# PHY1002 Physics Laboratory (2022-2023 Term 2)
## Short Report

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### Experiment 8. Resonance Air Column

1. Make a graph of Air Column Length versus Inverse Frequency ($L$ vs. $\frac{1}{f}$ ) in experiment 1. Note that the horizontal axis (x-axis) is the inverse of frequency. Analyze why the y-intercept isn't zero.

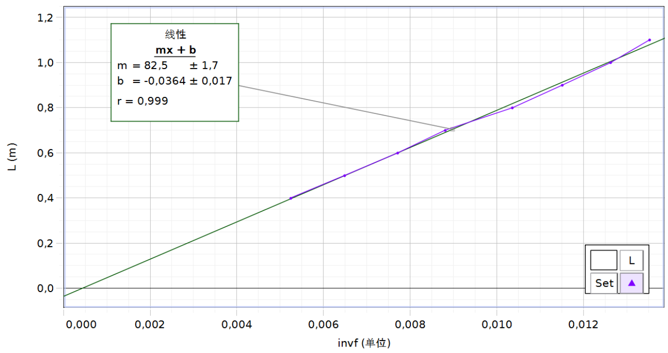


Figure 1: Air Column Length ($L$) vs. Inverse Frequency ($\frac{1}{f}$)

As shown, the collected data in the graph fits well in a straight line (for a linear function). However, the y-intercept of the graph is not zero, which can be attributed to various factors.

(a) End correction
When a sound wave reaches the open end of the air column, it does not abruptly stop but instead extends a little beyond the end of the tube. This causes the effective length of the air column to be slightly longer than the physical length.

(b) Measurement errors
The experimental setup and the measurements taken during the experiment may have inherent errors. These errors could be due to incorrect measurements, improper calibration of equipment, or uncertainties in the frequency and length measurements.

(c) Air temperature and humidity
The speed of sound in air depends on the temperature and humidity, both of which can affect the resonance frequency of the air column. If the temperature and humidity are not constant throughout the experiment, the relationship between $L$ and $\frac{1}{f}$ might be affected.

These factors, either alone or in combination, can lead to a non-zero y-intercept in the $L$ vs. $\frac{1}{f}$ graph in a resonance air column experiment.

2. In experiment 1, calculate the wavelength from the distance between the nodes. From this wavelength and the frequency of the Signal Generator, calculate the speed of sound.

When the frequency is set to 230 $Hz$, by adjusting the tube length, two nodes are found to have the position on $P_1 = 33.1 \pm 0.05\ cm$ and $P_2 = 107.9 \pm 0.05\ cm$.

In this experiment, the distance between the nodes is equal to half the wavelength in an open tube, as the air column represents half of the complete wave. Therefore, the wavelength ($\lambda$) is equal to twice the air column length ($\lambda = 2L$).

$\implies \lambda = 2L = 2(P_2 - P_1) = 2 \times (107.9 - 33.1) \times 10^{-2} m = 1.496 \pm 0.0020\ m$

Once the wavelength is calculated, we can use the formula $v = \lambda f$ to find the speed of sound, where $v$ is the speed of sound, and $f$ is the frequency of the signal generator. By performing this calculation for various frequencies and their corresponding air column lengths, we obtain an average value for the speed of sound in the medium.

$\implies v = \lambda f = (1.496 \pm 0.0020\ m) \times 230 Hz = 344.08 \pm 0.460 \frac{m}{s}$

It is important to note that the calculated speed of sound may differ from the theoretical value due to experimental errors and environmental factors. To evaluate the accuracy of the experiment, we can compare the experimental value to the theoretical value. The relative error is given by $\frac{|344.08-343|}{343} \times 100\% \approx 0.315\%$

3. In experiment 2, What should the ratio of the open-tube frequency to the closed-tube frequency be? Why? Calculate this ratio from your experimental data and figure the cause of difference (or state that there's no difference)?

Theoretically, the ratio of the open-tube frequency to the closed-tube frequency is given by:

$$\frac{f_{open}}{f_{closed}} = \frac{\frac{v}{\lambda_{open}}}{\frac{v}{\lambda_{closed}}} = \frac{\lambda_{closed}}{\lambda_{open}} = \frac{4L}{2L} = \frac{2}{1}$$

This is because an open tube has both ends free to vibrate, allowing for the formation of standing waves with antinodes at both ends. In contrast, a closed tube has only one end free to vibrate, with a node at the closed end and an antinode at the open end. Consequently, the closed-tube setup effectively doubles the length of the air column compared to the open-tube setup.

When calculating the open-tube to closed-tube frequency ratio from experimental data, differences from the theoretical 2 : 1 ratio may arise. These differences can be attributed to various factors, such as experimental errors, equipment limitations, or environmental conditions. The calculation from the experimental data is given by:

$$\frac{f_{open}}{f_{closed}} = \frac{(50+90.013)}{140-69.261} \approx 1.979$$

With the relative error calculated to be $\frac{|2-1.979|}{2} \approx 1.050\%$, we may conclude that there is no significant difference observed between the experimental and theoretical frequency ratios. This suggests that the experiment was conducted quite accurate and with minimal errors.

## Appendix

Attach the figure in tab Chart 2 in Capstone (You should write a clear and detailed caption for the figure), explain the relationship between the time in x-axis and frequency.

