Drexel-SDP GK-12 ACTIVITY

Activity Template

Subject Area(s): Sound

Associated Unit: None

Associated Lesson: None

Activity Title: Density and Pitch, is there a relationship?

Grade Level: 8 (7-9)

Activity Dependency: None

Time Required: 90 minutes

Group Size: 3-4 students

Expendable Cost per Group: US $0.50

Summary:
In this activity, students will determine the general relationship between pitch (frequency) and density through experimentation. As a result, students will learn about how sound travels through different media and the molecular arrangement of solids, liquids and gases. This will also give students an overview of density, matter and sound.

Engineering Connection:
Engineers working with sonar, underwater communication or acoustical oceanography must know the density of the medium the sound is traveling through in order make correct calculations. For example, boats and submarines use sonar to detect underwater objects, which could be other boats, submarines, or the ocean floor. To do this, a system sends a pulse of sound out into the water and then waits for its return. The sound is sent out at a certain frequency and the receiver expects that same frequency back. Therefore, the receiver must know the correct

density of the water to determine the speed of sound in the water and the expected frequency of the received sounds.

Keywords: density, sound, acoustics, pitch, amplitude, matter

Educational Standards

Science: 3.1 – Unifying Themes of Science
Math: None

Learning Objectives

After this lesson, students should be able to:

- Explain what density is and how it is measured
- Explain the difference between density and thickness
- Explain the general relationship between density and sound
- Write a formal lab report

Materials List

Each group needs:

- 4 – 250 mL beakers of equal height
- 50 mL of water
- 50 mL of maple syrup
- 50 mL of ketchup
- 50 mL of vegetable oil
- glass stir or pen
- copy of the lab sheet for each person

To share with the entire class:

- jug of water
- bottle of maple syrup
- bottle of ketchup
- bottle of vegetable oil

Introduction / Motivation

Many musical instruments are built on the same ideas that will be explored in this experiment. Relevant instruments to this lab consist of a tube closed at one end where an excitation or sound originates and an open end where the sound exits the tube. Think about the trombone, it consists of a mouthpiece where the vibration or sound begins. Then the sound travels through the pipes of the trombone, exiting at the bell. The beakers follow a similar design with the closed end as the bottom of the beaker and the open end being the top of the beaker. The excitation is generated from tapping the glass stir at the closed end and then the sound propagates upwards out of the top of the beaker. In this lab, the length of the closed tube or beaker has a fixed length. Therefore the

difference in pitch must be the result of another characteristic of the beaker or substance, but what is it? This lab investigates that question while teaching about the acoustics of a closed tube with an excitation source.

Vocabulary / Definitions

Word	Definition
density	the mass per unit volume
pitch	the fundamental frequency or the first harmonic in a series of harmonics
fundamental frequency	the lowest frequency produced in a harmonic series, often used in music

Procedure

Background

A closed tube produces a series of harmonic frequencies when an excitation source occurs at the closed end. The frequencies heard are based on the physical dimensions of the tube and the medium through which the sound travels. The first frequency in the harmonic series is called the fundamental frequency or pitch. These frequencies are heard because they resonate, which means that the waves have an antinode (crest of the wave) at the open end of the tube. The antinodes of these frequencies occur at one-fourth the wavelength. Therefore, the fundamental frequency has a wavelength that is four times longer than the tube. This leads us to the calculation for the pitch produced from the excitation source at the closed end of the tube. The pitch can be calculated using the following formulas:

