Name: ____________________

Partner(s): ____________________

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Date: ____________________

Resonance and the Speed of Sound

1. Purpose

Sound is a common type of mechanical wave that can be heard but not seen. In today's lab, you will investigate the nature of sound waves by exploring the phenomena of resonance and the propagation of sound waves in a tube.

2. Introduction

In today's lab, you will be studying the properties of sound waves using the resonance tube apparatus shown in Figure 1.

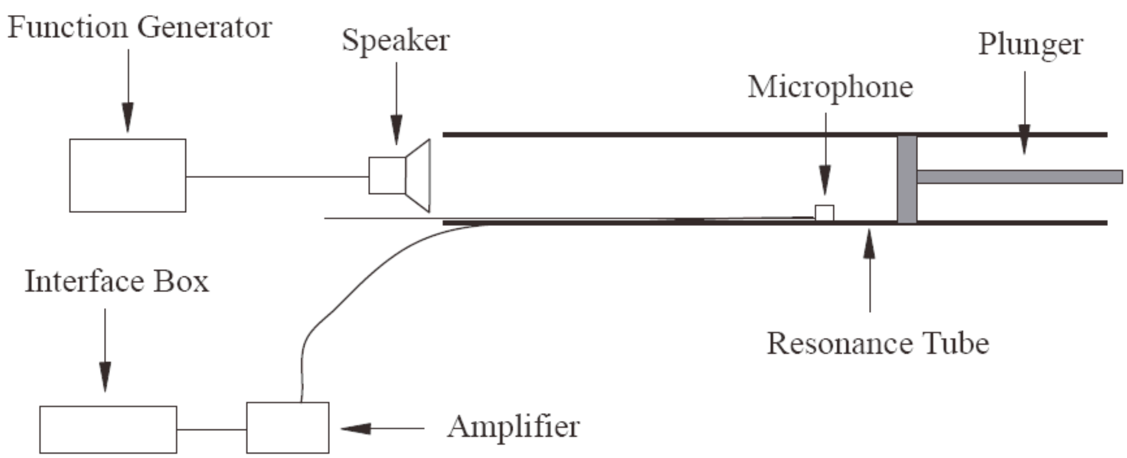


Figure 1

Sound waves are produced using a speaker that is located at one end of the tube. A microphone is used to probe the sound wave in a tube, whose length can be varied by moving the plunger.

The function generator will be used to control the speaker. Consult your TA's or lab instructor in how to use your function generator. The microphone should be connected to a BNC (Berkeley Nuclear Corp.) plug. The BNC plug should then be connected to a BNC to banana plug adapter, and then into the voltage probe to "CHANNEL A" of the interface box.

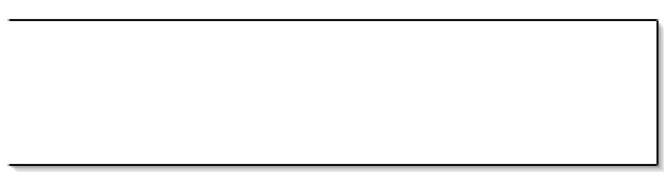
Before we begin taking data, let's first examine what we will be looking at and try to determine what we will expect to see. When a speaker vibrates near a tube, there are certain frequencies at which the tube will amplify the sound from the speaker. This happens because the sound wave propagates down the tube and is reflected back and forth from each end in the tube. As the wave travels away from the speaker, it will encounter the wave that has been reflected from the end of the tube. When this happens, you observe the sum of the two waves; this is known as superposition.

If the length of the tube and the wavelength of the sound wave are such that all of the waves are in phase with each other, a standing wave pattern is formed. This is known as a resonance mode for the tube and the frequencies at which resonance occurs are called resonant frequencies. At these frequencies, the sound will appear "louder". When the waves are out of phase, they will partially cancel each other, resulting in destructive interference. If the two waves are exactly out of phase, they will cancel completely. In this lab, we will examine standing waves for a tube that is open at one end (near the speaker) and standing waves for a tube that is closed at both ends.

When a standing wave is formed, the amplitude of the wave will vary as you move down the tube. The locations where the amplitude is a maximum are anti-nodes and the locations where the amplitude is a minimum are nodes.

