PCS 125 Lab 1 : Standing Waves

Instructor: *Dr. Yuan*

TA: *Meiyun Cao*

Section: *45*

Sayeed Ahamad
&
Tobi Ibiyeye

Student Number: *501209136 & 501163292*

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1 Introduction

In this lab, we got some hands-on experience with the physics behind sound waves and beats.

In this lab we will use the basics of traveling waves, and interference to understand the behavior of sound waves and how they work. In the experiment we examined beats, with similar frequencies but not exactly the same so we can understand interference of beats and how they relate to us in the real world.

To complete this experiment successfully we used various instruments such as speakers, microphone and tuning forks, to help generate and measure sound waves.

We also had to use a computer software which helps us interpret our data and allows us to plot graphs and get a better understanding of the experiment. Overall this lab is able to give us a good understanding of the physics behind waves and beats.

2 Theory

A lot was learned after completing this lab about sound waves and beats including their characteristics. By finding the frequencies of waves it makes it possible for us to learn many things about them. Some formulas that we used and the physics behind them is:

$$\Delta P = \Delta P_{max} \sin{(kx - \omega t + \phi)}$$

This is the equation for a wave, where ΔP is the change in pressure, ΔP_{max} is the maximum pressure, k is the wave number, x is the position, ω is the angular frequency, t is the time, and ϕ is the phase constant.

This formula is important because it allows us to calculate the beat frequency. This is the frequency at which the amplitude of the resultant wave oscillates due to interference between two waves of slightly different frequencies.

To calculate the fast and slow frequencies we can use the two formulas listed below.

$$P_1(t) = A\cos(2\pi f_1 t)$$

$$P_2(t) = A\cos(2\pi f_{21} t)$$

By using these two cosine trigonometric identities, we can easily determine the equations for f_{fast} and for f_{slow}.

$$f_{fast} = \frac{1}{2}(f_1 + f_2)$$

$$f_{slow} = \frac{1}{2}|f_2 - f_1|$$

3 Materials Required

- Vernier Microphone
- Vernier Computer Interface
- Logger Pro Software
- Tone Generator Software)
- Unknown frequency tuning forks
- Rubber Mallet
- Known frequency tuning fork

4 Procedure

4.1 Procedure I - In Equilibrium

1. Connect the microphone to CH-1 of the LabPro computer interface.
2. Open Logger Pro and check if your LabPro is properly connected, an icon should appear in the top left of the screen if it is.
3. Click Experiment → Zero to center the waveform on the axis.

4. trike your tuning fork with a rubber mallet. Hold the microphone close to the fork. In the Logger Pro application, click . The computer will take data for just 0.05s to display the rapid pressure variations. The vertical axis is related to the variation in air pressure, but given in arbitrary units (you will not need to calibrate the scale in Pascals for this lab).

5. Zoom in / scale your graph axes so that the period can be measured easily. Note that you can have your graphs automatically zoom by clicking the button. You can also zoom into a particular area by selecting an area on the graph and then clicking the button; the graph will zoom into the dark grey rectangle which you highlighted.

6. sing your collected waveform and Logger Pro, determine the period of the wave. You can do this by selecting Analyze → Examine and dragging the mouse over the graph. You should be able to read the time interval you selected (Δt) in the lower left corner. Record the period, and an estimate of its uncertainty.

7. Determine the amplitude of the wave (in arbitrary units) using the same method as above. Be careful in reading your graph if the sinusoidal curve is not centered on the x-axis. If this is the case, the easiest way to determine the amplitude is to determine the vertical distance between a peak and a trough and divide by two. Record the amplitude and a measure of its uncertainty.

8. Save the data by choosing Experiment → Store Latest Run. Hide the run by choosing Data → Hide Data Set, and selecting Run 1.

4.2 Procedure II - In Oscillation

1. Connect the microphone to CH-1 of the LabPro computer interface.

2. Open Logger Pro and check if your LabPro is properly connected, an icon should appear in the top left of the screen if it is.

3. Click Experiment → Zero to center the waveform on the axis.

4. Learn how to play a tone with a tone generator:

   (a) Make sure your computer's volume is set quite low. You can always increase the volume if the tone is too soft, but playing an extremely loud tone is unpleasant for everyone!

(b) Open the program Audacity which you can use to generate pure tones. To generate a tone, select Generate → Tone. Leave the waveform as “Sine”, enter the frequency and the amplitude (a number between 0 and 1), and select the duration (we recommend at least 10 seconds). Then click Generate Tone

(c) In the audacity program click the green arrow to play the tone.

5. Working with the group across from you, set up two tones to be played simultaneously using Audacity. The frequencies of the two tones should differ by no more than 10 Hz, and should have (roughly) equal volume. Play the two tones together.

