String Vibrations

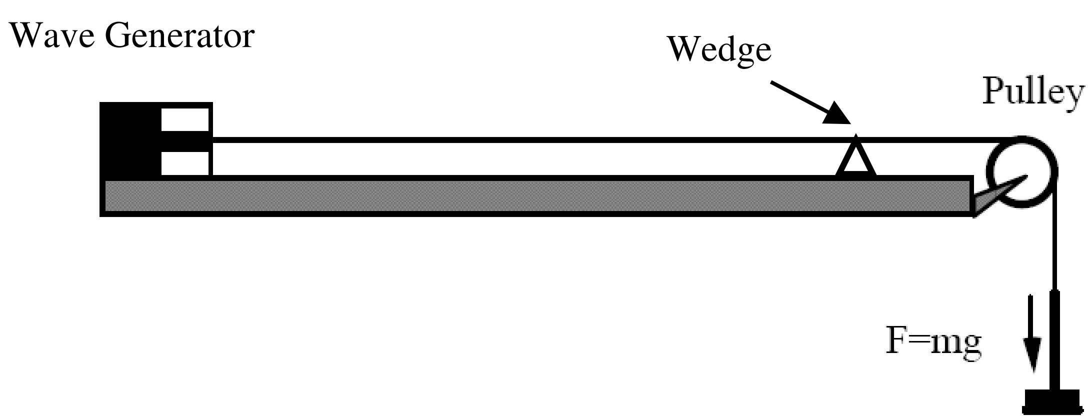
Introduction

A string stretched between two fixed supports can support the propagation of transverse waves. The speed of these waves depends on the tension in the string and the linear mass density of the string. The spacing between the two supports can be selected to be a multiple of the ½ integral wavelength of the wave. When this choice is made the standing wave condition is set up and the propagating wave will be reflected repeatedly from the supports with just the correct phase to reinforce the incoming wave. Under these conditions a standing wave pattern or resonance vibration results. This resonance vibration pattern is characterized by alternating regions of large amplitude (antinodes) and regions where there is no motion of the string (nodes).

The purpose of this lab is to use measurements of the standing waves patterns to calculate the frequency of the wave and compare it to the known frequency of the vibration generator.

Equipment

Computer with Logger Pro SW	Clamp, Humboldt (black)	Mass Set, Gram
Vibration Generator	Block, Wood w/ angle	Paper, White
Pulley, Table Clamp	Mass Hanger, 50 g	Scale, Digital
String		



Standing Wave on a String - Experimental Set Up

Theory

A wave travels down a string with a velocity:

$$v = \sqrt{\frac{T}{\mu}} \qquad \text{Equation 1}$$

where

T is tension and

μ is the linear density in mass of the string per unit length

where

$$\mu = \frac{mass_{string}}{lenth_{string}} \qquad \text{Equation 2}$$

The wave reflects from a rigid end and travels back. If the string is an integral number of half wavelengths long, the string will resonate and display this number of 1/2-waves as shown in Figure 1. The wavelength is:

$$v = f\lambda \qquad \text{Equation 3}$$

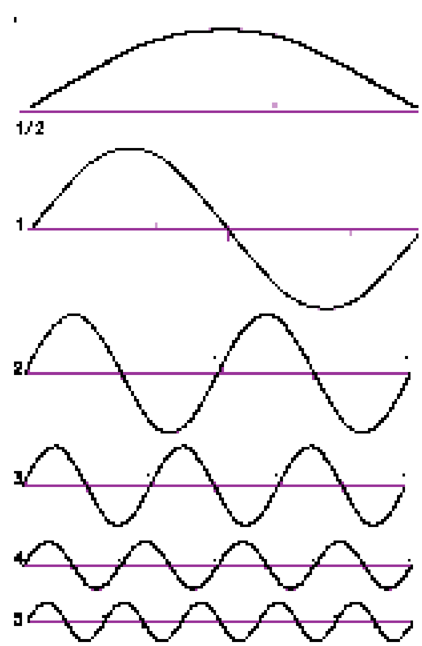
If we combine Equation 1 and Equation 3 we get

