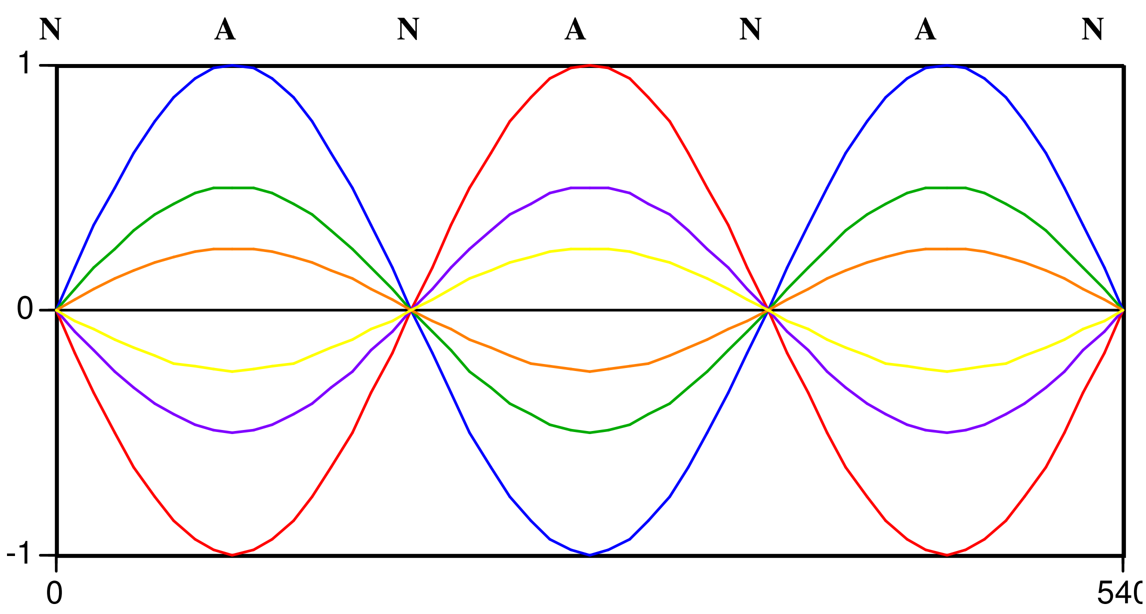
**Physics 216 Lab 2**
**Waves**

Objectives
To study the velocity of waves; to examine the relationship between velocity, frequency and wavelength under resonant conditions when standing waves are produced; and to observe sound waves from various sources.

This lab consists of two investigations. In the first one you will study pulses and standing waves on a long spring. In the second, you will observe sound waves from various sources. These investigations are independent of each other and can be done in any order.

Discussion
A wave can be defined as a disturbance which propagates through a medium. To a good approximation, the velocity of propagation is independent of the shape of the wave. Thus, it should make no difference whether we consider the velocity of a pulse, the velocity of a sinusoidal wave, or a wave of any arbitrary shape.

Traveling waves are waves which move through a medium and can be reflected and/or transmitted at a boundary with another medium. When the conditions are appropriate, it is possible for a traveling wave to produce a standing wave. A standing wave is a wave with a pattern which remains fixed in space. Certain regions of the medium do not oscillate (these are called nodes, N) while other regions of the medium, exactly 1/4 of a wavelength away, oscillate with the maximum possible amplitude (these are called anti-nodes, A, or loops). (See the following diagram.)




A standing wave arises when the reflected part of the traveling wave combines (interferes) with the incoming part of the traveling wave in such a manner that the resulting wave remains fixed in space. This condition is called resonance. In this laboratory you will be exploring resonance on a spring.

Resonance, a phenomenon which can be observed in many very different physical systems, can occur only if the parameters of the system are carefully adjusted. The simple systems we are considering have basically only three parameters to adjust: velocity, frequency, and length. In the case of the spring, the frequency will be varied to achieve a particular wavelength and thus resonance.

**Investigation 1: The Velocity of Traveling and Standing Waves on a Spring**

**Question 1**: Suppose you stretch a long spring until its length is L. You pluck a string at one end and the resulting pulse travels down the spring to the other end and returns. If the time it takes to make this trip is t, write an equation for the velocity of the pulse in terms of L and t.

**! Checkpoint 1**

**Activity 1-1: Measuring the velocity of a transverse pulse traveling along a spring**

1. You should have a long spring, a two meter stick, and a stopwatch. Take these either to the center of the laboratory or out into the hall. This is where you will do the experiment.
2. The spring should be placed on the floor with one person at each end. Stretch the spring until its length, L, is about twice its unstretched length. Measure this length and mark the location of the ends. (Masking tape or floor tile boundaries are useful for this.)
3. Now pluck the spring and measure the time, t, for the resulting pulse to travel to the far end and return. Repeat this process at least five times, and record your data in the table below.

   L = __________________m

| | | | | | | |
|---|---|---|---|---|---|---|
| Trial # | | | | | | |
| Time (seconds) | | | | | | |
| Velocity (m/s) | | | | | | |

4. Using the equation derived in Question 1, calculate the velocity associated with each time. Find the average of these values and the associated standard deviation. (You can use Excel or your calculator if you want.)

$v_{pulse}$ = ___________±___________m/s

5. Now stretch the spring to a longer length (between 2 and 3 times the unstretched length of the spring). Measure the length and repeat steps 3 and 4. Record the results below.

