PCS 125 Lab 1 : Standing Waves

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1 Introduction

This lab experiment demonstrates the different frequencies and amplitudes that will create a pattern of a sinusoidal wave with different "standing waves". A "standing wave' has nodes where there are points on the wave that do not move.

The lab is completed by vibrating a string with a sinusoidal oscillator where the frequency and amplitude is calibrated using a function generator. Different masses will be used to work with different tensions that affect the speed of the waves.

2 Theory

Before beginning this investigation we must know the methods and the theory behind the investigation and the due course of action.

2.1 Sinusoidal Function

As we are dealing with two sinusoidal waves with equal amplitudes and frequencies moving in opposite directions. These waves can be described mathematically as,

$$y_1(x,t) = A\sin(kx - \omega t)$$

$$y_2(x,t) = A\sin(kx + \omega t)$$

Where, k is the wave number ($k = 2\pi/\lambda$) and ω is the angular frequency of the system.

Therefore the sum changes of the vertical displacement can be expressed mathematically as,

$$\sum y(x,t) = y_1(x,t) = A\sin(kx-\omega t)+y_2(x,t) = A\sin(kx+\omega t) = 2A\sin(kx)\cos(\omega t)$$

2.2 Fundamental Frequencies

There exist's specific frequencies wherein the wave appears to not move and trave in any direction and has a presence of nodes, this interference between two waves traveling in opposite directions is exactly what happens if you send two wave pulses down a string which is fixed at one end. Waves will reflect off of the fixed end, travel back toward the source and interfere with the waves which have yet to hit the fixed end.

Mathematically these frequencies are given by,

$$f_n = \frac{n}{2L}\sqrt{\frac{T}{\mu}}$$

Where, n is the fundatmental frequency number, L is the length of the string, T is the tension in the string and μ is the linear density of the string. We know that,

$$\mu = \frac{M}{L} \approx 1.63 \times 10^{-3}$$

Therefore, we have,

$$f_n = \frac{n}{2L}\sqrt{\frac{mg}{\mu}} = f_n = \frac{n}{2.94}\sqrt{6.01 \times 10^3 m}$$

Where m, is the mass of the object and n is the fundamental frequency in question.

3 Materials Required

- Variable frequency oscillator
- String
- Three 100g Hanging Masses
- Variable frequency oscillator)
- Sinusoidal function generator
- Low Friction Pulleyr

- Wooden Bridge
- Rigid Support or clamp

4 Procedure

1. Set up all the materials and the apparatus like shown in the image above. Place the wooden underneath the string and slide it so the portion of the string that will oscillate is adjusted.
2. Turn on the generator and calibrate the amplitude (output rotary) so that the string begins to oscillate and the noise is quiet enough. Calibrate the amplitude so that there is a standing wave pattern with $n = 1$ and write down this frequency (Wait a couple seconds if using BK Precision Generator).
3. Identify a range for this type of standing wave and use it to identify the uncertainty and record it Increase the frequencies until the standing waves reach $n = 2$ to $n = 5$. Record the ranges and the uncertainties.
4. Increase the hanger to achieve a total mass of 200g and complete the previous two steps for this mass.
5. Increase the hanger to a total mass of 300g and repeat what was done for the previous step. Record the frequencies and uncertainties.

5 Experimental Data

n	Starting Frequency	Peak Frequency	Ending Frequency
1	16	26	30
2	30	42	50
3	50	70	85
4	85	92	105
5	105	116	126

Table 5.1: Fundamental Frequencies for $m = 100g$

n	Starting Frequency	Peak Frequency	Ending Frequency
1	6	7.4	9
2	9	11.2	32
3	32	47	56
4	56	68	74
5	74	82	86

Table 5.2: Fundamental Frequencies for m = 200g

n	Starting Frequency	Peak Frequency	Ending Frequency
1	13	19	28
2	28	34	49
3	49	60	82
4	82	84	88
5	88	96	101

