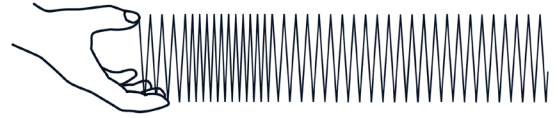




Name: _____ Class: _____ Date: _____

CRASH SCIENCE IN THE CLASSROOM

SONAR SLINKY



MATERIALS NEEDED

Per Group of Three Students

- » 1 Slinky®
- » 1 stopwatch
- » 2-3 metersticks or measuring tape
- » masking tape (10 cm)
- » 1 digital camera device (e.g., computer tablet or smartphone)

Per Student

- » “SONAR SLINKY” Student Activity Sheet
- » 1 pair of safety glasses

Key Question(s)

- » What types of waves do sensors in vehicle bumpers generate?
- » How do vehicles use bumper sensors to avoid collisions?

Purpose

- » Create longitudinal pulses and waves with a Slinky®.
- » Calculate the speed of a longitudinal pulse.
- » Describe the relationship between the amplitude and energy level of a longitudinal pulse.
- » Measure the wavelengths of longitudinal waves.
- » Describe the relationship between the frequency of a wave and its wavelength.
- » Use a diagram to explain how an ultrasonic crash avoidance sensor works.

Did you know?

Most new vehicles use SONAR or sound wave sensors in their bumpers to detect nearby objects when parking or backing up. Just as some animals, like bats, whales and dolphins, use sound waves for echolocation, most new vehicles emit sound waves from the sensors in their bumpers to detect nearby objects when parking or backing up (see Figure 1). In this activity, you will use a Slinky to simulate sound waves and explore how these sensors work.

Group Roles (switch roles at least once during the activity)

Students 1 and 2 – will firmly hold each end of the Slinky and generate pulses and waves.

Student 3 – will use the stopwatch, meterstick or measuring tape, and digital camera to measure and record data and observations.

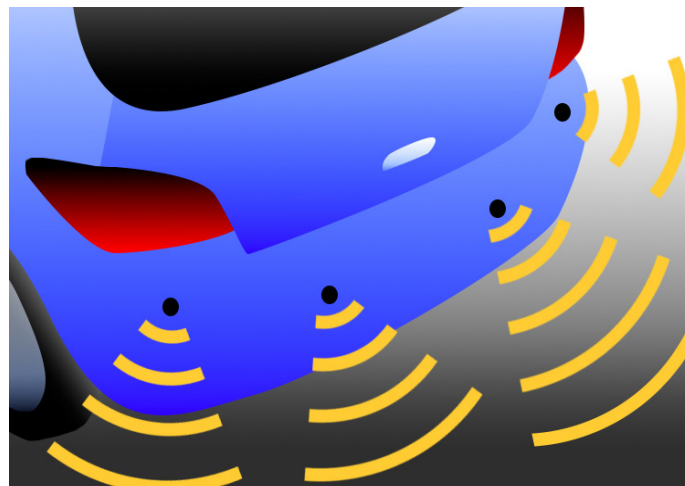


Figure 1. Sensors emitting sound waves during parking.



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Safety Notes

- » Firmly grip the Slinky and always hold it flat on the floor when it is stretched and moving.
- » Do not release the Slinky while it is stretched or it can become permanently tangled.
- » Wear safety glasses while the Slinky is stretched.
- » With your teacher's permission, use a tablet or phone camera to record video of the waves passing through the Slinky. Follow school rules when using the camera in the classroom. Do not record classmates' faces.