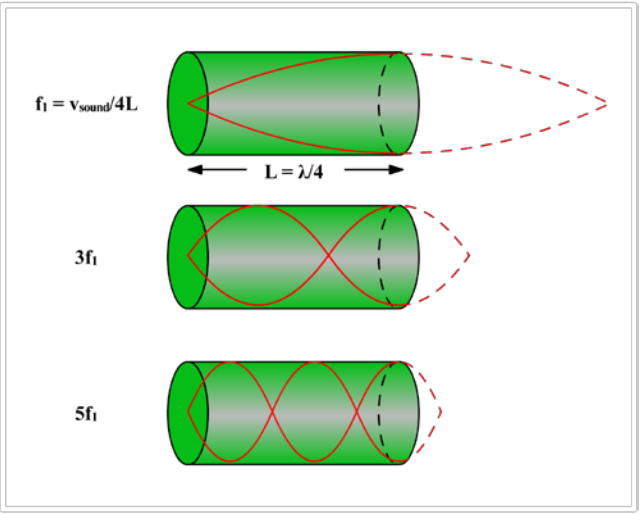
frequency = speed of sound / wavelength

$$f = \frac{c}{\lambda}$$

wavelength = 4 x length of tube

$$\lambda = 4L$$

Since we know our height of the beakers, L, we can calculate the frequency of an empty beaker because we know the speed of sound in air is approximately 343 m/s. The wavelength, λ, of the pitch can also be calculated. Use this fact as a means of explaining that the speed of sound must be changing for each substance used in the experiment.



Before the Activity

- Print out a copy of the lab for each student
- Prepare each set of four beakers for each group in the class with substances already poured into the beakers
- Test each set of beakers to make sure they are producing the desired result

With the Students

1. Ask the students what they think density means how would they define density
2. Explain to the students that their job is to determine the relationship between the pitch produced from a substance and the density of the substance
3. Demonstrate the proper procedure for performing the experiment, which includes tapping on the beaker at the same position (towards the bottom). Tell the students to wait for your permission to proceed after they have ordered the beakers from highest to lowest pitch
4. Distribute the materials to each group being careful to not get the substance on the walls of the beakers because this will affect the result
5. Have the students begin the lab following the procedure on the lab handout
6. After the students order the beakers from highest to lowest pitch make sure they have recorded their observations on the handout before giving them permission to proceed
7. Have the students then pour the substances together in any order into one beaker
8. The students will need to wait for 30 minutes or longer for the substances to settle
9. Go into discussion of the pitch observations for each group
10. Write the orderings of the substances observed by each group, in regards to the pitch, on the board and discuss the results
11. A good use of time while waiting would be to clean all of the beakers used and to ensure that each student has his or her lab handout completed up to the pitch data section
12. Once the substances have settled, have the students record their observations
13. Write the orderings of the substances observed by each group, in regards to the density, on the board and discuss the results
14. Discuss ideas about the relationship between the density and pitch of the substances
15. Tell the students what the true results should have been and discuss the factors that could cause inaccuracies in the observations (i.e., beakers imperfections, inaccuracies in the

amount of substance in each beaker, students focusing on the amplitude or loudness rather than pitch)

16. Wrap up by explaining the general mathematical relationship between density and pitch (answer: speed of sound changes and wavelength is constant so frequency must change, frequency = speed of sound/wavelength)

Attachments

- Density and Pitch Handout

Safety Issues

- The beakers and stir rod will be glass so the students must be careful not to break the glass

Troubleshooting Tips

The different substances should produce different pitches, but some will be similar in pitch due to the small contrast in density. This brings about a concern that should be explored before attempting to perform the experiment. Several factors will affect the differentiation of pitches for different beakers containing the same substance, such as the height of the beakers, accuracy of measuring the correct amount of each substance, deformities in the beakers and having substance on the sides of the beakers. The primary worry is the height of the beakers because they all MUST be the same. It would be beneficial to test each set of four beakers before the students arrive in class to make sure each set produces the correct results.

Investigating Questions

- What other liquid substances, besides the ones used, would have a higher pitch?
- What other liquid substances, besides the ones used, would have a lower pitch?
- Is it possible to use a beaker of water and beaker of maple syrup and get the same pitch from both of them by varying the amounts of the substances? Why or why not?