Table 5.3: Fundamental Frequencies for m = 300g

6 Theoretical Data

n	Frequency
1	8.3
2	16.7
3	25
4	33.3
5	41.7

Table 6.1: Fundamental Frequencies for m = 100g

n	Frequency
1	19.2
2	38.5
3	57.7
4	76.9
5	96.2

Table 6.2: Fundamental Frequencies for m = 200g

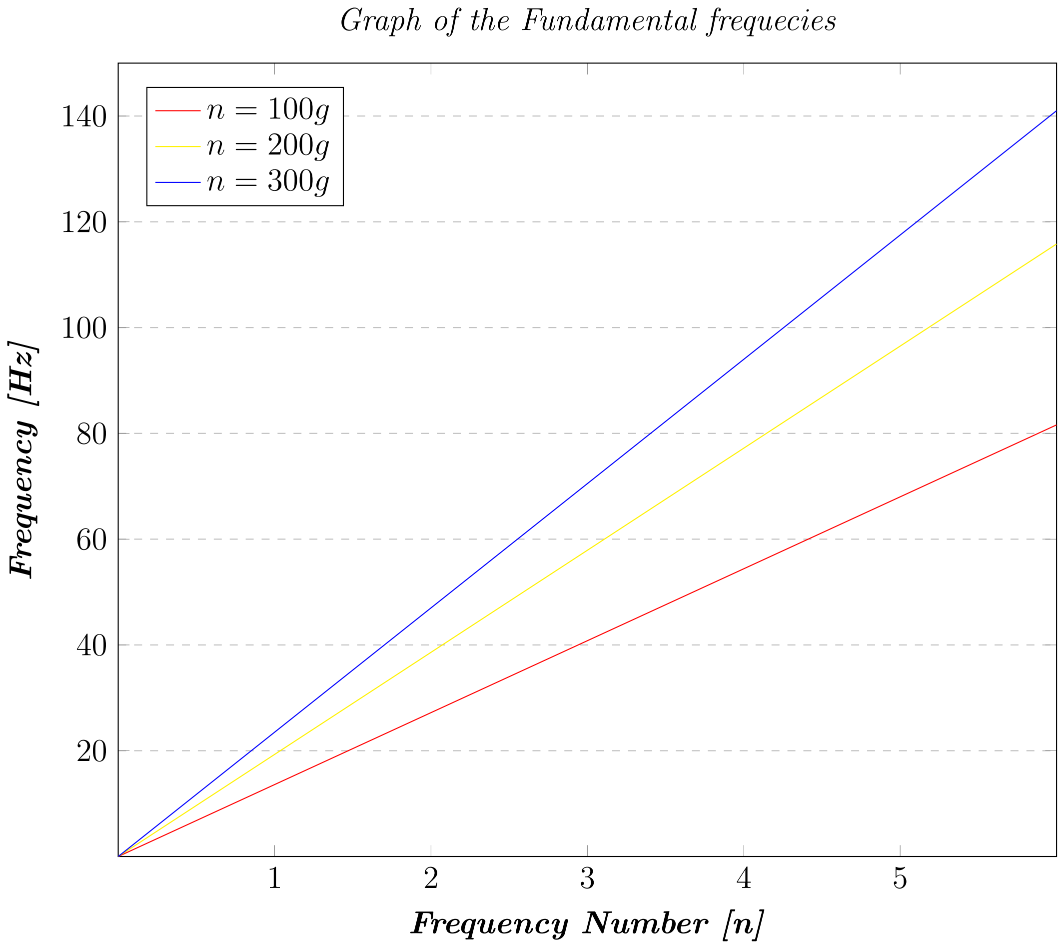
n	Frequency
1	23.6
2	47.1
3	70.7
4	94.3
5	117.8

