The Science of Sound

OVERVIEW

ESSENTIAL QUESTION

What is sound, and how are its characteristics explained scientifically?

OVERVIEW

In this lesson, students will analyze video clips of musicians playing various instruments in order to identify how sound is created. They then conduct three hands-on activities to gain a deeper understanding of the science of sound: the physical characteristics of sound, and how sound is scientifically explained and represented.

Sound is vibration. When a drum is struck, a string plucked, or any other object is moved in some way, it vibrates. These vibrations displace the surrounding air molecules, which in turn displace more air molecules, creating a chain reaction which eventually reaches the ear and/or body and is perceived as sound.

But these vibrations do not create a uniform, continuous trajectory of air molecules. Rather, the back-and-forth motion of a vibrating object creates waves of sound, where air molecules bunch together and expand out at a regular rate. This type of movement occurs in what is called a longitudinal wave, which moves via compression (when molecules are bunched together) and rarefaction (when molecules are spread apart).

While sound waves carry the characteristics of longitudinal waves, they are usually visually represented as transverse waves. Rather than staying parallel to the wave motion, transverse waves move perpendicular to the wave motion. In other words, transverse waves move up and down, creating hills and valleys, like waves in the sea. Representing sound waves as transverse waves rather than longitudinal waves allows their characteristics to be better observed, analyzed, and calculated.

OBJECTIVES

Upon completion of this lesson, students will:

1. KNOW (KNOWLEDGE):

- The science of sound as a phenomenon
- The physical properties and behavior of sound waves
- The difference between longitudinal and transverse waves
- The role of compression and rarefaction in wave mechanics

2. MASTERY OBJECTIVE:

- Students will be able to explain the science behind sound waves by conducting hands-on activities.

ACTIVITIES

MATERIALS NEEDED FOR THIS LESSON:

- 2 medium sized bowls
- Plastic wrap
- A metal coil, such as a Slinky®
- 1 cup of sugar, salt, or sand
- A tuning fork (the larger the better)
- A large baking pan
- A large wooden spoon
- Water
- A small piece of string or yarn

PREPARATION:

1. Create the following stations where students will conduct activities related to sound wave:
   - **Station 1: Drum/Vibrating Membrane Activity**
     - Tightly cover the plastic wrap over the top of the bowl. Place a spoon and cup of salt, sugar, or sand next to the bowl.
     - Provide copies of **Handout - Drum/Vibrating Membrane Activity** at the station.

- **Station 2: Coil Spring Wave Simulation**
    - Tie a short piece of string or yarn approximately in the middle of the metal coil.
    - Provide copies of **Handout - Coil Spring Wave Simulation Activity** at the station.
- **Station 3: Tuning Fork and Water Activity**
    - Fill a medium bowl with water, and place the tuning fork next to the bowl.
    - Provide copies of **Handout - Water and Tuning Fork Activity** at the station.

ACTIVITIES

MOTIVATIONAL ACTIVITY

1. Show students **Clip 1, Introducing the Mickey Hart Band**, which showcases musicians working with percussionist Mickey Hart. Direct students to pay attention specifically to the instruments in the video, and the ways they are performed.
2. After watching the video, and together as a class, create a list of the instruments featured in the clip. Then, go through the list and ask students to try their best to describe how each instrument is played. Finally, ask students:
    - Based on the observations we made on the board, how are these instruments being "activated" (played) to produce sound? Were they all "activated" in the same way, or a different way?
    - Using physics or motion, how could you describe how each instrument is "activated" to make sound?
3. Display **Image 1, "Oxford Dictionary Definition of Sound"** and ask a student to read the definition aloud for the class.
4. Return to the list the class created and ask students:
    - How did each of these instruments create vibration? (Play **Clip 1** again if needed.)

