Lesson Title: Using Waves to Communicate

Subject	Grade Level	Timeline
Physical Science	7 - 8	45 minutes

Objectives
This lesson investigates the difference between longitudinal waves and transverse waves, and how they are able to transmit energy from one location to another. Students will explore ways to deal with line of sight obstructions and consider the impact of such methods with regard to interplanetary communication.

Standards

Next Generation Science Standards
Middle School Physical Sciences Storyline
https://www.nextgenscience.org/sites/default/files/MS%20PS%20DCI%20Combined%206.13.13.pdf

Students who demonstrate understanding can:

4-PS3-2 Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.
MS-PS4-1 Use mathematical representations to describe a simple model for waves, including how the amplitude of a wave is related to the energy in a wave.
MS-PS4-2 Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials. [Clarification Statement: Emphasis is on both light and mechanical waves. Examples of models could include drawings, simulations, and written descriptions.] [Assessment Boundary: Assessment is limited to qualitative applications pertaining to light and mechanical waves.]
MS-PS4-3 Integrate qualitative scientific and technical information to support the claim that digitized signals are a more reliable way to encode and transmit information than analog signals. [Clarification Statement: Emphasis is on a basic understanding that waves can be used for communication purposes. Examples could include using fiber optic cable to transmit light pulses, radio wave pulses in wifi devices, and conversion of stored binary patterns to make sound or text on a computer screen.] [Assessment Boundary: Assessment does not include binary counting. Assessment does not include the specific mechanism of any given device.]

Materials
● Slinky ● pieces of yarn (Optional: video recording device and playback system to observe the waves in the Slinky)

Vocabulary

Line-of-Sight - the straight line path between a source of electromagnetic radiation (e.g. a light source, or a transmitting antenna for radio signals) and the receiving point (the viewer's eye, or a receiving antenna).

Ray - a straight line of light (or other EM radiation) pointing in the direction of energy flow, away from the source.

Longitudinal Wave - Any wave where the medium particles oscillate in a direction parallel to the wave ray.

Transverse Wave - Any wave where the medium particles oscillate in a direction perpendicular to the wave ray.

Lesson Plan

Part I: The nature of waves

Teacher Demonstration

1. Tie several small pieces of yarn to a Slinky, at different points along its length.
2. Stretch the Slinky out in an area where the class can see the length of it. Two trustworthy assistants are needed to hold the ends of the Slinky without letting go. The Slinky should be stretched, but be careful not to pull it far enough to damage it. A Slinky that has been pulled too far will not return to its original shape.
3. Demonstrate a **longitudinal wave** by bunching up the Slinky at one end, and then releasing the bunched up coils. An example video is linked in the Resources section below.
    a. Students should be able to clearly see that there is a disturbance traveling along the length of the Slinky. This disturbance is the wave, and it is transmitting energy from one end of the Slinky to the other.
    b. Ask students to compare the direction of the yarn to the direction of the wave. They should see the yarn moves in the same direction as the wave. Each piece of the Slinky is moving back and forth slightly along the length of the Slinky.

4. Demonstrate a **transverse wave** by sliding one end of the Slinky left and right, perpendicular to the length of the Slinky. Make sure the other end of the Slinky is held in place. An example video is linked in the Resources section below.
    a. Students should be able to clearly see that there is a disturbance traveling along the length of the Slinky. Again, this disturbance is the wave, and it is transmitting energy from one end of the Slinky to the other.
    b. Ask students to compare the direction of the yarn to the direction of the wave. They should see the yarn moves perpendicular to the direction of the wave. Each piece of the Slinky is moving a small amount back and forth, but not in the direction the wave is moving.

Explain:

- A **longitudinal wave** is sometimes called a “pressure wave.” Sound waves are an example of longitudinal waves.

- Light and other electromagnetic radiation are **transverse waves** of electric and magnetic energy.

- Scientists draw arrows called “rays” to show the direction a wave’s energy is moving..

Ask:

- What direction would the ray point for the longitudinal wave? (A: along the length of the Slinky.)
- What direction would the ray point for the transverse wave? (A: along the length of the Slinky.)

<u>Part II: Using electromagnetic waves for communication</u>

Background for teachers:

Communication between Earth and ISS is done via several types of radio signals, which send bursts of energy from a transmitter to a receiver. The pattern of energy the receiver gets from the radio wave is converted into forms of communication we find useful, like video, sound, files, etc.

