Sound

Strand Force, Motion, and Energy

Topic Investigating sound

Primary SOL PS.8 The student will investigate and understand the characteristics of sound waves. Key concepts include
- a) wavelength, frequency, speed, amplitude, rarefaction, and compression;
- b) resonance.

Related SOL PS.1 The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which
- m) models and simulations are constructed and used to illustrate and explain phenomena.

PS.8 The student will investigate and understand the characteristics of sound waves. Key concepts include
- c) the nature of compression waves; and
- d) technological applications of sound.

Background Information

Sound waves are produced by vibrations. These vibrations cause the matter around them to squeeze together, creating a compression, and spread apart, creating a rarefaction. A sound wave is a compression wave that consists of repeating patterns of compressions and rarefactions. Sound waves can be described by their wavelength (the distance between one compression and the next), amplitude (the amount of energy carried by the wave), frequency (the number of waves that pass a certain point in a given amount of time), and speed. Wavelength and frequency are inversely proportional; therefore, a wave with a longer wavelength has a smaller frequency. The wavelength and frequency of a sound wave determine the pitch of a sound. Pitch is how high or low a sound seems to a person. A wave with a higher frequency has a higher pitch. The amplitude of a wave determines the loudness of a sound wave. The greater the amplitude of a wave, the louder the sound is to a person.

Resonance is the tendency of a system to vibrate at maximum amplitude at certain frequencies. Musical instruments resonate at various frequencies to produce different pitches.

Materials

Introduction
- Wire hangers
- String

Station 1
- Five test tubes labeled A–E and filled with water to allow for the following amounts of remaining air in each tube:
  - A—Air column = 12.6 cm
  - B—Air column = 11.4 cm
  - C—Air column = 13.4 cm

  - D—Air column = 10.3 cm
  - E—Air column = 9.3 cm
- Test tube rack
- Pencil
- Beaker

Station 2

- Table tennis ball on string
- Tuning fork
- Pie pan with water

Station 3

- Tissue box
- Rubber bands of different thicknesses

Station 4

- Music box without sound board

Station 5

- Three identical bottles with varying amounts of water
- Ruler
- Pencil

Vocabulary

amplitude, compression, compression wave, frequency, pitch, rarefaction, resonance, sound, speed, vibration, wavelength,

Student/Teacher Actions (what students and teachers should be doing to facilitate learning)

Introduction

For each student, take one wire hanger, and tie a 15 cm string to one end of the hanger, and tie another 15 cm string to the other end of the hanger. Tie loops on the loose ends of the strings just large enough to fit an index finger through. Have students place the index finger of each hand through a loop and hold the hanger/string system in front of them. Students should knock the hanger into a desk and listen for the sound. Ask students to describe the sound. Most students will answer that the sound is very faint. Point out to students that the wire is vibrating and that they may be able to feel it through the string on their fingers. Have students place their fingers in their ears and repeat striking the hanger into a desk. Ask students to describe this sound. They should hear a gong-like sound that is much louder than the prior situation. Ask students to explain the difference in terms of vibration and materials.

Station 1: Musical Test Tubes

Station 1 is focused around the concept of how frequency determines pitch. If a material has the properties to vibrate quickly, the sound will be perceived as a high pitch. If the material vibrates slowly, the sound emanating from the material has a low pitch. A foundational concept for this station is that the source of sound is vibration.

1. Ask students to predict which of the test tubes will have the highest pitch and lowest pitch. Ask students to record their prediction in their notebooks.

2. Play the song as instructed. The song is "This Land is My Land," but do not reveal this to the students. It will be difficult for students to identify the song without rhythm. Hold a pencil by the point end. Tap out the following pattern on the test tubes with the eraser end:

   AABCABDDEDBABACA

3. Ask students, "Which test tube has the highest pitch? Which has the lowest pitch? What song is this?"
4. Tap the beaker. This beaker has the same height air column as note B in the test tube. Compare the note made in the beaker with the note made with the test tube.
5. Ask students to create another tune and share their pattern with the class.

Station 2: Sound Vibrations

Station 2 demonstrates more clearly that a tuning fork makes a sound due to vibrating tines. Careful observation of the relationship between the length of the string with the table tennis ball helps to reinforce the idea of resonance.

