# Lab 4: Sound Waves - Phys223 - Thursday (Ellis Roe)

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# Purpose

The end goal of each of the exercises in this week's lab was to obtain an estimate for the speed of sound. Exercise one used an adjustable tube (changing height of water level) to obtain the resonance measurements and thus the wavelength of sound. Using the wavelength, we can find the speed of sound through air. In the second exercise, we made direct measuremnts of sound using a microphone and an oscilloscope.

# Procedure

Exercise one was split in to two parts. First of which was to measure resonance distances of the speed of sound in a tube of water. We start with a speaker above the tube generating a wave with constant frequency. We slowly lower the water level until we here a noticeable change in the intensity of sound (also noting a spike on the oscilloscope). We take a measurement of this location and adjust for spacing between the speaker. Repeating this, we obtain the first few resonance distances for the tube. Using these values, we can obtain an average wavelength, and since we know the freqency, the speed of sound.

In the second part of exercise one, we use the Data Studio software to measure the FFT of the resulting sound wave after hitting a hollow plastic tube in front of a microphone. Noting the harmonic frequencies on the FFT, we can find the resonance locations. We find the speed of sound in the same way as part one.

Exercise two is broken in to three methods. Each approaches the calculation of the speed of sound in a different way. Method one uses the basic chop setting on the oscilloscope to view both input channels at the same time. We adjust the speaker distance slowly to measure one full wavelength. Since the frequency is set beforehand, we can calculate the speed of sound using this wavelength.

Method two uses the x-y setting on the oscilloscope to produce a Lissajous figure. By adjusting the speaker distance we can change the shape of the figure, and if we measure the distance between two identical figures, we get the wavelength. We calculate the speed of sound in the same way as method 1.

Finally, method 3 directly measures the time a sound pulse takes to travel a known distance. At this point we hook up a pulse generator to the oscillator and measure the time difference between pulses on the screen. We start with the speaker at some fixed point, noting the x offset, then shift the microphone as far away as possible. Using the oscilloscope, we measure the time difference between these two points. Dividing distance by time gives us the velocity.

# Data

In exercise one, we measure the resonant frequencies experimentally, but also calculate them theoretically. We list both values here and show the difference between them. We label $L^P$ the predicted length and $L^M$ as the measured length. Using $L^P$ we calculate the wavelength, $\lambda$.

| $L^P$ (cm) | $L^M$ (cm) | $\lambda$ (cm) |
|---|---|---|
| 8.5 | $8.7 \pm 0.1$ | 34.8 |
| 25.5 | $25.7 \pm 0.1$ | 34.27 |
| 42.5 | $42.8 \pm 0.1$ | 34.24 |
| 59.5 | $60.5 \pm 0.1$ | 34.57 |

Here we calculate $\bar{\lambda}$ as the average $\lambda$ in the table above:

$$\bar{\lambda} = \frac{\lambda_1^M + \lambda_2^M + \lambda_3^M + \lambda_4^M}{4} = 34.47\text{cm}$$

Using the equation $v = \bar{\lambda} f$ we calculate the speed of sound using frequency of 1000 Hz:

$$v_{\text{sound}} = \bar{\lambda} f = (34.7\text{cm})(1000\text{Hz}) = 344.7 \left(\frac{\text{m}}{\text{s}}\right)$$

For part two, we obtained the following frequencies for the first three harmonics: 351 Hz, 718 Hz, and 1006 Hz. Each measurement has an error factor of ± 1 Hz. We call the length $L_0$ which is equal to 46.25cm. Below are the calculations used to determine the speed of sound using each harmonic frequency:

$$2L_0 = \lambda_1 = 92.5\text{cm}$$

$$\begin{aligned} v_{\text{sound}} &= \lambda_1 f_1 \\ &= (92.5\,\text{cm})(351\,\text{Hz}) \\ &= 324\,{}^{\text{m}}\!/\!_{\text{s}} \end{aligned}$$

$$L_0 = \lambda_2 = 46.25\,\text{cm}$$

$$\begin{aligned} v_{\text{sound}} &= \lambda_2 f_2 \\ &= (46.25\,\text{cm})(718\,\text{Hz}) \\ &= 332\,{}^{\text{m}}\!/\!_{\text{s}} \end{aligned}$$

$${}^{2L_0}\!/\!_{3} = \lambda_3 = 30.8\,\text{cm}$$

$$\begin{aligned} v_{\text{sound}} &= \lambda_3 f_3 \\ &= (30.8\,\text{cm})(1006\,\text{Hz}) \\ &= 310\,{}^{\text{m}}\!/\!_{\text{s}} \end{aligned}$$

For exercise two, part one we have the have frequency set to 3500 Hz and we obtain the following measurements for the wavelength:

| $x_1$ | $x_2$ | $\lambda$ |
|---|---|---|
| 55 cm | 45 cm | 10 cm |
| 45 cm | 35 cm | 10 cm |
| 35 cm | 25 cm | 10 cm |

Since each $\lambda_i$ is equal to 10 cm we can just use $\bar{\lambda}$ = 10 cm, which gives $v_{\text{sound}} = \bar{\lambda} f = 350\,{}^{\text{m}}\!/\!_{\text{s}}$.

In the second part of exercise two, we did nearly the same thing, but instead of matching up the phase, we matched the shape of the Lissajous figure. Here are the distances for which the figure was the same, which gives us wavelength:

| $x_1$ | $x_2$ | $\lambda$ |
|---|---|---|
| 55 cm | 45 cm | 10 cm |
| 40 cm | 30 cm | 10 cm |

Which again gives us $v_{\text{sound}} = \bar{\lambda} f = 350\,{}^{\text{m}}\!/\!_{\text{s}}$. Finally, in the last part of exercise two, we are measuring the time difference in sound pulses. Here we display the offset and time at the two locations which allows us to find Δx and Δt, and thus $v_{\text{sound}} = {}^{\Delta\text{x}}\!/\!_{\Delta\text{t}}$.

| $x_1$ | $x_2$ | $t_1$ | $t_2$ | $v_{\text{sound}}$ |
|---|---|---|---|---|
| 58 cm | 5 cm | 0.2 ms | 1.6 ms | 378.5 m/s |
| 58 cm | 50.5 cm | 0.2 ms | 0.4 ms | 375 m/s |

## Analysis

We calculated the speed of sound many different ways in this lab, some being much more accurate than others. Exercise one seemed to produce the most accurate results as it was a combination of many different resonance lengths. In part two of exercise one, though, not only were all the estimates for the speed of sound very wrong, but they weren't even consistently wrong. I would at least partially blame this on the excess noise in the room we were recording. It was hard to find a graph of the FFT in Data Studio that did not include a lot of noise. In a perfectly quiet room, this may not have been a problem.

In exercise two, we also had quite different results between subexercises. In addition, all three values were off by quite a bit from the true value of the speed of sound.

## Conclusion

Determining the speed of sound is not an easy task, and different methods return very different results. My preferred method would be similar to exercise one, where we can fine tune the value across multiple harmonics..