S3b: Standing Waves on a Vibrating String

Introduction:

Waves lapping up on the beautiful beach shore, the ripples that occur after a pebble is dropped in a pond, the sound of a physics instructor's voice (sound) as he or she explains the concepts behind wave theory, and even the music that emerges from the radio (radio waves). All of these phenomena have one major thing in common: waves. A wave is commonly defined as the movement of a disturbance away from the point of origin, with the energy being propagated through the medium it travels through. This commonly accepted definition is by no means a concrete standard, and, due to the complexity of what a wave is and how it behaves, Wave Theory in physics is one of the more complex branches of study.

Therefore, in an effort to provide familiarity with waves and their behavior, this experiment is designed to examine the relationship between wavelength, linear density, frequency, and tension of a vibrating string. A string is tied to an electromagnetic vibrator and then given various tensions via use of suspended weights. From measurements of the wavelength, tension, and linear density, the resulting frequency may be calculated. This experimental frequency may then be compared with the known frequency produced by the electromagnetic vibrator.

Apparatus:

- Function Generator
- Oscillator
- Pulley
- Mounting hardware
- String
- Mass hanger
- Set of masses
- Meter stick

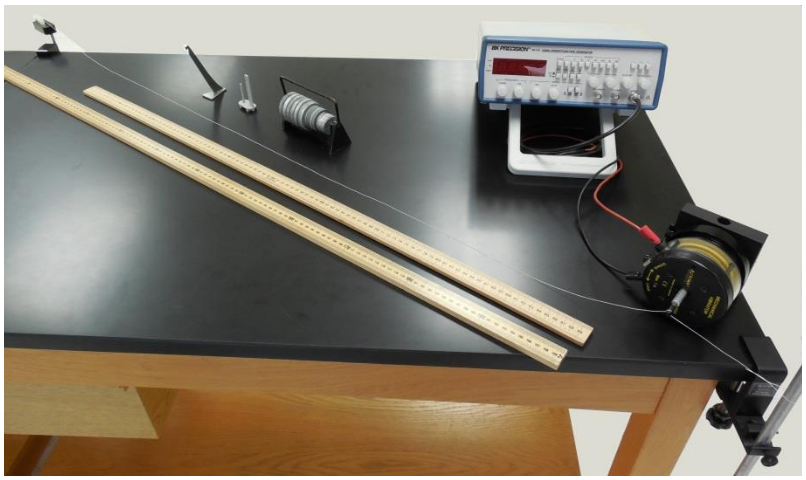

Figure 1

Discussion:

Rather than try to establish a universal definition for what it means to be characterized as a wave, instead the focus will center on the behavior of waves as they travel down a vibrating string. A wave can then be understood as shape normally portrayed when one considers a sine or cosine function: a repetitive curve. The form of a wave can be represented graphically by a wavy line in which the distances from a central straight line represent the displacements of the successive particles from their equilibrium positions, also known as amplitude. Consider the representation offered on the next page in **Figure 2**.

The frequency (f) of a wave is the number of waves generated per unit time, and it is usually expressed in vibrations (cycles) per second. The period, the time required for the generation of a single wave, is reciprocal to the frequency. This can be represented via the following formula:

$\mathrm{T} = \frac{1}{f}$: where T represents the object's period, and where f represents the frequency.

The wavelength is the distance between successive corresponding points on a wave, e.g., between successive crests or valleys, also to be seen within **Figure 2**. A simple relationship exists between frequency and wavelength. If f waves are generated per second, and each wave is λ long, each wave will be traveling at $f\lambda$ units per second. In other words, the velocity v of the wave is given by the equation:

$$v = f\lambda$$

In the set up for this lab, waves reach the end of the string fairly soon, where they are reflected. Hence two wave "trains" traveling in opposite directions are present simultaneously. If the proper relationship exists between the frequency, the length and the tension, a standing wave is produced. When conditions are such as to make the amplitude of the standing wave a maximum, the system is said to be in resonance.

It can be shown mathematically and demonstrated experimentally that the velocity of a transverse wave in a cord is given by the expression:

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

where F is the force (tension), and ρ is the linear density, or mass per unit length.