$$f\lambda = \sqrt{\frac{T}{\mu}} \qquad \text{Equation 4}$$

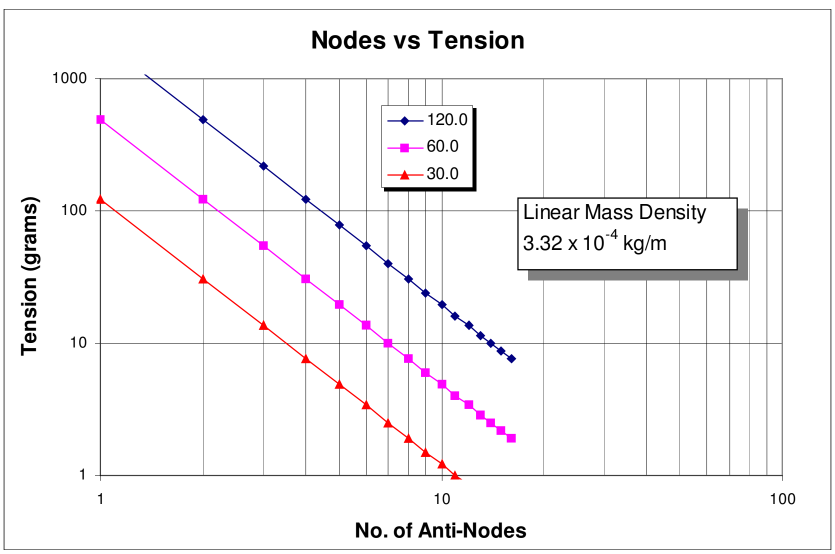
Solving Equation 4 for f we get

$$f = \frac{\sqrt{\frac{T}{\mu}}}{\lambda} \qquad \text{Equation 5}$$

Figure 1



Number of antinodes as a function of Tension.
Each curve represents a different fixed frequency. As the tension is decreased the number of antinodes goes up because the wavelength also decreases and more 1/2 wavelength patterns can fit into a given length. A string length of 1.0m is assumed.



Examples of Standing Wave Patterns

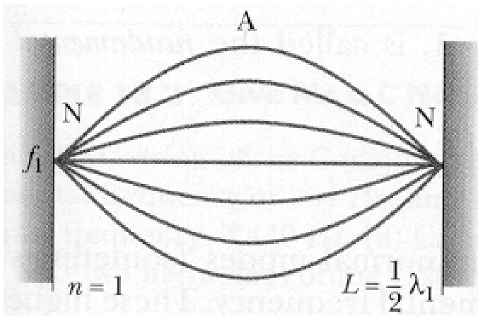


Figure 2. shows a typical half-wave

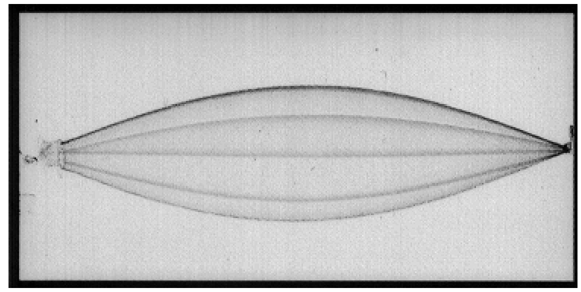


Figure 3. shows an actual photograph of the same half-wave

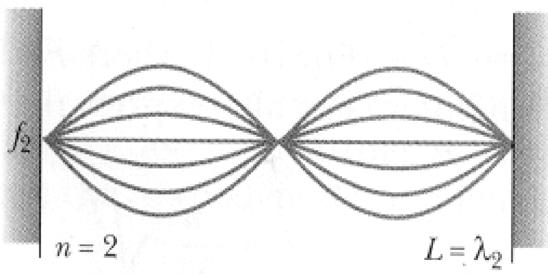


Figure 4. A typical full wave

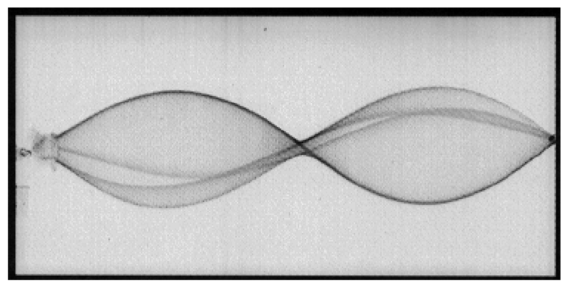


Figure 5. An actual photo of the same full wave.

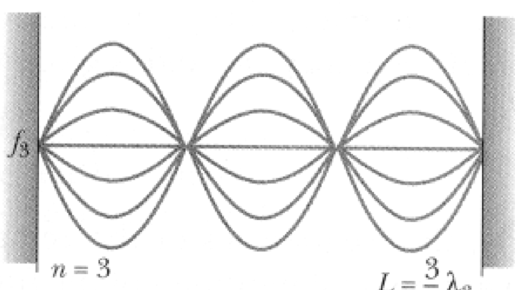


Figure 6. Shows a 3/2 wavelength wave.

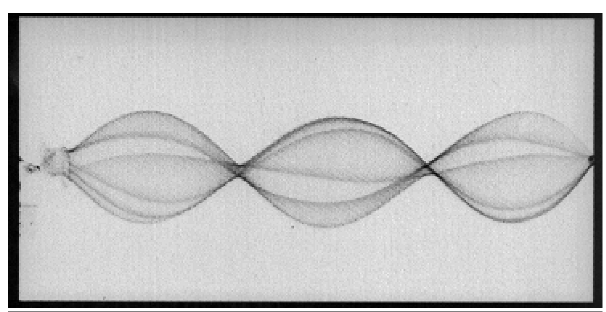


Figure 7. An actual photograph of the same 3/2 wavelength wave.

