Waves on Ropes and Strings PH1140

Introduction

We begin our experimental study of waves with the simplest type, waves on a rope. We refer to these waves as "one dimensional" for the reason that they travel along a medium, the rope, that is essentially one dimensional. If the rope is long and comparatively thin, its thickness has little effect on the nature of the waves. Waves are easy to create on a rope. Two people hold opposite ends of the rope and pull to apply a steady tension. Then one person oscillates one end at a fixed frequency to create transverse waves. The oscillations may be oriented left and right or up and down, or may even be circular. With a little practice, you learn to keep a constant tension while you shake the rope. A wave can be a traveling wave train, a single pulse, or a standing wave. A third person can "thump" the rope to create a pulse that travels both directions along the rope and is felt a moment later by the people holding the ends.

Tension is required to achieve a standing wave. As you vary the tension in the rope, you find you must vary the frequency to maintain a standing wave. You can find the fundamental mode (lowest frequency, longest wavelength mode) by shaking slowly, and as you shake faster and faster, you find successively higher and higher modes of standing waves. How high can you go? You can also create helical traveling waves and circular standing waves on the rope. Instead of shaking one end left and right, move the end in a circle to make helical waves. It is also possible to create circular waves by applying linear oscillations at the ends. Can you do this? You might attempt to measure the wave speed by timing a pulse as it travels down the length of the rope. This method is not easy since the pulse is fleeting. Having made such a rough measurement, you may then relate the wave speed to the tension and mass density of the rope. By also measuring the tension, you could even calculate the mass density. But there is a much more accurate way to do this.

Setup for Rope Experiment

Two lab partners hold opposite ends of a long rope, and pull to apply a constant tension to the rope.

Informal Procedure, Waves on a Rope

Practice making waves on the rope. Play around and develop a little skill with keeping a steady tension and shaking the rope at just the right frequency to create standing waves. Make traveling wave trains and pulses. Are you able to see the reflection of a pulse from one end? Explore the effect of tension on wave characteristics (shape, speed, period, wavelength and mode).

Formal Procedure, Waves on a Rope

1) Create planar modes on the rope in the vertical plane by applying a motion to one end of the rope.
2) Create planar modes on the rope in the horizontal plane by applying a motion to one end of the rope.
3) Create circular modes on the rope. Use three different methods:

- **a)** hold one end still and oscillate the other end in a circular motion;
- **b)** oscillate both ends, one vertically, the other horizontally; and
- **c)** oscillate both ends, both clockwise, both counter-clockwise, or oppositely.

For **(1)** through **(3)**, describe with words and sketches the applied motions required to create the modes. Describe each motion in terms of shape (linear, circular), direction, amplitude, frequency and tension.

Setup, Waves on a String

As shown in the second figure above, mount a string vibrator on the lab bench, attach a string to the vibrator, place the other end of the string over a fixed pulley and attach a mass hanger from the string to apply tension to the string.

Informal Lab Procedure, Waves on a String

Power-up the string vibrator and with your fingers apply "weight" to the hanger to create various standing modes on the string. Observe how the amplitude resonates with particular weights. Note that the string length varies with applied weight, which affects the mass density μ of the string. Also inspect the node nearest the vibrator tip, and note how the node does not always coincide with the tip.

4) Describe how to take into account the length variations in order to determine the mass density of the un-stretched string.

5) Describe how to measure the length of the vibrating string as a whole number of half-waves.

Formal Lab Procedure, Waves on a String

Place mass on the hanger to produce a standing wave on the string. Find the best resonance by adjusting the mass to maximize the amplitude of the wave.

6) Why make the effort to find the best resonance?

<u>Simple procedure:</u>

7) Record the length L of the string, mode number n and mass m to produce the mode. Calculate the string's linear mass density μ. For this you need the oscillation frequency, which is $f = 120\ Hz$.

Challenge procedure (optional):

8) Record the un-stretched string length L, the stretched string length L', the mode number n and the mass m required to produce the mode.

9) Calculate the string's stretched linear mass density μ'. For this you need the oscillation frequency, which is $f = 120\ Hz$.

10) Calculate the string's un-stretched linear mass density μ.