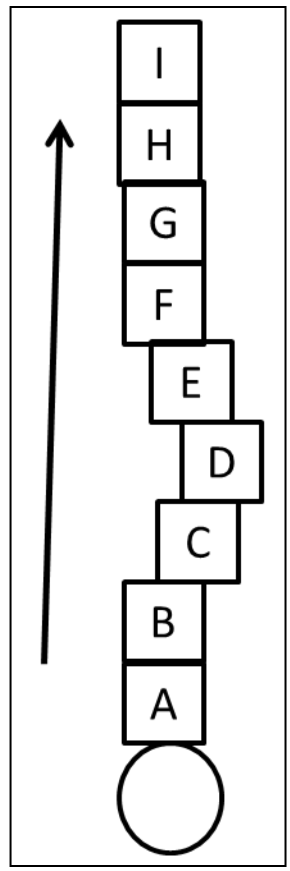
Name: ______________________________ Date: ____________________

Guided Learning: Seismic Waves (Part 2)

The first part of this guided learning described seismic waves in general and discussed how seismic waves, like all other waves, can superpose on one another. This part describes each of the separate kinds of seismic waves and illustrates other wave behaviors they exhibit.

Surface waves
There are two kinds of surface seismic waves: **Love waves** (L-waves) and **Rayleigh waves**.

Love waves, named after British mathematician A.E.H. Love, are surface waves that shake the ground from side to side. They cause the greatest damage to buildings as foundations absorb their energy, causing the material to crack. Love waves can generate furrows as one segment of ground splits away from another.



Molecules in a solid are generally held in a rigid structure by intermolecular forces. Because the structure is rigid, moving all the molecules in one region will cause molecules nearby to move as well. This allows L-waves to move along the Earth's surface; as molecules in one area move to the right or left, they tug on the molecules in front of them, causing them to move as well. The figure to the right portrays this property of solids. Each box represents a segment of rock. The molecules in segment D pull those in segment E toward the right. Similarly, those in segment E pull against the molecules in segment F, which will soon shift to the right as well.

Molecules in a fluid do not have this rigid structure, so L-waves cannot move through liquids. An L-wave can cause a few inconsequential surface waves if it reaches a pond or lake, but very little of its energy can be transferred across the water.

Even though L-waves cannot move through liquids, they can move around them. Seismic waves are not limited to straight lines. They can bend around obstacles. This phenomenon is known as **diffraction**. L-waves can have very long wavelengths, which allows them to bend around almost any barrier. Even though most of the Earth is covered with water, diffraction allows some L-waves to travel around the entire Earth several times.

Rayleigh waves are the second kind of surface seismic wave. Instead of rembodying side-to-side motion, Rayleigh waves are a combination of forward/back and up/down motion and cause Earth's surface to ripple up and down.

Like L-waves, Rayleigh waves bend around corners, reflect off barriers, and suffer dispersion. However, unlike L-waves, Rayleigh waves can travel through water.

1. Why can L-waves only travel through solids? ____

____

____

2. Would it be possible for an L-wave to travel cross the Pacific Ocean by traveling under it?

____

____

3. The illustration to the right shows an L-shaped desk. A domino stands at point D. Someone strikes the desk at X with a mallet, causing the desk's surface to tremor up and down. The domino at point D falls over.

   A. How does this illustrate diffraction?

   ____

   ____

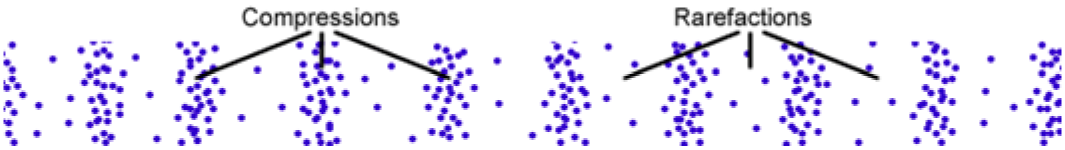
   B. Was the noticeable tremor an L-wave or a Rayleigh wave? Explain. _______________

   ____

Body waves

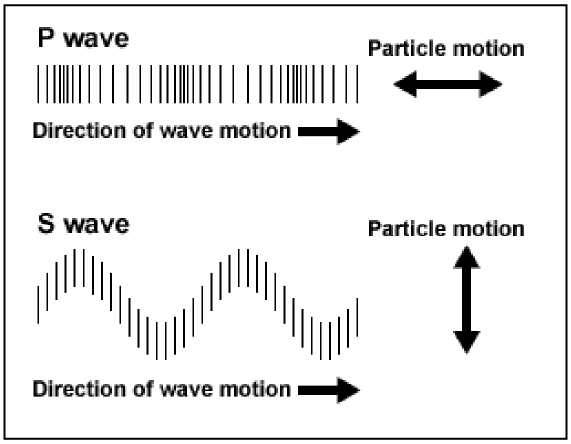
Surface waves are important to understand because they cause greatest loss of human life and destruction of structures. Body waves are important as well because they allow scientists to analyze the Earth's internal structure.

When a drumhead vibrates, it causes the air particles around it to bunch up in certain places and spread out in others. This creates regions of high pressure (compressions) and low pressure (rarefactions). A sound wave is a pattern of these high- and low-pressure areas moving through space.



Something similar occurs in solid matter. When energy is released in the Earth's crust, it generates a pressure wave similar to a sound wave. Instead of air particles colliding against one another, molecules in the rock are being shoved back and forth.

The seismic waves generated by these motions are called **P-waves**. The "P" is for "primary," because they are the fastest seismic waves, so they are the first ones registered by a distant seismograph.



