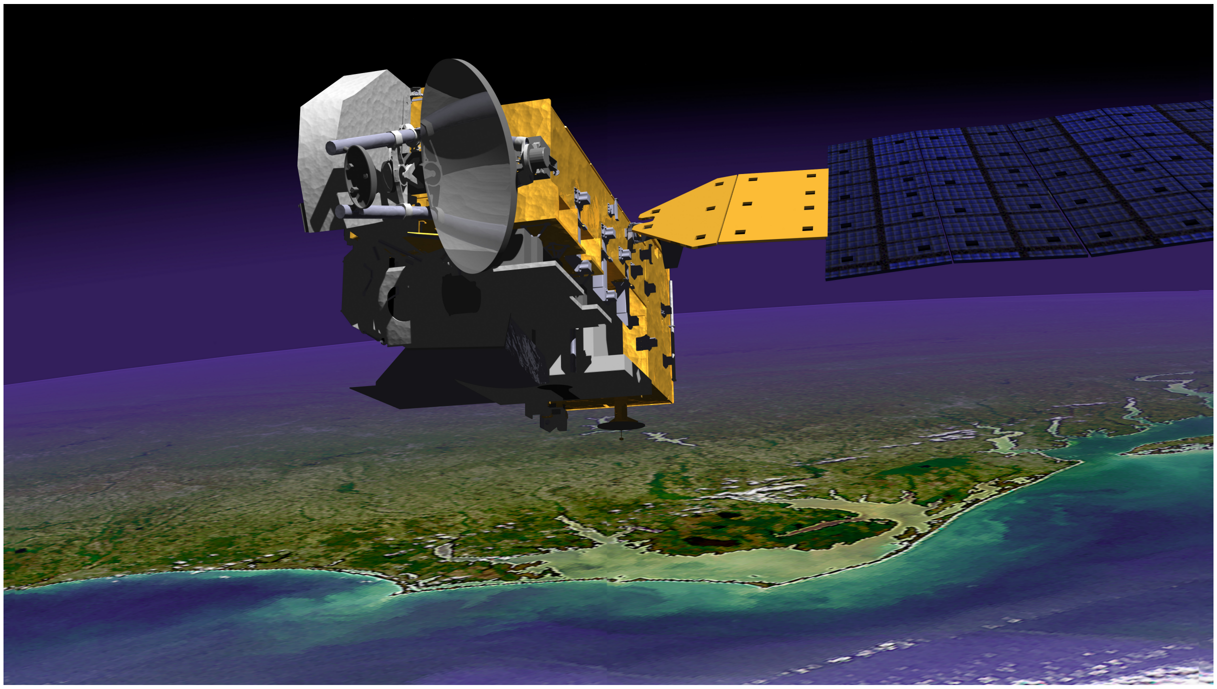
Sensors, Circuits, and Satellites
Lesson 1: Wave Generator



Sensors, Circuit, and Satellites is a collection of classroom lessons created by NASA's Aura mission education and outreach that explore the electromagnetic spectrum and NASA remote sensing instruments using student assembled circuits. These lessons integrate inquiry with active-learning experiences to engage students in the properties of electromagnetic energy and remote sensing. The investigations are sequenced to help the learner construct their knowledge about the electromagnetic spectrum while offering real world examples from NASA.

Credits:
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Lesson 1: Wave Generator

Summary: This lesson uses sound to demonstrate how energy travels waves. Students will investigate sound energy created by vibrations of a speaker and visibly experience the energy as vibrations create waves in a liquid. Concepts of wavelength and frequency are introduced.

Student Objectives: Students will identify different types of energy and when they transfer from one to another. Students will explore how sound is energy and travels in waves and then explain how wavelength and frequency are used to describe waves.

Key Terms: Potential energy, kinetic energy, sound energy, electrical energy, compression waves, wavelength, frequency

Approximate Time: 30-45 minutes

Materials:

- littleBits™ components: power, wire, speaker, bright led
    - *ALTERNATE MATERIALS – Amplified speaker without grill/screen cover and with input connecter for MP3 player or other audio source*
- plastic spoon, repositionable tape (low tack masking tape)
- opaque liquid such as milk (small liquid coffee creamers work well)
- MP3 player or computer with ability to play music
- Access to internet during or before demonstration

NGSS – Disciplinary Core Ideas

- **MS-PS4-1** Waves and Their Applications in Technologies for Information Transfer - Use mathematical representations to describe a simple model for waves that includes how the amplitude of a wave is related to the energy in a wave. [Clarification Statement: Emphasis is on describing waves with both qualitative and quantitative thinking.] [Assessment Boundary: Assessment does not include electromagnetic waves and is limited to standard.
  **In addition to amplitude, energy of a wave can vary by wavelength and frequency. The discussion in this lesson relates energy of a wave to the frequency.
- **MS-PS4-2** Waves and Their Applications in Technologies for Information Transfer - Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials. [Clarification Statement: Emphasis is on both light and mechanical waves. Examples of models could include drawings, simulations, and written descriptions.] [Assessment Boundary: Assessment is limited to qualitative applications pertaining to light and mechanical waves.]

