Lab-05:
26-Feb-24

Objective: Measure the sound amplitude profile, P(x), of the first harmonic (fundamental) inside the tube.

Determine the speed of sound using the frequencies of harmonics in an open tube.

Procedure:

1. Refer to Figure 1 for the initial setup of the speaker and microphone.
2. Connect the speaker to the function generator and the microphone to the oscilloscope, as shown in Figure 2 .
3. Perform a sweep with the function generator at both high and low frequencies without the tube.
4. Observe the oscilloscope for changes in wave amplitude and period (Figure 3 for high frequencies and Figure 4 for low frequencies).
5. Place the tube around the microphone as depicted in Figure 5 .
6. With the tube in place, observe the changes in the oscilloscope readings (Figure 6). You should notice clearer signals due to reduced external interference.
7. Continue to adjust the function generator's frequency until you observe a significant spike in amplitude on the oscilloscope. This spike represents the resonance frequency corresponding to the first harmonic.
8. Use the oscilloscope to measure the frequency (f) at the first harmonic.
9. Measure the length of the tube (L) using the ruler or meter stick, as recorded in the materials table.
10. Apply the formula $v = f\lambda$, where v is the speed of sound, f is the frequency measured, and λ is the wavelength.
11. For the first harmonic in an open tube, the wavelength λ is twice the length of the tube (since the tube length is half a wavelength for the fundamental frequency). Therefore, $\lambda = 2L$.
12. Substitute the measured frequency and calculated wavelength into the formula to find the speed of sound: $v = f2\frac{L}{n}$.

Equations:

1. $v = f\lambda$
   This equation relates speed of sound v, to frequency f, and wavelength λ

2. $v = 2f\frac{L}{n}$

This equation relates the harmonic of the pipe n, to the length of the pipe for the equivalent harmonic L, to frequency f,

Important to know that pressure is directly proportional to amplitude.

Test and Try:

Mapping the pressure distribution curve by comparing displacement from the speaker versus the amplitude.

Finding Fundamental Frequency $F1$

Table 1. Amplitude of the voltage versus distance from the speaker for the fundamental

Distance in meters (m)	Uncertainty of distance in meters (m)	Voltage in volts (V)	Uncertainty of voltage in volts (V)
0	0.0005	0	~~0.5~~ 0.05 (Edit to change uncertainty to 0.05V by adjusting the resolution on the oscilloscope)
0.05	0.0005	0.258	0.05
0.1	0.0005	0.589	0.05
0.15	0.0005	0.702	0.05
0.2	0.0005	0.890	0.05
0.25	0.0005	0.923	0.05
0.3	0.0005	0.900	0.05
0.35	0.0005	0.810	0.05
0.4	0.0005	0.641	0.05
0.45	0.0005	0.510	0.05
0.5	0.0005	0.160	0.05

