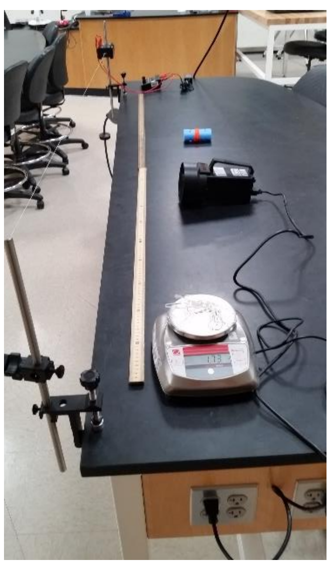
Physics 197 Lab 1: Traveling Waves on a Slinky and Standing Waves on a String

Equipment:

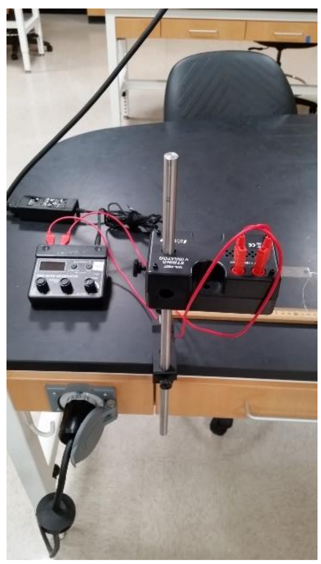
Item	Part #	Qty per Team	# of Teams	Total Qty Needed	Storage Location	Qty Set Out	Qty Put Back
Sensitive Balance for string	Ohaus Valor 3000	Shared	8	2			
Regular Balance for slinky, spring	Scout Pro 200g	Shared	8	2			
Slinky for Waves		1	8	8			
Spring for Waves		1	8	8			
Lab Stand		1	8	8			
Spring Scales for Tension 500g, 2kg	Ohaus, Sargent W	Shared	8	?			
Timer	Mychron	1	8	8			
Meter Stick		1	8	8			
Sine Wave Generator	Pasco WA-9867	1	8	8			
String Vibrator	Pasco WA-9857	1	8	8			
String Vibration Mounting Hardware		1 set	8	8 sets			
Set of 2 strings with different density		1 set	8	8 sets			
500 g mass		1	8	8			
Banana plugs		1 set	8	8 sets			
Stroboscope	Extech	Shared	8	2			

Layouts:

Slinky and Spring for Travelling Waves



Vibrating String Set-up



Sine Wave Generator and String Vibrator

String Pulley and 500g mass

Summary:

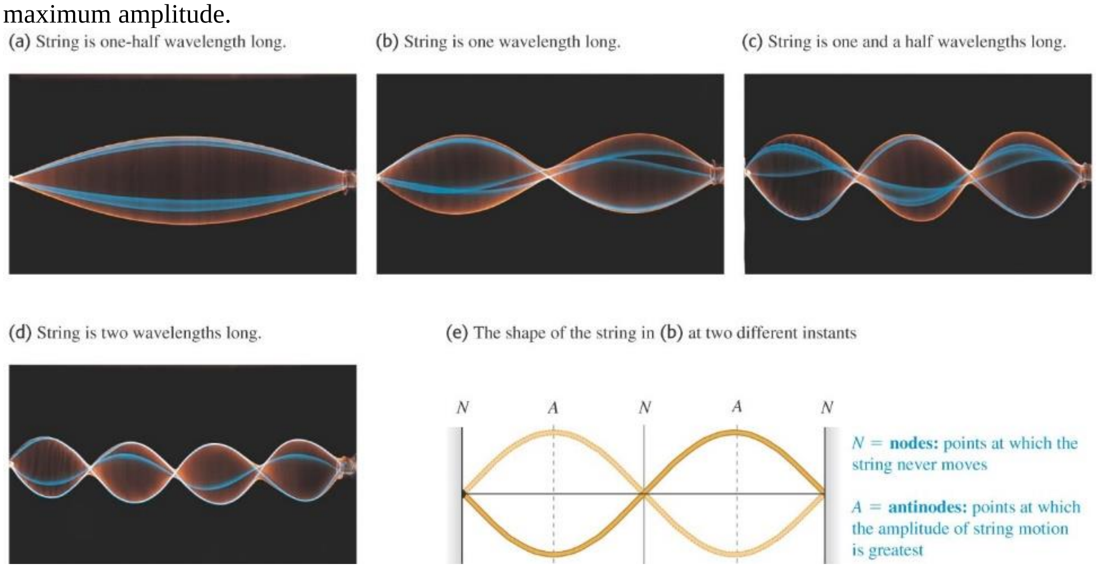
In this lab, students will investigate travelling waves and standing waves. Longitudinal traveling waves will be observed along a stretched slinky, while transverse traveling waves will be observed using a stretched spring. The velocity of the traveling waves will be measured as the length of the slinky or spring is changed, and related to the tension in the spring. Standing waves will be investigated by looking for resonances in a stretched string when vibrated at particular frequencies. The fundamental resonant frequency and its harmonics will be compared to theoretical values based on string linear density, length, and tension. A strobe light will be used to make it appear as if the string is standing still so the sine wave nature of the standing wave can be seen directly.