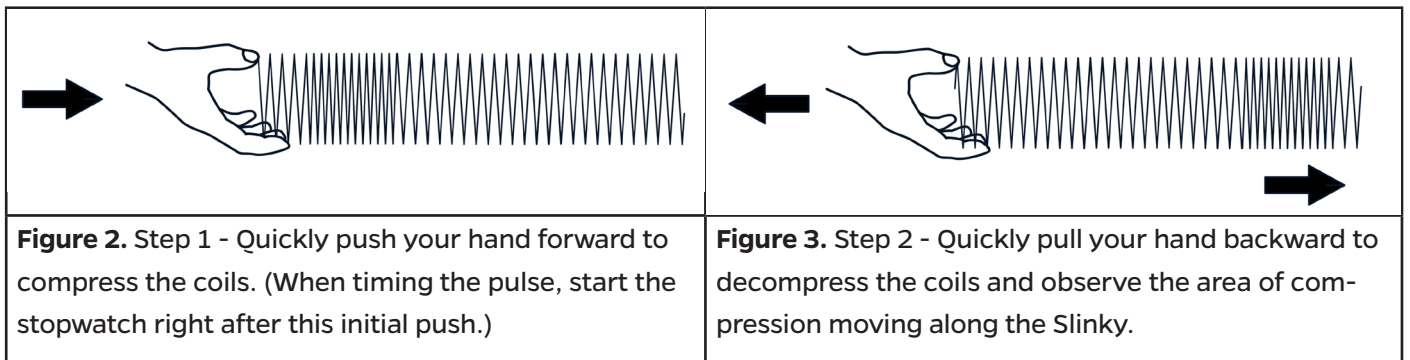
Procedure

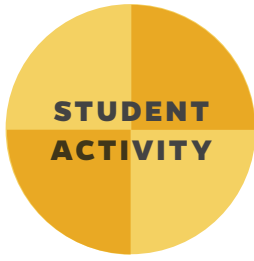
Part 1 - Creating and Timing Longitudinal Pulses

1. View the Introduction video for this activity at classroom.ihs.org to watch Dr. Griff Jones use a Slinky to create a longitudinal pulse and longitudinal waves.
2. Students 1 and 2: Sit on the floor about 3 meters apart from each other.
3. Student 3: Mark the distance the Slinky will be stretched between Students 1 and 2 by sticking a small piece of masking tape (around 5 cm long) in front of Student 1 and in front of Student 2.
4. Student 3: Measure the length of the stretched Slinky (distance between the edge of each piece of tape closest to Students 1 and 2) in centimeters and record it below:

Length of stretched Slinky: _____ cm

5. Student 3: Carefully place the Slinky on the floor between Students 1 and 2. Remind them to put on their safety glasses (you, too) and to hold the Slinky ends firmly on the floor and not let go. Next, stretch the Slinky between Students 1 and 2.
6. Students 1 and 2: Keep the Slinky on the floor and hold your end of the Slinky at the edge of the piece of tape that is closest to you.
7. Student 2: Hold your end of the Slinky firmly at the edge of the tape and do not let it move while Student 1 generates a longitudinal pulse.
8. Student 1: Create a single longitudinal pulse (as shown in the Introduction video and Figures 2, 3, and 3a below).
9. Let the Slinky stop moving before creating a new pulse.





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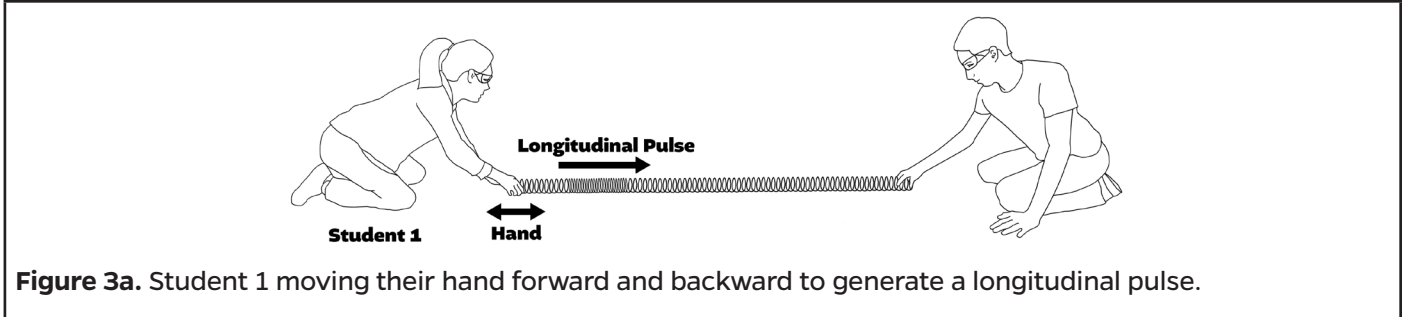


Figure 3a. Student 1 moving their hand forward and backward to generate a longitudinal pulse.