Figure 1: Distribution graph for the fundamental frequency

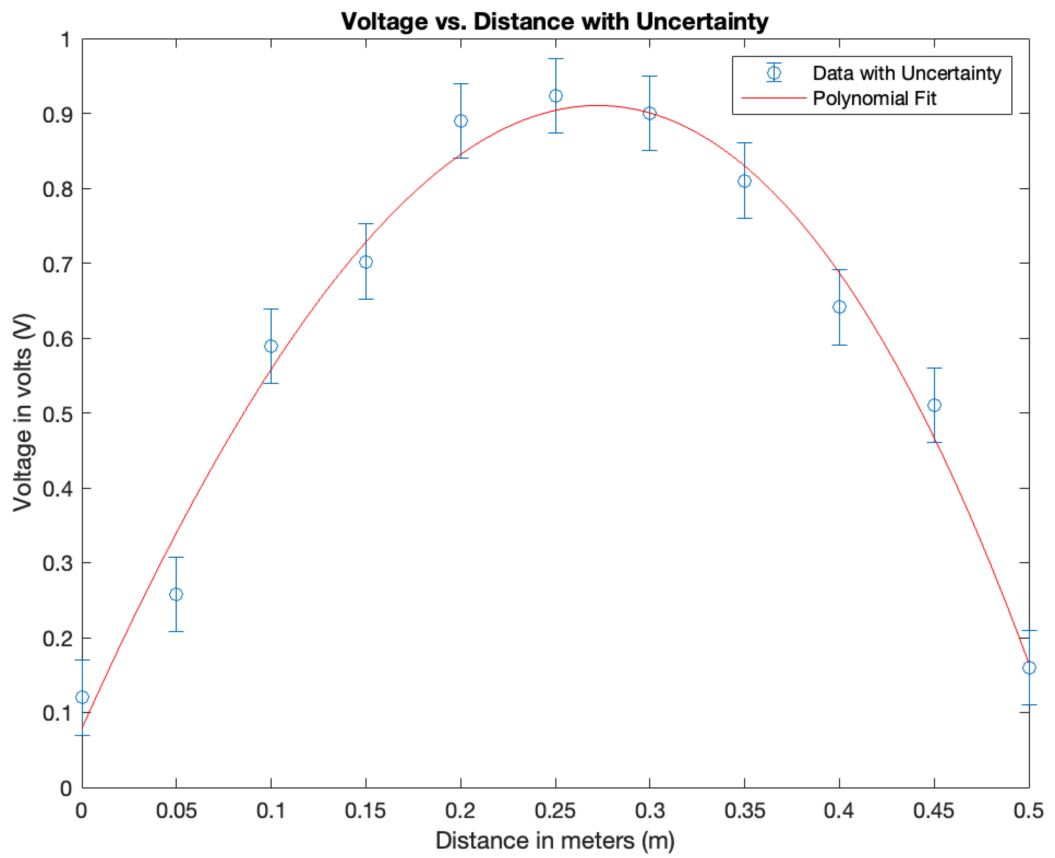
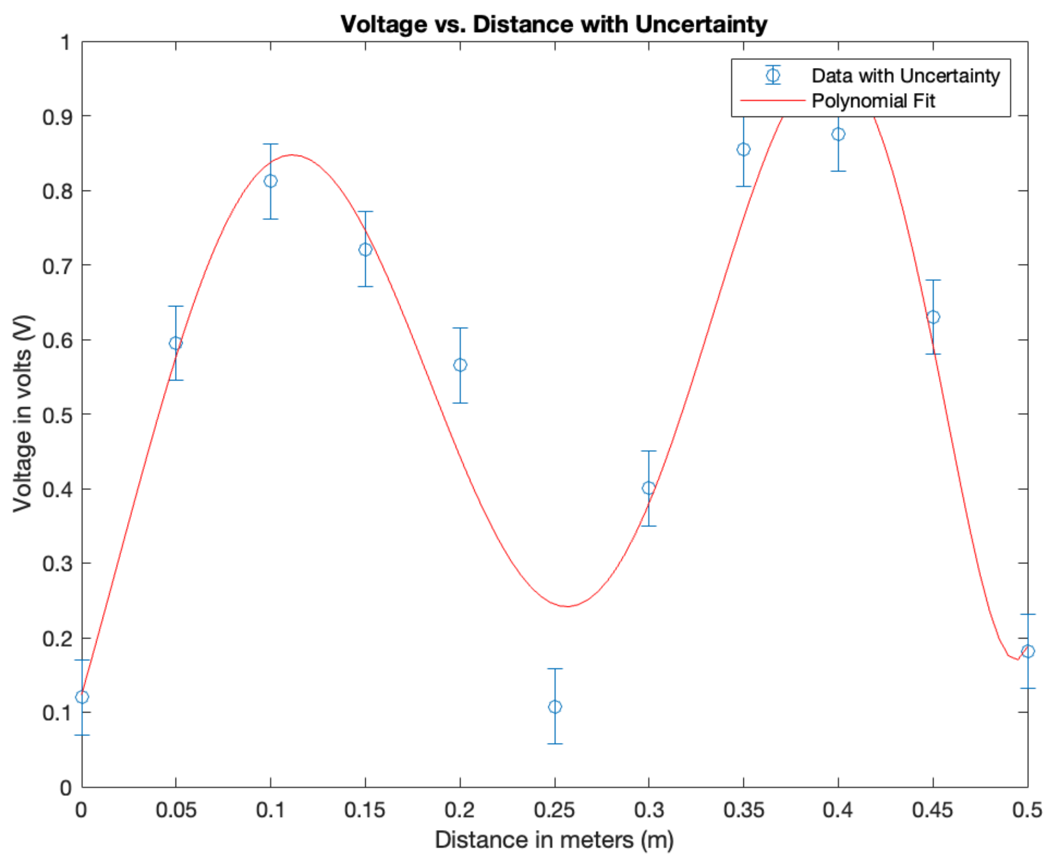


