Acoustics: How does sound travel?
Student Advanced Version

In this lab, you will learn about where sound comes from, how it travels, and what changes the loudness of a sound or the pitch of a sound. We will do this using a slinky and a rubber band guitar.

Key Concepts:

- Sound comes from moving objects
- Sound is made of vibrating molecules that push against one another
- Molecules don't travel across the room to get the sound to us; they vibrate in a very small space and transfer sound energy by collisions
- The harder the molecules push each other, the louder the sound we hear
- The faster the molecules push each other, the higher the pitch we hear
- Sound reflects off of dense objects as an echo. In a musical instrument, reflected sound is trapped to form standing waves, which we hear as tones

Sound is created by **moving objects**. For example, a plucked guitar string vibrates, sending sound waves in all directions. **Sound waves contain energy**, and we mainly sense this energy reach us with our ears. Sound travels through space in **longitudinal waves**. An object waves quickly back and forth, so the air around it starts to wave too. The waves can't be seen in air, but look like this when measured:

Figure 1: Longitudinal Waves

Sound waves also can be drawn like this, which is important when talk about them further:

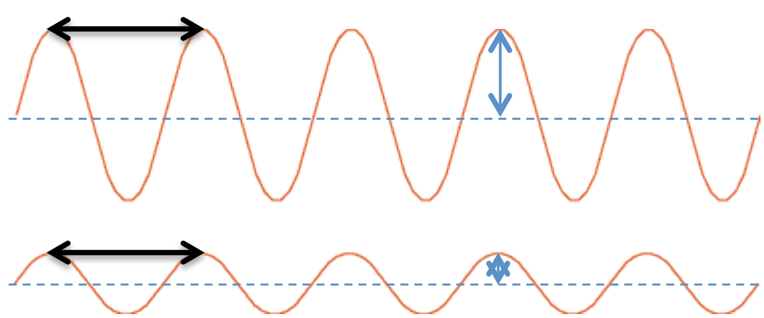

Figure 2: Sound Wave Drawings

The dotted line is the line the wave travels left to right. The thick arrow measures the **wavelength**, the distance from peak to peak (in meters or centimeters). The thin arrow measures the **amplitude**, from the midline to the top of a peak. The two waves above have the same wavelength, but the taller sound wave has a bigger amplitude. A third measurement, called **frequency**, is the number of peaks that move past a point in a given amount of time.

Sound waves with bigger wavelengths sound lower, like a big tugboat's horn. A smaller wavelength sounds higher, like a bird tweeting. Mathematically, wavelength (λ) and frequency (f) are just the inverse of each other:

$$f = \frac{1}{\lambda}$$

So we can talk about one and easily find the other. Note that the shorter the wavelength, the higher the frequency; and the longer the wavelength, the lower the frequency. The frequency (or pitch) of sound is measured in **Hertz** (Hz), which are cycles/sec. Amplitude is just volume: bigger means louder and smaller means quieter.

The two waves in Figure 2 have the same wavelength but different amplitude.

Q1. Do they sound the same? Yes / No
If no, which one is louder? Wave on top / wave on the bottom

Part 1: Core Concepts Experiments
(to be completed with the whole group):

Pool of Sound

1. Fill the tub with water until it is three inches from the top.
2. Pick an object to bob in the water. You can push it up and down if it floats

Q2. What shape are the waves that go out from the object?

Can you count them?

How big are they?

What changes can we make that affect the size and number of these waves?

Q3. What causes the waves to build up so high that they almost (or totally) run over the sides?
Can we affect our movement of the object in the water to prevent or promote this?

Sound Round-up

1. Tie or fix one end of the rope or Slinky to a stationary object.
2. Send a wave down it.
    - With the rope, jerk the rope quickly up and down or side to side.
    - For the Slinky, stretch and push back on it

Watch the wave move down the line.

Q4. Does the wave only move in one direction along the length?

Does it come back?

What are the pieces of rope or Slinky doing at different times?