PROCEDURE

1. Inform students that they will be exploring the science of sound: how it operates, and how it is explained and represented scientifically and mathematically.
2. Explain to students that to understand the science of sound, they will first have to understand the physical principles of sound by conducting a variety of activities and making observations. Direct students

to go to the stations around the classroom (students can either volunteer to go to a particular station or be assigned to one). Explain to students that at each station they will be conducting activities and answering the questions as described in each station handout:

- **Station 1: Drum/Vibrating Membrane Activity**
    - Handout - Drum/Vibrating Membrane Activity
    - Optional: Video Demonstration
- **Station 2: Coil Spring Wave Simulation Activity**
    - Handout - Coil Spring Wave Simulation
    - Optional: Video Demonstration
- **Station 3: Tuning Fork and Water Activity**
    - Handout - Tuning Fork and Water Activity
    - Optional: Video Demonstration

3. Have students share with the class what they observed as a group by providing the answers they gave for the handout questions. Ask students:
    - What might these activities say about the nature of sound waves, or waves in general?
    - In each activity, you could visually experience the effects of sound waves. After having seen waves in operation, what might be some ways to measure waves? What variables exist that change the effects of sound waves? (if helpful, provide a list of student answers on the board). **(Note: If this lesson is broken into two class sessions, this is an ideal place to end the first session.)**

4. Explain to students that the class will summarize what they learned while doing the activities using a graphic organizer. Pass out **Handout - Longitudinal Vs. Transverse Wave Graphic Organizer** to each student. Encourage students to take notes in the organizer as they learn about the science of sound in class.

5. Explain that sound waves operate as **longitudinal** waves, which have characteristics students observed in the three activities.

6. Direct students to examine Figure 1 in the graphic organizer handout. Ask students:
    - When striking the bowl rhythmically, what did you notice about the sugar/salt/sand? Did the sugar/salt/sand continuously move in one direction, or did it move back and forth?
    - At what point were the sugar/salt/sand grains close together, and at what point were they separate?

7. Explain to students that the sugar/salt/sand acts in a similar way as air molecules react when producing sound waves. Like the sugar/salt/sand moving up and down, air molecules are not pushed out at a constant rate, but "pumped" according to how rapidly the material is vibrating.

8. Direct students to examine Figure 2 in the graphic organizer handout. Ask students:
    - Is the illustration in Figure 2 similar to what you observed when doing the coil activities?

9. Explain to students that, much like the sugar/salt/sand in the membrane activity and air molecules in a sound wave, the coils

expanded and contracted. The point at which the coils are farthest apart is called **rarefaction**. When the coils are closest together, it is called **compression**. Direct students to label the moments of compression and rarefaction in Figures 1 and 2.

10. Explain to students that the coil activity revealed another characteristic of longitudinal waves: that the molecules move in parallel with the energy source. The piece of string in the middle of the coil moved in parallel with the energy source, in the activity the energy source was the student's moving hand.

11. Direct students to examine Figure 3 in the graphic organizer handout. Explain that in this activity students actually used the longitudinal waves produced from the pitch fork to create **transverse** waves, which move perpendicular to the energy source. The classic example of transverse waves are water waves, which move up and down. When the tuning fork was placed in the water, ripples appeared.

12. Direct students to examine Figure 3 in the graphic organizer handout. Explain that while longitudinal waves operate differently than transverse waves, they are mathematically represented as transverse waves. Modeling longitudinal waves like this makes it easy to mathematically represent the measurable variables of any wave.

SUMMARY ACTIVITY

1. Using their graphic organizer for support, direct students to turn to their partner and briefly explain the science of sound and how sound operates.

2. Pass out **Handout - Ancient Theories of Sound**. Read the handout aloud as a class. Ask students:

   - According to the handout, how did the ancient cultures understand sound?
   - How would you explain the theory of "cosmic vibration"?
   - How does the author relate these ancient conceptions of sound to modern science? Does he argue they are similar or dissimilar?
   - According to the handout, how did the ancient cultures described understand sound?
   - How would you explain the theory of "cosmic vibration"?
   - How does the author relate these ancient conceptions of sound to modern science? Does he argue they are similar or dissimilar?

- What similarities exist between ancient conceptions of sound and the contemporary science of sound?
- Ancient civilizations believed that sound was the "audible" manifestation of greater vibrations that can not be directly observed. Do you think this is an accurate statement? Are there examples of vibrations in the universe that can not be directly observed?
- Why did ancient civilizations "revere" sound?
- Do you think we "revere" sound today? What examples might you give of the ways people continue to "revere" or appreciate sound?