Table 2. Amplitude of the voltage versus distance from the speaker for the second harmonic

Distance in meters (m)	Uncertainty of distance in meters (m)	Voltage in volts (V)	Uncertainty of voltage in volts (V)
0	0.0005	0.120	0.05
0.05	0.0005	0.595	0.05
0.1	0.0005	0.812	0.05
0.15	0.0005	0.721	0.05
0.2	0.0005	0.565	0.05
0.25	0.0005	0.108	0.05

0.3	0.0005	0.400	0.05
0.35	0.0005	0.855	0.05
0.4	0.0005	0.875	0.05
0.45	0.0005	0.630	0.05
0.5	0.0005	0.182	0.05

Figure 2: Distribution graph for the second harmonic



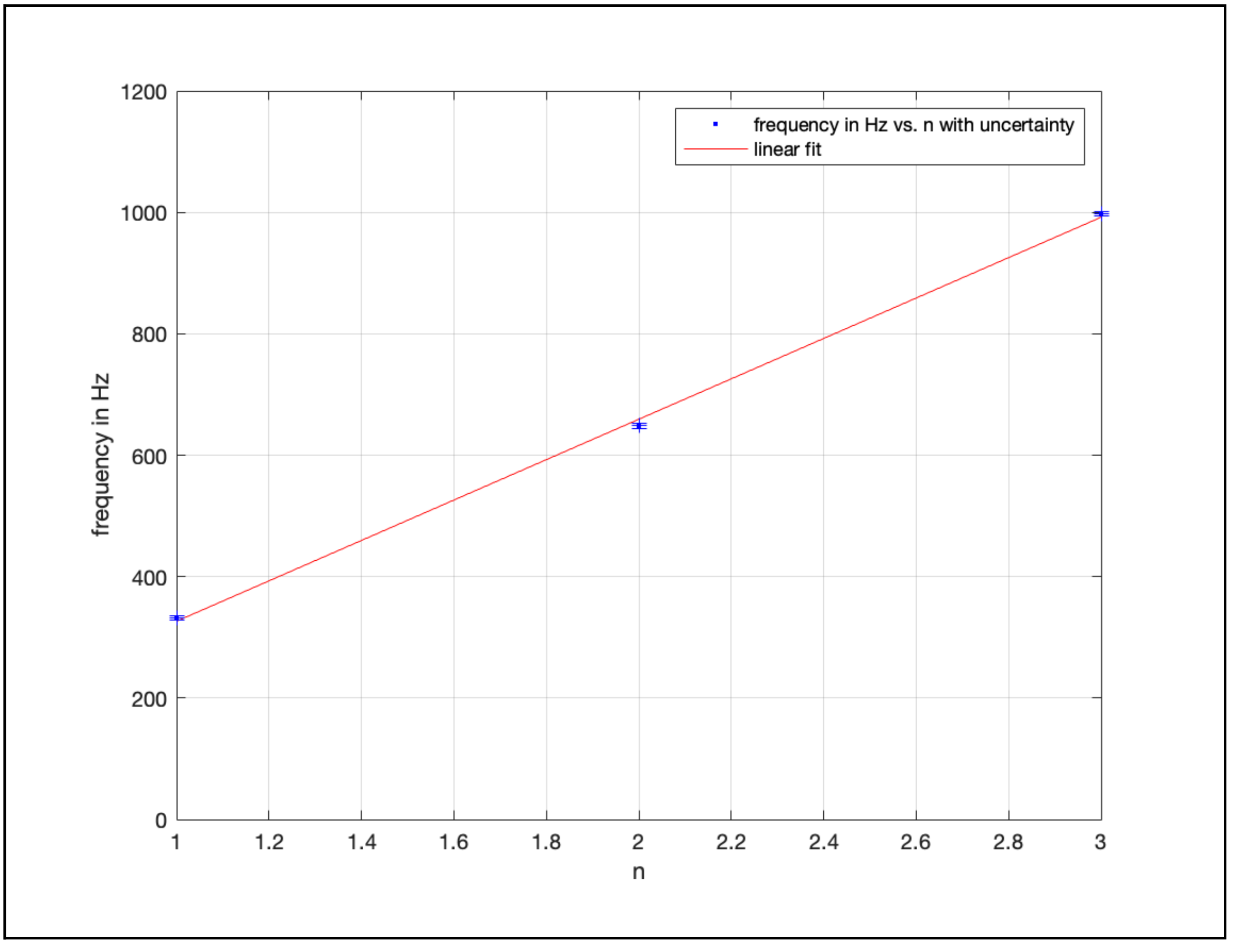
Now one may notice that this graph does not look like a typical second harmonic graph. This is because we are unable to see negative variables in the oscilloscope. Therefore, this is actually the absolute value of the voltage.