6. Again, working with the group across from you, set up two tones to be played simultaneously, but make the frequency of the two tones differ by 50-100 Hz.

7. Play the two tones (which differ by 50-100 Hz) together, and place your microphone in a position where both tones can be heard. While the tones are playing, switch back to Logger Pro and collect data by pressing .

8. As you did before, select Analyze → Examine. Determine the beat period (the time between successive beats)

9. Store this run by choosing Experiment → Store Latest Run.

5 Results & Calculation

Using the curve fit feature on logger pro, a sinusoidal function in the form $y = A\sin(Bt + C) + D$ can be derived. With this the measured value of frequency and the derived value can be compared to determine the accuracy of the experiment and further understand the concepts of sound waves and beats.

5.1 Run 1

The derived values of the first run with their uncertainties are:

Run 1	*Values*	*Uncertaintanty* (±)
A	0.2424	0.0004813
B	3023	0.2279
C	1.546	0.003962
D	-0.003235	0.0003399

Table 5.1: Value of Function Constants

This gives us the equation $y = 0.2422 \sin(3023t + 1.546) - 0.003235$

5.1.1 Derived Frequency

$$B = \omega$$

$$\implies \omega = 2\pi f$$

$$\therefore f = \frac{\omega}{2\pi} = \frac{3023}{2\pi} \approx 481.1 \text{ Hz}$$

5.1.2 Measured Frequency

Beat Periods (s)
0.00193
0.001758
0.001691
0.001776

In order to find the frequency we can take the average of the measured periods and find the inverse, giving the average frequency.

$$\text{Average Period} = \frac{0.001930 + 0.001758 + 0.001691 + 0.001776}{4} = 0.001789 \text{ s}$$

$$f = \frac{1}{T} = \frac{1}{0.001789} \approx 559 \text{ Hz}$$

Looking at the two values, there is great disparity between them. This is likely to be due to inaccuracies in the measurement of the beat periods. When using the derived frequency to determine the period, a value of 0.002078 s is found, which is also in good proximity to the first measured beat period 0.00193 s.

Combined with lack of precision from both the curve fit and the measurement of the beat periods. The two frequencies should be expected to have a reasonable disparity.

5.2 Run 2

The derived values of the first run with their uncertainties are:

Run 2	*Values*
A	0.1354
B	200
C	5.429
D	0

Table 5.2: Value of Function Constants

This gives us the equation $y = 0.13544 \sin(200t + 5.429)$.

5.2.1 Derived Frequency

$$B = \omega$$

$$\omega = 2\pi f$$

$$\therefore f = \frac{200}{2\pi} \approx 31.8 \text{ Hz}$$

5.2.2 Measured Frequency

Beat Periods (s)
0.01416
0.01494
0.01416
0.014126

In order to find the frequency we can take the average of the measured periods and find the inverse, giving the average frequency.

$$\text{Average Frequency} = \frac{0.01416 + 0.01494 + 0.01416 + 0.014126}{4} \approx 0.01435 \text{ s}$$

$$f = \frac{1}{T} \approx 67.7 \text{ Hz}$$

Cleary the two values differ by a large margin. This can be attributed to inaccuracies in the process of the curve fit.

This clearly shows that taking the inverse of the period of a wave is the more effective method of determining a wave's frequency than attempting to use the curve fit feature on Logger pro.

Finding an Unknown Frequency with Logger Pro

The curve fit feature on logger pro can also be used to determine the frequency of two tuning forks struck at the same time. If the curve fit values for a sine graph are as follows.

Parameters	Values
A	0.02
B	1400
C	4.813
D	-0.003835

Table 5.3: Value of Function Constants

$$B = \omega$$

$$\omega = 2\pi f \implies f = \frac{1400}{2\pi} \approx 222.8 \text{ Hz}$$

6 Discussion & Conclusion

This experiment can be said to be a success.Although there were a number of inaccuracies, we were able to achieve all the goals of the experiment and further understand wave interference.

By experimenting with both constructive and destructive interference. We determined that the most effective way of finding the frequency of a wave is finding the inverse of its period.

The principle of wave interference also has a lot of applications when it comes to the real world, affecting the sounds and music we hear.

Take for example two violins playing in an orchestra, the instruments have to be tuned in order to produce the same wave assuming the two violinists are playing in sync, this allows constructive interference, increasing the amplitude of the note being played.

This can be seen with destructive interference in noise canceling headphones, which work by matching the waveform of the ambient sound and playing that wave completely out of sync with the ambient sound.

Bibliography

[1] Serway, R. A., Jewett, J. W. (2018). Physics for Scientists and Engineers. Cengage Learning.