Properties of Waves

Activity Description & Estimated Class Time

During this 50-minute activity, students explore examples of energy transmission through waves. Students discuss how energy moves from place to place in these examples, then simulate transverse and longitudinal waves with a spring. Afterward, they begin exploring concepts of frequency and amplitude using the spring.

Correlations to NC Science Standards

PS.6.3.1 Use models of a simple wave to explain wave properties in seismic, light, and sound waves that include: waves having a repeating pattern with a specific amplitude, frequency, and wavelength, and the amplitude of a wave is related to the energy of the wave.

Learning Targets

Students will demonstrate knowledge and understanding of the following concepts:

- energy causes things to move
- waves transmit energy
- waves can move through different substances

Brief Science Background

Many forms of energy travel as waves through space and through materials. Forms of energy that travel as waves include sound, light, radiant heat, radio, and earthquakes. Generally, some form of energy starts a wave going, and when the wave reaches its destination, it adds some energy to the place it arrives. Sometimes, a wave can start out as one form of energy and become a different form of energy when it arrives. For example, a light wave travels from its source to a solar collector, where it becomes electricity. For more information see the Appendix on page 12.

Common Student Preconceptions

Children generally do not think of light, radio waves, sound, or earthquakes as waves in the same category as waves on water. These phenomena appear to be very different. Their wave nature is invisible. It is difficult to directly experience these forms of energy as waves in the way we experience waves rolling on the ocean. As a result, most people, including children, take scientists' word for it that these forms of energy travel in similar ways.

Part 1 — Waves and Energy Stations

Materials

Materials for the whole class

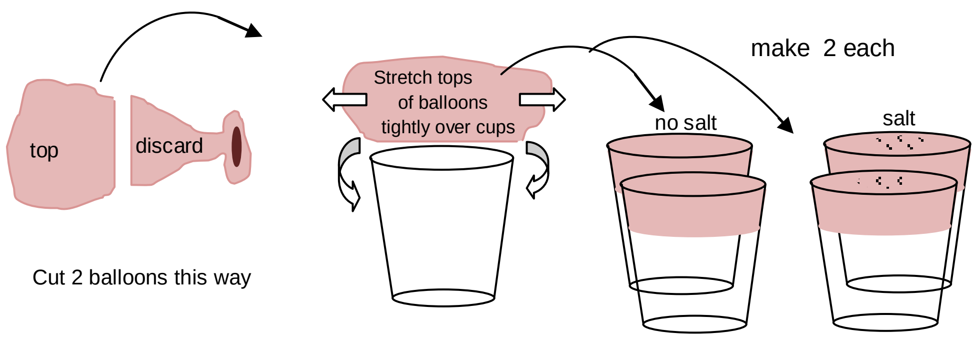
- 4 tall 9-oz cups
- 4 balloons to stretch over the cups
- 5 restaurant salt packets
- 2 photovoltaic cell-motor-light setups
- 2 5 x 8 inch plastic trays
- 2 ping-pong balls
- 2 1 oz cup lids
- 2 clamp lights with 75-watt bulbs and extension cords
- 1 plain white sheet of copier paper, cut in half across its width (supplied by teacher)
- water (supplied by teacher)
- 2 copies of Directions for Wave Stations (SD 1)
- Waves and Energy Student Activity Sheet (SD 2), 1 per student

Preparation

allow for approx. 20 min.

Set up six stations as follows:

1. **Two stations with cups and balloons** - Stretch balloon tops over four tall 9 oz cups, as shown below. Open one salt packet and put a pinch of salt on top of the balloon on one cup, then do the same with another cup. Leave the other two cups without salt. Place a pair of cups, one with salt and one without, at each of the two stations. Leave a copy of balloon cup directions from Directions for Wave Stations (SD 2) at both stations. Keep the balloon cups to use in the Types of Waves lesson.



2. **Two stations with water in trays** - Put about 3/4 inch of water in two 5 x 8 plastic trays. Set up two stations with a tray, a cup lid, and a ping-pong ball at each. Leave a copy of water tray directions from SD 1 at both stations.
3. **Two stations with a light, solar cell, and motor** - Be sure the motor runs when the light is on. Leave the light off after you check. Leave a sheet of paper and a copy of clamp light and solar cell directions from SD 1 at both stations.