Procedure

1. Figure 8 shows how to anchor the vibrator in place with the Humboldt clamp.
2. Figure 9 shows the wood block, pulley and string arrangement.
3. Figure 10 shows the pulley and weight arrangement.
4. Begin with a mass of 20g added to the weight hanger. The block should start out close to the pulley. You will be moving the block slowly toward the vibrator until a resonant standing wave pattern is achieved.

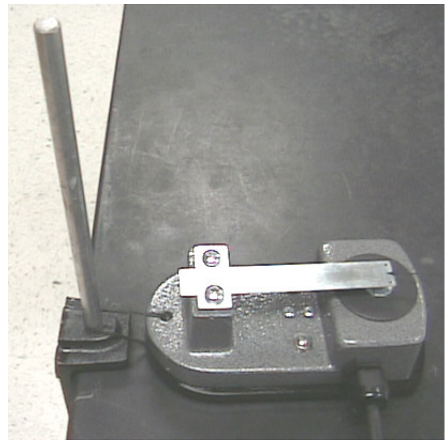


Figure 8

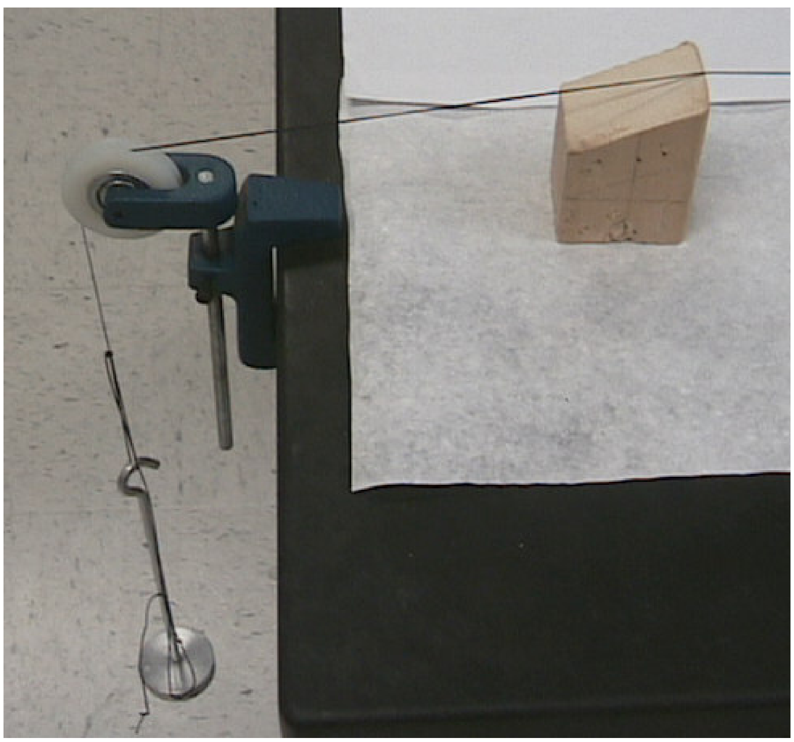


Figure 9

Figure 10

5. You should be able to see the standing wave pattern in the string similar to the illustration in Figures 3, 5, or 7. The tighter the nodes the better your wave is resonating.

   Special notes and hints:

   a. The vibrating configuration should resemble one of the illustrations.
   b. Don't use the node at the end of the vibrator. Use the next node as your FIRST NODE.
   c. White paper under the string makes the waveform easier to see.

d. Try not to allow the hanging mass to swing. Include the mass of the weight hanger.

e. You need to find the wavelength of one wave for your calculations.

i. $\lambda = \frac{2L}{n}$

ii. L = the length of the string from the FIRST NODE to the wood block.

n = the number of antinodes.

6. After you find the first resonant point continue to move the block toward the vibrator until you find another resonant point. You can find 2, 3, or possibly as many as four resonant points over the length of the string.
7. When you have gathered all the data for the 20g. mass add 50g. to the weight hanger and go through the data gathering procedure again getting as many resonant points as possible.
8. Continue adding 50g. increments until the TOTAL hanging mass reaches 320g.
9. Repeat for a second frequency

Data Table

Linear Mass Density: μ = ________________(kg/m)

Total Hanging Mass M (kg)	Tension T = Mg (N)	Length L(m)	n anti-nodes	$\lambda_{predicted}$ = 2L/n (m)	f = $(n/2L)(T/\mu)^{1/2}$ (Hz)	% difference (from 120 Hz)
0.070						

Frequency f_2 (Hz) __________

Total Hanging Mass M (kg)	Tension T = Mg (N)	Length L(m)	n anti-nodes	$\lambda_{predicted}$ = 2L/n (m)	f = $(n/2L)(T/\mu)^{1/2}$ (Hz)	% difference (from f_2)
0.070						

Lab Report

On the back, discuss the sources of errors and their impact on your results.