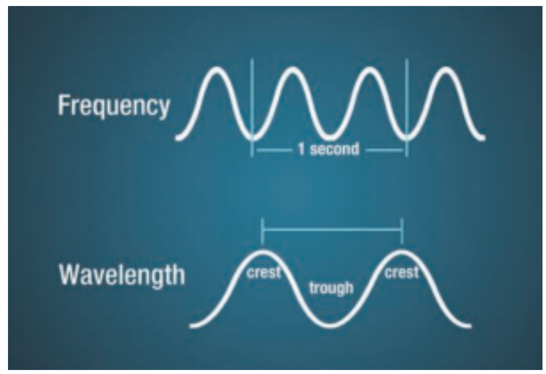
Can You See the Music?

Are We on the Same Wavelength?

Overview

Grades: 5-8
Time: 20-30 minutes
Subject: Physics

Wavelength, frequency, and amplitude are all close friends in the world of sound. Let's get to know them better!



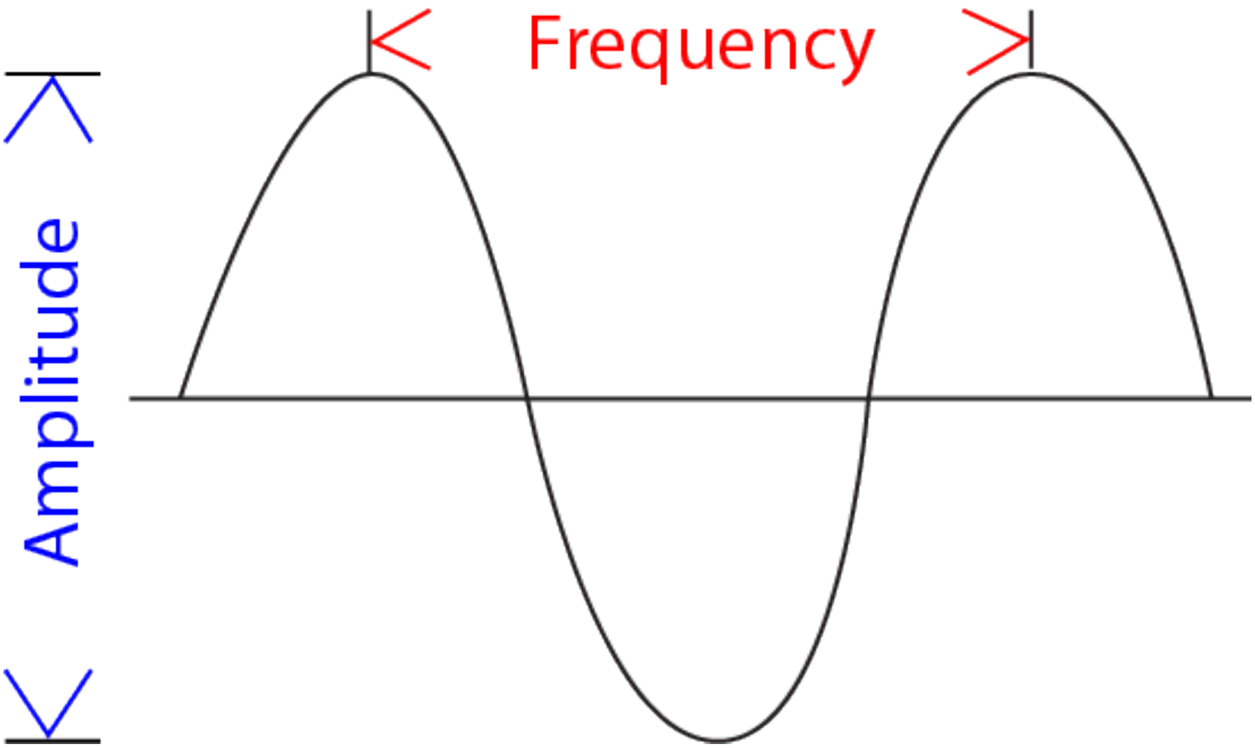
Background

When you look at a representation of a simple sound wave (let's say the note "C") on an oscilloscope or another visualization tool, you will see a squiggly line going up and down in a regular pattern. This pattern, the sound wave, contains three attributes: wavelength, frequency, and amplitude.
Put simply, the amplitude is the height of the wave from its highest point to its lowest, frequency is how many complete wave cycles occur per second, and the wavelength is the distance between waves which you can measure from wave crest to wave crest. Wavelength and frequency are tied very closely together since sound waves travel at a particular speed through a medium.
The shorter the wavelength then, the higher the frequency!