P-waves are longitudinal waves, they are caused by particles moving back and forth parallel to the wave's motion. However, particles can also move laterally, as in the L-waves described in the *Surface waves* section. Body waves caused by particles shifting side-to-side are called **S-waves** (secondary waves). Like L-waves, S-waves cannot move through liquid.

1. P-waves and S-waves are both body waves, meaning they can travel beyond Earth's crust into the mantle. How does this show that the mantle cannot be liquid?

____

____

2. P-waves can go all the way through the Earth, starting at the North Pole and being detected at the South Pole. However, S-waves cannot make it all the way through. How does this support the theory that some part of the core is liquid?

____

____

Wave boundary dynamics

When a wave hits a boundary, which is anything that either blocks the wave or causes an abrupt change in its speed, three things normally occur:

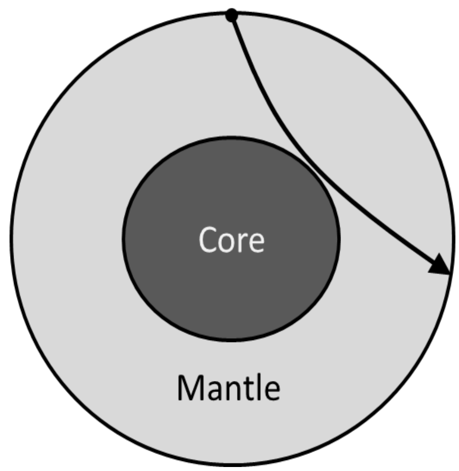
- Part of the wave is reflected.
- Part of the wave is absorbed by the new material.
- Part of the wave is transmitted by the material, possibly in a different direction. This only occurs if the material on the other side of the boundary can support the wave.

One example of this behavior occurs when light passes from air into water. Some of the light is reflected, allowing us to see an image on the water's face. Some of the light is transmitted and bent, like light passed through a prism. This is why droplets of water can create rainbows. Some of the light is absorbed by the water, raising its temperature slightly.

Sound waves can also be transmitted, reflected or absorbed. We can hear underwater, so we know that some sound is transmitted when sound waves pass from air to water. We are used to hearing echoes, which occur when sound waves bounce off barriers. And the only reason we can hear sound waves at all is that some of their energy is absorbed by our eardrums and the surrounding bones, causing them to vibrate. A very loud sound can rupture an eardrum.

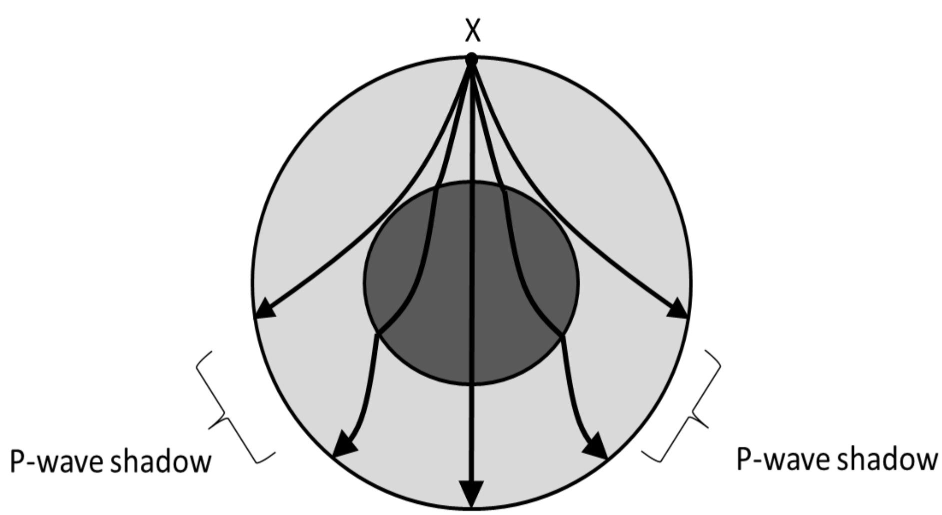
The sound wave example illustrates a key point: when a material absorbs a wave, it can cause a vibration. This has an interesting effect in the context of seismic waves. If a P-wave moving through sandstone hits a patch of limestone, the limestone will absorb part of the energy and begin vibrating. These vibrations can generate both P-waves and S-waves in both directions.

This means that when a P-wave or S-wave strikes a boundary, up to four new waves can be generated because both P-wave and S-waves can be refracted and both P-waves and S-waves can be reflected. This phenomenon in which a portion of the energy is converted into a different type of wave is called **mode conversion**.



Waves reflect, refract, and are absorbed at boundaries, but they can also refract anytime their speed changes, even if it changes gradually. The speed of seismic waves increases with pressure, so seismic waves generally move faster the deeper they go into the mantle because the pressure increases. This gradual change in wavespeed causes seismic waves to curve, as shown in the picture to the right.

The outer part of Earth's core is liquid, so S-waves cannot enter the core from the mantle. P-waves can pass through the boundary, but they slow down signficantly. When a wave hits the boundary between the mantle and core, it will bend toward the core because that is the slower material. When it leaves the core to re-enter the mantle, it will bend toward the core again. The net effect of these two refractions is a **P-wave shadow**. The figure below shows this shadow. No waves starting from point X can resurface in this shadow because waves that don't go through the core are bent away by the mantle, and those that go through the core are bent too much the other way at the Mantle-Core and Core-Mantle boundaries.



1. Why do seismic waves refract while traveling through the mantle? ____________________

____

____

____

2. The center of Earth's core is thought to be solid. Is it possible for an earthquake to cause S-waves there? If no, explain why not. If yes, explain how they can get there.

____

____

3. If seismic waves refracted in the opposite way (toward the core rather than away from it), would it be possible for an S-wave to travel from the North Pole to the South Pole? Explain. (You might want to draw a picture in the space below the answer blanks.)

____

____

____