Experiment 4

Sound Resonance In Air Columns

In this experiment you set up **resonant** standing wave vibrations in an air column. A speaker emitting sound at a fixed frequency is placed near the air column and the column length is adjusted. Standing waves are set up in the air, analogous to the standing waves in a stretched string. One result of the lab is a determination of the speed of sound in air.

Preliminaries.

This experiment investigates the resonance conditions of a simple system consisting of a column of air closed at one end and driven at the other by an external speaker.

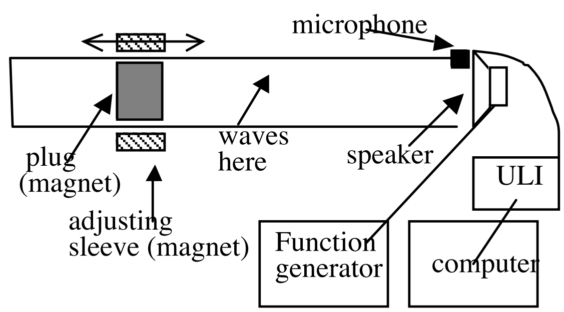

Figure 1. Schematic for Standing Sound Waves Experiment

Any vibrating object that can compress and rarify a gas can produce traveling sound waves in that gas. These waves are **longitudinal** waves, where the transporting medium oscillates in the *same* direction as the wave velocity (i.e. molecular motion is parallel to the direction of wave energy flow). In this experiment, a speaker sends traveling waves from the open end down a column of gas (air). See Figure 1. If the length of the column is adjusted properly by moving the adjusting sleeve, a loud sound characteristic of a **standing wave** is heard.

The standing wave pattern is fixed in space, as shown in Figure 2. The planes in the tube where, on average, there is no net molecular motion are the displacement nodal planes or simply displacement **nodes**, while the points where molecules undergo maximum oscillation about their equilibrium positions are called displacement **antinodes**.

➤*Note:*

The **displacement** designation is to specify that the wave being considered is parameterized by molecular displacement from equilibrium. It is also common in the study of sound waves to consider **pressure** waves, which are related to the density of gas molecules. The nodes of the pressure wave correspond to the antinodes of the displacement wave, and vice versa.

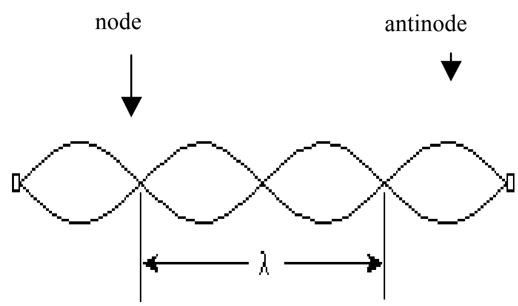

Figure 2. Example of a Standing Wave Pattern

Since gas molecules are not free to longitudinally oscillate at the surface of the plug, any standing wave produced in the tube must have a node at the plug surface, as shown in Figure 3. Although the antinodes are found one quarter of a wavelength from the nodes, they are not simply related to the physical properties of the tube. There is an antinode close to the physical open-end of the tube. The distance between the antinode and the physical open tube end is the **end correction**, labeled δ in Figure 3. δ is positive if the antinode is outside the tube, as shown.

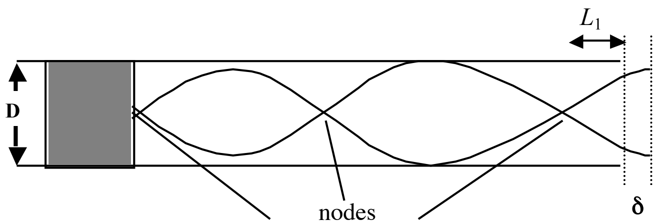

Figure 3. The Standing Wave in the Tube

There are two things we don't know. One is the speed of sound that we wish to measure. And the other is the exact location of the anti node… that is δ. In this experiment, you will try to find both of them. You can change frequency and the position of the plug.

In this experiment, the presence of a standing wave is detected by a microphone placed in the tube. The output from the microphone is displayed on a computer.

Things you may want to think about

a) What does theory tell you and what are you expecting to find? In particular, what is a good frequency to start with? Imagine the corresponding wavelengths.
b) Measure everything you think may be relevant.
c) You might want to try this with different placements of the speaker to see what works best for you.

Procedure

- Develop and write a good procedure.
- Everything is working as it should if the "Collect" arrow in the upper right of the screen is green.
- Click on the (green) "collect" button. The computer displays the microphone output, continually refreshing the screen.

  ➤*Note:*

  The computer is trying to collect and display a lot of data from the microphone. It takes a while to do this. The data refresh rate, the rate at which the computer updates the microphone output, is low. Rapid changes in the microphone output can be missed. Therefore, *the plug must be moved very slowly* so that the computer can keep up. Make sure the plug is moved slowly enough so that that the variation of amplitude observed on the computer display is smooth.

- Can you find resonance? Can you make it resonate in more than one plug position for each frequency? Is this important?

Questions (Answer clearly and completely).

1. How is the distance between adjacent nodes related to the wavelength?

2 Can a sound wave reflect back from an open (unplugged) tube end?

3. As the plug is moved from one standing wave position to another, how does the wave frequency change? How does the wave wavelength change? How does the wave speed change?

4. What value do you determine experimentally for the wave speed? You can look up the theoretical value at room temperature, or I'll provide it for you. What is the percent difference of the experimental value from the theoretical value?

5. What value do you determine experimentally for the end correction? What is the percent difference of this value from the theoretical value? Again, you can try to find this value or I can give it to you.

6. If the experiment were to be redone at the same frequency with the speaker held firmly against the end of the tube, what would change: the locations of the plug at resonance? the internodal distance? the wave speed in the tube?

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