For the tube that is closed at one end, where will the nodes and anti-nodes be? How about a tube that is closed at both ends?

The frequencies that produce standing waves for a given tube length are referred to as harmonics. The lowest frequency that produces a standing wave is known as the fundamental frequency, or first harmonic. On the figure below, draw what you expect the first few harmonics to look like for a tube that is closed at one end.



- ❖ From your sketch, is there a relationship between the length of the tube and the wavelength of the standing wave? What is it?

- On the figure below, draw what you expect the first few harmonics to look like for a tube that is closed at both ends.

- From your sketch, is there a relationship between the length of the tube and the wavelength of the standing wave? What is it?

3. *Procedure*

3.1 Qualitative Examination of Standing Waves

- Create a tube that is closed at one end by inserting the plunger and leaving a small gap, ~1-cm, between the speaker and the resonance tube.
- Set the plunger at the 80-cm mark on the tape inside the resonance tube. You can vary the length of the tube by moving the plunger in and out.
- Set the frequency of the speaker to 1000-Hz or a frequency different from other groups. As you vary the length of the tube, use a microphone mounted at the end of the tube to measure the amplitude of the sound wave.
- Record the lengths of the tube when you have relative maxima and minima.
- Record as many of the frequencies corresponding to relative maxima and minima as possible.

> As you do this, keep in mind that a microphone is a pressure transducer. This means that when the microphone produces a maximum signal, you are actually looking at a pressure anti-node. Similarly, a minimum signal corresponds to a pressure node. You do not need to amplify the signal from the microphone at this point.

- To view signals as they change in time, use the oscilloscope feature in Data Studio. Drag the "***Scope***" icon onto the measured voltage from the microphone. The scope window will look exactly the same as what is seen in Figure 2 if you ignore the signals. The signal measured by the microphone will be the only one on the "Scope".

- Before you measure, you need to set the sample rate for the voltage sensor to 40,000-Hz, the voltage scale to roughly 0.02-V, and the gain to 100. If you need assistance, consult your TA's or lab instructor.

