Elastic Wave

Demonstration

Participants will learn how waves add and subtract by interactively creating waves.

Number of Participants: 2-10

Audience: Elementary (ages 5-10) and up

Duration: 5-10 mins

Difficulty: Level 1

Materials Required:

- Latex Hose

Setup:

1. Have two students stand opposite from each other, each holding one end of the hose
2. Have one student shake the hose up and down at a slow speed until a standing wave is established.
3. Have the second student shake the hose up and down at a fast speed
4. Have both students shake the hose at their respective speeds (fast or slow)

Figure 1: An example of a standing wave (Source: Physics LibreTexts[1])

Presenter Brief:

Understand what a wave is and how waves can add or subtract. Be able to discuss why only certain speeds on arm moving make a wave pattern. Know why there are different patterns (number of wavelengths) that can be established.

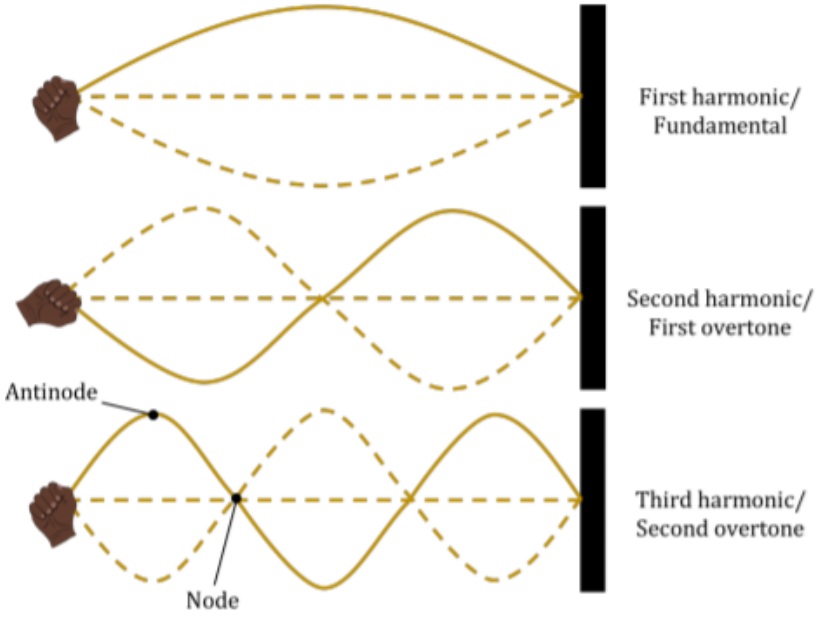

Figure 2: the first, second, and third harmonic, shown by highlighting the number of nodes/antinodes (Source: Physics Libretexts[1])

Vocabulary:

- Wave - A disturbance that can transmit energy and information while not transporting the medium.
- Frequency - How many cycles per time an oscillation happens, measured in Hz or cycles/second.
- Wavelength - The distance between two corresponding points, such as peak to peak, on sequential waves.
- Fourier Transform - A mathematical process which simplifies waves into their specific sinusoidal frequencies.

Physics & Explanation:

Elementary (ages 5-10):

Waves move up and down. Think of a wave on water and how there are high points and there are low points (see *Figure 1*). What's really cool is that waves aren't just in water. Light and sound are both waves. What scientists love to do is to add waves together. You can combine waves to make new waves. Since sound is a wave, by combining different sound waves together, we can create new sounds. What this demonstration is going to show is how waves can be combined.

