Human Waves Demonstrate How Seismic Waves Travel

Time: 5-10 Minutes

Target Grade Level: Any level

Content Objective: Students will be able to describe how P and S waves travel through solid and liquid.

Introduction

Remember the "stadium wave," when one person stands and raises his hands in the air and the motion is translated completely around the arena? This simple demonstration uses a similar principal by sending seismic waves through a line of people to illustrate the difference between P waves and S waves Webster's Dictionary defines a wave as "a disturbance or variation that transfers energy progressively from point to point in a medium." Suppose the medium were the audience in a football arena. .

Procedure

To simulate seismic wave propagation in solids and liquids have a line of people stand shoulder to shoulder. Have about 10 people stand at the front of the room, side by side, with their feet about shoulder width apart. Instruct the group to not be too rigid or too limp when pushed from the side. They should give with the force that they will feel from the person next to them, but not fall over, and then return to their upright position. In other words, they should be "elastic." Have a "spotter" (or wall) at the end of the line in case the last person begins to fall. (It is important to stress these instructions to the participants so that the demonstration will work effectively.)

To represent wave propagation in a solid, have group stand side by side, shoulder to shoulder. Push on the person at the end of the line and the "deformation" will propagate down the line of people approximating a P wave (Figure 1B). Although each person was briefly subjected to a deformation or disturbance, the individuals did not move from their original locations. The motion of each person is in the direction of propagation so that the people moved closer together (compression), and then apart (dilation) to return to their original positions. Also, the propagation down the line takes time; there is a velocity for the wave propagation.

To simulate the S wave in a solid, have each person put their arms over the shoulders of the person next to them ("chorus line style"; the "molecules" or "particles" of the solid are tightly bonded). Make the first person at the end of the line bend forward at the waist and then stand up straight. The transverse or shear motion will propagate down the line of people (Figure 2B). Again, the wave takes some time to propagate and each person ends up in the same location where they started even though a wave has passed. Also, note that the shear motion of each particle is perpendicular to the direction of propagation. Which one moves faster? One of the observers can time the P and S wave propagation in the human wave using a stopwatch. Because the shear wave motion is more complicated in the human wave, the S wave will have a slower velocity (greater travel time from source to the end of the line of people), similar to seismic waves in a solid.

To represent wave propagation in a liquid, have the people stand shoulder-to-shoulder, without their arms around each other. Make the person at the end of the line bend forward at the waist—a transverse or shear disturbance (Figure 3). However, because the "molecules" of the liquid are more loosely bound, the shearing motion will not propagate through the liquid (along the line of people). The disturbance does not propagate to the next person because the liquid does not support the shearing motion. (Compare pressing your hand down on the surface of a solid such as a table top and on the surface of water and moving your hand parallel to the surface. There will be considerable resistance to moving your hand on the solid.) One could even push the entire table horizontally by this shearing motion. However, there will be virtually no resistance to moving your hand along the surface of the water.) Only the first person in the line – the one that is bent over at the waist – should move because the people are not connected. If the next person bends, "sympathetically," not because of the wave propagating, ask that person if he or she felt, rather than just saw, the wave disturbance, then repeat the demonstration for S waves in a liquid.

Materials: Stop watch & group of students

Background for Seismic Waves:

For a short animation & Background PDF that describes seismic waves, please visit:
http://www.iris.edu/hq/programs/education_and_outreach/animations/6

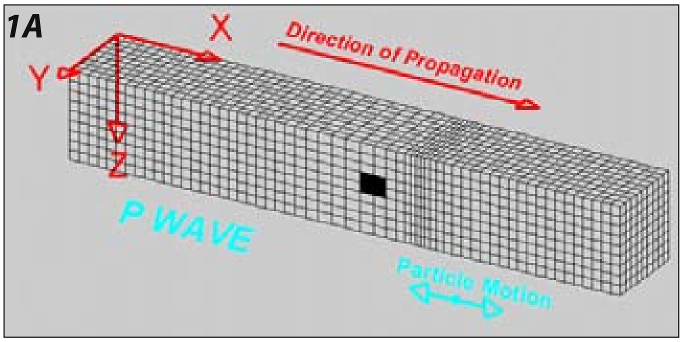
Watch video and animations in the folder:
2. ANIMATIONS_Earthquake & Tsunami
> 4. ACTIVITIES_Earthquake & Tsunami
>The Wave_How People Make Seismic Waves

Science Standards (NGSS; pg. 287)