Table 6.3: Fundamental Frequencies for m = 300g

7 Analysis

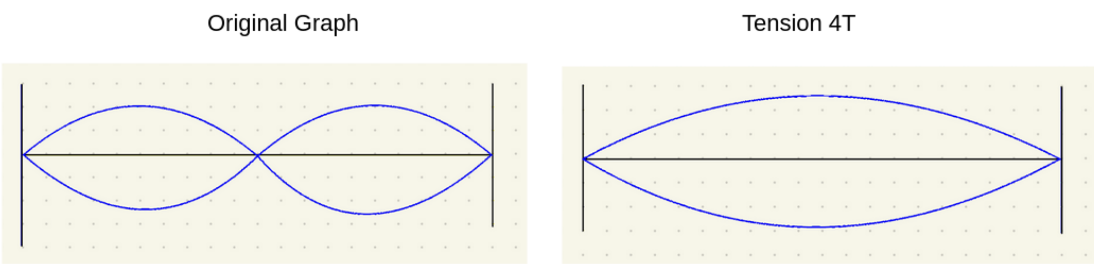
n	$m = 100g$	$m = 200g$	$m = 300g$
1	0.68	0.61	0.17
2	0.60	0.70	0.27
3	0.64	0.18	0.15
4	0.63	0.11	0.10
5	0.64	0.14	0.18

Table 7.1: Error Margin of the experimental data



8 Discussion

1. The note heard on a musical string instrument (e.g. a guitar, violin, etc...) is related to its fundamental frequency. A guitarist tunes their instrument by turning pegs on the bridge causing the tension in the string to increase or decrease. If a guitarist notices that a certain string is sounding "flat" (meaning it is playing a note with a lower frequency than desired), should she tighten or loosen the string ?



Answer:

2. Suppose that for a particular setup, the hanging mass is 200g, and the $n = 3$ mode is found to have a driving frequency of 80Hz. If the mass is changed to 300g, what frequency will lead to the $n = 4$ mode with this heavier mass?

Answer: This specific set up uses 2 different nodes, 2 different masses and a frequency and is required to find the second frequency, $m_1 = 0.25kg$, $n_1 = 3$, $f_1 = 80Hz$ & $m2 = 0.3kg$, $n_2 = 4$, $f_2 = ?$. We have,

$$\mu_1 = \mu_2$$

$$\frac{m_1 n_1^2}{4 f_1 L^2} = \frac{m_2 g n_2^2}{4 f_2 l^2}$$

$$f_2 = \sqrt{m_2 n_2^2 \frac{f_1^2}{m_1 n_1}} \approx 131 \text{ Hz}$$

3. Suppose that instead of both ends being fixed, the end of the string at $x = L$ is free to move up and down. Then, the point at $x = L$ is an antinode and not a node. Start with the equation for a standing wave $y_{standing}(x,t) = 2A\sin(kx)\cos(wt)$ and derive the condition for the resonant frequencies f_n in terms of n, v and L ?

Answer: Equation used for standing waves on a string is $y(x,t) = 2A\sin(kx)\cos(\omega t)$ (where k represents the wave number, A represents amplitude, ω represents angular frequency, x represents position and t represents time.). Due to $x = L$ being an anode, these conditions show, $y(0,t) = 0$ & $y'(L,t) = 0$. Also as $k = n\pi/L$, $\omega = vk$ & $\omega = vn\pi/L$, we have, Resonance frequency of $f_n = vxn/2L$

There are many things that can be taken away from this experiment such as theory vs. practical and potential vs kinetic energy. With the experiment only taking place within 5 seconds, not much can interfere with the results. Calculations were done to find different values using the data observed. If the experiment was done with a larger time interval, the calculations could have been different. This is due to air resistance which would have made the oscillations slow down.

On the topic of theory, this experiment supports the theory that potential energy and kinetic energy are opposite to each other. When the graph was completed, the lines that represent each type of energy were always opposite to each other. This is because potential energy transforms into kinetic energy and vice versa.

Bibliography

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