WORLD OF LIGHT LABORATORY
LAB 1
Standing Waves

INTRODUCTION

As part of our study of waves, today we will be investigating a particular type of wave phenomenon called the "standing wave." Standing waves are wave patterns that do not move; that is, the medium supporting the wave oscillates, but the overall shape, or "envelope," of that oscillation remains stationary. Examples include vibrating strings on stringed instruments and vibrating columns of air in organ pipes, wind instruments, or a person's vocal tract. Standing waves are also partly responsible for your microwave heating foods unevenly.

As you will observe, a vibrating medium of fixed length will only support standing waves with certain discrete wavelengths. Each distinct standing wave pattern is called a "resonant normal mode," or simply a "normal mode," of the system. In a uniform one-dimensional vibrating system like a string, the wavelengths of the resonant modes have a simple relationship with the length of the string. Also, each wavelength is excited by a different "driving frequency"; in other words, different driving frequencies excite oscillations of different wavelengths, or different normal modes of the system. Your main goal in today's lab is to determine the relationships between wavelength and driving frequency for the resonant normal modes or standing waves of a one-dimensional string of a fixed length.

EQUIPMENT

This lab requires the use of a mechanically driven string. The string is supported between a rod and a pulley. The string also extends over a mechanical driver which vibrates the string in the vertical direction, creating transverse oscillations of the string. A tension is placed on the string by suspending an object from the end hanging over the pulley. The vibration of the mechanical driver is controlled by the settings of the audio driver. The audio driver has three knobs. The left knob sets the vibration frequency range, such as around 50 Hz, 500 Hz, or 5000 Hz. The middle knob sets the vibration frequency amplitude, from low to high. And the right knob sets the actual vibration frequency. The driver has a digital display which shows the frequency, in Hertz. A meter stick and some weights are also provided.

PROCEDURES:

Part 1. Qualitative exploration

Adjust the frequency of the audio driver until you produce standing waves. Sketch the standing wave in the space below. Identify: (a) a *node*. (b) an *anti-node*. (c) one *wavelength*. Label these on your diagram. (Note that the distance between adjacent nodes, or anti-nodes, is half a wavelength.)

Vary the frequency to see what different kinds of standing wave patterns you can produce. Note such things as how the string responds when the frequency is not tuned to a resonance, how sharply-defined the resonances are, and so on. As you increase the frequency, does the wavelength increase or decrease? As you increase the frequency, do you get more or fewer nodes? Do more nodes correspond to longer or shorter wavelengths? What effect does changing the amplitude have on your standing wave pattern? Does it change the wavelengths or resonant frequencies? Do you see other interesting behaviors? Make comments about these things in the space below.

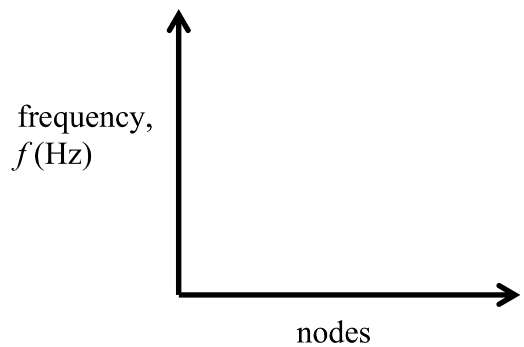
Part 2. <u>Quantitative exploration</u>

In the quantitative exploration, you are to investigate some of the properties of standing waves on a string and their effect on frequency.

(A) Number of nodes. Determine the relationship between frequency, f, and the number of nodes, n. Record the frequency for as many values of n as you can. Include *one* of the fixed ends when counting nodes, but not the other fixed end. Thus, $n = 1$ is the case where there is antinode, which is in the middle of the string. Also, record the string length (the relevant vibrating part, between the pulley and the driver) and the weight on the string. Plot the normal mode frequencies as a function of the number of nodes.

