

Lab 12: Standing Waves

Name:

PES 115 Report

Lab Section

Objective

The purpose of this lab was to understand how standing waves get set up on a string. Furthermore, we attempted to explore the relationships between frequency, wavelength, tension, and density.

This day has been a long time coming, but it is finally time for you to leave the nest and try writing the reports on you own!

Data and Calculations

Before starting the experiment, we collected some data to determine the mass density of the string being used.

Length of String (m)	Mass of the String (kg)
1.25	0.038

The mass density is typically calculated using the mass and the volume of the object. However, since we do not know the gauge (diameter) of the string being used, we cannot do a volume calculation.

$$\mu = \frac{\text{mass}}{\text{volume}} = \frac{\text{mass}}{\pi \left(\frac{d}{2}\right)^2 l}$$

Hence, we will use the following estimation for the calculation of the linear mass density:

$$\mu_{\text{linear}} \equiv \frac{\text{mass}}{\text{length}} = \frac{0.038 \text{ kg}}{1.25 \text{ m}} = 0.0304 \frac{\text{kg}}{\text{m}}$$

This will be used as our theoretical value when comparing the measured value from the velocity and tension in the string.

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First we calibrated the Force Sensor (even though the lab mentioned not to do this). We then set up the lab as follows:

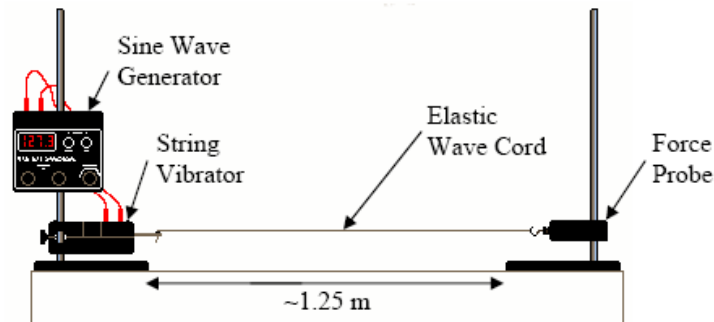


Figure 1: Experimental Setup of the Apparatus for Standing Waves

We set up standing waves on the string to get 1-5 modes. We then measured the wavelength, frequency and tension in the string for each of those modes. We collected the following data:

Mode	Frequency (Hz)	Wavelength (m)	Tension (N)
1	6.1	2.50	6.62
2	12.0	1.25	6.69
3	23.8	0.63	6.77
4	48.0	0.31	6.78
5	96.1	0.16	6.89

**** NOTE: Although not explicitly mentioned in the directions, we tried not to adjust the amplitude of the wave once it was set. We found that force (tension in the string) is directly proportional to the amplitude (which makes sense – the further the string is stretched to reach the amplitude, the tighter the string is pulled). ****

The equation for wavelength as a function of frequency is:

$$\lambda = \frac{v}{f}$$

Since frequency and wavelength are not directly, but inversely related, we need to calculate 1/frequency from the table above.

Mode	Frequency (Hz) [measured]	Wavelength (m) [measured]	1/Frequency (sec) [calculated]
1	6.1	2.50	0.16393443
2	12.0	1.25	0.08333333
3	23.8	0.63	0.04201681
4	48.0	0.31	0.02083333
5	96.1	0.16	0.01040583

Next we plotted wavelength versus 1/frequency. The slope of that line will give us the group speed (velocity) of the wave traveling down the string.