Calculating Speed of Sound:

Table 3. Frequencies when compared to different harmonics

Harmonic number (n)	Frequency in hertz (Hz)	Uncertainty of frequency in hertz (Hz)
1	331.8	4
2	648.6	4
3	997.3	4

Figure 3. Frequencies when compared to the harmonics



Calculations:

$n=1$ 331.8 Hz $\pm$ 4 Hz $m = 332.75$ $L = 0.50m$

$n=2$ 648.6 Hz $\pm$ 4 Hz $\delta m = 5.1449$ $\delta L = 0.0005m$

$n=3$ 997.3 Hz $\pm$ 4 Hz

Taking equation 2

$V = 2f \frac{L}{n}$ $v = (332.75)(2(0.5))$

$\frac{L}{n}$ is slope $= 332.75 m/s$

Uncertainty

$$\frac{\delta v}{v} = \sqrt{\left(\frac{5.1449}{332.75}\right)^2 + \left(\frac{0.0005}{0.50}\right)^2}$$

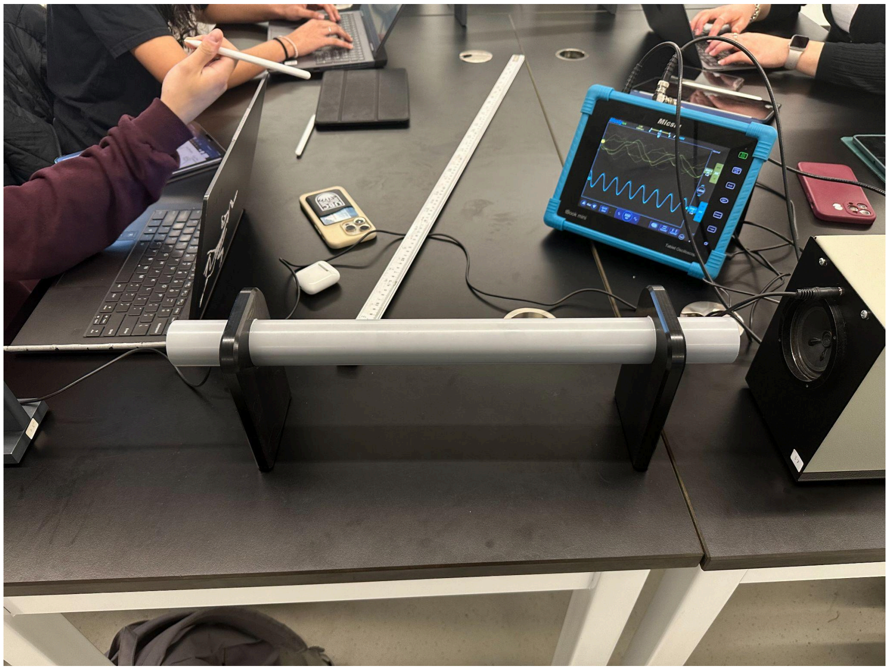
$\delta v = 5.155$

Result:

Speed of sound = 333m/s $\pm$ 5m/s

Diagram

Figure 4. Diagram of our experimentation set up



Revised Procedure

1. Setup of the Microphone and Speaker
1.1. Carefully insert the microphone entirely into the pipe. Position it as close as possible to the speaker without any physical contact. This step ensures accurate sound capture by minimizing external noise and reflections.