PreLab:

The goal of the first part of the lab will be to measure the wave speed on both a long spring and a slinky as they are stretched to different lengths by timing how long a wave impulse takes to go down the spring and back (reflecting off of a fixed end). Look up and write down a formula for how the wave speed in a string or spring depends on the Tension and the Linear Density (mass per unit length). If the length of the spring is doubled, what happens to the linear density? If the spring's length is doubled (once it has been stretched a little), what happens to the tension? Using your formula, what do you expect to happen to the wave velocity? What will happen to the round trip time?

The goal of the second part of the lab will be to investigate standing waves on a string. Please review the following discussion, and tape it into your lab notebook.

THEORY: Standing waves can be produced when two waves of identical wavelength, velocity, and amplitude are traveling in opposite directions through the same medium. Standing waves can be established using a stretched string to create a train of waves, set up by a vibrating body, and reflected at the end of the string. Newly generated waves will interfere with the old reflected waves. If the conditions are right, then a standing wave pattern will be created. A Stretched string has many modes of vibration, i.e. standing waves. It may vibrate as a single segment; its length is then equal to one half of the wavelength of the vibrations produced. It may also vibrate in two segments, with a node at each end in the middle; the wavelength produced is then equal to the length of the string. It may also vibrate in a larger number of segments. In every case, the length of the string is some integer multiple of half wavelengths. So, if a string is stretched between two fixed points, the ends are constrained not to move; hence, these are the **nodes.** In a standing wave the nodes, or the points that do not vibrate, occur every half wavelength; thus, the ends of the string must correspond to nodes and the whole length of the string must accommodate an integer number of half wavelengths. Roughly midway between the nodes are **antinodes**, which is where the standing wave has maximum amplitude.



Remember that a wave traveling along a string will have a velocity given by $v=(F_T/\mu)^{1/2}$ where FT is the tension in the string and μ is the linear density of the string. If the wave velocity is "right", then the standing wave will have a wave velocity of $v=\lambda f =(F_T/\mu)^{1/2}$ so the frequency $f=(F_T/\mu)^{1/2}/\lambda$.

Thus the fundamental frequency for a particular string (where FT and μ are constant) would be $f_1 = v/\lambda = v/2L$

Notice that the length of the string is L and that a standing wave of the fundamental frequency is ½ $\boldsymbol{\lambda}$, so $\boldsymbol{\lambda} = 2L$. The other allowable frequencies (that generate standing waves) would be integer multiples of this fundamental frequency. This can be written as

$f_n = nf_1 = nv/2L$.

Lab 1A: Travelling Wave on a Spring and Slinky

(This part of the lab should take about an hour)

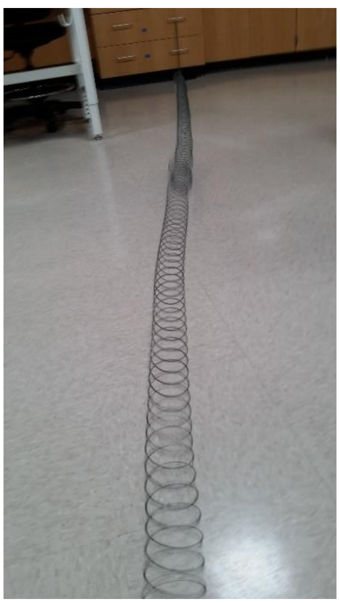
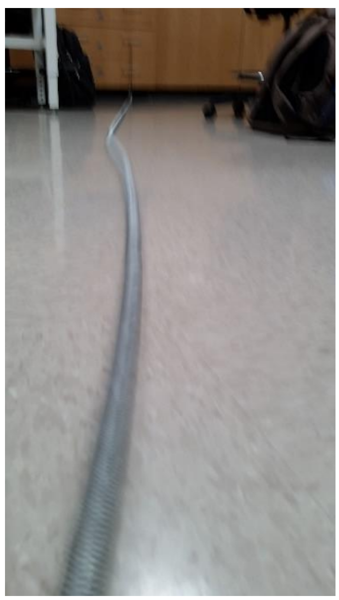
1. Using the Scout Pro balance, measure the mass of the long spring and of the slinky

