VIBRATING STRING

Objective

To examine the relationships between tension, mass, and the period of resonances of a string.

Equipment

A PASCO vibrator with power supply, ring stand, clamps, pulley, two strings of different linear mass densities, a set of weights, a weight hanger, paperclips, triple beam balance, and a meter stick or metric tape measure

Introduction

Figure 1 illustrates a string stretched between two supports. The left support is the arm of the vibrator and the other is the top of the pulley. The string extends over the pulley where a weight is attached to provide tension on the string. For a vibrator oscillating with a fixed frequency, standing waves can be set up in the string when the length of string between the supports is an integer multiple of half the wavelength of the waves in the string. For the situation illustrated in Figure 1, the string vibrates so that there are two anti-nodes and three nodes. Can you locate them?
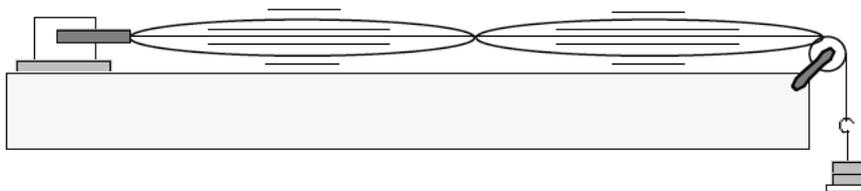
Figure 1: Vibrating String Apparatus.

The speed of the wave on a string may be expressed as:

$$v = \sqrt{\frac{T}{\mu}} \tag{1}$$

where T is the tension in the string and μ is the mass per unit length of the string, also known as the liner mass density. The speed of the wave is also related to the wavelength, λ, and frequency, f, through:

$$v = f\lambda \tag{2}$$

Upon combining these relationships we find that:

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

In trying to reason what you might expect, remember that a larger tension in the string causes the restoring forces to be larger which accelerates the string faster and causes the oscillations to happen quicker (i.e., have a shorter period). By the same reasoning, a heavier string will accelerate slower and have a longer period.

In this experiment, we will be measuring λ, T, and μ. Using a plot of this data, we will be able to find the frequency of vibration of the string, and compare it to the actual value.

Activity 1.

1) Measure a long length (3-4 meters) of the string using the meter stick or metric tape measure. Record this value, in meters, on your data sheet. Weight this length of string on the triple beam balance to find its mass. Record this value, in grams, on your data sheet.

2) Calculate the linear mass density (mass/length) from these values and record the answer on your data sheet.

Activity 2.

3) Clamp the PASCO vibrator on the ring stand and the pulley to the desk. Attach the string to the hole of the vibrators arm. Run the string from underneath, up through the hole and then knot it. Measure the distance from the hole of the vibrators arm to the pulley. Record this value on your data sheet.

4) Suspend the weight hanger on the string for tension and turn the vibrator on. Slowly increase the tension on the string by pushing down on the weight hanger with one finger. At some particular tension, the string will go into a single or double loop of vibration. Estimate the force you applied with your finger and place an equivalent weight on the holder.

5) Adjust the weight for maximum amplitude of the loops. Test for maximum amplitude by gently pushing down or raising up the weight hanger with a finger. Either increasing or decreasing the force should decrease the amplitude of the loops if the weight is correctly adjusted. Lighter weights can be obtained by using paper clips in place of the weight hanger and/or weights.

6) Document the number of loops obtained. Measure the average length of one loop, that is, the internodal distance. Notice that the loop nearest the vibrator is usually not well defined. Record the number of loops and the length value (in cm) on your data sheet. Convert the length from cm to m and record.

7) Record the weight (in g), measured on the triple beam balance, to obtain this number of loops.

8) Change the tension to give four more different numbers of loops and repeat activity 2 for each. You should have data for five different numbers of loops.

Activity 3.

9) Using the internodal distance, in m, from the previous activity, calculate the wavelength, λ. Record this value on your data sheet.

10) Using your values of λ, and the value of μ from activity 1, calculate $\lambda^2\mu$ for each number of loops.

11) Using the mass found in activity 2 for each number of loops, calculate the tension, T, for each number of loops.

Activity 4.

12) Using a spreadsheet, preferably Microsoft Excel, or other graphing software, prepare a graph of the tension, T versus $\lambda^2\mu$. Make sure to label the axes and give your plot a title.

13) Using the trend line function, add linear trend lines to your plot. Make sure you turn on the trend line values to see the equation of the line.

14) Using equation 3 above, we can rearrange to obtain:

$$T = f^2\lambda^2\mu \tag{4}$$

which is of the form $y = mx + b$, with T equal to y and $\lambda^2\mu$ equal to x. From equation 4, we can see that the slope of the trend line will be an experimental value for the vibrational frequency squared, f^2. Record your experimental value for f^2 on your data table. The units will be $1/s^2$.

15) Calculate the vibrational frequency, f, from the value found above. Record this value on the data table in the data sheet. The units will be $1/s$, or Hertz (Hz).

Activity 5.

16) The actual vibrational frequency is based on the frequency of the AC power lines in the USA. This value is $60Hz$. Compare your experimental value of f to the standard value by computing the percent error. The percent error is given by the difference between your result and the standard value divided by the standard value and converted to a percent.

$$\text{percent error} = \left|\frac{\text{experimental value} - \text{standard value}}{\text{standard value}}\right| * 100 \tag{5}$$

Record the percent error on your data sheet.

VIBRATING STRING
DATA SHEET
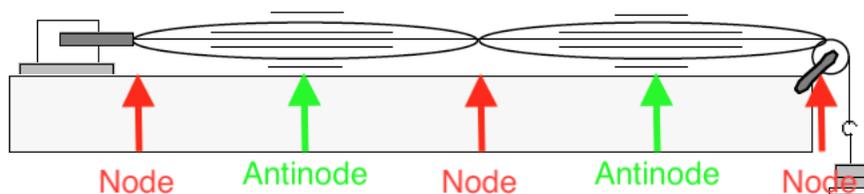
Figure 2: Nodes and Antinodes

Activity 1.

Length of string (m): ——————————————

Mass of string (g): ——————————————

Linear mass density, μ, of the string (g/m): ——————————————

Activity 2.

Table 1: Record data fron Activity 2.

Number of Loops	Mass (g)	Internodal Distance (cm)	Internodal Distance (m)

Length between vibrator and pulley (m): ——————————————

Activity 3.

Table 2: Record data fron Activity 3.

Number of Loops	Wavelength, λ (m)	$\lambda^2\mu$	Tension (mN)

Activity 4.

Include a copy of your plot with this assignment. Make sure your plot is in the proper format. For example, are your axes labeled and show the proper units?

Table 3: Record data fron Activity 4.

f^2 $(1/s^2)$	f (Hz)

Activity 5.

Compare your experimental value of f to the standard value, $60\ Hz$, by computing the percent error.

Percent Error: _____