Since it has been shown that $v = f\lambda$, the previous equation can be expressed as

$$f = \frac{1}{\lambda}\sqrt{\frac{F}{\rho}}$$

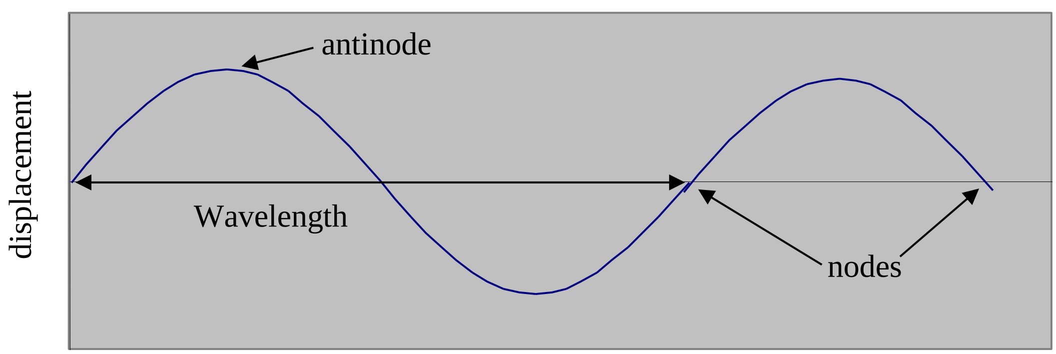

Figure 2

Procedures:

1. Measure the string length and string mass as precisely as possible. Determine the linear density of the string. Verify your value with the lab instructor before continuing.
2. Connect the string to the apparatus.
3. Turn on the function generator with the connected oscillator. Please see a lab instructor for assistance with this step and instruction on using the equipment.
4. Suspend the heavy mass hanger at the end of the string. Add masses until only one loop is produced on the string. Find the largest amplitude of the wave possible by changing the mass in small amounts up or down.
5. Measure the internodal distance for the single loop. This is the distance between two consecutive nodes. Reference **Figure 2** for a clearer picture of internodal distance.
6. Measure the total mass suspended from the string. Include the mass of the mass hanger as well in the measurement.
7. Calculate the wavelength, the tension in the string, the frequency and the wave velocity for this first trial.
8. Compare the frequency calculated to the frequency of the oscillator. Confirm your result with the lab instructor before continuing.
9. Next, decrease the amount of suspended mass until 2 loops are visible. Again vary the masses slightly until the largest amplitude is found. Again, determine the internodal distance and measure the total suspended mass.
10. Calculate the wavelength, the tension in the string, the frequency and the wave velocity.
11. Continue with these steps for the first oscillation frequency obtaining standing waves of one, two, three, four and five loops. Note, each trial requires less mass to and produces a greater number of standing waves.
12. After the five loops trial is completed adjust the function generator for the next frequency provided by the lab instructor.
13. Suspend the heavy mass hanger at the end of the string. Add masses until two loops are produced on the string. Once again find the largest amplitude of the wave possible by changing the mass in small amounts up or down.
14. Determine the internodal distance and measure the total suspended mass.
15. Calculate the wavelength, the tension in the string, the frequency and the wave velocity.
16. Continue with these steps for the second oscillation frequency obtaining standing waves of two, three, four, five and six loops.
17. Calculate the mean and standard deviation of the frequency for each set of trials. Compare the mean frequency to the frequency set on the function generator.

Experiment S3b: Standing Waves on a Vibrating String

Student Name____

*Lab Partner Name*____

*Lab Partner Name*____

Physics Course____

Physics Professor______________________________________

Experiment Start Date__________________________________

Lab Assistant Name	*Date*	*Time In*	*Time Out*

Experiment Stamped Completed

Data Sheets: S3b: Standing Waves on a Vibrating String

NAME: ______________________________ **DATE: __________________**

string length (m)________________________ frequency 1______________________

string mass (kg) ________________________ frequency 2______________________

string linear density______________________

# loops	internodal dist.	wavelength	mass	tension	frequency	velocity

mean frequency____________ stdev.______________

# loops	internodal dist.	wavelength	mass	tension	frequency	velocity

mean frequency____________ stdev.______________