10. Let Students 2 and 3 also take turns creating longitudinal pulses.
11. Student 3: Using a stopwatch, measure the time it takes (in seconds) for one pulse to travel the entire length of the Slinky starting as soon as the Slinky has been pushed forward. Record the time below.
 - » Time for one pulse to travel the length of the Slinky = _____ seconds

Part 2 - Observing the Amplitude of Longitudinal Pulses

12. Students 1, 2, and 3: Take turns creating different size pulses by changing how much energy you put into compressing the Slinky coils.
 - » Larger pulses are created by pushing forward harder and faster thereby tightly packing together or compressing more coils. See Figure 4 below.
 - » The size or energy level of a pulse is called its amplitude. The greater the number of coils tightly packed together in the pulse, the greater the pulse's amplitude.
13. Students 1, 2, and 3: While firmly holding and compressing together at least 6-8 Slinky coils, take turns sending one pulse at a time down the Slinky to reflect off your partner's hand.
 - » When creating new pulses, allow the Slinky to stop moving first.
 - » When receiving pulses, observe how hard different types of pulses "push" when they reflect off your hand. Do pulses with larger amplitudes push harder against your hand than pulses with smaller amplitudes?

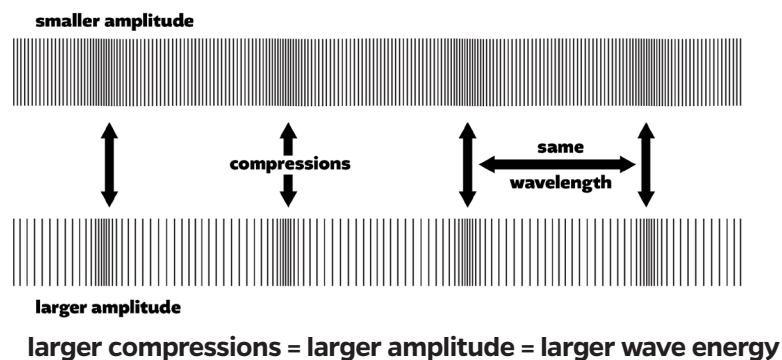


Figure 4. Two longitudinal waves with same wavelength but different amplitudes.



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Part 3 - Creating and Measuring the Wavelengths of Longitudinal Waves

14. Students 1 and 2: Create a longitudinal wave by quickly compressing the Slinky forward and back several times in a row. If needed, rewatch the Introduction video of Dr. Jones creating longitudinal waves.
15. Take turns creating longitudinal waves.
16. Refer to Figure 5 below to visually identify the wavelengths of longitudinal waves you create in your Slinky.

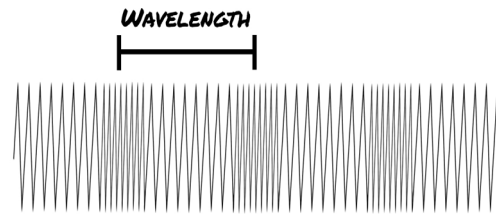


Figure 5. The distance between two identical points along a wave is called the **wavelength**. (In this diagram the measured distance is between the center of two areas of compression.)

17. Try changing the number of areas of compression in your waves by changing how fast you move your hand forward and backward when generating the individual wave pulses.
 - » The number of times your hand moves back and forth in one second is the frequency at which you generate the wave. More hand movements per second = high wave frequency.
 - » Practice creating and observing the visual differences in longitudinal waves of different frequencies.
18. Follow these steps to create and videotape longitudinal waves with different frequencies:
 - » Student 3: Place two metersticks end-to-end alongside the Slinky to create a 200 cm meterstick (or stretch out a 200 cm length of measuring tape). See Figure 6 below.
 - » Students 1 and 2: Take turns creating low frequency longitudinal waves.
 - » Student 3: Using the digital camera, record a 5-10 seconds long video of a lower frequency wave. Make sure that both the Slinky and the meter sticks or measuring tape next to the Slinky are clearly visible in the video.
 - » Student 3: Replay and pause the video after a few seconds. With the video paused, you should be able to drag your finger along the bottom of the screen to slowly scroll through the video. (This may vary with different types of devices.) Slowly scroll until you find a good spot in the video that allows you to see the distance between two successive areas of compression along the Slinky and pause the video. See Figure 6 below.