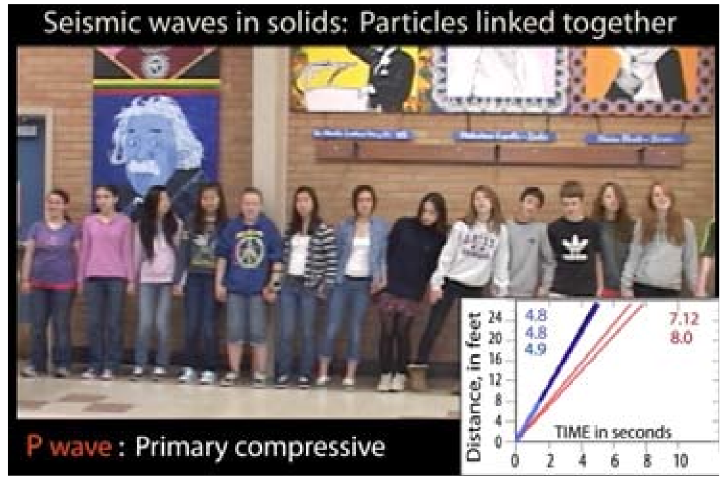
- From Molecules to Organisms—Structures and Processes: MS-LS1-8
- Energy: MS-PS3-5
- Waves and Their Applications in Technologies for Information Transfer: MS-PS4-1, HS-PS4-1, MS-PS4-2

Graphics used with permission from Larry Braile's "**Seismic Waves and the Slinky: A Guide For Teachers**."

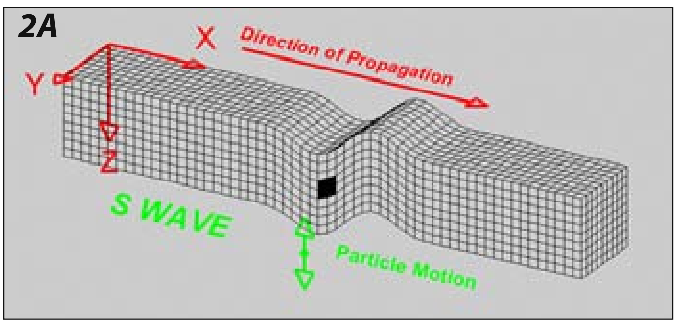
1A



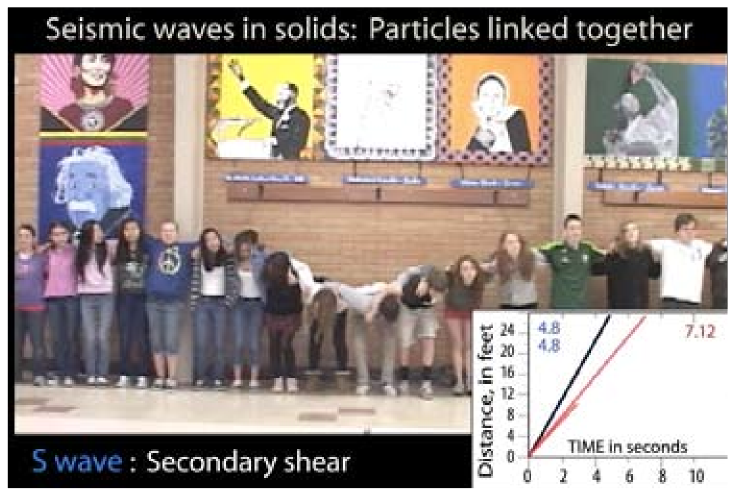
1B



Figures 1A & B—LEFT: P wave through a solid or liquid.
RIGHT: *When a P wave bumps the first person (molecule), the bumping down the line happens quickly. P waves travel easily within a liquid or solid.*
From Video of an P-wave demonstration taken in Roger Groom's Mount Tabor Middle School Earthl-science class. The travel times are graphed. See **Animation folder** *on previous page.*



2B



Figures 2A & B — LEFT: *S wave through a solid.* ***RIGHT:*** *The line of people (molecules) forms an elastic solid by linking arms or placing arms over shoulders to show that when the S wave "shears" the first person pulls the next into a bend. Note that the motion of each person is perpendicular to the direction that the wave travels. As each person bends and straightens, they pull their neighbor into the same motion. This is a slower effect than the P wave.*

3

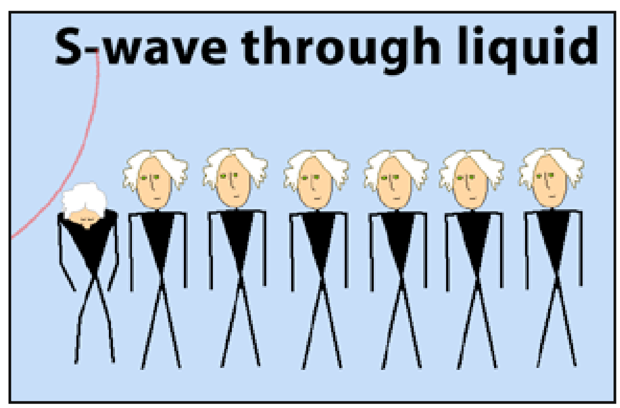


Figure 3*—An S wave can't travel through a liquid. The line of people (molecules) forms a liquid by unlinking their arms. Activity uses the S wave concept of "shearing" into a bend, but because arms aren't linked into an elastic solid, the rest of the line doesn't bend. This and similar simple animations are in folder:*