Part 2: Design Your Experiment

Rubber Band Guitar (Chordophone)

Stretch the rubber bands around the open end of the box so they are arranged like strings over the sound hole of a guitar. Pluck the strings and listen.

Q5. Which ones sound lower or higher?

List them in order from lowest sound to highest sound

Lowest					*Highest*

Q6. Does the sound change by how much we tug on the rubber band when plucking?

Try inserting the craft stick between the strings toward one end of the instrument. Pluck the strings from the other end.

Q7. Does the craft stick change the sound?

Record your observations:

Straw Reed Instrument (aerophone)

Design and construct your own wind instrument that uses a vibrating reed and makes sounds with four different pitches.

1. Flatten one end of drinking straw by rubbing it between your nail or a straight edge. Make a straw reed by cutting a wedge about 1 cm (1/2 inch) long at one end of a plastic drinking straw.

   Be sure the two cuts are even in length and their angle to the tip of the straw.

2. Punch 3 holes in the side of the straw using a hole punch. Space the holes out equally, starting 2 inches from the tip of the reed at least. It will help if you make the holes so they are at the top of the instrument when you play it. Note: don't punch through both sides of the straw! Rather, press the straw in half and insert the folded edge halfway into the hole punch.

3. To make a longer instrument, flare the end opposite the reed by inserting a pencil and stretching the plastic. Remove the pencil and fit another straw of the same size into the flared end.
4. Insert the reed in your mouth, slightly past the lips. Blow a steady, strong stream of air. Adjust the amount of straw in your mouth and the strength of your blowing the reed vibrates and a sound comes out.

Experiment with your instrument.

Q8. What part is moving?

How did you get it to move?

Try to make the pitch higher or lower by covering the holes.

Q9. What do you have to do to make a louder or softer sound?

Write down what you did to change the sound, and the result

What I changed	*The Result*

To make a slide instrument, take two straws-- one thick and one thin. At one end of the smaller straw, make a reed. Insert the other end of the thin reeded straw into the thicker straw.

Experiment with this instrument.

Q10. What does sliding the straws in and out do to the sound?

Q11. How is this like covering the holes?

Extension Activity: Tuning

1. Find a partner with a different instrument than you (Guitars pair with Reeds)

Guitarists:

1. Pick a rubber band and measure its length in centimeters from end to end. Record in Table 1.
2. Insert the craft stick at the halfway point, so that only half the string will be able to vibrate when played. Measure this length.
3. Slide the craft stick around to 2 other positions, measuring the length of the rubber band piece and recording it. You should have 4 data points when finished.
4. *Copy your partner's data from their Table 2 to your Table 2.*

Reed Instrument Players:

1. Measure your instrument from reed tip to the other end in centimeters. Record in Table 2.
2. Measure it from the reed tip to the farthest hole. Record.
3. Measure it from the reed tip to the next farthest, and then the next farthest. Record these lengths. You should have 4 data points.
4. *Copy your partner's from their Table 1 to your Table 1.*

Table 1

	1.	2.	3.	4.
Length (L)				
Frequency (1/L)				

Table 2

	All holes covered	One hole uncovered	Two holes uncovered	Three holes uncovered
Length (L)				
Frequency (1/L)				

Partners:

2. Compare the distances you recorded in Table 1 to those in Table 2.

Q12. Are any of them similar?

3. Play your instruments together at these positions.

   Q13. Do the numbers correctly predict if they will sound the same? Yes/No

4. Try tuning your instruments using just your ears. Try to make them sound the same.

   Q14. Do you think musicians tune the first way (by measuring their instruments) or the second way (by ear)?

Concept Questions

Q15. How are sound waves like water waves? How are they different?

Q16. Name 2 ways you changed the sound coming out of your instruments you made.

Q17. How can an instrument with only 4 strings make more than 4 sounds?

Q18. When a trumpet player pushes a value on the trumpet, it opens up an extra loop of tubing. What does this do to the trumpet? To the sound?

Q19. How is measuring the instruments' lengths supposed to predict their sound?