Some important background for this activity:

- The speed of sound varies depending on the medium it travels through. For example, it travels faster through water than air because the molecules are more closely packed and transmit the vibrations faster.
- The speed of sound is the distance traveled per unit time by a sound wave as it propagates through an elastic medium. At 20 °C (68 °F), the speed of sound in air is about 343 meters per second (1,234.8 km/h; 1,125 ft/s; 767 mph; 667 kn), or a kilometer in 2.9 s or a mile in 4.7 s. [1]

A jet aircraft "breaking the sound barrier" - traveling faster than 343 m/s



- Frequency and amplitude, when visualized as numbers or in a waveform, correspond to “pitch” or tone, and “intensity” or loudness.
- There is a very cool math formula known as the “wave equation” that enables you to calculate wavelength if know your frequency and your speed of sound. Check it out here!

Wavelength Calculation	V (m/s)	f (Hz)	Wavelength (m)	Wavelength (m) Guess
My low hum	343			
My medium hum	343			
My high hum	343			

Objectives

Understand:

- That sound is transmitted in waves.
- A *microphone* (sound sensor) vibrates from sound waves and converts this *vibration* to electrical energy.
- Sound intensity is measured in *decibels* – a unit of measurement.
- Wave properties of *frequency*, and *amplitude*.
- A sound wave needs a medium through which it can travel.
- Sound travels at different speeds through different mediums.
- How wavelength can be determined mathematically by frequency.

What You'll Need

- databot™ + Google Science Journal + Arduino IDE

Important Terms

Microphone: A **microphone**, sometimes referred to as a **mike** or **mic** (both IPA pronunciation: [maɪk]), **converts sound into an electrical signal.**

Sound Wave: Sound is a vibration that travels in waves through a medium, such as air (or water, wood, etc.), a disturbance which travels through some medium.

Vibration: Vibration is an oscillating (back and forth) movement, like a vibrating reed in a clarinet. This vibration results in a sound wave that then travels through a medium, like the air.

Pitch: *Pitch* is the highness or lowness of sound. Pitch is how humans hear different frequencies

Frequency: Frequency is determined by the number of vibrations per second. The highest key on a piano, for instance, vibrates 4,000 times per second.

Amplitude: The **amplitude** or **peak amplitude** of a wave is a measure of how big its oscillation is.

Decibel: (db): Sound intensity is measured in units called decibels. A **decibel** (or **dB**) measures ratios of power or intensity. It expresses them as an exponential function.

Medium: In physics, a transmission medium is the substance that transmits the energy from a wave. The standard transmission medium for sound that we know well is air. Water, wood, clay – which of these have you heard sounds penetrate? If sound can be transmitted, it's a medium.

Prep (5 mins)

Arduino IDE

- Upload the IDE Frequency & Amplitude sketch to databot™.
- Open the Serial Plotter to display the sound data and test by humming into the microphone. You should see two data streams displayed.

Google Science Journal

- Upload the GSJ Frequency and Amplitude sketch to databot™.
- Connect GSJ to your databot™ and open the Frequency and Intensity cards displaying databot™ data.

Experiment (15-25 Mins)

- Watching the frequency reading, hum or sing "Mary had a Little Lamb" or other favorite tunes to databot™ and watch how the frequency changes with your pitch. *Does the frequency go higher or lower when you go from a low to high note?*
- Watching the intensity reading this time, sing your song again. *Does it change as you sing a higher or lower note? Can you hold intensity perfectly level while you sing or hum your song? Sound is measured in decibels. What is the decibel level you are singing at?*
- Challenge yourself to make a square graph of sound intensity that repeats as close to a perfect square wave as possible. *Can you get close? Try and create three perfect square waves in a row.*
- Repeat this challenge with the frequency data display, can you control your voice to create a perfect square wave based on your pitch? *Do you have a "perfect" pitch?*
- Place databot™ farther away from you when singing and observe the data. What happens to sound intensity as the source of the sound moves farther away from databot™? Try to establish a sound source of constant intensity and frequency. Move databot™ away and watch the changes to frequency and intensity.
- *Sound waves have three major attributes, frequency, amplitude, and wavelength. By experimenting with pitch and intensity, you have experienced frequency and amplitude. Wavelength we can't see directly, but you can calculate it from the data you know. Let's check out wavelength!*

Look at the Wave Equation again below.

Wavelength Calculation	V (m/s)	f (Hz)	Wavelength (m)	Wavelength (m) Guess
My low hum	343			
My medium hum	343			
My high hum	343			

It is important to know that sound travels at different speeds through different mediums. If you are hearing sound underwater, for example, it is traveling much faster than if you hear it when it travels through the air. This is because sound is a vibration that requires "something" to vibrate in order for it to travel. The speed of sound in air, based on the sound wave transferring vibrations through air molecules, is 767 miles per hour or 343 meters per second (343 m/s). Note this actually changes based on temperature – this speed is assuming normal room temperature of 20 degrees C.