3. Watch **Clip 2 - Vibrational Expressionism.** Ask students:

- How does Mickey Hart create his paintings? What is his process in painting?
- Scientifically speaking, why would different sounds, when amplified into a canvas with paint on it, result in different patterns?
- What is Hart attempting to achieve in his painting process?
- Do Hart's ideas of sound and vibration relate to how ancient people conceptualized sound and vibration? How so?

4. See the lesson **The Mathematics Behind Sound** to learn about the variables of sound, how they are measured, and the mathematical relationships between them.

EXTENSION ACTIVITIES

1. Before computers were able to visually represent soundwaves, German scientist Ernst Chladni used metals plates and sand to visualize the characteristics of sound waves. Watch the video from the Smithsonian Institute demonstrating a Chladni plate (https://youtu.be/KEttRmu2kGk). Then, using your notes from the **Handout - Longitudinal Vs. Transverse Wave Graphic Organizer**, write a brief paragraph considering how Chladni plates might represent the physical characteristics of sound.

2. Can sound be felt or experienced without being heard? Work through **this Distance Learning Pack** to discover the ways deaf and hard of hearing people experience music.

STANDARDS

NEXT GENERATION SCIENCE STANDARDS

4-PS3-2: Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.

4-PS4-1: Develop a model of waves to describe patterns in terms of amplitude and wavelength and that waves can cause objects to move.

COMMON CORE STATE STANDARDS

College and Career Readiness Reading Anchor Standards for Grades 6-12 for English Language Arts

Reading 1: Read closely to determine what the text says explicitly and to make logical inferences from it; cite specific textual evidence when writing or speaking to support conclusions drawn from the text.

Reading 2: Determine central ideas or themes of a text and analyze their development; summarize the key supporting details and ideas.

Craft and Structure 4: Interpret words and phrases as they are used in a text, including determining technical, connotative, and figurative meanings, and analyze how specific word choices shape meaning or tone.

Craft and Structure 6: Assess how point of view or purpose shapes the content and style of a text.

Integration of Knowledge and Ideas 7: Integrate and evaluate content presented in diverse media and formats, including visually and quantitatively, as well as in words.

Integration of Knowledge and Ideas 9: Analyze how two or more texts address similar themes or topics in order to build knowledge or to compare the approaches the authors take.

Range of Reading and Level of Text Complexity 10: Read and comprehend complex literary and informational texts independently and proficiently.

College and Career Readiness Anchor Standards for Speaking and Listening for Grades 6-12

Comprehension & Collaboration 1: Prepare for and participate effectively in a range of conversations and collaborations with diverse partners, building on others' ideas and expressing their own clearly and persuasively.

Comprehension & Collaboration 2: Integrate and evaluate information presented in diverse media and formats, including visually, quantitatively, and orally.

Presentation of Knowledge 4: Present information, findings, and supporting evidence such that listeners can follow the line of reasoning and the organization, development, and style are appropriate to task, purpose, and audience.

College and Career Readiness Anchor Standards for Speaking and Listening for Grades 6-12

Language 1: Demonstrate command of the conventions of standard English grammar and usage when writing or speaking.

Vocabulary Acquisition and Use 4: Determine or clarify the meaning of unknown and multiple-meaning words and phrases by using context clues, analyzing meaningful word parts, and consulting general and specialized reference materials, as appropriate.

Vocabulary Acquisition and Use 6: Acquire and use accurately a range of general academic and domain-specific words and phrases sufficient for reading, writing, speaking, and listening at the college and career readiness level; demonstrate independence in gathering vocabulary knowledge when encountering an unknown term important to comprehension or expression.

RESOURCES

VIDEO RESOURCES

1. Clip 1, Introducing the Mickey Hart Band
2. Clip 2 - Vibrational Expressionism By Mickey Hart - Coral Springs Museum of Art

HANDOUTS

1. Handout - Coil Spring Wave Simulation Activity
2. Handout - Drum/Vibrating Membrane Activity
3. Handout - Water and Tuning Fork Activity
4. Handout - Longitudinal Vs. Transverse Wave Graphic Organizer