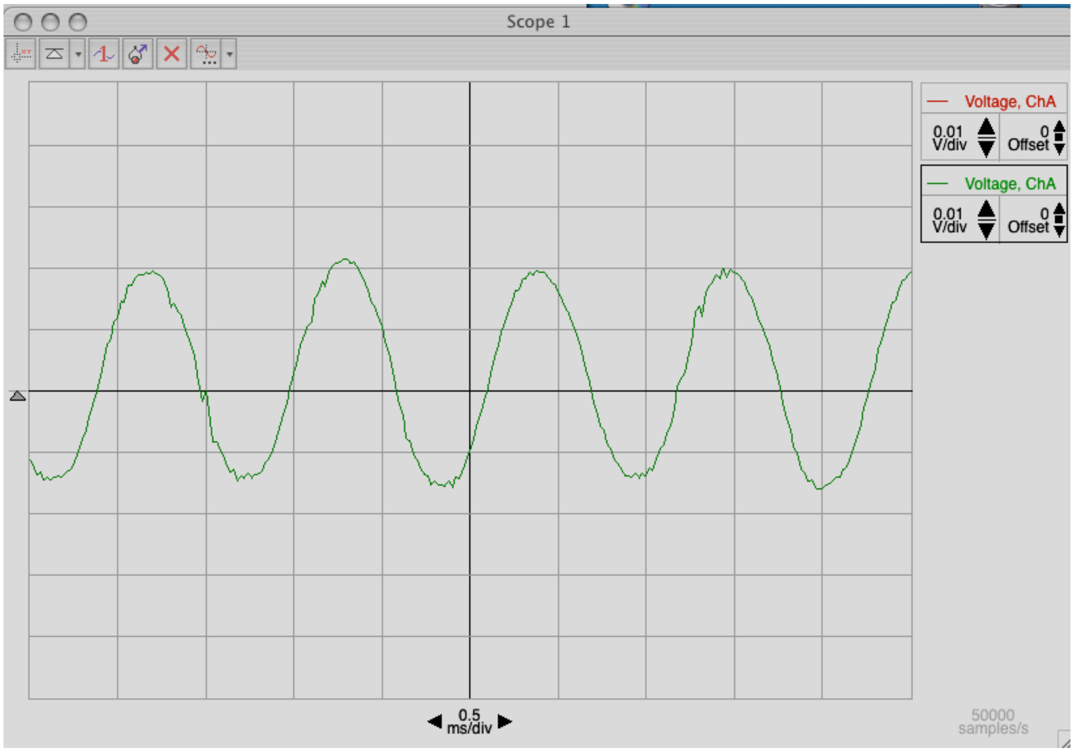


Figure 2

Frequency: ______Hz

Trial	Length ( )	Maxima/Minima
1		
2		
3		
4		
5		

Trial	Length ( )	Maxima/Minima
6		
7		
8		
9		
10		

- Is there some sort of relationship between the length of the tube and the occurrence of the relative maxima and minima? How does this compare with your expectations?

Let's now repeat this experiment using a tube that is closed at both ends. Your data can be recorded below.

Frequency: _____Hz_

Trial	Length ( )	Maxima/Minima
1		
2		
3		
4		
5		

Trial	Length ( )	Maxima/Minima
6		
7		
8		
9		
10		

- ❖ Is there some sort of relationship between the length of the tube and the occurrence of the relative maxima and minima? How does this compare with your expectations?

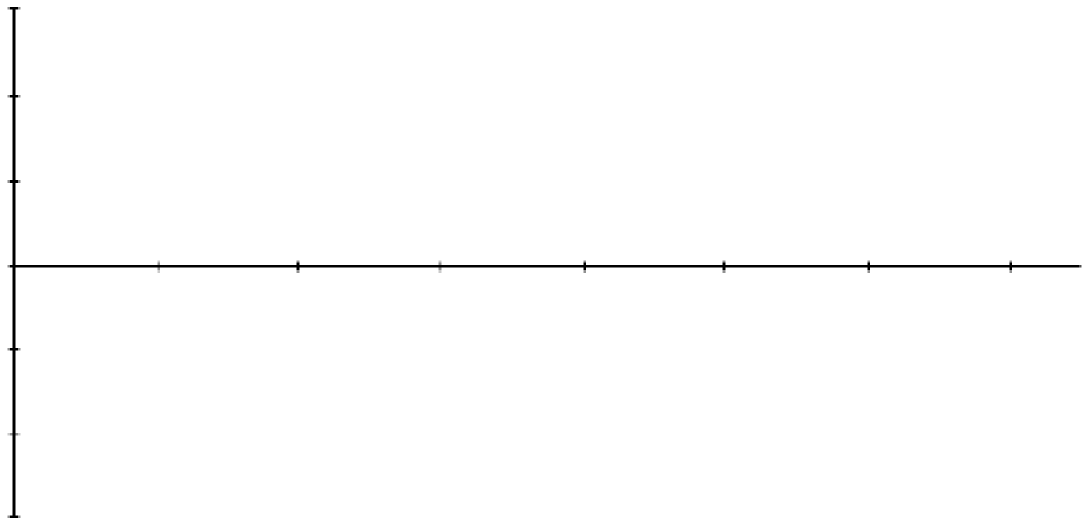
- ❖ How does it compare to what you saw with the tube that is closed at one end.

3.2 Examining the structure of standing waves

Let's now examine the structure of the standing waves.

- ➢ To do this, select one of the resonance configurations that you used in Part 1.
- ➢ By sliding the microphone down the resonance tube, you can probe the structure of the standing wave.
- ➢ The microphone should initially be at the end of the tube near the speaker.
- ➢ Once you have ***turned the microphone on***, move the microphone through the tube.
- ➢ Record the amplitude of the wave as a function of position as you move it through the tube. Before you measure the amplitude, you need to set the sample rate for the voltage sensor to 40,000-Hz, the voltage scale to roughly 0.02-V, and the gain to 10.
- ➢ Plot the amplitude as a function of position in the air column. Be sure to have many

data points so that you have a feel for the structure of the wave.



❖ Does the structure of the standing wave agree with your expectations?

❖ What is the wavelength of the standing wave?

➢ At this point, you know the frequency of the standing wave, because we set this using the signal generator. Additionally, you know the wavelength of the standing wave because we just measured it. This means that you can calculate the speed of sound. After describing how you would calculate the speed of sound below, calculate the speed.