NGSS – Cross-cutting concept

- Structure and Function: Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used.

Set-up:

- Put together the circuit using littleBits™ components: power + microphone (with audio cable) + wire + speaker
- Attach MP3 player or computer via the audio cable and queue up music. (try this ahead of time with your own music to find a song that creates easily visible waves

– some genres that work well are hip hop, funk and pop as long as there is a good base track)

Engage: This demonstration should be done by the teacher in a central location so that the students might be standing or sitting in a circle around the demo so that all can see. Tip - try it a few times yourself before demonstrating in front of students.

1. Ask students if they can identify any types of energy presented in this circuit. [Chemical and/or stored energy = Battery. Electrical energy = the power bit & cable. Kinetic energy and/or sound energy = the vibration of the speaker.]

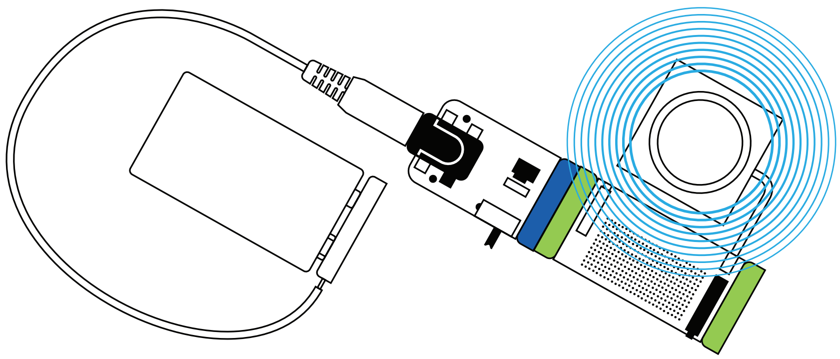
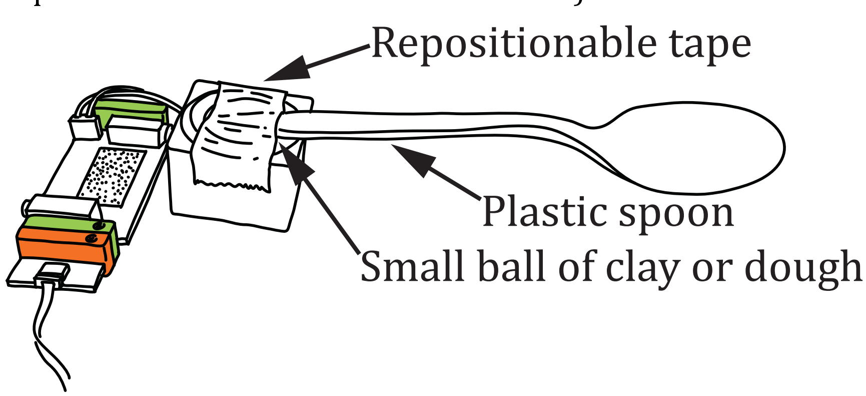


image credit: littleBits ™

2. Play a song and ask a few student volunteers to gently touch the speaker. "What is happening?" [Introduce or reinforce 'kinetic energy'] What is happening that our ears can hear the sound from the speaker?
3. Then connect a plastic spoon to the speaker. Use 'repositionable' tape (commonly used for scrapbooking) to attach the end of the spoon handle to one edge of the speaker. The spoon handle should touch the center silver part of the speaker, the part that vibrates. (Hint: a small ball of clay placed between the center of the speaker and the spoon handle will help make the physical connection so the vibrations transfer from the spoon handle to the liquid. Try this ahead of time with the liquid to ensure the vibrations are visible.)



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4. Fill spoon with a small amount of opaque liquid and play music. Ask students to watch what happens. Ask a student volunteer to chart student Ask student

volunteer to chart students' responses to the questions: What is happening? What do you see? What do you hear?

Explore: Play different types of music - classical music and songs with a lot of bass work well. With each type of music, ask what is happening? What do you see? What do you hear? (Again a student volunteer can chart responses, or students can each record their observations in their own journal)

Explain: Ask students to share their ideas about what is happening between the vibrations of the speaker with the liquid in the spoon. The vibrations from the speaker vibrate the spoon causing waves to form in the liquid. They can actually see sound energy creating waves in the liquid! The waves in the liquid are also energy in the form of pressure (or compression) waves. Like waves in the ocean, it is an example of energy traveling through a medium (water) as waves. *Teacher note – the waves in the liquid are not 'actual' sound waves. We are seeing the affects of the vibrations from the speaker in the liquid. Sound waves are compression waves in the air (or through the plastic of the spoon) produced by the vibration of the speaker. The lengths of sound waves are much longer (see extend).*

Ask students to share their ideas about the vibrations of the speaker and the sound we hear. How are we able to hear the music with our ears? If we know that energy travels in waves, what is happening between the speaker and our ears? Do you think there is sound in outer space? Why or Why not?

The speaker is transferring the electrical energy to sound energy by creating sound waves in the air. As the cone on the speaker vibrates, it pushes on the air molecules creating waves. The vibrations move through the air causing the surrounding molecules to vibrate in a particular pattern represented by a wave. The vibrating air then causes the listener's eardrum to vibrate in the same pattern. Thus, our ears detect this energy – these compression waves – as sound.

