PHYS 1111L - Introductory Physics Laboratory I

Laboratory Advanced Sheet
Standing Waves Laboratory

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1. Objective. The objective of this laboratory is to study standing waves on strings by measuring wave speed.

2. Theory.

a. The wave speed on a string is given by

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

where

v is the wave speed,
F is the tension in the string, and
μ is the mass per unit length of the string.

b. If the ends of a string or wire are fixed, standing waves can be set up as a result of superposition of incident and reflected waves. The wavelengths of the normal modes of vibration are related to the length of the string by

$$n\lambda_n /2 = L$$

where

n is an integer greater than or equal to 1 indicating the n^{th} normal mode of vibration,
λ_n is the wavelength of the n^{th} normal mode of vibration, and
L is the length of the string.

Since the wave speed of any wave is given by

$$v = f \lambda$$

where

f is the frequency of the vibration,

the wave speed can then be expressed as

$$v = 2 f_n L / n$$

where

f_n is the frequency associated with the n^{th} normal mode of vibration.

c. In this experiment, a weight will be used to provide the tension in the string. The wave speed will be determined by two methods and compared:

1) Measurement of the mass providing the weight that in turn provides the tension in the string, and the mass per unit length of the string give the wave speed using the relationship in paragraph 2a above. This value of the wave speed will be used as the "accepted" value for comparison purposes.

2) Variation of the driving frequency of vibration will be used to determine several normal frequencies of vibration using the same tension as in the first method of finding the wave speed. These frequencies along with their mode number and the length of the string can then be used to find the wave speed using the relationship given in paragraph 2b. These wave speeds will be the "measured" values for comparison purposes.

3. Apparatus and experimental procedures.

a. Equipment.

1) Meter stick.

2) String (several types).

3) Rods and clamps.

4) Pulley.

5) Mass set.

6) Triple-beam balance.

7) Power amplifier.

8) Wave driver.

9) Computer interface and computer.

b. Experimental setup. The experimental setup is shown in Figure 1 (provided by the student).

c. Capabilities. To be provided by the student.

4. Requirements.

a. In the laboratory.

1) Each laboratory group will make measurements on standing waves in three different types of string.

2) Measurements of the masses of selected lengths of each type of string will be performed by your instructor using a mass balance capable of measuring small masses to high precision. Data from these measurements should be recorded in Annex A.

3) Measure the masses providing the tension in the string, and the lengths of the strings.

4) Use the power amplifier to vary driving frequency. By observing the the wave form on the string, determine the frequencies of the first four normal modes of vibration on each of the three string types.

b. After the laboratory. Complete the following portions of the laboratory report.

Para. 3. Apparatus and experimental procedures.

1) Provide a figure showing the experimental setup.

2) Provide a description of the capabilities of the equipment used in the experiment.

Para. 4. Data.

1) Provide a copy of your original data.

2) Provide a copy of your spreadsheet with calculations. Include the following:

a) Calculations of the "accepted" wave speeds for the three types of string.

b) Calculations of the "measured" wave speeds from the power amplifier frequency variation experiments. For each of the three materials, calculate the wave speeds for the first four normal modes of vibration. Use the mean of each set of four wave speed determinations to provide the "measured" value of the wave speed for each of the three types of string.

c) Calculate the percent discrepancy between the "measured" and "accepted" values of the wave speed for the three types of string.

Para. 5. Results and Conclusions.

1) Provide a table of the "accepted" values of the wave speeds for the three types of string.

2) Provide a table of the "measured" values of the wave speeds and percent discrepancies for the three types of string.

3) Describe sources of error in the experiment.

Annex A
Data

1. Measurements for the determination of μ, the mass per unit length of the three materials*.

material	sample length (m)	sample mass (g)
string 1		
string 2		
string 3		

* Check with instructor before beginning the laboratory measurements. The mass of the strings vary with humidity.

2. Measurements with string 1.

mass attached to string = _____ kg

length of string = _____ m

normal mode (n)	frequency (Hz)
1	
2	
3	
4	

3. Measurements with string 2.

mass attached to string = _____ kg

length of string = _____ m

normal mode (n)	frequency (Hz)
1	
2	
3	
4	

4. Measurements with string 3.

mass attached to string = _____ kg

length of string = _____ m

normal mode (n)	frequency (Hz)
1	
2	
3	
4	