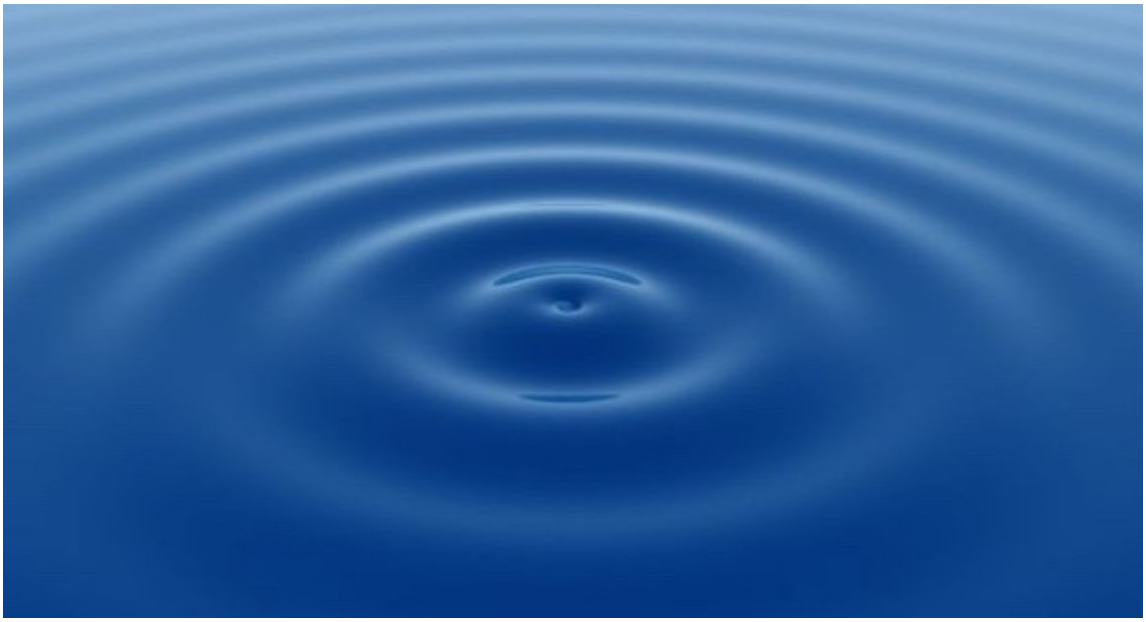

Figure 3: waves/ripples in a pond. Notice the high points (peaks) and the low points (troughs) (Credit: Huff Post[2])

When you move the cord up and down fast enough you can create a wave. If you move your arms too slowly, you won't get a wave. When you move your arms fast enough to create a wave, that's called resonance (a fancy word you can tell your friends). If you make a fast wave, then the distances between the top points (peaks) are small. When you move the cord up and down slowly, you create longer waves and the distances between the peaks are larger. In sound this is how pitch is made. The shorter the distance the higher pitch it is.

Middle (ages 11-13) and general public:

Waves are very important in physics. There are many things that come in waves. Sound, light, and water are all examples of things that are commonly associated with waves. It's important to learn what makes up a wave. When you think of a wave, you might think of waves someone might surf on or the waves that appear if you throw a rock in a pond (See *Figure 1*). Using this imagery we can identify some key features of waves.

The reason we get different peaks (see *Figure 2*) is a result of resonance and frequency. At certain frequencies, or how fast the wave is moving, the wave will experience an effect called resonance where the nodes will be very visible. The best way to find these frequencies is to multiply the base frequency by the number of nodes plus 1.

The first key feature is that waves have high points and low points called peaks and troughs. The distance between these peaks is called the wavelength. The shorter the wavelength, the more energy a wave has. The reverse is true for longer

wavelengths. In sound, a shorter wavelength means a higher pitch and a longer wavelength means a lower pitch. How loud the sound is comes from the amplitude of the wave, or how high it goes. See *Figure 4* for a labeled diagram of a wave. When using the cord to create waves, the students can see how different wavelengths combine. Peaks and peaks add together, whereas a trough and a peak subtract. This will show some very interesting looking waves. Try experimenting with different frequencies.

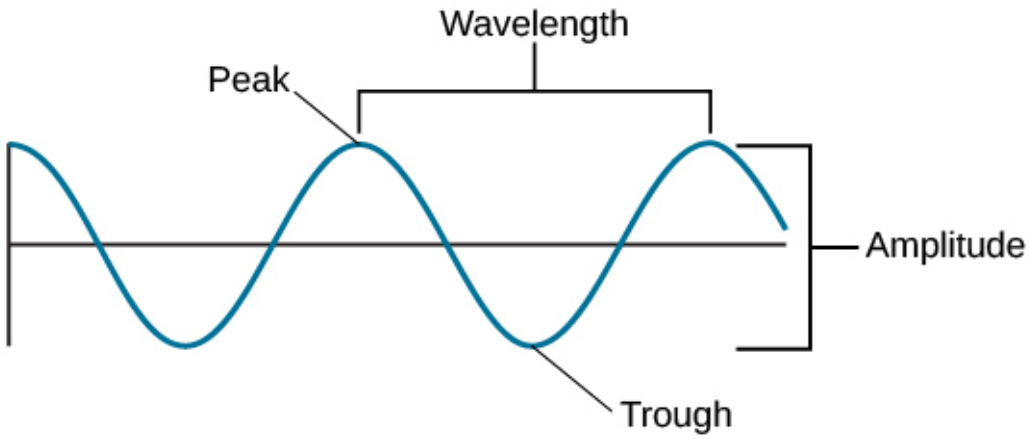

Figure 4: a wave with key components labeled (Source: Lumen Learning[3])