If you look in your textbook, you will find that the speed of sound in air depends on temperature, *T* (in *Celsius*), of the air and is given by Equation (1).

$$v_{sound} = 331 + .6T \qquad (1)$$

❖ How does your value compare with the expected value?

3.3 Measuring the speed of sound

At this point, let's measure the speed of sound directly. We can do this by creating a pulse of sound and measure how long it takes the pulse to travel down the tube and back. A sound pulse can be created using a square wave with a frequency of 10 Hz. When you turn the signal generator on, you should hear a clicking sound.

From your previous work, you have noticed that sound travels distances over a short amount of time. As such, we would like to make the distance that it travels as large as possible. Thus the plunger should be as far from the speaker as possible.

As a single sound pulse passes the microphone, you will see a signal similar to what is seen in Figure 3. This ringing is caused by the sudden voltage increase of the square wave applied to the speaker. (Perhaps this is damped oscillatory motion, hmm…)

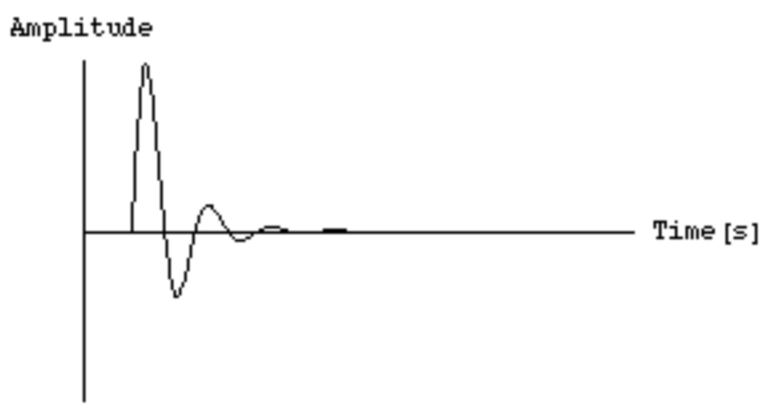
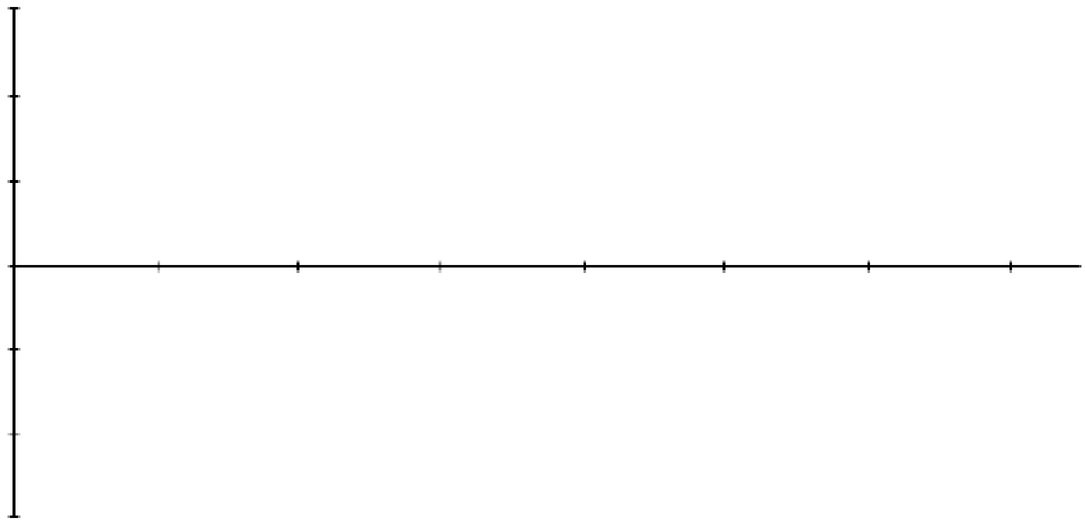


Figure 3

When this pulse reaches the end of the tube it will be reflected, creating an echo. What will the reflected pulse look like?

The echo will travel back to the speaker and be detected by the microphone. It will then be reflected from the speaker and travel back down the tube. This process will continue, resulting in observing a series of pulses. As the wave travels, the intensity will decrease. Based on what you have just worked through, what will you see as you plot the voltage measured by the microphone as a function of time?