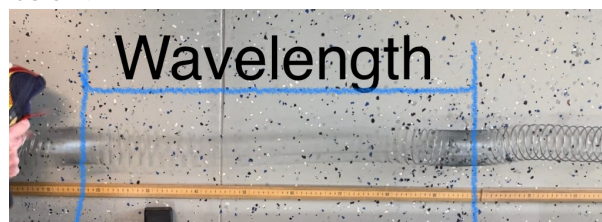


Figure 6. In this example, the wavelength is 83 cm.



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19. With the video paused, follow these steps to measure the wavelength of the wave in the Slinky:

- » Look closely at the metersticks in the video and count the centimeters between the centers of two areas of compression. Record the wavelength for the lower frequency wave in Table 1 below. (You may need to zoom in on the metersticks to better see the measurements. If the meterstick is out-of-focus, repeat Step 18 and focus the camera on the meterstick by tapping on the meterstick on the video display screen before videoing.)
- » Next, create a higher frequency longitudinal wave and repeat the videoing and measuring steps above. Record the wavelength of the higher frequency wave in Table 1 below.

Table 1. Wavelengths of Lower and Higher Frequency Longitudinal Waves

Wave frequency	Wavelength (cm)
Lower	
Higher	

Analysis Questions

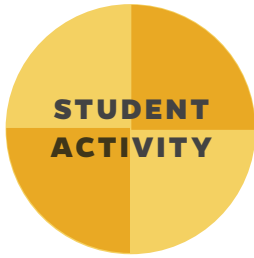
Part 1 - Creating and Timing Longitudinal Pulses

1. Calculate the speed of a pulse by dividing the distance the pulse traveled one-way down the length of the Slinky (the distance you measured between the pieces of tape in Step 4) by the time it took the pulse to travel the length of the Slinky (measured in Step 11). Record your values in Table 2 below.

$$\text{Speed of pulse} = \frac{\text{distance pulse travels one-way down the slinky}}{\text{time for pulse to travel one-way down the slinky}}$$

Table 2. Calculating the Speed of a Longitudinal Pulse

Pulse type	Distance the pulse traveled one-way down the Slinky (cm) (see Step 4)	Time for pulse to travel one-way down the Slinky (s) (see Step 9)	Speed of pulse (cm/s)
Longitudinal pulse			



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Part 2 - Observing the Amplitude of Longitudinal Pulses

2. Did the speed of the pulse appear to change as it moved through the Slinky? Explain what happened.

3. What happened to a pulse when it reached your partner's hand at the other end of the Slinky?

4. When pulses reflect off a hand, do you think the pulses with larger amplitudes transfer more energy, less energy, or about the same amount of energy as pulses with smaller amplitudes? What sensory observations from this activity support your answer?

Part 3 - Creating and Measuring the Wavelengths of Longitudinal Waves

1. In Table 3 below, use vertical lines to draw examples of a lower frequency longitudinal wave and a higher frequency longitudinal wave. Mark and label the wavelengths in each wave.

Table 3. Illustrating the Wavelengths of Lower and Higher Frequency Longitudinal Waves

Lower frequency	
Higher frequency	

2. As the frequency of a longitudinal wave increases, what happens to its wavelength?



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Crash Science Questions

1. The most common frequency of the ultrasonic sensors used in vehicle bumpers to assist with parking (see Figure 7) is around 52,000 pulses in one second or 52,000 Hertz (Hz). Examine Table 4 below and **circle** the animals that can hear these ultrasonic sensors.