Radio signals are a form of electromagnetic radiation, just like visible light, X-rays, or even Wi-Fi. These all follow the same rules and limitations of light, and they all travel at the same speed as light (“c” = 300,000 km/s or 670,000 mph). And as with visible light, radio waves can be partially obscured or even completely blocked by objects that are in the way, including planets, moons, and the Sun.

Ask: Have you ever experienced a situation where radio signals or Wi-Fi signals were being blocked?
Explain: Some material that is transparent to visible light is actually opaque to other forms of electromagnetic radiation (such as windshield glass, which blocks UV rays).
Radio, Wi-Fi, and cell phone signals are able to pass through some walls, depending on what they are made of and how thick they are. But many people experience a loss of these signals in the depths of buildings, especially in elevators or interior stairwells. These signals can also be blocked by tunnels, mines, or mountain ranges.

Ask: How is it possible to see around corners in hallways?
Explain: Mirrors are sometimes used to see around corners, especially in high-traffic areas such as busy hallways, tight alleys, or difficult to see driveways. A well-placed mirror can allow us to see things that are not in our direct line of sight.

Light, radio, and all electromagnetic radiation are waves that travel in straight lines (“rays”) and transmit energy from one location (the source) to another location (the receiver).

Student Activity: Line of sight challenge

Build a simple maze in the classroom and have students plan the placement of mirrors to overcome the line of sight problem the maze presents! You will need a “transmitter” (a light source or easily seen object) and a “receiver” (a camera or even just your eyes).

- Place several boxes, stacks of books, or other obstacles throughout the classroom so that there is some known object that cannot be see from across the room. This object is the “transmitter,” and it might be a lamp, a window, or just about anything that is able to be clearly seen from across the room if the boxes and other barriers were not there.
- Pick a place for the observer to stand, from which their line of sight to the “transmitter” is blocked by the barriers.

- Have students work in groups to discuss where mirrors could be placed in the room to defeat the barriers. The barriers cannot be moved, and the mirror placement should be planned before being attempted. How many mirrors each group will need depends on how the teacher has placed the barriers.
- Can a visual signal be sent from the source to the receiver, bouncing off the mirrors? The signal could be turning the light on, or having somebody wave from the source location and be seen at the receiver location.

Explain:

- This is how we can send radio signals from Earth to ISS when the Station is on the other side of the planet from NASA communications facilities. The mirrors represent our communication satellites.
- This is also how we could use satellites to communicate with astronauts who are on the side of the moon facing away from Earth. A team of satellites in orbit around the moon would be able to relay the radio signals just as the mirrors were able to relay the light to our eyes.
- For astronauts to someday visit other planets, like Mars, we would need a way to bounce signals from our planet to theirs, even when Mars and Earth are on opposite sides of the sun and there is no line of sight.

Extensions

The line of sight challenge can be expanded to a larger scale. For example, where can mirrors be placed to enable students to see from one classroom into another?

Time delay

The speed of light is “c” = 300,000 km/s or 670,000 mph.
Have students calculate how much time it would take for a signal to travel the following distances:

1. 384 million meters (238,900 miles)
2. 400 billion meters - that’s 400,000,000,000 meters! (249 million miles!) When Mars and Earth are on opposite sides of the Sun, this is how far apart the two planets are.

Explain: The time it takes light to travel these distances is the time that would lapse between when you hit “send” on your message and when the other person gets the message. Imagine a video or voice conversation with that much delay between when you spoke and when the other person heard you. Is that kind of conversation reasonable between Earth and the moon? What about between Earth and Mars?

Resources

NASA's LCRD: The Laser Communications Relay Demonstration mission proposes to revolutionize the way we send and receive data, video and other information, using lasers to encode and transmit data at rates 10 to 100 times faster than today's fastest radio-frequency systems. We can't send the signal itself faster, but we can process it much faster at both the transmission and the receiver. Why would we need more bandwidth to communicate between Earth and people who someday travel to the Moon or Mars?
https://www.nasa.gov/mission_pages/tdm/lcrd/index.html

How to make a wave machine:
https://www.youtube.com/watch?time_continue=1&v=VE520z_ugcU