchange of energy between water molecules also makes the ocean crisscrossed with waves traveling in all directions. At times, these waves meet and their interaction is called interference, of which there are two types. The first occurs when the crests and troughs between two waves align and they combine. This causes a dramatic increase in wave height. Waves can also cancel each other out though when a crest meets a trough or vice-versa. Eventually, these waves do reach the beach and the differing size of breakers hitting the beach is caused by interference farther out in the ocean.

Ocean Waves and the Coast

Since ocean waves are one of the most powerful natural phenomena on Earth, they have a significant impact on the shape of the Earth's coastlines. Generally, they straighten coastlines. Sometimes though, headlands composed of rocks resistant to erosion jut into the ocean and force waves to bend around them. When this happens, the wave's energy is spread out over multiple areas and different sections of the coastline receive different amounts of energy and are thus shaped differently by waves.

One of the most famous examples of ocean waves impacting the coastline is that of the longshore or littoral current. These are ocean currents created by waves that are refracted as they reach the shoreline. They are generated in the surf zone when the front end of the wave is pushed onshore and slows. The back of the wave, which is still in deeper water moves faster and flows parallel to the coast. As more water arrives, a new portion of the current is pushed onshore, creating a zigzag pattern in the direction of the waves coming in.

Longshore currents are important to the shape of the coastline because they exist in the surf zone and work with waves hitting the shore. As such, they receive large amounts of sand and other sediment and transport it down shore as they flow. This material is called longshore drift and is essential to the building up of many of the world's beaches.

The movement of sand, gravel and sediment with longshore drift is known as deposition. This is just one type of deposition affecting the world's coasts though, and have features formed entirely through this process. Depositional coastlines are found along areas with gentle relief and a lot of available sediment.

Coastal landforms caused by deposition include barrier spits, bay barriers, lagoons, tombolos and even beaches themselves. A barrier spit is a landform made up of material deposited in a long ridge extending away from the coast. These partially block the mouth of a bay, but if they continue to grow and cut off the bay from the ocean, it becomes a bay barrier. A lagoon is the water body that is cut off from the ocean by the barrier. A tombolo is the landform created when deposition connects the shoreline with islands or other features.

In addition to deposition, erosion also creates many of the coastal features found today. Some of these include cliffs, wave-cut platforms, sea caves and arches. Erosion can also act in removing sand and sediment from beaches, especially on those that have heavy wave action.

These features make it clear that ocean waves have a tremendous impact on the shape of the Earth's coastlines. Their ability to erode rock and carry material away also exhibits their power and begins to explain why they are an important component to the study of physical geography.

Waves transfer energy but not mass

When we watch surf waves coming into shore, it's easy to think that individual water particles are moving towards us, but that's not actually the case. The particles involved in waves move back and forth perpendicularly to the way the wave is going, but don't move significantly in the direction of the wave. The particles 'take part' in the wave by bumping into one another and transferring energy. This is why energy can be transferred, even though the average position of the particles doesn't change.

How does this work? It can help to think of a buoy bobbing in the ocean. The buoy is moved up and down by the waves that pass by it, but doesn't move directionally across the water.

You could also think about a Mexican wave at a sports match. The wave moves around the arena, but the audience members don't move around with it – they only stand up and sit down (a perpendicular movement to the wave direction).

Particles in a water wave exchange kinetic energy for potential energy

When particles in water become part of a wave, they start to move up or down. This means that kinetic energy (energy of movement) has been transferred to them. As the particles move further away from their normal position (up towards the wave crest or down towards the trough), they slow down. This means that some of their kinetic energy has been converted into potential energy – the energy of particles in a wave oscillates between kinetic and potential energy.

Thinking about potential energy can help us understand why tsunamis can be so damaging. When a tsunami approaches the shore, it shoals (becomes much higher), so the water particles are displaced further from equilibrium. They acquire a lot of potential energy, and this is released when the wave interacts with land.

Name:______________________________________ Date:__________ Period:_____

Water Waves

1. What are water waves?

2. What is a crest?

3. What is a trough?

4. What is a wavelength?

5. How is the wavelength determined?

6. What are waves based on?

7. How are tsunamis created?

8. What is a swell?

9. What is moving in a water waves?

10. What do waves normally do for Earth?

11. What are the water particles doing while the waves "move"?

12. What is kinetic energy?

13. What is potential energy?

14. Explain what happens to the particles in water when they become part of a wave.