L = _______________m

| | | | | | | |
|---|---|---|---|---|---|---|
| Trial # | | | | | | |
| Time (seconds) | | | | | | |
| Velocity (m/s) | | | | | | |

$v_{pulse}$ = ___________±___________m/s

**Question 2:** How does the speed of the wave change as the spring is stretched further? Note that for waves on a string (or spring) the wave speed should follow this relationship: $\sqrt{\frac{F_{Tension}}{\mu}}$, are your results consistent with this result? (Hints: How should F scale with the extra stretch? What happens to the mass density with the extra stretch?)

**! Checkpoint 2**

**Activity 1-2: Predicting the period of a standing wave on a spring**.

**Question 3**: How many wavelengths are there in the standing wave shown on the first page of this lab? What is the wavelength of this wave in terms of the length, L, of the spring?

**Question 4:** Write a general expression for the wavelength of a transverse standing wave on a spring fixed at both ends in terms of the length of the spring, L, and the number of anti-nodes, n.

According to the equation developed in class, the phase velocity of a wave (either traveling or standing) is given by:

$$v_{phase} = \lambda f = \lambda/T \qquad (1)$$

where λ is the wavelength, f the frequency, and T the period. For a standing wave, the possible wavelengths can be found using the results of Question 4. To predict the periods that will give standing waves, you also need to know the speed of the wave. You measured the speed of a wave pulse in Activity 1-1; if the wave speed doesn’t depend on the shape of the wave, it should be the same in this activity, provided that the spring is stretched the same amount.

**Question 5:** Sketch the standing wave patterns for the three longest wavelength standing waves that can be produced in a spring fixed at both ends (that is, for waves with 1, 2, and 3 antinodes). For each pattern, write the wavelength in terms of the length, L, of the spring, and also write the period T in terms of L and v.

n=1:

n=2:

n=3:

1. Use your equations from Question 5 and the measured wave speeds and lengths from Activity 1-1, parts 3 and 4, to predict the period for the three longest wavelength standing waves that can be formed in the spring when it is stretched to about twice its unstretched length. Include uncertainties.
T(n=1):

T(n=2):

T(n=3):

2. Use the same spring as you did in Activity 1-1, and stretch it to the first length for which you measured the wave speed. Set up a standing wave by moving one end back and forth in a transverse motion. Use the stopwatch to measure the period for each of the three longest wavelength standing waves. Measuring the time for several (say, 10) full cycles and dividing by the number of cycles will give a better result for the period than trying to measure the time for just one period. Record your results below, along with uncertainties.
measured T(n=1):

measured T(n=2):

measured T(n=3):

**Question 6:** Compare your predicted and measured values of the period. Do they agree? Why/why not?

**Question 7:** Do your results indicate that the wave speed for the waves that make up the standing wave is the same as for a wave pulse? Explain.

**! Checkpoint 3**

Remove any tape from the floor.

**Investigation 2: Observing sound wave patterns**

For this part of the experiment, you will use a microphone that is interfaced to your computer in order to observe the waveforms produced by tuning forks and your voices.

1. Open *Logger Pro*. To open the proper experiment file, select *File/Open* and follow the following path:
   Go to: *Experiments* | *_Physics with Vernier* ;
   then select *34 Tones Vowels Telephone*;

Your computer screen should display two graph types. The top one will plot pressure vs. time, that is, it will give you a sample of the waveform over a length of time. The second graph will give you a frequency spectrum. It plots the strength (intensity) of a particular frequency vs. frequency.

2. You are now ready to collect data. As a quick test to determine if the microphone is working, gently hit a tuning fork with the rubber mallet, hold it over the microphone, and click on *Collect*. A "Please Wait" message should appear over the graphs. When the computer has gathered the data, it will display it.

3. What we want to determine from the waveform graph is the period, T, the time for one cycle. However, to minimize uncertainty, we will measure the time for several cycles and divide by the number of cycles. The easiest way to do this is to use the Examine feature. Click on the *Analyze* menu and select *Examine*. Use the cursor to select a range which includes <u>exactly</u> a whole number of cycles. Do this as carefully as you can. Determine the associated time interval. By dividing this time by the number of cycles you will have the period. Repeat this process several times and record the values. Are they consistent? Find the average of these values and the associated uncertainty.

T = _______________±___________s

4. Now, calculate the average frequency ($f = 1/T$) and the associated uncertainty.

f = _______________±___________cycles/s

**Question 8**: How does the frequency determined above compare to the number stamped on the tuning fork? Is there good agreement?

5. The frequency can also be determined directly from the frequency spectrum displayed in the second graph. This is a spectrum of the frequencies which are present. Record the main frequency displayed and its uncertainty.

f = _______________±___________cycles/s

**Question 9**: How does the frequency determined from the frequency spectrum compare to the value found from the top graph? To the frequency of the tuning fork? Is there good agreement?

6. Store this data (*Experiment/Store Latest Run*), and repeat this procedure using a tuning fork which produces a different frequency. Compare the two waveform vs. time graphs. (Note that the frequency graph records only for the most recent data set.)

**Question 10**: According to the graphs, which tuning fork has the higher frequency? Does this agree with what's stamped on the tuning forks and with what you can hear? (Frequency is also described as pitch.)

Notice that the amplitudes of the two waveforms are also probably different.

**Question 11:** How can you change the amplitude? Try it. What feature of the sound you hear corresponds to the amplitude?

There is one other attribute of a sound which we can explore: the quality of sound. When a guitar, a saxophone, and a trumpet all play the same note, each sounds different, even though the pitch is the same. This particular property of sound is called the quality. You can explore this property using your own voice.

7. With your voice, try to match the pitch of the tuning fork using the word "ah". Record the resulting pattern. Repeat the procedure using different vowel sounds. How do the patterns differ? How do the frequency spectrums differ? Compare the patterns produced by your lab partners.

**! Checkpoint 4**