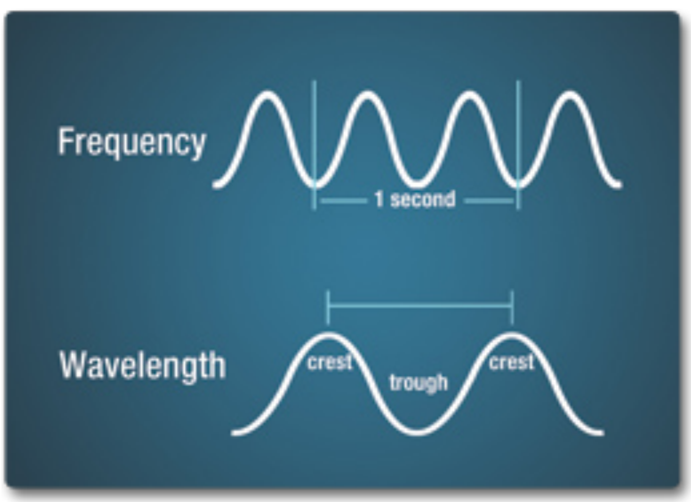
To demonstrate this concept for visual learners, have two students hold each end of a slinky. Then, have one of the students create a compression wave pulse by quickly tapping the back of their hand that is holding the slinky. Students can observe the wave moving through the slinky. Sound is created by the air being compressed by vibrations just like the slinky, it creates a wave by compressing the coils.

Explore: Play a tone at different frequencies. Tones by specific frequency – Hertz – can be generated online at web sites such as http://onlinetonegenerator.com) Try three or more tones between 60 and 600 Hertz. *Teacher note – if you do not have access to the Internet during this lesson, you can download the tones from the website in advance.* Ask students to describe the relationship between what they are hearing, the number of Hertz, and what they are seeing in the liquid. Before each new tone, ask students to predict how this new tone will sound different and look different in the liquid. *Teacher note – higher frequencies have shorter wavelengths, have higher pitch and have smaller waves or ripples in the liquid. The lower the frequency, the wavelength is longer and the pitch lower. Since the wavelengths are longer, there is a larger impact on the dish and possibly splash out.*

Extend: Waves can be described by their wavelength (distance from crest to crest) or by their frequency (number of waves that pass through a point in a second). Hertz is a term used to measure the frequency as one cycle (from crest to the next crest) per second. If we know the speed of sound is 343 meters per second (mps), then we can divide it by the frequency to determine the length of the wave.

$$\frac{\text{speed of sound}}{\text{frequency}} = \text{wavelength}$$

Share explanation about frequency. A low frequency means fewer waves (just one for 1 Hertz) can cycle past a given point in one second. A higher frequency - such as 600 Hertz –a larger number of waves can cycle in one second. For more waves to cycle in second, they would have to have smaller wavelengths. So a low frequency has a longer wavelength than a higher frequency.



Evaluate:

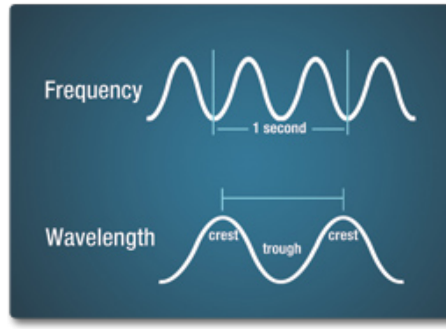
Using the worksheet, Understanding WaveLENGTH, Students will put the four examples in the following worksheet, Understanding WaveLENGTH, in order of wavelength – from longest to shortest and provide evidence for their answers (Answer: C, D, A, B - evidence provided by the associated conversion equation noted in red next to each answer).

- A. Middle C on a piano is 261 Hz (343 mps/261 Hz =1.31 m)
- B. Shortest wavelength of sound a bat can hear is 3 millimeters (3mm = 0.003 m)
- C. Lowest frequency an Elephant can hear is 5 hertz (343 mps / 5 Hz = 68.6 m)
- D. Shortest wavelength of sound a human can hear is 17 meters (17 m)

Name: ____

Understanding Wave LENGTH

Waves can be described by their **wavelength** (distance from crest to crest) or by their **frequency** (number of waves that pass through a point in a second). **Hertz** is a term used to measure the frequency as one cycle (from crest to the next crest) per second. If we know the speed of sound is *343 meters per second (mps)*, then we can divide it by the frequency to determine the length of the wave.



$$\frac{\boldsymbol{speed\ of\ sound}}{\boldsymbol{frequency}} = \boldsymbol{wavelength}$$

Put the following four examples in order of wavelength – from longest to shortest and provide evidence for your answers. Hint: Use the equation above and the information from the paragraph to convert frequency to wavelength if necessary.

A. Middle C on a piano is 261 Hz

B. Shortest wavelength of sound a bat can hear is 3 millimeters

C. Lowest frequency an Elephant can hear is 5 hertz

D. Shortest wavelength of sound a human can hear is 17 meters

_______________, _______________, _______________, _____________

Shortest Longest