2. Connecting the Equipment
2.1. Establish connections for signal monitoring and generation:
    2.1.1. Connect a wire from the scope port on the speaker to the first channel (channel one) on the oscilloscope. This setup allows you to visualize the speaker's output signal.
    2.1.2. Attach a wire from the sine-in port on the speaker to the second channel on the oscilloscope, and then from channel one on the oscilloscope to the function generator. This configuration is crucial for directing the generated signal through the system and into the speaker.

3. Identifying Fundamental Frequency
3.1. Power on the function generator and begin to slowly adjust the frequency setting.
3.2. Keep an eye on the oscilloscope's display, watching for the waveform to stabilize at its peak amplitude without fluctuation.
3.3. Once the wave stabilizes, note down the frequency displayed on the function generator as the fundamental frequency. Pay attention to the wave's fluctuations around this point to estimate the uncertainty in your measurement.

4. Recording Amplitudes
4.1. With the fundamental frequency established, use the oscilloscope's cursor functions to measure and record the amplitude of the wave. This involves noting the change in Y-value (voltage) at the peak of the waveform.

5. Adjusting Pipe Distance
5.1. Alter the length of the pipe incrementally by 0.05m (5cm) to explore how it affects the amplitude of the sound wave captured by the oscilloscope.

6. Amplitude Data Collection
6.1. Repeat the amplitude recording process for each new pipe length setting, ensuring you do this process multiple times to gather a robust set of data points, totaling a multitude of different amplitudes.

7. Data Visualization
7.1. Input your amplitude and corresponding pipe length data into Excel to create a scatter plot. This graph will illustrate the relationship between displacement (pipe length adjustment) and the observed voltage (amplitude).

8. Measuring Pipe Length
8.1. Use a measuring tool to accurately determine the full length of the pipe. This measurement is essential for calculations related to the speed of sound within the pipe.

9. Harmonic Frequency Measurement
9.1. Utilize the oscilloscope to measure the frequencies associated with the first through fourth harmonics of the sound wave. This is done by observing and recording the frequencies at which distinct nodes (points of minimal amplitude) occur.

10. Calculating Sound Speed with MATLAB
10.1. Compile the gathered frequency and length data into a table suitable for MATLAB analysis.

10.2. Input this data into MATLAB and apply a gradient function to determine the speed of sound based on your measurements. This process involves analyzing the slope of the relationship between frequency and harmonic order to calculate the sound's velocity.

The revised explanation significantly enhances the original procedure by providing detailed insights into each step of the experiment aimed at determining the speed of sound in a pipe. It clarifies the setup and connection of the equipment, the rationale behind the frequency adjustments, and the method for capturing and analyzing sound wave data. By elaborating on the technical aspects, such as the importance of microphone placement and the interpretation of oscilloscope readings, the revised version offers a more comprehensive guide to the experiment. This includes an improved explanation of how to measure and calculate the speed of sound, making the procedure more accessible and understandable for readers, thus facilitating a smoother experimental process.

Reflection:

The final result of the speed of sound experiment, 332.75 m/s, closely aligns with the expected value of approximately 343 m/s at room temperature, indicating the procedure's success and consistency with other groups' findings. The procedure was effective, utilizing a systematic approach with an oscilloscope and function generator. The reported uncertainty of ±5 meters per second is reasonable, considering the practical limitations and environmental factors.

Improvements for future iterations could include more controlled environmental conditions, the use of more precise measuring instruments, and calibration of equipment before experiments. Additionally, exploring the impact of tubes of different lengths or materials and applying statistical analysis to increase measurement accuracy could refine the results further. Overall, the experiment was successful, with reasonable accuracy and reliability, suggesting the methodology is robust with acceptable uncertainty levels.