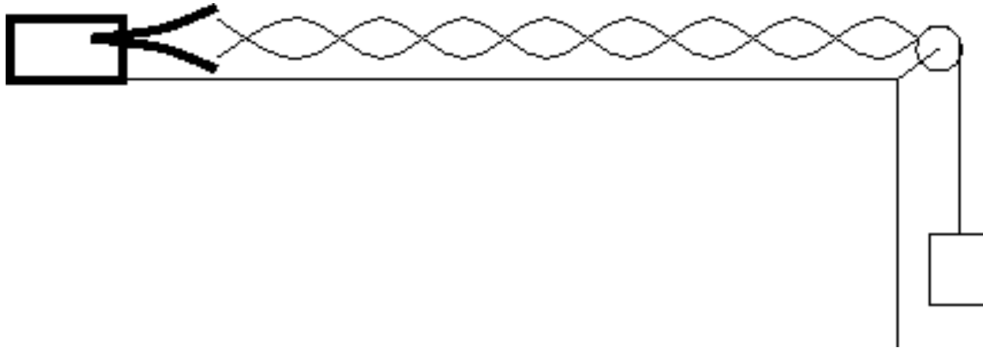# Lab 4:
Transverse Standing Waves

Prof. Olness

PHYS 1320
Fall 2019

1 Introduction

Today's experiment consists of a tuning fork mounted to the lab bench, which vibrates a horizontal string that can be draped over a pulley and loaded with mass as in the figure below.

Adding mass to the hanger will change the tension in the string. This will change the wave speed in the string. With the frequency and string length fixed throughout the experiment, we will generate different standing wave modes with different wavelengths. We will measure the wavelengths of the various standing waves and find the relationship between tension and wavelength.

The frequency for a standing waves in a string under tension is,

$$f = \frac{v}{\lambda} = \frac{1}{\lambda}\sqrt{\frac{T}{\mu}}$$

where f is the linear frequency of oscillation, v is the wave speed in the string, λ is the wavelength of the vibrations, T is the tension in the string, and μ is the linear mass density (mass per unit length) of the string.

2   Procedure

2.1   Attach the mass hanger to the free end of the string over the pulley

Use the c-clamp to secure the tuning fork to one end of your lab table. Make sure that the string is as long as possible and parallel to the lab table. Ask the TA to help you adjust the spark gap on your tuning fork for efficient operation. Measure the length of your string from the pulley to the tuning fork and record it in your lab notebook.

2.2   Add some mass to the hanger and turn on the tuning fork vibrator

Do NOT supply more than 7 volts DC to the vibrator! You probably will not see a standing mode initially. Now it is time to adjust the weight on the hanger.

2.3   Observe six or seven normal modes of vibration

The fundamental requires about 1.5 kg on the hook. Find the fundamental and record the mass required in your lab notebook. The higher normal modes are obtained by decreasing the mass on the hook. *Slowly* change the amount of mass on the hook. Try and achieve the best precision possible when you measure the mass on the hanger. What is the error for your measurements?

Eventually, the mass of the empty hook (50 g) will limit the number of normal modes that you can observe. Try to find as many as possible so that your mean measurement has as small an error as possible (the "Error on the Mean").

2.4   Normal Modes

- Determine the tension in the string, $T = mg$ where m is the mass in kilograms, and $g = 980$ cm/s^2 is the average acceleration due to gravity at Earth's surface.

- Determine the wavelength of oscillation for each normal mode by dividing the length of the string in centimeters by the number of anti-nodes in each mode.

- Determine the normal mode, $n = (N - 1)$, where N is the number of nodes. *Remember:* There is a node at each end where the string is fixed.

2.5   Repeat

Find as many different normal modes as possible. Record all data in a neat table in your lab notebook. Don't forget to report errors and give exaples of each calculation.

2.6   Find the Linear mass density (μ)

The TA will measure the linear mass density of the string and provide this value to the class.

3   Analysis

- Plot the quantity m vs. λ^2 ,where m is mass, and λ is wavelength. Put λ^2 on the horizontal axis, and m on the vertical axis. Don't forget to include an appropriate title on your plot and indicate units. Is this a straight line?

- Start with the formula from the prelab relating linear frequency, string tension, linear mass density, and wavelength. Write a formula for the linear frequency of vibration in terms of measured quantities only (hanger mass, length, string mass, and number of nodes).

- Is the manufacturer's linear frequency $f = 80$ Hz within your error bounds? In other words, can you verify that the tuning fork is operating as advertised within the uncertainty on your measurement?

- Identify at least two sources of statistical error and comment on how to reduce these errors.

- Identify at least two sources of systematic error and comment on how to reduce these errors.

- As usual, include Abstract, Conclusions, and other comments in your lab write-up.