3. ACTIVITIES_Earthquake & Tsunami
> **The Wave_People Make Seismic Waves**

THOUGHTS ON FURTHER DEVELOPMENT OF THIS ACTIVITY: *Needs a student "worksheet" or suggested discussion questions to go along with the activity—suggest that at least a few evaluate the components of the model (what each step represents, similarities and differences of the model and the advantages and disadvantages of using it as a model), calculating the speed of the wave (d/t=r) and discussion of the forces involved and how kinetic energy is transferred from one "atom" to other "atoms" nearby.*

Extension Idea—*have students figure out how to model materials with different densities or cohesiveness such as sand vs. solid rock. 9-12 should evaluate wavelength, amplitude and frequency.*

Participants in the 2008 TOTLE Workshop make a human wave wherein the compressive P wave is propagated from the person behind you, and you transfer the energy to the back of the person in front of you.

Velocity of Wave Propagation Experiment
Light waves vs. Sound waves*

Developing an understanding of seismic wave propagation and of the velocity of propagation of seismic waves in the Earth is aided by making measurements of wave speed and comparing velocities in different materials. For waves that travel an approximately straight line (along a straight ray path), the velocity of propagation is simply the distance traveled (given in meters or kilometers, for example) divided by the time of travel (or "travel time") in seconds. Using a stopwatch for measuring time and a meter stick or metric tape for measuring distance, determine the wave velocity of water waves in the wave tank, the P wave in the slinky, and the P wave in the human wave experiment. Also, determine the velocity of sound in air using the following method. On a playfield, measure out a distance of about 100 meters. Have one person with a stopwatch stand at one end of the 100 meter line. Have another person with a metal garbage can and a stick stand 100 meters away from the person with the stopwatch. Have the person with the stick hit the garbage can so that the instant of contact of the stick with the garbage can is visible from a distance. The person with the stopwatch should start the stopwatch when the stick strikes the can and stop it when the sound generated by the stick hitting the can is heard. The measured speed of sound will be the distance divided by the travel time measured on the stopwatch. (This measurement assumes that the speed of light is infinite—a reasonable approximation as the actual speed of light is about 3×10^8 or 300 million meters/second, much faster than the speed of sound, and that the reaction time for the person operating the stopwatch is about the same for starting the watch when the can is struck and for stopping the watch when the sound is heard. The measurement should be repeated a few times to obtain an estimate of how accurately the measurement can be made. An average of the time measurements can be used to calculate the sound speed. The difference between the arrival of a light wave and associated sound is commonly used to determine how far away a lightning strike is in a thunderstorm. For example, because the speed of sound in air is about 330 m/s, if the difference in time between seeing a lightning strike and hearing the associated thunder is 3 seconds, the lightning is 1 km away; similarly, 6 s for 2 km away, etc.) Make a list of the wave velocities (in m/s) for the water waves, slinky, human wave, and sound wave in air. (Measured wave speeds should be approximately 0.25-0.5 m/s for water waves in a wave tank, 2 m/s for the compressional human wave, 3 m/s for P waves in the slinky, and 330 m/s for sound waves in air.) Compare these wave velocities with the compressional wave velocity in the Earth which varies from about 1000 m/s for unconsolidated materials near the Earth's surface to about 14,000 m/s in the Earth's lowermost mantle (1 to 14 km/s). The seismic velocity in solid rocks in the Earth is controlled by rock composition (chemistry), and pressure and temperature conditions, and is found to be approximately proportional to rock density (density = mass/unit volume; higher density rocks generally have larger elastic constants resulting in higher seismic velocity). Further information on seismic velocities and a diagram showing seismic velocity with depth in the Earth is available in Bolt (1993, p. 143) and Shearer (1999, p. 3).

Attenuation of Waves

To demonstrate the property of anelasticity, a model with two slinkys can be constructed. Anelasticity is the absorption of energy during propagation which causes waves to attenuate in addition to the attenuation caused by the energy spreading out (for example, like the spreading of water waves created by dropping a pebble into a pond). This effect is an important concept in evaluating earthquake hazards and comparing the hazards in two locations such as the western United States and the eastern United States. Seismic waves propagate very efficiently in the eastern United States resulting in damage over a wide area from a large earthquake. In contrast, waves propagating in the western United States are attenuated by absorption of energy to a much greater degree. Thus, although earthquakes of a given size occur much more often in the western US, the earthquake hazard in the eastern US is significant because the area of damage (for equivalent earthquakes) is larger in the eastern US.

*From **Larry Braile's** activity:
Seismic Waves and the Slinky: A Guide for Teachers