Procedure

1. Give each student a Waves and Energy Student Activity Sheet (SD 2) then divide the class into six groups of roughly equal size.
2. Explain that there are six stations around the room, but only three different types of station. Each group will go to a station, follow the directions there, and record what they find out on SD 2. Tell the class that you will allow 1 minute to do the activity, call time, then 4 minutes to write, and then call time to move to the next station. Students will move to a station that is different from the one they just visited. They are to go to all three different types of stations.
3. Ask each team to go to a station.
4. Demonstrate only if necessary. Be ready to:
   - Hold the cup with no salt about 8-10 inches away from the cup with the salt grains on it. Then pinch the balloon on the cup you are holding, pull it back, and release it with a snap such that the salt on the other cup moves.
   - Put a cup lid in one end of the water tray, and drop the ping-pong ball in the water at the opposite end.
   - Switch on the light over a solar cell and motor; then switch it back off.
5. After all students have completed the stations, ask them to return to their seats.
6. Hold a class discussion and ask students to describe what they saw, including cause and effect.
   Snapping a balloon on one cup made salt grains move on the other cup; light made the motor turn; the ball dropping in water made the plastic lid move.

Content Connection

1. Continue the discussion by reminding the class that any change or movement requires energy. Starting with the ping-pong ball and water tray, ask students to describe and document on SD 2 what changed or moved and what kind of energy caused it. Ask the following questions to get students' ideas. Don't explain anything until you get all responses. Ask:
   - What was the source of the energy?
   - How did the energy travel from place to place?
   - What medium did the energy go through as it traveled?

   Rather than go over these answers with students, try to facilitate the discussion to tie their responses to these ideas.

   Water tray: a student put energy into the ping-pong ball by lifting it up against gravity. That energy became kinetic energy when the ball fell. The kinetic energy moved the water where the ball landed. That movement traveled as a wave across the tray. When the wave reached the other end, it moved the cup lid. The wave moved through water.

   Balloon cups: stretching the balloon on the plain cup put mechanical energy into the balloon. When the balloon was released with a snap, the mechanical energy vibrated the air surrounding the cup and became sound energy. The sound traveled to the other cup as a wave that traveled through the air and hit the balloon on the other cup. That balloon responded to the sound wave by vibrating and moving the salt.

   Light, solar cell, and motor: electrical energy came into the light bulb through wires from generators at a power station. The light bulb gave off light energy that traveled as a wave. When the light wave struck the solar cell, it produced enough electricity to turn the motor. The energy traveled through the air.

2. Summarize the main ideas as follows:
   - Energy caused things to move.
   - Some of the energy in these examples moved as waves. In some cases, students have to take your word for this. For example, with the light/solar cell, their experience does not support this claim. They saw energy but not waves.
   - Waves can move through different substances, such as air and water.

Formative Assesment/ Guided Practice

Have students answer the following questions using complete sentences and evidence from their observations and the discussion:

1. What is the evidence that energy causes a change in motion?
   Acceptable answers include: snapping the balloon caused the salt to move, directing light caused the solar panel to create power to spin the motor, dropping the ping-pong ball caused the water to move, snapping the balloon created a sound. In all cases we used energy to make a change.
2. What is evidence that energy travels as a wave?
   Possible answer: We saw the water move in wave form, and or we saw the salt “jump” so something had to travel to make it move.

Part 2 — Wave Simulation

Materials

Materials for pairs of students

- 1 spring toy
- 2 Wave Simulation Student Activity Sheets (SD 3)

Procedure

Use tabletops if they are five feet long or more. If these are not available, this activity can be done on an uncarpeted floor. Ask students to work in pairs and give materials to each pair.

1. In each pair, have one of the students hold one end of the spring and the other student hold the opposite end. Then ask them to work together to stretch the spring until it is 5-8 feet long. Next, challenge them to find different ways to send energy from one end of the spring to the other without lifting either end from the surface. They can move the ends of the spring in any way except lifting it from the surface.
2. Have students draw the ways they moved the spring and describe the ways they sent energy through the spring on their Wave Simulations Student Activity Sheets (SD 3). Have them give evidence to support their claim that energy traveled from one end of the spring to the other. Discuss ways that students described energy moving along the spring.
3. Still working in pairs, ask students to make an S-like wave and describe two things about it:
   - the motion of their hand (including the direction) in making the wave;
   - the motion of the wave moving on the spring (including the direction).