1. Have students put the table tennis ball close to the tuning fork, and strike the tuning fork on their desks. Ask them to record their observations.
2. Have students try the same experiment holding the table tennis ball by different lengths of string in their hands. Ask them if there is a certain length of string that works better. Ask them to explain the behavior of the table tennis ball.
3. Have students strike the tuning fork on their desks, and immediately put the tuning fork in the pie pan full of water. Ask them to record and explain their observations.
4. Have students strike the tuning fork and put the handle of it on their foreheads. Ask them to explain what happens to the sound.

Station 3: Stringed Instruments

Station 3 shows different ways materials can be altered in order to produce different pitches. Students should realize that the faster the material vibrates, the higher the pitch. Reducing the amount of material allowed to vibrate has the same effect.

1. Have students pluck one of the rubber bands. Ask them to keep the same tightness, but create a shorter wavelength. They should do this by making the rubber band shorter by putting their fingers in the middle of it. Then have them pluck it and describe the difference.
2. Have students pull the rubber band tighter and pluck. Ask them to explain what happens.
3. Have students try a thicker rubber band. Ask them to explain the sound difference.

Station 4: Sound Boards

Station 4 displays the utility of a sound board. When the inside workings of the music box are turned without any material around it, the sound is very soft and weak. When the music box is placed on a table, the sound is much louder. Students begin to see that sound waves can travel more effectively through solids. Close inspection of the music box shows that the high notes are played by short tines and the low notes are played by long tines. The length of the tines change the frequency of the wave produced.

1. Hold a small music box in your hand and carefully turn the handle. Ask the students if they can hear anything.

2. Put the music box on the desk and turn the music box. The sound travels through a solid this way. Ask the students how the sound changes.
3. Ask the students how the speed of a wave is affected by the medium through which it travels.
4. Ask the students to describe the pitch made by short prongs.
5. Ask the students to describe the pitch made by the long prongs.
6. Ask the students to describe the relationship between the length of the prongs and the frequency of the wave produced.

Station 5: The Reversing Pitch

Station 5 helps students to parse out the source of sound. Within the same flask of water, two sounds can be produced. If a student strikes the flask, the water vibrates. When a student blows across the top of the flask, the air vibrates. The station is set up so that students will hear different pitches from different vibrations.

1. Lift bottle A with two fingers around the neck and hit the side of the bottle with a ruler. Do the same with bottles B and C. Ask the students to identify the bottle with the highest pitch.
2. Now blow over the mouth of each bottle and listen for the pitch. Ask students to identify the bottle with the highest pitch.
3. Ask the students to identify the source of the vibration when the bottles were hit on the sides.
4. Ask the students how the tone was produced when you blew into the bottle.
5. Ask the students why a bottle produces the same pitch when hitting it or blown across.

Observations and Conclusions

1. Have the students go through each station and discuss the questions. Lead students to conclusions rather than merely telling them the "answers."

Assessment

- **Questions**
  - How is the pitch of a sound related to the frequency of the wave?
  - When the tines on a tuning fork vibrate, how are compressions and rarefactions formed?
  - How can you tell if the swinging frequency of the table tennis ball is in resonance with the frequency of the tuning fork?
- **Journal/Writing Prompts**
  - Describe how columns of air can be changed to make different notes.
  - Explain how you can change the pitch of a stringed instrument.
  - Explain why a guitar and a piano need to have a body or case around the strings.

Extensions and Connections (for all students)

- Create a musical instrument from scratch. The instrument can be percussion, wind, or string. Explain the following concepts using your instrument: source of sound, loudness, pitch, frequency, amplitude, and quality of sound. Play a familiar tune on the instrument and explain how you tuned the instrument.

- Have students research how the bones and other parts of the human ear work. Explain to the class how the sound waves get converted into messages to the brain.
- Have students create a poster of the causes of hearing damage and ways people can prevent hearing loss.

Strategies for Differentiation

- Obtain an oscilloscope if possible for students to be able to see the sound waves.
- Have students discuss their observations rather than writing responses.
- Provide written, simplified, step-by-step procedures at each station.
- Assist students in drawing a compression wave. Have students label the wavelength and amplitude of their wave. Discuss how it would change as frequency and volume of sound changed.
- Have students fill various shoe boxes with round materials (e.g., marbles, jaw breakers, billiard balls) and describe how small materials represent higher frequencies and larger materials represent lower frequencies when shaken.
- Have students use an audiogram of sounds to give a pictorial representation of familiar sounds.