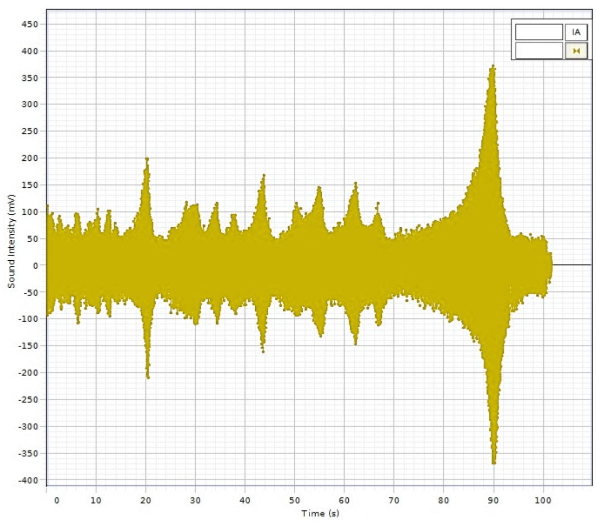


Figure 2: Frequency Peak of the First Harmonic of an Open Tube

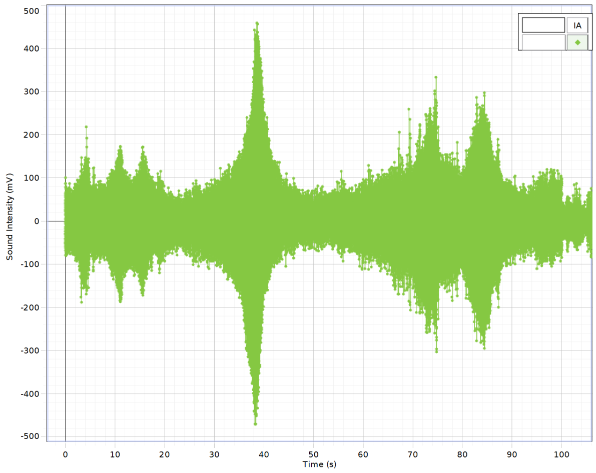


Figure 3: Frequency Peak of the Second Harmonic of an Open Tube

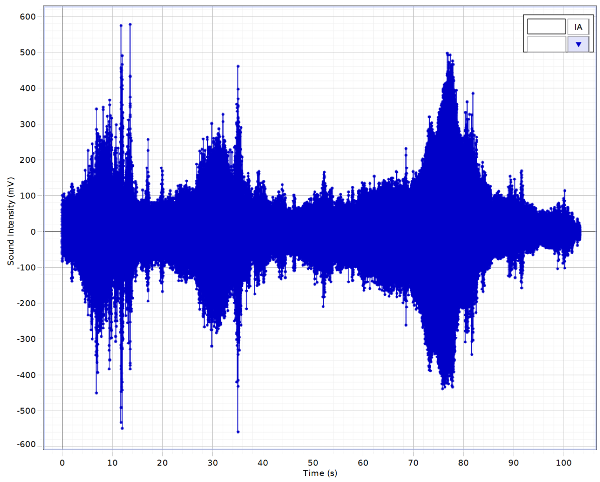


Figure 4: Frequency Peak of the Third Harmonic of an Open Tube

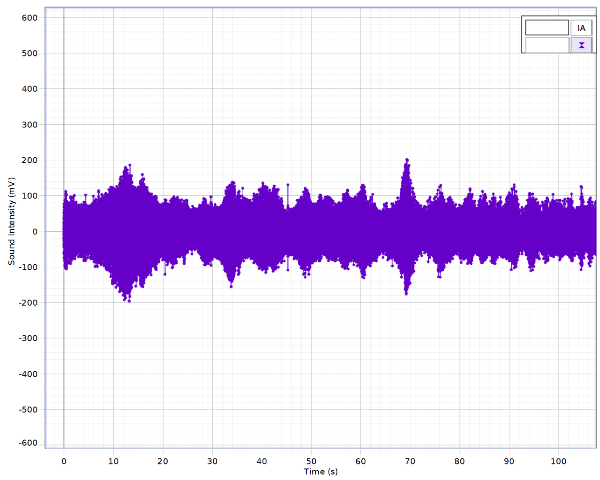


Figure 5: Frequency Peak of the First Harmonic of a Closed Tube

The first three attached figures have the x-axis representing time in seconds, with each unit corresponding to an increase in the frequency of $1Hz$, and the y-axis represents the sound intensity in arbitrary units (a.u.). These three plots display the relationship between time and frequency for open tubes at various frequency ranges:

- Figure 2 has a frequency variable that varies from $50Hz$ to $150Hz$,
- Figure 3 has a frequency variable that varies from $240Hz$ to $340Hz$, and
- Figure 4 has a frequency variable that varies from $340Hz$ to $440Hz$.

The last attached figure also has the x-axis representing time in seconds; however, each unit corresponds to a decrease in the frequency of $1Hz$, and the y-axis represents the sound intensity in arbitrary units (a.u.). The Figure 5 plot displays the relationship between time and frequency for a closed tube that has a frequency variable that varies from $140Hz$ to $40Hz$.

All figures demonstrate the resonant frequencies of each tube configuration, which correspond to peaks in sound intensity, and illustrate the effect of tube closure on the observed frequency spectrum.

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