Straw Oboe

Workshop

By constructing a simple straw "oboe," participants learn about sound waves and closed pipe resonance.

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Number of Participants: 2-30

Audience: Elementary (5-10) and up

Duration: 20-30 minutes

Difficulty: Level 2

Materials Required:

- Scissors
- Drinking straws

Setup:

1. Flatten 3-5 cm of the end of a straw using your teeth, as shown in Figure 1.
2. Cut the straw as shown in Figures 2 and 3.

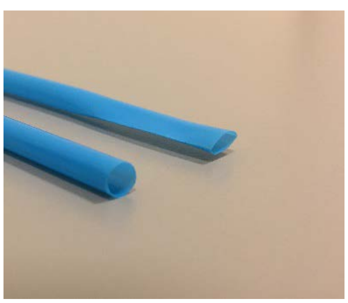

Figure 1: Drinking straw with flattened end.

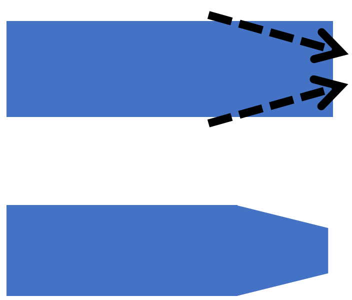

Figure 2: Dashed lines indicate where and in which direction to cut.

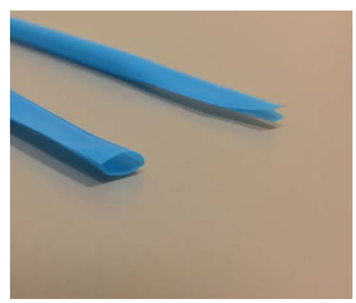

Figure 3: Image of the flattened straw before and after cutting.

3. Blow gently through the trimmed end until a sound is heard. It might take several iterations of cutting to find the optimal angle and length of the cuts. Be sure to practice before your workshop, as each kind of straw is a little different. Sometimes applying pressure with your teeth while you blow can help.

Presenter Brief:

General knowledge of sound waves is required. The presenter should be able to distinguish between a longitudinal and transverse wave and understand how we hear sound. In addition, the presenter should understand how the openings in the straw create nodes/antinodes and standing waves.

Vocabulary:

- Wave – A disturbance that can transmit energy and information while not transporting the medium.
- Longitudinal Wave – A wave where vibrations are in the same direction as wave propagation.
- Transverse Wave – A wave where vibrations are perpendicular to wave propagation.
- Frequency – The recurrence rate of an event (such as vibrations) per second, expressed in hertz (Hz).
- Hertz – An SI unit that is defined as one per cycle. Abbreviation is Hz.
- Wavelength – The distance between two corresponding points on two sequential waves.
- Waveform – A graph of some quantity, such as pressure or displacement, as a function of time.
- Amplitude – Maximum displacement of a waveform from equilibrium.
- Node – A point or region where minimal motion takes place.
- Antinode – A point or region where maximum motion takes place.
- Superposition – Individual waves add linearly. The motion of the resultant wave at any point is the summation of the wave motions that would occur for each independent wave.

Physics & Explanation:

Elementary (ages 5-10):

Explain that a wave is caused by some initial disturbance, like a vibration, and carries energy and information through a medium. For example, dropping a rock in a pond creates waves in the water. These waves make the water move up and down but the waves move away from where the rock was dropped.

Just as waves travel in a pond, a different kind of wave can travel through air. What we perceive as sound is really just vibrations of the air. Objects that move back and forth rapidly cause the air around them to move back and forth as well. This makes small variations in the air pressure, called vibrations, and these air vibrations move from the sound generator to our ears. Our ears have small hairs inside the cochlea (inner ear) which pick up these vibrations, and that's how we hear.

Any sound that we hear is caused by small pressure vibrations travelling through the air.

For example, when you clap your hands, a big air disturbance (pressure wave) is created in the air around your hands. The rapidly moving hands create a pressure wave which travels through the air and eventually reaches your ears.

Sound waves are vibrations in the air created by disturbances.

Some objects, like musical instruments, are shaped so that they easily create vibrations in the air.

Instruct the participants to flatten and cut their straws as described above. Explain that, compared to the original straw, the new shape allows the cut part to vibrate, which is good at creating vibrations when air is blown through.

Demonstrate how to use the straw, and encourage participants to do the same.

It may take some practice to get just right, but the straw essentially works like a double-reed woodwind instrument. The air you blow through the straw creates vibrations which form sound waves.

Middle (ages 11-13) and general public:

After completing the previous section, explain that a wave can be described by its amplitude, wavelength, and frequency.

Explain each:

Amplitude is the distance from the center line to the highest or lowest point, and represents the overall maximum magnitude of the wave.

Wavelength is the distance between any two identical points on a wave and frequency describes the number of waves passing by a given point in a given amount of time. Wavelength (λ) and frequency (f) are related to the speed (v) of the wave by the general wave relationship $v = f\lambda$.

