Standing Waves on a String

Purpose

Problem 1: to find the speed of a wave on a string.
Problem 2: to check how the wave speed depends on the tension in the string.

Note: There are two problems in this lab. You must complete all seven sections of Problem 1 before start Problem 2.

Introduction and Theory

A standing wave pattern can be created on a string that is fixed at both ends by vibrating the string near one end. Waves travel along the string and are reflected at the fixed ends of the string. At certain frequencies, the waves and their reflections interfere constructively, giving rise to large stationary amplitudes. They are called standing waves. The frequencies of the standing waves are called resonance frequencies f_n. For a string fixed at both ends, the resonance frequencies are:

$$f_n = \frac{nv}{2L} \qquad (1)$$

where $n = 1, 2, 3, 4\ldots$ is called the harmonic number (or the number of antinodes)
v is the speed of the wave on the string
L is the length of the string between the fixed ends (see Figure 1)

The smallest resonance frequency f_1 is called the "fundamental frequency".

In Problem 1 of this lab, you will measure the first 6 resonance frequencies f_1, f_2, … , f_6, and find the wave speed v from the slope of the f_n versus n graph, using Eq. (1).

Alternatively, the speed of the wave on the string depends on the medium and is determined by the tension F_T in the string and the linear mass density μ (mass per unit length) of the string

$$v = \sqrt{\frac{F_T}{\mu}} \qquad (2)$$

This will give you your reference wave speed for Problem 1. In Problem 2 of this lab, you will test the tension dependence of the wave speed in Eq. (2).

Standing Waves on a String – Prelab

Print this page and finish the questions before coming to the lab.

If you want to double the wave speed, by what factor should you change the tension? Why? (Assume that the linear mass density does not change.)

If the wave speed is doubled, what will happen to the fundamental frequency f_1? Why?

If the initial tension in the string is (2.00 ± 0.01) N, calculate the tension (and its uncertainty) that would double the wave speed. This is the "reference value" for Problem 2.

Problem 1 The Speed of Waves on a String

Apparatus

Draw a labeled diagram of the apparatus (see Figure 1) and list all other apparatus required. Obtain wire leads (BNC/coax cables), a 4-beam balance and a function generator from the shelves and cabinets on the back wall of the lab.

Data

Before you make any knots on the string, measure the appropriate quantities to determine the linear mass density of the string, using the 4-beam balance and metre sticks.

Set up the apparatus as shown in Figure 1. The string must be threaded through the *small* hole (not the larger hole) in the shaft of the wave driver and attached to the C clamp.

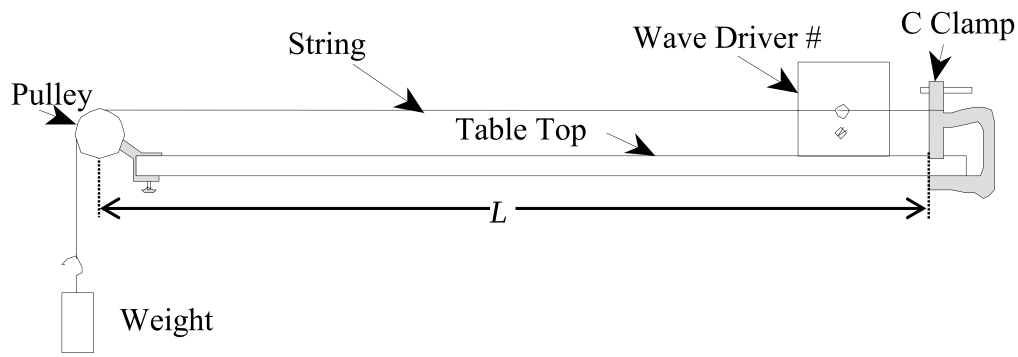

Figure 1

Attach a total weight of 2.00 N (± 0.01 N) to the end of the string. Connect the main output of the function generator to the wave driver. Set the function generator to output a sine wave of maximum amplitude.

Find and record the resonance frequencies of the first 6 harmonics, f_1 through f_6. While making the measurement, determine the uncertainty for both f_n and n. Then measure the length L of the vibrating part of the string (see Figure 1). Record all data in proper table format, with units and uncertainties.

Calculations

Graph the resonance frequencies as a function of the harmonic number and use your graph to determine the experimental value for the speed of the wave on the string. (Refer to your "Graphing Lab".)

Calculate a reference value for the speed of the wave, using Eq. (2).

Uncertainty Analysis / Conclusions / Discussion (do them as separate sections in your report!)

Complete as usual. Do not forget to calculate the uncertainties in your speeds of the wave. State both the measured and reference wave speeds in proper format, and state whether they agree within the uncertainties.

Problem 2 Tension Dependence of the Wave Speed

Apparatus

Same as problem 1.

Data (All data must be recorded in proper table format)

In this part, you will test Eq. (2) by measuring the tension needed to double the wave speed. Recall from the prelab that the tension that doubles the speed also doubles the value of the fundamental frequency.

Set the function generator to two times the fundamental frequency that you found in Problem 1. Record this frequency. You should see two antinodes or $n = 2$. Now, we want to change the tension so that this frequency becomes the new fundamental frequency. Pull gently but firmly on the string until you only see one anti-node. The tension in the string now is the tension that doubles the fundamental frequency, and it is what you want.

To find the value of this new tension, hang different weights on the end of the string until you get the fundamental resonance of the largest amplitude. List in a table the sets of weights you use for each trial, and also note the amplitude and look of the wave pattern produced. Be sure to change the weight by the smallest increment both ways from when you get the largest amplitude to verify that you do indeed have the tension that gives the maximum amplitude. Moreover, considering the smallest increment should tell you the uncertainty in the tension, which is likely to be larger than the sum of the uncertainties of the individual weights ($\pm$ 0.01 N each).

Return the equipment to where you got it.

Conclusions / Discussion

No calculations/uncertainty analyses are needed for this problem.

What is the tension to double the wave speed based on your measurements? What do you expect it to be based on the theory (refer to Pre-lab)? Do they agree within the uncertainties? What do you conclude on how the wave speed relates to the tension, based on your data?

Discuss any physical factors that could have caused deviations from the theory.