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**Lab 1: Waves**

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PHYS 262 – 001

With:

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**Objective**

The objective of this lab is to verify the linear relationship between the speed of an induced wave traveling through a string versus the wavelength and frequency of that wave.

**Theory**

The theory being tested is the ability to describe a wave using the wave equation.

Eq. 7-1

Eq. 7-1 conjects that a wave can be described by three fundamental properties. These properties are the speed of the wave *v*, the frequency of the wave’s periodic emissions *f*, and the length between the two antinodes in a standing wave, or the wavelength *λ*. Based on this equation, and assuming a constant velocity, the ratio between these three values respectively should also remain constant.

To be able to validate this conjecture concerning the application of the wave equation, we need to be able to adjust the parameters of the wave equation and compare the results of our observed relationships against some participating control variable. The speed of a wave on a stretched medium, such as a string, is given by

Eq. 7-2

where *T* is a tension pulling on the medium and *μ* is the linear mass density of the medium. With the velocity of a wave describable in two ways, these two equations can be conjoined upon velocity *v* to describe

Eq. 7-3

which allows us to measure against an experiment constant in the linear mass density of the medium.

**Procedure**

The achievement of this experiment’s goal was extruded into three scenarios. Each scenario involved a string, a pulley, a wave-inducing modulator, and one or more weights of varying mass. The string was tied to the output prong of the wave modulator, laid over the pulley, and attached to by the weights for each scenario’s iterations. Measurements taken would be the mass of the collective weights, the current output frequency, and the distance between nodes of the standing waves.

**Scenario 1**

For the first set of iterations, the mass at the end of the string was kept at a constant 100 grams to impart a steady 0.98 Newtons of tension. For each iteration, the output frequency of the modulator was adjusted until a standing wave with a new number of nodes was observed.

**Scenario 2**

For this set of tests, the output frequency coming from the modulator was set to a constant 60 Hertz. The tension on the string was adjusted by adding and removing weights until standing waves of different nodal counts were observable.

**Scenario 3**

For this collection of measurements, we wanted all runs to result in the same standing wave. We decided to reach for 3 nodes in the standing wave across all runs, modifying the output frequency and tension to achieve this. To make sure that the same standing wave is achieved, an initial standing wave was found that we would replicate. The nodes of this standing wave were marked on the string with a marker. Standing waves in following runs would be calibrated so that their nodes would align with the markings as best as possible.

**Data**

Shown below is the table of correlated measurements taken the runs of all scenarios.

|  |  |  |  |
| --- | --- | --- | --- |
| N | Freq (Hz) | Tension (N) | Wavelength (m) |
| Scenario 1 | | | |
| 2 | 40.4 | 0.98 | 1.16 |
| 3 | 53.9 | 0.98 | 0.74 |
| 4 | 71.2 | 0.98 | 0.56 |
| 5 | 90.7 | 0.98 | 0.43 |
| 6 | 111.5 | 0.98 | 0.37 |
| Scenario 2 | | | |
| 3 | 60 | 1.176 | 0.75 |
| 2 | 60 | 3.136 | 1 |
| 1 | 60 | 9.506 | 2.16 |
| 6 | 60 | 0.294 | 0.36 |
| 4 | 60 | 0.686 | 0.57 |
| Scenario 3 | | | |
| 3 | 37.8 | 0.49 | 0.78 |
| 3 | 41.6 | 0.588 | 0.78 |
| 3 | 48.3 | 0.784 | 0.78 |
| 3 | 55.2 | 0.98 | 0.78 |
| 3 | 56.7 | 1.078 | 0.78 |

**Table 1-1.** The table of frequency, tension, wavelength, and node count measurements from each run of each scenario.

**Analysis**

**Scenario 1**

To achieve an estimate for the linear mass density, the inverse of the wavelength measurements was plotted against the frequency measurements, and a best-fit line was calculated.

**Figure 7-1.** Wavelength measurements plotted inversely against frequency measurements. The slope of the best-fit line represents the velocity of the wave.

Applying Eq 7-2, the velocity extrapolated from the correlated data in Figure 7-1, and the constant tension for Scenario 1’s runs (Table 7-1), we can derive an estimate for the linear mass density of the string involved in the experiment. Our calculations resulted in **6.67764 · 10-4 kg/m**.

**Scenario 2**

For this scenario, the configurable values were Tension and Wavelength. To obtain a linear mass density approximation for the string, the wavelength was plotted against the tension in each run.

**Figure 7-2.** Wavelength measurements plotted against the tension pulling on the string for each run. Because tension is under a radical in the collected Equation 7-3, the relationship is non-linear (square), so a second-degree power fit was used.

Applying Eq 7-2, the velocity extrapolated from the highest-degree coefficient for the correlated data in Figure 7-2, and the constant frequency for Scenario 2’s runs (Table 7-1), we can derive an estimate for the linear mass density of the string involved in the experiment. Our calculations resulted in such **6.37739 · 10-4 kg/m**.

**Scenario 3**

For this scenario, the configurable values were Tension and Frequency. To obtain a linear mass density approximation for the string, the wavelength was plotted against the tension in each run.

**Figure 7-3.** Frequency measurements plotted against the tension pulling on the string for each run. Because tension is under a radical in the collected Equation 7-3, the relationship is non-linear (square), so a second-degree power fit was used.

Applying Eq 7-2, the velocity extrapolated from the highest-degree coefficient for the correlated data in Figure 7-3, and the constant wavelength for Scenario 2’s runs (Table 7-1), we can derive an estimate for the linear mass density of the string involved in the experiment. Our calculations resulted in such **8.28666 · 10-4 kg/m**.

**Conclusions**

Above is the concise exposition of this experiment’s results. The control against which an accurate value could be calculated and compared was the linear mass density of the string used in the experiment. Scenarios 1 and 2 resulted in comparatively close linear mass density results. It can be reasoned thusly that those two results maintain some significance in terms of accuracy due to the similarities in those calculation. The result for the third scenario was much more removed from the other two and is probably not significantly close to the actual measure of linear mass density. I believe this discrepancy is a result of the third scenario’s dependence on manual control as well as the limitations of the resources used in the experiment. After marking the string, we were not always able to recreate a standing wave with a different configuration of frequency and tension where the nodes aligned exactly with those markings. This is because the smallest weight we had to work with was 10 grams. Being able to express more well-defined tension in this experiment would have allowed us to recreate the standing waves much more accurately. Overall, the linear mass densities resulting from scenarios 1 and 2 are more reliable due to the experiment method and should be used to uphold the wave equation.