Because all of this happens very quickly, we will need to take a lot of data over a small amount of time. You can tell the computer how much data to take, so this will not be a problem. However, at the same time, we don't want to be overwhelmed with a huge amount of data. Fortunately, we can also tell the computer when to start taking data. To do this, you first need to delete any data that you may currently have saved.

- To change how frequently data is taken, you need to change the "*Sample Rate*" such that you can see the reflected pulses. Increase this value to no more than 40000-Hz.
- To tell the computer when to start taking data, select "Sampling Options" under the "Experiment" menu. You should see the window shown in Figure 4.
- Select Channel "*Output Voltage"* and set the value to 0.02V *"Falls Below"*, as seen above. This causes the computer to start taking data once the speaker stops creating a pulse.
- To tell the computer when to stop taking data, select "Automatic Stop" under the "Experiment Setup" menu. You should see the window shown in Figure 5. Set the time to an appropriate value.
- To perform your measurement, graph your data as a function of time using the graph feature. Do not use the oscilloscope feature.
- Before you start your measurement, you need check that the sample rate for the voltage sensor to 40,000-Hz, the voltage scale to roughly 0.02-V, and the gain to 100.

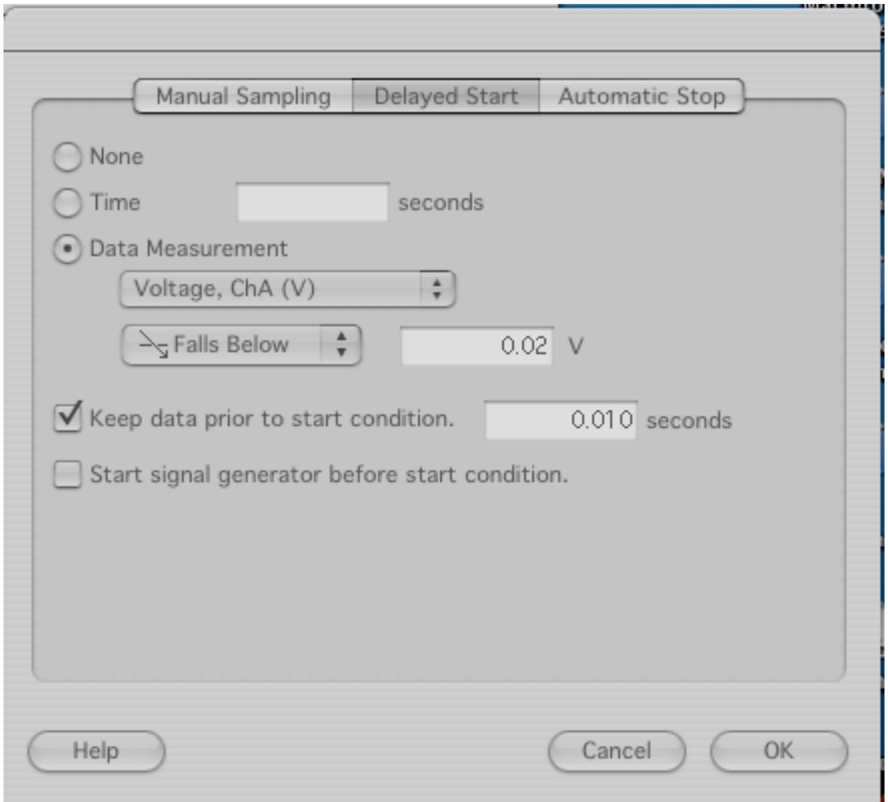


Figure 4

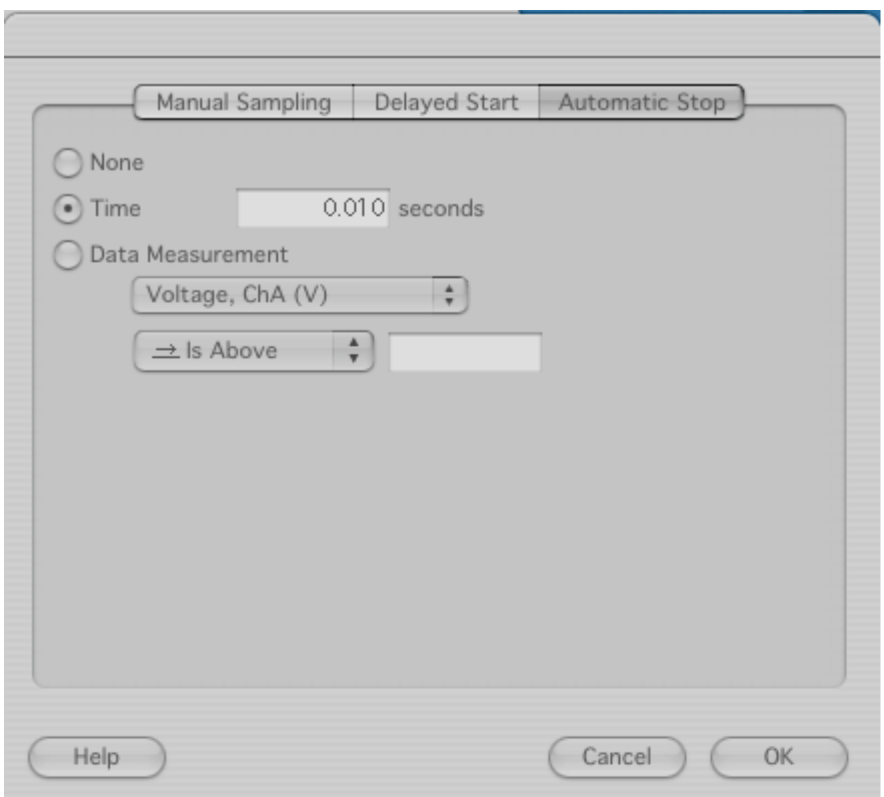
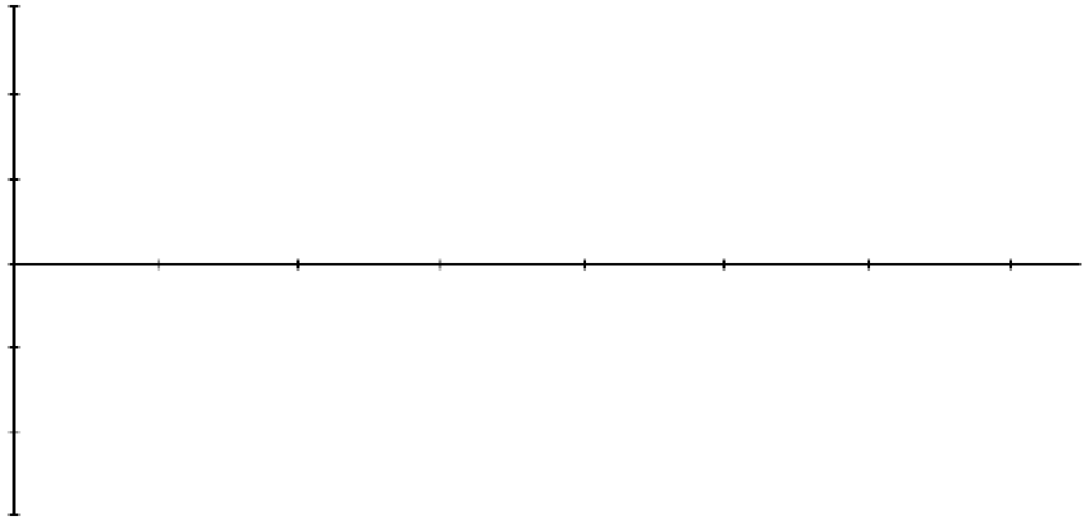


Figure 5

➢ Let’s take the data. In the space below, sketch what the microphone measures.



❖ How far does the sound wave travel in between each pulse?

➢ In the table below, record the distance traveled and the time taken to travel these distances.

Time ( )	Distance Traveled ( )

❖ Do these results agree with your expectations? Discuss.

- Using your favorite plotting routine, plot the distance traveled by the wave as a function of time. Be sure to attach your plot to the lab.

4. Questions

i. Is the speed of sound constant? Justify your answer using your data.

ii. What is the speed of sound? Explain how you found this value.

iii. How does this value compare with your previous result? With the theoretical expectation?

5. Initiative

6. Conclusions