2. Measure the (back and forth) pulse propagation time for the long spring at a range of spring lengths. (It can stretch pretty far, but don't stretch it past its elastic limit). One end of the spring can be attached to a lab stand held in place. For this spring, use a quick transverse vibration at the free end. Make 4 pulse propagation time measurements at 6 different lengths spread fairly evenly to the maximum length chosen. (For example: 3m, 4m, 5m, 6m, 7m, 8m). Also attempt to use the spring scales to measure the tension at each spring length. This may be a little tricky with the spring on the floor. The 20N Ohaus Spring Scale or 25lb. Viking Spring Scale should work for this. (1 lb. = 4.45 N)

3. Tabulate the data neatly in a table. Have columns for measured spring length, for measured round trip pulse times, average of measured round trip pulse times, and calculated wave velocity (2 x length/time). Add columns for spring tension (even if extrapolated from shorter length) and theoretical wave velocity (from prelab). Finally, add a column for percent difference between the two wave velocity values.

4. Discuss reasons why the measured and predicted wave velocity values might not agree. If your measured round trip pulse propagation times were similar for different spring lengths, discuss why this might be the case.

4. Repeat steps 2-4 for the slinky. The 500g OHaus Spring Scale should work for the slinky.

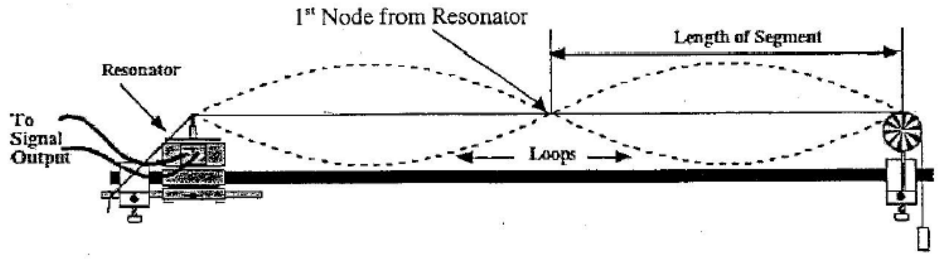



Slinky with Longitudinal Wave   Spring with Transverse Wave

Lab 1B: Standing Waves on a String

The purpose of this lab is to study the relationship between stretching force (FT), wavelength (**λ**), vibrational frequency (f), linear mass density (μ), and wave velocity (v) in a vibrating string and to observe standing waves and the harmonic frequencies of a stretched string.

The Pasco sine wave generator, the Pasco string vibrator, one of the strings, a pully and a 500g mass will be set up something like in the following diagram. (Also see the pictures on the first page of the write-up).



Set up of Apparatus

1. First take a piece of string about 2.5 meter long, and measure its length when "taut". Using the sensitive balance, measure the string's mass. Using the measured values, calculate the linear density of the string.

2. Tie one end of the string to the vibrator arm. Pass the other end over the pulley and attach it to the 500g mass. Be sure the string is parallel to the table top. Measure the length of the string from the vibrator arm to the pulley and record. Calculate the tension FT in the string.

3. Make a table in your lab notebook with columns for number of segments n (going from 1-8), calculated vibration frequency for that number of segments (using formula based on length, linear density and tension in prelab discussion), measured vibration frequency and percent difference. (The table should have 4 columns and 8 rows).

4. Turn on the sine wave generator and start the frequency at 10 Hz. Increase the frequency until you establish a 1 segment (2 nodes) standing wave pattern. To adjust the frequency, first turn the course frequency knob. If you believe you have one segment but might not have maximum amplitude, adjust the fine frequency knob. Record the measured resonant frequency in the appropriate column in your table.

5. Increase the frequency, and record the value where you get 2 segments. Continue for 3, 4, 5, 6, 7 and 8 segments.

6. Calculate and record the percent differences between your expected and measured resonant frequencies. Discuss possible reasons for any differences between calculated and observed frequencies. (If there is a huge difference, you should first check your theoretical calculation for mistakes).

7. Repeat steps 1-6 for a second, different string. Is the linear density larger or smaller for the second string? Do you expect this string to have a higher or lower fundamental frequency than the first one?

8. Use the strobe light to make the vibrating string appear to stand still. (We may have to do this as a class with the room lights out. It should be possible to observe something like the following picture). The orange string works best for this.

9. Be sure to include a conclusion in your lab notebook discussing what you learned in today's lab.