   Tell students that this is called a **transverse wave.** It is the way water waves and light move.
4. Ask students to make the other kind of wave (push-like) and to describe the same two things:
   a. the motion of their hand (including the direction) in making the wave;
   b. the motion of the wave moving on the spring (including the direction).

   Tell students that this is called a **longitudinal wave.** It is the way sound waves travel from the source of a sound to a person's ears.

Content Connection

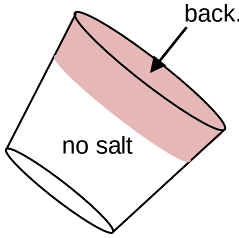
1. Have students define both types of waves in their own words.
2. Ask students what they noticed about the spring after the wave moved through it.

SD 1

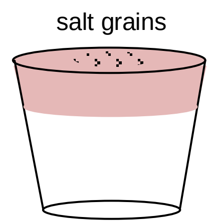
Directions for Wave Stations

Cut these out and place at the appropriate stations.

Pinch here, pull, and let go so that the balloon snaps back.



Lift the cup without salt a few inches above the table and hold it 8-10 inches from the cup that has salt on it. Pinch the center of the balloon on the lifted cup and stretch the balloon away from the cup. Let go with a snap. Watch the salt grains on the other cup.

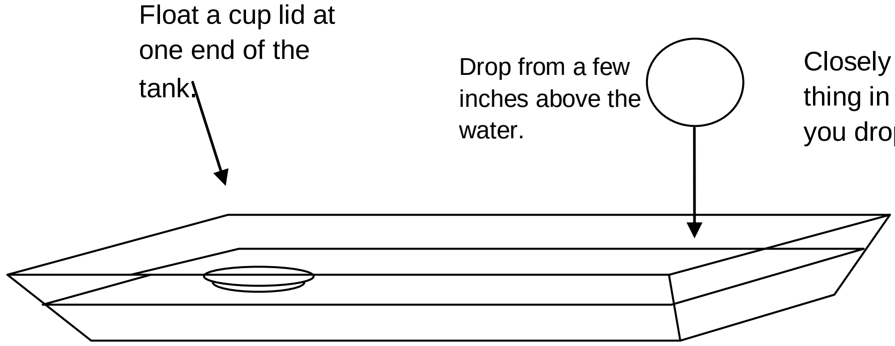


Drop a ping-pong ball at the opposite end of the tank.

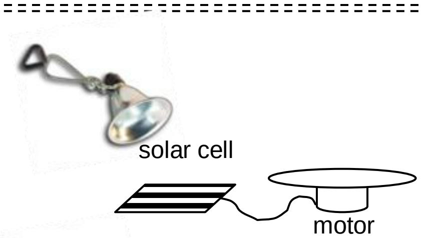
Float a cup lid at one end of the tank.

Drop from a few inches above the water.

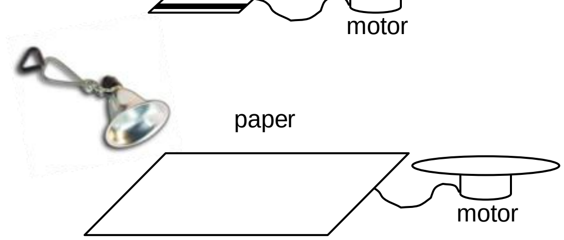
Closely watch everything in the tank when you drop the ball.



Start with the clamp light off and the motor still. Turn the light on. Watch what happens when the light is turned on, and again when it is turned off.



With the clamp light off and the motor still, put a piece of paper over the solar cell and then turn on the light. Watch what happens. Then, with the light still on, remove the paper covering the solar cell. Observe what happens.



SD 2
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Waves and Energy Student Activity Sheet

Circle the station you are observing: ballon cup water tank light and motor What did you notice at this station?   What does this make you think about?
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What caused all the changes you noticed?

SD 2
pg. 2 of 2

Waves and Energy Student Activity Sheet

As you talk with the class, complete the chart.

Station	Source of Energy	How did it travel?	Medium
Water Tray			
Balloon Cups			
Light, Solar Cell, and Motor			

Answer the following in your own words. Use complete sentences and evidence from your observations and the discussion.

What is evidence that energy causes a change in motion?

What is evidence that energy travels as a wave?

