Standing Waves

Physics 114

Fall 2025

The goal of this lab is to observe standing waves on a string, then determine the mass per unit length of the string by measuring features of the standing waves.

Introduction

Consider a system consisting of a taut string that is fixed at both ends, with one end being driven (shaken up and down) in simple harmonic motion. The vibrations create waves that travel along the string. The waves will reflect from the other end, and the reflected waves will interfere with the incoming waves. Generally, the interference is *destructive*: the net effect is that the string oscillates very weakly, despite being driven continuously. However, at certain driving frequencies, the string will oscillate with a large amplitude and form a *standing wave* pattern.

For any wave, the speed v, the frequency f, and the wavelength λ are related by

$$v = f\lambda \tag{1}$$

The speed of a wave on a string can also be related to the tension T and the mass per unit length μ by

$$v = (T/\mu)^{1/2} \tag{2}$$

Combining equations 1 and 2 and doing a little algebraic rearranging gives

$$\frac{T}{\lambda^2} = \mu f^2 \tag{3}$$

You will use equation 3 to measure the mass per unit length of the string.

Apparatus

The apparatus consists of a string, a string vibrator, a pulley, and some weights as shown in figure 1. The amount of tension in the string is equal to the total weight (in newtons) hanging from the end. The frequency of the vibrator is controlled by a sine wave generator. Both the frequency and the tension can be changed to set up standing waves on the string.

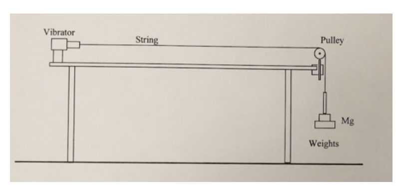

Figure 1: The apparatus.

Procedure

First, hang about 200 to 600 grams from the end of the string (including the mass of the hanger). Some apparatuses have string that stretches quite a bit, so choose your initial value such that the hanger does not come close to touching the floor, but is large enough to keep the string taut. The tension in the string is equal to the weight of the hanging mass.

Next, turn on the sine wave generator and adjust the frequency, using values below 200 Hz, until a standing wave pattern is observed. Fine tune the frequency until you have the wave with maximum amplitude. You may find that reducing the generator amplitude gives a more stable wave and reduces the noise that the string vibrator will sometimes make.

On the standing wave, you will see *nodes*: positions where the string is not moving. The ends of the string at the vibrator and at the pulley are also nodes. Measure the wavelength of the wave by determining the distance between two nodes: **neighboring nodes are separated by one half wavelength**. The best way to do this is to measure the total length of the string between the vibrator and pulley, which will not change during the lab, then divide by the number of observed *antinodes* (positions where the string has maximum displacement from equilibrium). Record the frequency and wavelength values for the standing wave with appropriate uncertainties.

Next, change the generator frequency until you get a different standing wave - one with a different number of antinodes. Record the frequency and wavelength, with uncertainties, for this wave. Continue changing the frequency until you have frequency and wavelength measurements for 8 different standing waves for frequencies below 200 Hz. Organize the frequency and wavelength data into a table, ordered from lowest frequency to highest.

Repeat the entire procedure above for two more string tensions. Choose tensions that are significantly different from each other, such as double or half the previous value, but take care that the mass hanger doesn't touch the floor. You will now have three sets of f and λ data.

Analysis

Equation 3 predicts that a plot of T/λ^2 vs. f^2 will be a straight line with a slope of μ. Further, equation 3 predicts that you should get the same slope for all three tensions. Make this plot for each of your data sets (three plots, one for each tension) and determine the mass per unit length of the string from the slope of each plot. Record the uncertainty on each slope and use it to calculate the uncertainty on each measurement of μ.

Question 1: Do your three measurements of the mass per unit length agree within uncertainties?

Informal Lab Report Guidelines

Write your informal lab report on a separate sheet of paper that includes the following items in this order:

1. The lab title, your name, and the names of your partners.
2. Three well-organized data tables, one for each tension, of the measurements of f and λ and their uncertainties. Be sure to indicate the value of the tension that corresponds to each table. Explain how you determined the uncertainties on the measurements of f and λ.
3. The three plots you made as part of the data analysis. Each plot should have a title, axis labels with units, and a line of best fit.
4. Report the three measurements of μ with uncertainties. Explain how you determined the uncertainty on μ.
5. Answer Question 1 in the Analysis section of this lab handout.