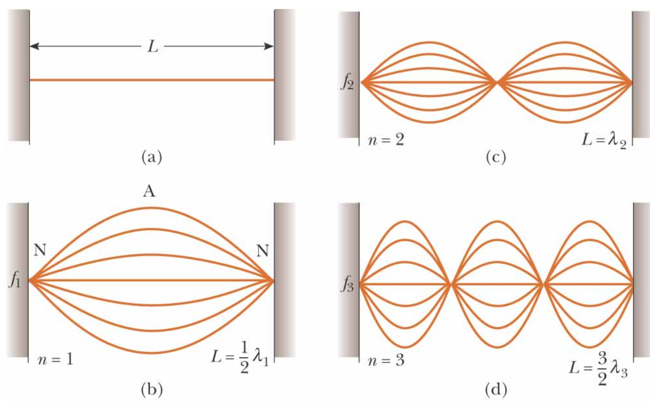
Lab #3
Standing waves on a string

1. Objective

Study and understand the properties of transverse standing waves on a vibrating string fixed at both ends.

2. Theory

Standing waves are produced by the superposition of two sinusoidal traveling waves of the same wavelength and speed traveling in opposite directions. The fixed ends of a string, must necessarily have zero displacement and are by definition nodes. This forces the string to oscillate in very specific modes illustrated below.



The wavelength λ of the standing wave is determined by the number of antinodes or segments (n) in the string. In general the wavelengths of the various normal modes for a string of length l fixed at both ends are

$$\lambda_n = \frac{2l}{n} \qquad n = 1, 2, 3, \ldots$$

since $\lambda f = v$, where the propagation speed in the string $v = \sqrt{T/\mu}$ depends on the tension T in the string and its linear mass density μ, it is possible to express the natural frequencies of a taut string as

$$f_n = \frac{n}{2l}\sqrt{\frac{T}{\mu}} \qquad n = 1, 2, 3, \ldots$$

In the following experiment, the frequency will remain unchanged, while the tension in the string is changed by changing the hanging mass

3. Apparatus

- 120 Hz motor
- string
- slotted weights and hanger
- meter stick
- triple beam balance

4. Procedure

1) Obtain a piece of thin black string a bit longer than the table. Measure its exact length as precisely as possible, making sure that there are no loops or knots. Measure the mass of your string on the balance. From your measurement determine the linear density, μ, of the string.

2) Attach one end of the string to the weight hanger and the other to the motor as shown in figure 1. Connect the motor to a socket and add mass to the hanger until a stable standing wave of 8 segments/loops ($n = 8$) is produced. Record the total amount of mass, including the hanger. The system will be sensitive to mass differences of as little as 1 gram. Repeat for 7, 6, 5, 4, and 3 segments. ***DO NOT ATTEMPT LESS THAN 3 SEGMENTS!!!***

3) Measure the exact value of the length l, shown in figure 1. This is not the same length that you measured in step 1.

5. Analysis (done in your logbook)

1) Make a table giving the values of n, λ, m, T, λ^2, and their associated uncertainties.

2) Make a graph of λ^2 versus T. From the slope of your graph, and the calculated value of the linear density, obtain a value for the frequency of vibration f, with uncertainties. Compare the obtained value to the theoretical value of 120 Hz.

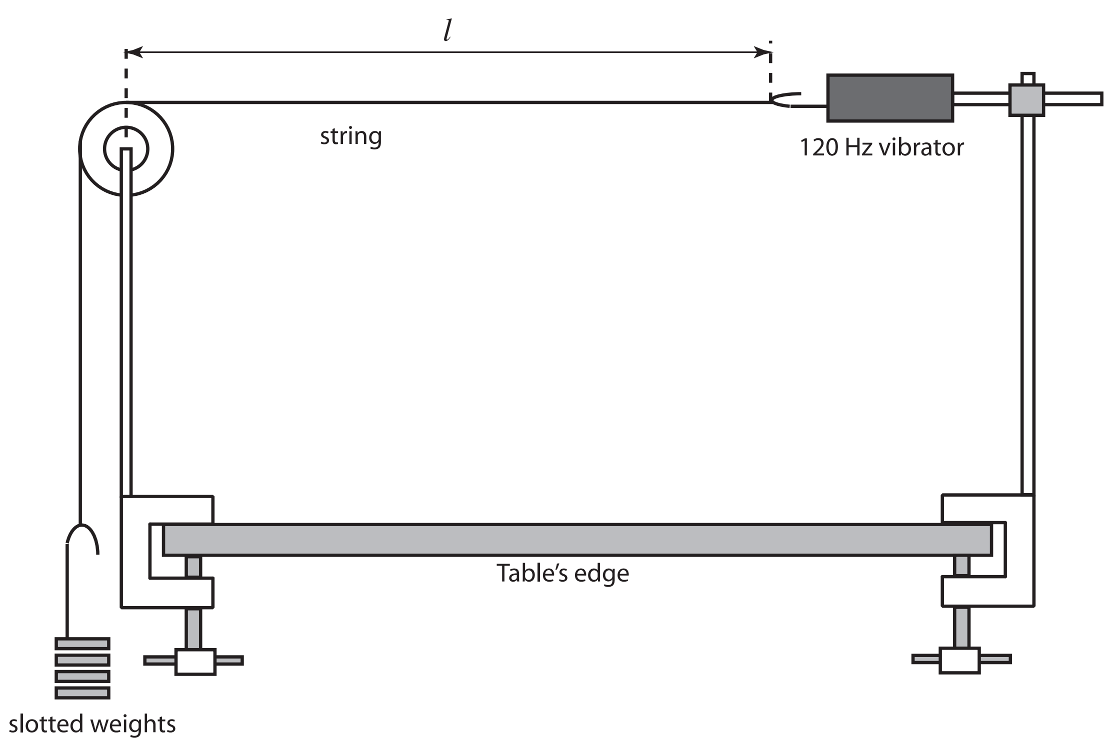


Figure 1