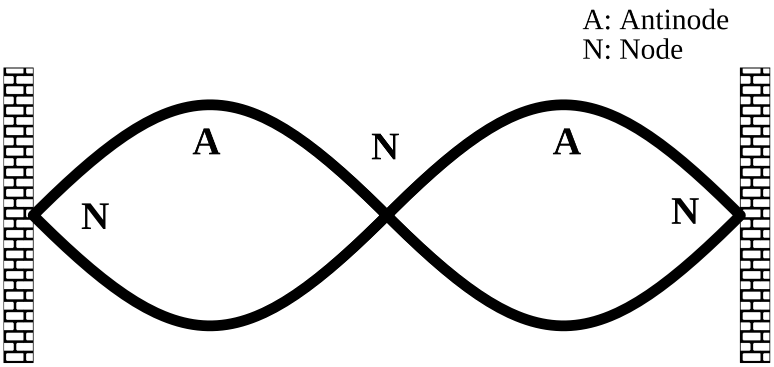
Lab #3: Resonance

Introduction

It is possible to increase the amplitude of an oscillating medium to very large levels, and with a seemingly small amount of energy, by shaking the system at a particular frequency. Loosely speaking, this phenomenon is called ‘‘resonance.’’ One example of resonance is the famous case of the crystal champagne glass and the opera singer. If you tap a champagne glass lightly with a spoon, it produces a musical note. This oscillation frequency of the glass when it is allowed to vibrate freely is its ‘‘natural’’ frequency. When the singer sings at this frequency, the glass absorbs the sound energy, oscillates with ever increasing amplitude and then breaks when the glass vibrates too much. In this lab you will observe the phenomenon of resonance in a vibrating column of air and measure the speed of sound in air.

Simplified Theory

If two waves of the same frequency travel in opposite directions in this medium and meet, the disturbance they will produce will look like a wave that is neither moving one way or another. We say that a **standing wave** is produced. It is a result of the **interference** of the two waves. At some points, called **nodes**, the interference causes the amplitude of the oscillating medium to be zero and the interference is said to be completely destructive. At other points, called **antinodes**, the waves reinforce one another so that the amplitude is largest here and the interference is said to be constructive. The following diagram represents a standing wave for a vibrating string:



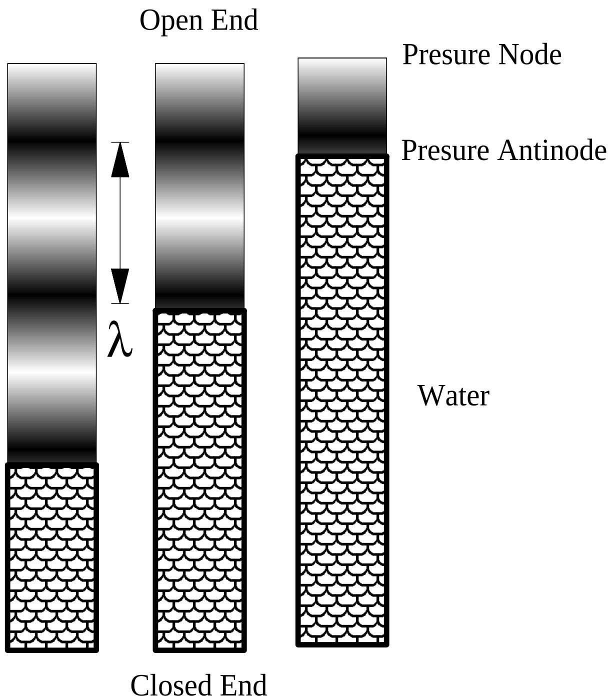
The standing wave is on a string that is fixed at both ends. The nodes, labeled "N" occur at the fixed ends and in the center at 1/2 the wavelength. The antinodes occur at "A." Such a standing wave can also occur in a resonant cavity for sound waves. An example is the all familiar organ pipe. In the case of the sound wave, the pressure varies as the air molecules vibrate and are displaced from their equilibrium positions.

Any medium (i.e., water or a stretched wire) that can support travelling waves can be made to resonate. When a medium is made to resonate, energy is efficiently exchanged between whatever is vibrating the medium and the medium itself. The standing-wave concept can be used to determine the resonant frequency of air columns. Imagine a column of air that is open at the top but closed at the bottom. Suppose a tuning fork or other suitable single-frequency sound source excites this column of air. The column will resonate (you will hear a loud sound) when the tuning fork source excites the air column at one of its natural (resonant) frequencies. The resonant frequency of the column occurs when its length L is such that an antinode occurs at the open end where air molecules are free to vibrate, and a node occurs at the closed end where the air molecules are not allowed to vibrate. In general, the condition for an antinode at the open end and node at the closed end is $L= n \lambda / 4$, where $n = 1, 3, 5, 7, \ldots$. In this case, the wavelength λ of the standing wave is defined by $\lambda = 4 L / n$. Varying the amount of water in a tube changes the length of an air column. The following diagram illustrates this:

The pressure nodes in the diagram correspond to those places where the pressure does not change at all, while the pressure antinodes are the places where the variation ion the pressure is a maximum.

We can ‘‘tune’’ the air column length to resonate with a tuning fork of known frequency. From the above condition for resonance, you can determine the wavelength of the resonant standing waves and if the frequency of the tuning fork is given, you can the use the following relationship to calculate the velocity of sound:

$$v = f \lambda \qquad (1)$$



where v is the speed of either one of the travelling waves that make up the standing wave, f is the frequency of the standing wave, and λ is the wavelength of the standing wave. Note that the standing wave and both of the travelling waves that compose it have *identical* frequencies and wavelengths.

This lab will familiarize you with the phenomenon of resonance and allow you to measure the speed of sound in air. You will then compare tour experimental value to the accepted value.

The speed of sound in air depends on the temperature. The "accepted speed" for sound in air is given by the formula:

$$v=332\ \text{m/s} \pm 0.6\ \text{m/s/°C}$$

Procedure:

Note: Use tuning forks with frquency greater than 256 HZ.

1 Fill the metal can reservoir with water when it is in a relatively low position.
2 Hold a vibrating tuning fork over the open end of the tube while changing the water level. Locate a fundamental resonance (loudest sound) by manipulating the water level and reactivating the fork.
3 Read the water levels X_1 and X_2 at two successive resonance points (loudest sound) and record them on the data sheet. Calculate the wavelength from the formula: $\lambda = 2\,|X_1 - X_2|$ (Eq.2)
4 Record the frequency of the tuning fork used. Calculate the velocity of sound with the help of equations (1) and (2), and record it.
5 Repeat the above steps for three different frequencies of tuning forks.
6 Record the room temperature with a thermometer. Calculate the accepted speed of sound.

Conclusions

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1. Describe your results for this experiment.

2 Name the different factors necessary for resonance and a standing wave in this apparatus. You may want to draw a sketch.
3 If both the ends of the tube were closed (i.e., fixed and rigid), sketch the standing wave and identify the nodes and antinodes.
4 Do you think that the diameter of the tube has an effect on the resonance? (Think about the speakers on your stereo.) Explain.

Error Analysis

1 How well do you think you could measure the water level positions that correspond to resonant conditions? Explain your error estimate.

2 Calculate the percentage error for your value of the speed of sound. Explain what you think caused a difference from the accepted value.

Resonance

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Name: ____________________________________Section: _______________

Abstract

Data

Room temperature: ________

Accepted value for speed of sound in air *(v)*: ____________________

Test #	1	2	3
F_{fork}			
X_1			
X_2			
λ			
V_{sound}			
% error			

Calculations:

Conclusions:

Error Analysis: