Speed of Sound
Determining the Speed of Sound in Air

The speed of sound varies with temperature and the gas through which it is traveling. The equation for calculating the speed of sound is:

$$v = (331 + 0.6T_C)\,\text{m/s}$$

where the speed of sound is 331 m/s at 0ºC and T_C is the temperature in Celsius. Although not written explicitly, the units associated with the factor 0.6 are meters per second per Celsius degree [m/(s·ºC)].

In a closed tube only certain frequencies of sound will resonate. The wavelength of the lowest note (lowest frequency, longest wavelength) that will resonate in a closed tube is related to the length of the tube by the following equation:

$$\lambda = 4L$$

If we include the correction for the diameter of the tube we obtain the equation that will be used in this laboratory exercise.

$$\lambda = 4\left(L + 0.3d\right)$$

where:

- λ is the wavelength of the note
- L is the length of the closed tube
- d is the inside diameter of the tube

A wall of water will close the tubes that you will use in this experiment. The sound will enter the top of the tube and reflect off of the water closing the bottom of the tube, setting up a standing wave which resonates inside the tube at certain lengths.

You will use the wave equation $v = f\lambda$

where:

- v is the speed of sound in the medium in m/s
- f is the frequency of the tuning fork in Hz
- λ is the wavelength of the sound in meters

PURPOSE

In this activity you will use resonance in a closed tube to determine the speed of sound in air.

MATERIALS

2 tuning forks of various frequencies (shared)
deep water receptacle
PVC pipe
tuning fork striker
meter stick or ruler
classroom thermometer

PROCEDURE

1. Measure and record the temperature in the room.

2. Fill the deep container almost to the top with water.

3. Measure and record the inside diameter of the tube.

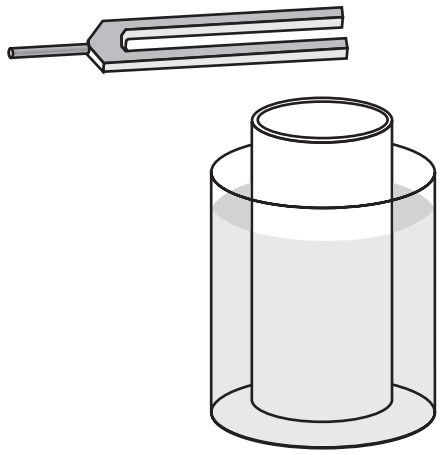
4. Put the tube in the water and support it with your hand.

5. Remembering that tuning forks are delicate instruments, use the striker to start the vibration.

6. Hold the tuning fork over the top of the tube and slowly raise and lower the tube until you hear an enhancement of the sound. This is hard to determine at first and will take some time to master. A quiet room and a group of ears will help. Strike the tuning fork again and check your results.

7. When you are convinced that you have resonance, carefully measure the length of the tube *above* the water. Be sure that the tube remains motionless during this process.

8. If your teacher instructs, repeat this experiment with a second tuning fork of different frequency.



Name _____

Period _____

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DATA AND OBSERVATIONS

Complete the following table.

Data Table	
Room temperature	°C
Inner diameter of the tube	m
First tuning fork frequency	Hz
Second tuning fork frequency	Hz
Resonant length for the first tuning fork	m
Resonant length for the second tuning fork	m

ANALYSIS

1. Use the temperature in the room and the temperature relationship to determine the speed of sound in the room.

2. Use the length and inside diameter of the tube to determine the wavelength of the frequency resonating in the tube.

3. Use the wave equation, the frequency, and the wavelength to calculate the speed of sound.

4. Assume that the speed of sound determined in question 1 is correct. Determine the percent error in the speed of sound using the experimental value you found in question 3.

5. Repeat these calculations for the second tuning fork if applicable.

CONCLUSION QUESTIONS

1. Suppose that the atmosphere in the tube consisted of carbon dioxide, CO_2. What would the length of the tube for resonance have to be if the frequency of the tuning fork were 256 Hz? The speed of sound in carbon dioxide is 258 m/s at 0°C and the correction is 0.4 m/s for each degree above and below zero. Assume the tube has an inner diameter of 0.045 m and that the temperature in the room is 21°C.

2. How does the speed of sound depend on the density of the medium through which it travels? Write a general statement expressing the relationship between the density of the medium and the speed of sound in the medium, and briefly explain why sound travels faster in certain media than in others.

3. Briefly explain why the sound produced by the tuning fork is much louder when the tube is a certain length above the water.