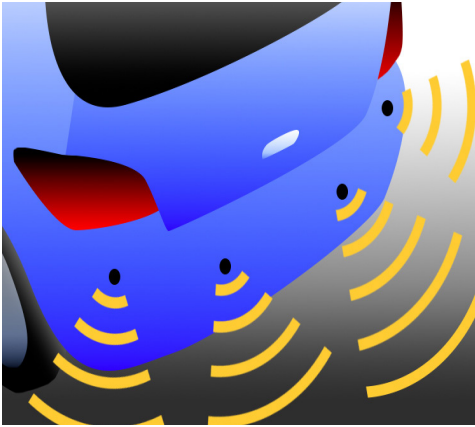


Figure 7. Vehicle backing up with ultrasonic sensors

Table 4. Animal Hearing Ranges (Hz)

Animal	Hearing Range (Hz) (approximately*)
Bat	2000 - 110,000
Cat	45 - 64,000
Dog	67 - 45,000
Dolphin	90 - 105,000
Elephant	16 - 12,000
Guinea pig	54 - 50,000
Human	20 - 20,000
Owl	200 - 12,000

*RR Fay & AN Popper, eds. 1994. *Comparative Hearing: Mammals*, Springer Handbook of Auditory Research Series. Springer-Verlag, NY.
RR Fay. 1988. *Hearing in Vertebrates*, Hill-Fay Associates, Winnetka IL.

2. Explain why people cannot hear the sound waves emitted from a vehicle's ultrasonic sensors when it is parking or backing up.

3. Follow Steps (a) – (d) below to analyze and complete Figure 8 illustrating how ultrasonic sensors work.

- a) Read the following paragraphs:

Since the sound waves created by bumper sensors have frequencies higher than the upper limit of human hearing (above 20,000 Hz), they are referred to as ultrasonic sensors. The term "ultrasonic" refers to sound waves that are "ultra" (beyond) the "sonic"(sound) range that humans can hear.

Ultrasonic pulses generated by a vehicle's sensor create ultrasonic waves that travel as longitudinal waves away from the vehicle's rear bumper and reflect off a nearby wall or other solid surfaces nearby. The sensor measures the round-trip time for the waves to travel out and back after hitting the solid surface. Next, the sensor's computer divides this time in half to calculate the one-way travel time. Finally, the computer multiplies the one-way travel time by the speed of sound waves in air to calculate the distance between the sensor and the solid surface. If necessary, the vehicle's computer warns the driver and may also automatically brake the vehicle to prevent a collision.



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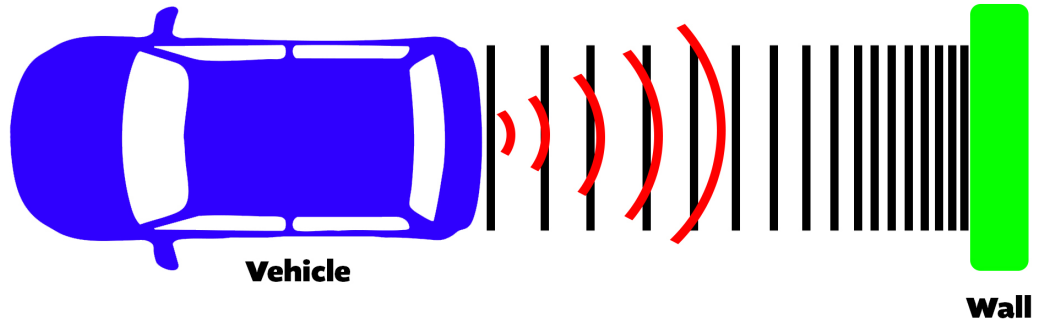


Figure 8. One ultrasonic sensor detecting a wall.

- b) Examine Figure 8 and notice the 5 curved lines. The curved lines represent the ultrasonic waves emitted by the vehicle's sensors as they travel toward the wall.
 - » Draw 2-3 more curved lines to complete the wave's trip to the wall.
 - » Draw an arrow above the ultrasonic waves emitted from the vehicle's bumper sensor indicating the direction the emitted waves are traveling.
 - » Label the curved lines as "emitted ultrasonic waves."
- c) Find the narrowly spaced vertical lines near the wall that represent the reflected ultrasonic waves bouncing back from the wall.
 - » Draw an arrow above the reflected waves to indicate the direction the reflected waves are traveling.
 - » Label the straight lines as "reflected ultrasonic waves."
- d) Fill in the blanks to complete the formula the bumper sensor's computer uses to calculate the distance between the vehicle and the wall.

Distance to wall = _____ **x** _____