High School (ages 14+):

Waves are very important in physics. There are many things that come in waves. Sound, light, and water are all examples of things that are commonly associated with waves. It's important to learn what makes up a wave. When you think of a wave, you might think of waves someone might surf on or the waves that appear if you throw a rock in a pond (See *Figure 1*). Using this imagery we can identify some key features of waves.

The first key feature is that waves have high points and low points called peaks and troughs. The distance between these peaks is called the wavelength. The shorter the wavelength, the more energy a wave has. The reverse is true for longer wavelengths. In sound, a shorter wavelength means a higher pitch and a longer wavelength means a lower pitch. When using the cord to create waves, the students can see how different wavelengths combine. Peaks and peaks add together, whereas a trough and a peak subtract. This will show some very interesting looking waves. Try experimenting with different frequencies.

A very important part of waves is understanding the math behind them. The most essential equation is that $v = f \times \lambda$, where $v$is the speed of the wave, f is the frequency, and $\lambda$is the wavelength.

Another very important aspect of standing waves is the fact that waves will reflect off of a surface. In fact, this is the very reason why we get standing waves. The

reflection is a direct mirror of the incident wave, causing the nodes and antinodes to remain stationary along the x-axis. See *Figure 5* to see a visual representation.

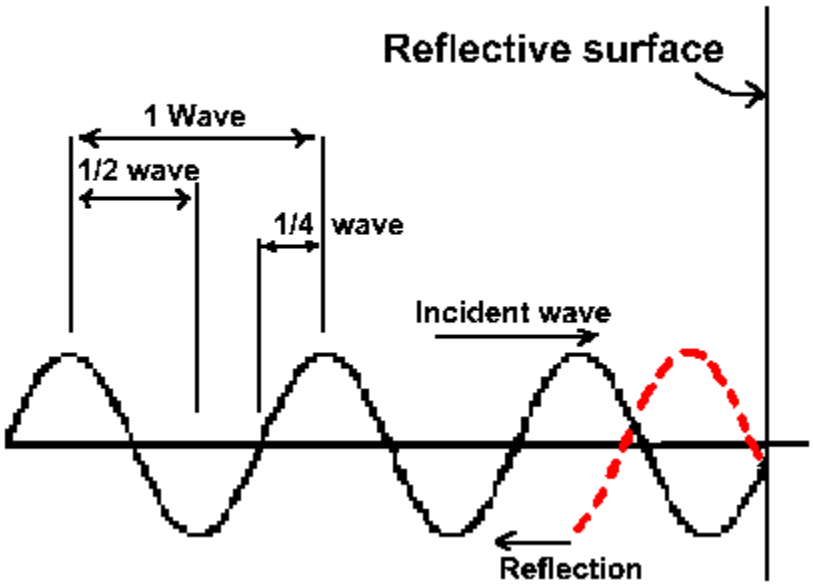

Figure 5: a diagram of an incident wave and a reflected wave (Source: Rick Oleson[4])

Ask the students if they have ever heard of a fourier transform. Explain that a fourier transform is essentially a way to split complex waves down to their simple parts and look specifically at the frequencies that make up that wave.

Additional Resources:

- **Video:** But What is the Fourier Transform?

  https://www.youtube.com/watch?v=spUNpyF58BY&ab_channel=3Blue1Brown

References:

1. https://phys.libretexts.org/Bookshelves/University_Physics/Book%3A_Introductory_Physics_-_Building_Models_to_Describe_Our_World_(Martin_Neary_Rinaldo_and_Woodman)/14%3A_Waves/14.07%3A_Standing_waves
2. https://www.huffpost.com/entry/ripples-in-the-cosmic-pon_b_9245144
3. https://courses.lumenlearning.com/atd-bhcc-intropsych/chapter/waves-and-wavelengths/
4. http://rick_oleson.tripod.com/index-166.html