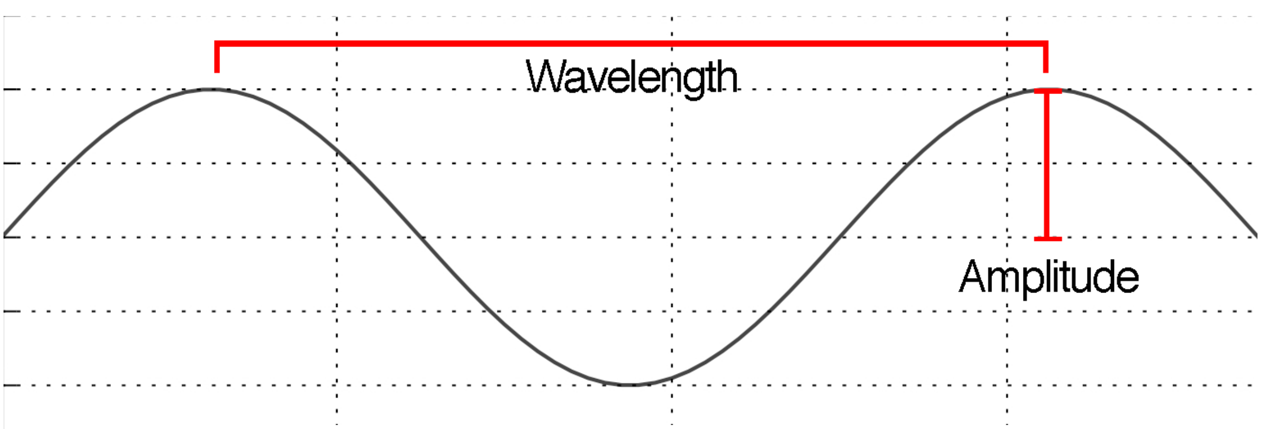

Figure 4: An illustration of a sinusoidal wave with wavelength and amplitude highlighted.

Waves are described by several properties: amplitude, wavelength, and frequency.

By moving air through the trimmed end of the straw, standing waves are set up within the tube. These standing waves are determined by the straw length and comprise the sounds that we hear.

The length of the tube sets the base, or lowest, wavelength. Since wavelength and frequency are related, the length of the straw also determines the frequency.

> Use scissors to trim the length of the straw and demonstrate how the sound changes as the length of the tube is shortened. In addition, you may create holes in the top of the straw and demonstrate how the sound changes by covering and uncovering the holes. To make the straw longer, insert a second straw into the first one.

🔑 The properties of the wave, and therefore the sound we hear, are determined by the size and shape of our straw.

The wave formed inside the straw is a standing wave, meaning that multiple waves are interfering to generate an aggregate waveform, as illustrated in Figure 5. As a result, nodes (points of least displacement) and antinodes (points of maximum displacement) exist in the straw and can be seen in Figure 4.

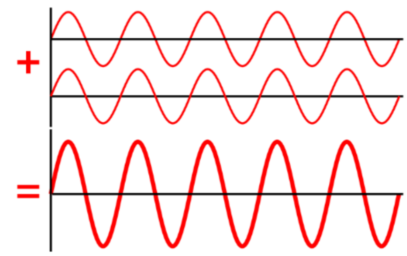

Figure 5:Illustration of the linear superposition (simple adding) of two waves to form a larger wave (in bold)

The combining of waveforms that share the same space is called superposition. In wave linear superposition, the displacements for waves at any one location in which they overlap is arithmetically added or subtracted together.

For example, when two overlapping superimposed waves with equal amplitudes are combined, a singular wave with twice the amplitude is generated, as seen in Figure 5. In a standing wave, a node is where the two waves happen to *always* cancel each other out (or add to zero), leaving a location in the wave that does not move at all. Conversely, there will be a point where the amplitude of the waves adds together to reach the maximum possible displacement for the whole wave; this point is called an antinode.

> Revisit the wave relationship to show how changing the straw's length affects the sound. Show that when the wavelength is decreased, the frequency increases since the speed does not change. Make sure to reference the wave equation and note which aspects of the wave are changing and which are remaining constant.

🔑 Since the speed of sound is not changing, different length straws will create sound at different frequencies

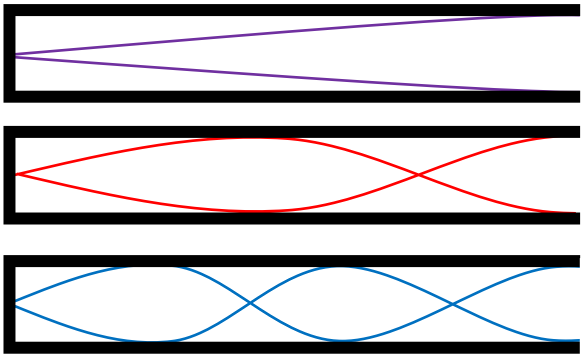

Figure 6: Notice how standing waves form in a closed-end pipe, with one node at the closed end and an antinode at the open end. Each harmonic adds one more half wavelength to the standing wave (and therefore is twice the frequency).

Additional Resources:

- Rossing, Moore, & Wheeler. *The Science of Sound*, 2002. (p 64 – 66)
- Demonstration of woodwinds and associated sound wave behaviors https://www.youtube.com/watch?v=N5Ch2NThFvY

Useful Equations:

Wave Velocity	$v = \lambda f$

$v = velocity\ of\ wave\ in\ meters\ per\ second\ (m/s)$

$\lambda = wavelength\ in\ meters\ (m)$

$f = frequency\ in\ hertz\ (s^{-1})$