SD 3

Wave Simulation Student Activity Sheet

pg. 1 of 2

Work with a partner and a spring. Each of you should hold an end of the spring. Stretch the spring until it is 5-8 feet long. Do NOT lift your end of the spring off the floor or table top. Find different ways to send energy from one end of the spring to the other. You can move it any way except lifting it.

In the space below, draw the ways you moved the spring.

Give evidence to support the claim that energy moved through the spring.

SD 3
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Wave Simulation Student Activity Sheet

Make the two types of waves again with your spring then complete the chart.

Type of Wave	Motion of your hand to create the wave with a spring	Your drawing of the wave moving through the spring	Science term for this wave	Type of energy that travels this way.
S-Like Wave				
Push-like Wave				

What did you notice about the spring after the wave moved through it?

Appendix

Detailed Background Information

In physics, a wave is defined as a repeating disturbance that carries energy as it moves through a medium from one place to another. While we can see ocean waves and feel the kinetic energy they carry, the waves we most commonly experience are light and sound waves, which we can neither see nor feel in the same way as ocean waves. Nevertheless, in the 19th century several physicists conducted ingenious experiments that led to the widely accepted wave theories of light, sound, and several other forms of energy.

Light waves are examples of transverse waves, which resemble the S-shapes a child's spring toy (e.g., a Slinky™) can make when lying on a flat surface. These are similar to the way ocean waves move with their characteristic high parts (peaks) and low parts (troughs). Transverse waves can vary in their amplitude and wavelength.

Amplitude is the height of the peaks from a horizontal line that splits the waves into equal top and bottom halves. It is also the depth of the troughs from that same line. The amplitude of a wave is related to the amount of energy it transports. High amplitude waves carry more energy than low amplitude waves. High-amplitude sound waves sound loud, and low amplitude sound waves sound quiet.

Wavelength: The distance between two adjacent peaks or two adjacent troughs. In other words, it is the horizontal distance traveled by one complete wave. A complete wave consists of one whole peak and one whole trough; it can also be thought of as an S lying on its side (rotated 90°). The shorter the wavelength, the more energy the wave carries.

The period is the amount of time it takes for one complete wave form. For example, the time that elapses from the moment when one crest passes a point until the next crest passes the same point. Periods are measured in seconds. The shorter the period, the more energy the wave carries.

Frequency is the number of complete waves that occur in a certain amount of time. Frequencies are generally stated in cycles per second, with one cycle being the same as one complete wave. Physicists use the term hertz (named for the German Physicist Heinrich Hertz) instead of cycles per second to describe a wave's frequency. One hertz is equal to one cycle per second. A hertz is abbreviated as Hz. This abbreviation is often preceded by another, such as k, meaning kilohertz (one thousand hertz, or kHz) or M, meaning megahertz (one million hertz, or MHz). The higher the frequency, the more energy the wave carries.

Radio waves are a subset of a broader category known as electromagnetic waves, which also includes microwaves, infrared light, visible light, ultraviolet light, X-rays, and gamma rays. Of these transverse waves, radio waves have the lowest frequencies – as low as 3 kHz (3000 cycles per second), although the frequencies used by commercial radio stations range from 535-1700 kHz for AM stations, and 88-108 MHz for FM stations. Radio waves also have the longest wavelengths – up to 100 km (about 64 miles), but commercial radio waves range from 560 meters (AM) to 2.8 meters (FM). Besides radio stations, many common consumer devices use radio waves, including cell and cordless phones, garage door openers, and GPS units.

Starting with radio waves and followed by microwaves, infrared light (also known as radiant heat), and the rest of the electromagnetic waves listed in the order above, wavelengths decrease as the list proceeds. Microwave ovens, for example, typically produce

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wavelengths of about 10-30 centimeters. Light that is visible to humans travels in waves of lengths from about 700 nanometers (700 billionths of a meter) for red, to 400 nanometers for violet. Medical X-rays machines produce waves that are about 10,000 times shorter than those of violet light.