string length_________ weight___________

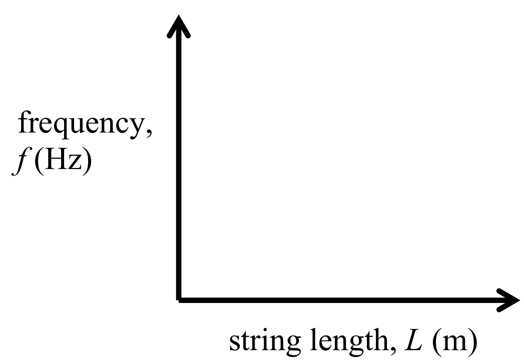
nodes	frequency



(B) Length. Determine the relationship between frequency and the string length, L. First, choose a number of nodes that was relatively easy to find before (e.g. 3). Find the frequency for this many nodes again. Then, move the driver to a different position along the string. This changes L, the length of your vibrating string. Now determine what frequency f once again gives you your chosen number of nodes. Do this for at least 5 different lengths, recording f and L for each measurement. Plot the frequency for the resonant normal modes as a function of length. What kind of mathematical relationship does this look like?

number of nodes________ weight___________

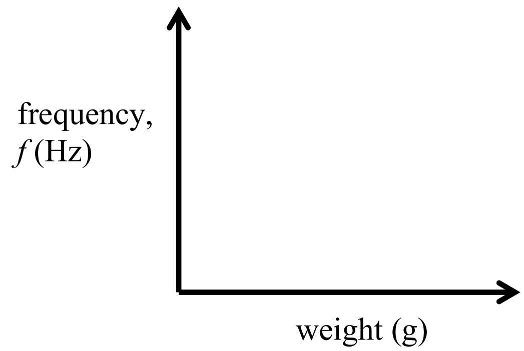
length	frequency



(C) Tension. Determine the relationship between the frequency and the string tension, which is proportional to the weight that's on the end of the string. First, choose a convenient string length and a convenient number of nodes. Vary the weight on the end of the string and adjust f such that you return to the same resonant normal mode.

number of nodes______ string length________

weight	frequency



Part 3. **<u>Data analysis</u>**

Enter your data for the three parts into the Excel spreadsheet provided. Compare the spreadsheet figures with yours. If things don't look roughly the same, figure out why and make corrections.

This spreadsheet includes a "theory" column as part of each data table. It computes the frequency for the conditions that you used according to the equation

$$f = \frac{n}{2L}\sqrt{\frac{T}{\mu}}$$

where: n is the number of nodes, L is the string length, T is the string tension, and μ is the mass per length (m/L) of the string. The string tension is $T = mg$, where m is the mass of the weight that you added and g is the acceleration due to gravity (10 m/s^2). You measured all of the parameters in the equation, except for the string mass per unit length. Thus, change this in the Excel spreadsheet until the "theory" line in the graphs lines up reasonably well with the data points. Record this mass per unit length.

Lab report

This lab explanation and worksheet is purely for your own use, and does not need to be turned in. Instead, turn in a more polished lab report, prepared using Microsoft Word or equivalent. It should have five clearly labeled sections: Introduction, Methods, Results, Discussion, and Conclusions.

Introduction

• Write a few sentences about why standing waves are important.
• From part 1, sketch a standing wave and label a node, anti-node, and a wavelength.
• Give the answers to the qualitative questions that were asked in part 1. As much as possible, don't just give the answers, but explain why you gave those answers.

Methods

• Briefly (3-4 sentences) explain what your experimental methods were. Note that this is not instructions for someone else to follow, but just a brief explanation of what you did.

Results

• Present your raw data in table format and all 3 of your graphs. The graphs should include the best-fit lines. These graphs should be copied from Excel, not hand-drawn. Please keep the data tables relatively small, and shrink the graphs down so that they take less paper.
• Include some text which explains what each graph shows.

Discussion

• Describe how well your data agreed with the theory.
• Why do you think the data did not agree with the theory better? In particular, what are some things that could have caused experimental errors in this lab? (Errors does not mean your mistakes; it means limitations from the equipment or the procedure.)

Conclusions

• Summarize the principle results that you found in this lab in 4-5 sentences. This is *not* about how much you learned, or how fun the lab was. It is about the scientific findings. Include the key qualitative results, and how well your experimental results agreed with theory. If someone else wants to get the gist of what you did with minimal reading, this is what they will read.

Lab report grading will be based about 50% on whether you included the required topics in your lab report, and about 50% on what you presented. Note that longer reports typically say more, and thus get higher grades.