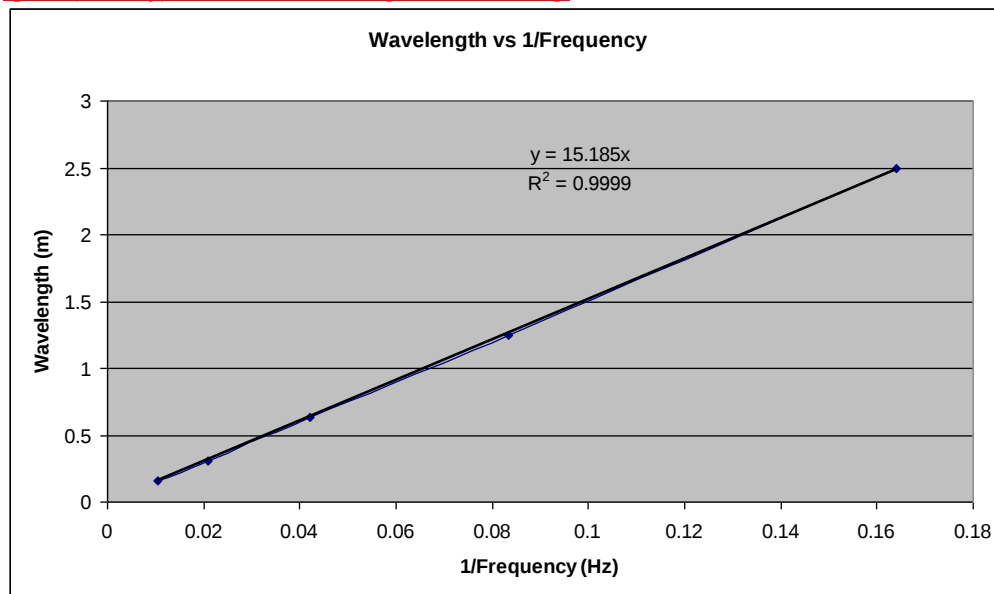


Figure 2: Plot of Wavelength versus 1/Frequency

Using the trendline feature in Excel, we got the following best fit line:

$$y = \left(15.185 \frac{m}{s}\right)x + (0 \text{ m})$$

It is of particular interest to note the regression determined by Excel. This came out to be a value of 0.9999. This means that the "linear nature" of the data is *extremely good*.

If we compare the equation for wavelength as a function of 1/frequency with the found trendline, we can easily see by evaluation that the following constants correlate directly:

$$\lambda(f) = v \left(\frac{1}{f} \right) + 0$$

$$y = \left(15.185 \frac{m}{s}\right)x + (0 \text{ m})$$

Thus:

Velocity [m/s]
15.185

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Next, we can calculate the mass density of the string using the tension in the string and the velocity found above:

$$v = \sqrt{\frac{F}{\mu}}$$

Solving this for the mass density gives:

$$\mu = \frac{F}{v^2}$$

Where F is the average tension in the string and v is the velocity of the wave in the string.

Solving for the average tension in the string:

$$\langle F \rangle = \frac{1}{5} \sum_{i=1}^5 F_i = \frac{1}{5} (F_1 + F_2 + F_3 + F_4 + F_5)$$

$$\langle F \rangle = 6.75 \text{ N}$$

We can now solve for the theoretical mass density of the string:

$$\mu_{\text{Measured}} = \frac{(6.75 \text{ N})}{\left(15.185 \frac{\text{m}}{\text{s}}\right)^2} = 0.02927 \frac{\text{kg}}{\text{m}}$$

We can now compare this with the theoretical linear mass density calculated at the beginning of the lab:

$$\% \text{ difference} = \frac{|\mu_{\text{Theory}}| - |\mu_{\text{Measured}}|}{|\mu_{\text{Theory}}|} \times 100\% = \frac{\left(0.0304 \frac{\text{kg}}{\text{m}}\right) - \left(0.02927 \frac{\text{kg}}{\text{m}}\right)}{\left(0.0304 \frac{\text{kg}}{\text{m}}\right)} \times 100\%$$

$$\% \text{ difference} = 3.717\%$$

Part A:

Additional Questions

question 1

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Conclusion

You are intelligent scientists. Follow the guidelines provided and write an appropriate conclusion section based on your results and deductive reasoning. See if you can think of any possible causes of error.

** NOTE: There are several components of error which could significantly modify the results of this experiment. Some of these are listed below:

- Parallax
- Amplitude adjustment
- Force sensor calibration
- Clarity of instructions
- Other ...

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A few of the potential errors listed above may be applicable to YOUR experiment.