Gamma rays, which are another form of radioactive waves that travel to Earth through outer space, have even shorter wavelengths, and they also have the highest frequencies of the electromagnetic waves. In fact, for all of these waves, there is an inverse relationship between wavelength and frequency. Radio waves, having the longest lengths, have the lowest frequency range, from 3,000 Hz up to about 1 billion Hz. The waves produced by microwave ovens have frequencies of about 1-3 billion Hz, while the frequencies of visible light range from about 250 trillion Hz (for red) to 850 trillion Hz (for violet). Medical X-rays cycle at the unimaginable rate of 1 quintillion (1,000,000,000,000,000,000) Hz.

Although their wavelengths and frequencies differ, all types of electromagnetic waves have one thing in common: they all travel at the same speed of 299.8 million meters per second, also known as the speed of light.

Sound waves move in a very different way than light and the other electromagnetic waves. While electromagnetic waves are all examples of transverse ways, sound waves are examples of longitudinal waves. Keeping in mind that a wave is a repeating disturbance within a medium, which carries energy as it moves from one place to another, a transverse wave displaces particles of the medium in directions that are perpendicular to the direction the wave is traveling. An ocean wave models this idea very well: the wave moves horizontally toward the shore, but the water (the medium) moves vertically as peaks and troughs form.

In longitudinal waves, however, the particles of the medium move back and forth in the same direction as the wave itself, that is, parallel to the wave's movement. In longitudinal waves, the particles are alternately pushed together, or compressed, and then bounce back to their original, uncompressed positions. Physicists refer to the compressed regions as compressions and the uncompressed regions as rarefactions. If we could actually see the particles, the wave would look like alternating bands of lighter (rarefied) and darker (compressed) areas moving in a straight line, as if they were traveling through a pipe.

In a longitudinal wave, just as in a transverse wave, the wavelength is the distance spanning one complete wave. Therefore, a longitudinal wavelength is the distance from the start of one compression to the start of the next compression (or the start of one rarefaction to the start of the next rarefaction). Likewise, the period of a longitudinal wave is how long it takes for one complete wave, that is, one compression plus one rarefaction, to pass a given point. The frequency is the number of complete waves that pass a given point in one second, just as in transverse waves. In sound waves, the pitch of the sound is determined by its frequency, with lower pitches having lower frequencies and higher pitches having higher frequencies.

The amplitude of a longitudinal wave is a measure of how closely packed together the compressions are, or how spread out the rarefactions are. It takes more energy to pack particles of the medium together in a longitudinal wave, just as it takes more energy to move particles vertically in a transverse wave. Louder sounds have higher amplitudes, and vice versa.

While both transverse and longitudinal waves transport energy from one place to another, they do not move particles of the medium from one place to another. If they did, sound

Appendix cont.

waves, for example, would push particles of air ahead of them and we would feel a breeze at our ears every time we hear a sound, or wind gusts if the sound was very loud. Instead, the disturbance that moves through the air is only temporary, and the displaced particles return to their original positions once the wave passes.

Waves travel through a variety of media. Light waves from the sun travel through the vacuum of space, and then through air once they reach the atmosphere. They can also travel through water, but not through solid materials. Radio waves can travel through the air and then through solid materials to reach our radios (receivers), where the energy they carry is converted to the sound energy we hear as music and speech from the radio speakers. Sound waves can travel through liquids, which is how dolphins and whales communicate, and gases (such as air), but they can't travel in a vacuum. While in orbit, NASA's Space Shuttles travel at speeds of about 17,500 miles per hour, but they do so in silence.

The waves of kinetic energy that occur in an earthquake travel through the solid materials comprising the earth's surface. The very first waves that occur are longitudinal waves, known as the P-waves, or primary waves. These radiate out from the location where a pair of tectonic plates move relative to each other, either colliding or pulling apart. These longitudinal waves are followed within seconds by the secondary waves, known as S waves, which are transverse waves. The last, slowest moving waves are the most destructive, because they produce both the side-to-side motions of a longitudinal wave and the up-and-down motions of a transverse wave. These waves are known as Rayleigh waves. All three types of earthquake waves have higher amplitudes in major earthquakes than in minor earthquakes.

The waves of tsunamis are examples of water waves having very high amplitudes, and thus carrying a lot of damaging energy. In order to keep things simpler, throughout this set of lessons we use water waves as an example of transverse waves. However, water waves are actually a combination of transverse and longitudinal waves, as shown in another animation at the website above. This animation, like those of the other wave types, also clearly demonstrates the fact that the particles of the medium (water) do not travel with the waves. If they did, there would be no water left in the middle of our oceans!