Since we know two parts of our Wave Equation, frequency (f), and the speed of sound through air is V, the speed of the wave at 343 m/s, we can calculate the wavelength of a sound!

Here is your challenge!

- Create a table for doing your calculations like this one:
- Now, guess the wavelength of different sounds. Hum three notes, low, medium, and high. Write down your guess of the wavelength of each of them using meters as your unit of measurement.
- Use databot™ to identify the three sound frequencies that you hummed – low, middle, and high. Add this to your table.
- Using the Wave Equation, divide the speed of sound by the frequency and you will have your wavelengths. Fill these in and your table should be complete!
- Physically illustrate the wavelength of each of your three sounds somehow. Draw the three lengths on a whiteboard for example to see the difference.

Were your guesses close? Are you surprised at the wavelength calculation or was it about what you expected? What do you think is the wavelength of a sound like a loud, throaty motorcycle? How about a chirping bird?

Wrap it up!

If you have some time left do some further experimentation with databot™ do some exploring. What experiments can you conduct to learn more about sound? Do different objects have different frequencies when they are dropped? Different intensities if dropped from the same height? Get creative and learn more about the sound you can't see!

Educator Info

<u>Prep: (10 Minutes)</u>

- Read through the Background and Experiment, load the sound program and conduct the activity yourself viewing the sound wave display and identifying frequency and pitch in the display. Think about classroom management with this activity. If you are using multiple databot™s among students, you will need to plan for how to alternate student noisemaking. An entire classroom of students singing to databot™ may be difficult to handle!

- Also, prepare yourself, some student will quickly realize the interesting results produced by screaming. Review how to calculate wavelength and determine the age-appropriate approach for having your students do this activity. If you are using Science Journal encourage the students to record and store their observations, have them take a picture of their wavelength table to document it.

<u>Objectives:</u>

Understand:

- That sound is transmitted in waves.
- A microphone (sound sensor) vibrates from sound waves and converts this vibration to electrical energy.
- Sound intensity is measured in decibels – a unit of measurement.
- The wave properties of wavelength, frequency, and amplitude.
- A sound wave needs a medium through which it can travel.
- Sound travels at different speeds through different mediums.
- How wavelength can be determined mathematically by frequency.

<u>NGSS:</u>

- NGSS PS4.A Wave Properties

<u>Misconceptions:</u>

- The images we see of a sound wave displayed as a sine wave on an oscilloscope or in our diagrams shown here are not an accurate representation of what a sound wave actually looks like. Look at the sound barrier photograph as an example. https://www.explainthatstuff.com/sound.html
- It is easy to confuse pitch and intensity.
- Wavelength is not affected by how loud a sound is.

<u>Guiding Questions:</u>

- If a tree falls in the forest and there is no one around to hear it, does it make a sound?
- If two asteroids collide in space, how close do you need to be to hear it?
- Will sound travel faster underwater or through the air if you need to cry “shark” to your friends?
- What is the difference between frequency and wavelength?
- What is the difference between frequency and intensity?
- Is a sound with a longer wavelength louder when compared to a sound with a shorter wavelength?”
- What do you think is the wavelength of a sound too low for us to hear? A sound too high?

Additional Resources:

CDC: What Noises Cause Hearing Loss?
https://www.cdc.gov/nceh/hearing_loss/what_noises_cause_hearing_loss.html

NASA – The Sounds of Space
https://www.nasa.gov/vision/universe/features/halloween_sounds.html

Misconceptions about sound
http://amasci.com/miscon/opphys.html

Explain that Stuff – Sound
https://www.explainthatstuff.com/sound.html

Temperature and the Speed of Sound
https://www.nde-ed.org/EducationResources/HighSchool/Sound/tempandspeed.htm

Online Tone Generator (useful for making pure frequency sounds)
https://www.szynalski.com/tone-generator/

Virtual Oscilloscope
https://academo.org/demos/virtual-oscilloscope/

References:

Wavelength Image – Wikimedia Commons
https://commons.wikimedia.org/wiki/File:Tour-of-the-EMS-TAGGED-v7_0.pdf

Frequency and Amplitude Image – Wikimedia Commons
https://commons.wikimedia.org/wiki/File:SoundWaveDiagFreqAmp.png

Sound Barrier Image – Wikimedia Commons: By Ensign John Gay, U.S. Navy – This Image was released by the United States Navy with the ID 990707-N-6483G-001. Public Domain, https://commons.wikimedia.org/w/index.php?curid=11927