Assessment

Pre-Activity Assessment

Class Discussion:

- Talk with the students about examples of objects with similar dimension and ask which one is more dense and why (i.e., golf ball and ping pong ball)
- Talk with the students about an example of an object with large volume and small mass and an object with small volume and large mass and ask which one is more dense and why (i.e., balloon and a bowling ball)

Activity Embedded Assessment

Lab handout/worksheet: Have the students fill out the lab handout and review their answers as a measure of the concept comprehension

Post-Activity Assessment
Lab Report: Have the students write a lab report in similar format to the lab handout, but in a formal manner with greater detail. The report should begin by with stating the problem and the predicted hypothesis of the student with reasoning. The materials and procedure sections should follow with enough detail for someone to replicate the experiment exactly, adding details to the procedure in the lab handout when needed. The observations will be written informally on the handout, but should be redrawn on the lab report in color. The results section is a restatement of the observations with analysis of the data, such as the general relationship between the pitch produced by a substance and its density. Last is the conclusion paragraph, which states whether or not the hypothesis was correct or not and why. This formally written report will judge overall comprehension of the activity.

Activity Extensions

- The students could experiment with other liquid substances for homework or during free time
- Have a set of solids that students can experiment with to see if there is the same relation between density and pitch for solids

Activity Scaling

- For lower grades, the intensity of explanation will need to be reduced to more general concepts without mathematical detail
- For upper grades, the complexity of detail should be increase with mention of the exact mathematical formulas used to calculate the speed of sound in different types of matter (solid, liquid, gas)

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Density and Pitch Handout

Name: _____

Problem

How does the density of liquids affect pitch?

Hypothesis

If I place the same amount of water, syrup, vegetable oil and ketchup in their own glass and tap each glass with a pencil then I believe _____

_____

because _____

_____

_____

_____.

Materials

- 4 – 250 mL beakers of the same size
- 50 mL of water
- 50 mL of maple syrup
- 50 mL of ketchup
- 50 mL of vegetable oil
- Glass Stir/pencil

Lab Instructions

1. Put 50 ml of each substance into separate identical beakers (teacher ONLY).
2. Strike the side of the beaker with water and listen to the pitch produced.
3. Strike the beaker with syrup (at the same height on the beaker as the water) and listen to the pitch produced.
4. Repeat steps 2 and 3 as needed to compare the two pitches to determine if there is a difference.
5. Record the data.
6. Strike the side of the beaker with oil and listen to the pitch produced.
7. Compare the sounds of the oil, water, and syrup and put the beakers in order from highest to lowest pitch.
8. Record the data.
9. Strike the side of the beaker with ketchup and listen to the pitch produced.

10. Compare the pitch of the ketchup with the pitches produced from the beakers of other liquids.
11. Record the data
12. Place the liquids in order from highest to lowest pitch.
13. STOP inform the teacher that you are finished and WAIT until you receive permission to proceed.
14. Pour all of the liquids into the large beaker in any order and allow substances to settle.
15. Record the observations.
16. After the liquids have mostly settled draw and label your observations in the density graph below.

Observations

Order the substances by pitch:

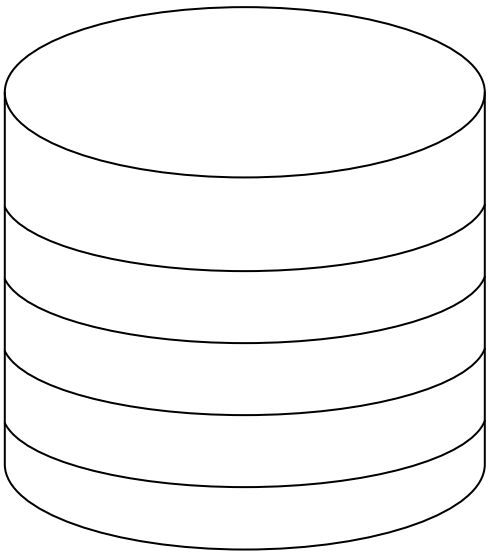
Highest Pitch 1. _____

2. _____

3. _____

Lowest Pitch 4. _____

Density Graph



Results

Compare the order of the pitches produced and the order of the densities of the substances. Is there a general relation between the pitch and density? Explain your reasoning for either answer.

_____

_____

_____

_____

_____

_____

Conclusion

My hypothesis was _____ because _____

_____

_____

_____

_____.