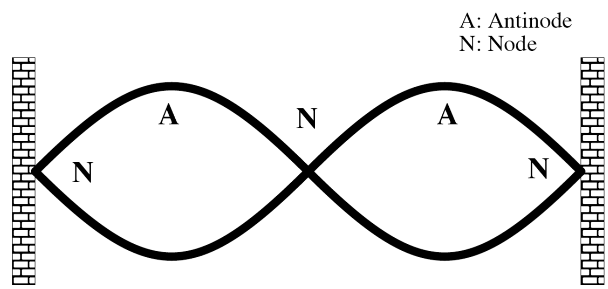
PreLab 4 – Standing Waves in a String

Standing waves are set up in the strings of musical instruments when they are plucked, bowed or struck. They are set up in wind instruments when air is blown through them. For example, a violin bow will excite a unique standing wave vibration of the string. The string's vibrations are a result of waves moving back and forth in opposite directions along the string. These waves interfere with each other in such a way that the string as a whole does not appear to be moving; hence the name **standing waves**. Also standing waves only occur when the frequency of the vibration in the string allows for constructive (positive) reinforcement.

In our lab the string is "fixed" at one end by a pulley with a hanging mass. At the other end of the string is the vibration driver or oscillator, which vibrates with a very small amplitude. Since this amplitude is small compared to the peak amplitude of the wave, we will treat this location as a fixed end also.

Standing waves in a string



If two waves of the same frequency travel in opposite directions in this medium and meet, the disturbance they will produce will look like a wave that is neither moving one way or another. We say that a standing wave is produced. It is a result of the interference of the two waves. At some points, called **nodes**, the interference causes the amplitude of the oscillating medium to be zero and the interference is said to be completely destructive. At other points, called **antinodes**, the waves reinforce one another so that the amplitude is largest here and the interference is said to be constructive. The standing wave is on a string that is fixed at both ends. The nodes, labeled "N" occur at the fixed ends and in the center at 1/2 the wavelength. The antinodes occur at "A."

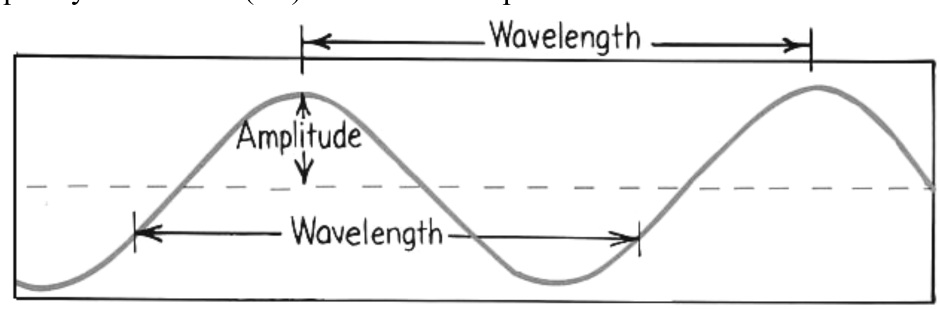
The allowed frequencies occur when its length L is such that nodes occurs at both ends where the string is not allowed to vibrate. In general, the condition for an node at both ends is $L = n\lambda/2$, where $n = 1, 2, 3, 4, \ldots$. In this case, the wavelength λ of the standing wave is defined by $\lambda = 2L/n$.

From the above condition for standing waves, you can determine the frequencies of the resonant standing waves using the following relationship with the velocity of a transverse vibration in the string, v_s,:

$$\lambda f = v_s, \quad \text{where} \qquad v_s = \sqrt{\frac{T}{\mu}},$$

T being the tension in the string and μ its mass per unit length.

The term **amplitude** refers to the distance from the midpoint to the crest, maximum point of the wave, or trough, minimum point of the wave. So amplitude is the maximum displacement from equilibrium. The **wavelength** of a wave is the distance from the top of one crest to the next, or the distance between any successive identical parts of the wave. How frequently a vibration occurs is called its **frequency**. The unit of frequency is the hertz (Hz). One vibration per second is 1 Hz.



LAB 4 & Lab Report

Name: ___________________________ **Section**: _______________

Properties of Waves

Equipment: Ripple tank, mechanical vibrators

Although you cannot directly see sound waves there are a number of ways to help you visualize how sound waves (and other types of waves) behave and what some of their more important properties are. The purpose of this experiment is to familiarize you with one of the techniques for investigating the properties of waves and to point out what some of these properties are.

The ripple tank is a large glass-bottomed tray that can be filled with a small depth of water. A lamp is placed above the tank to project light through the water onto a surface below, thus making any ripples generated in the water clearly visible. Ripples can be generated on the surface of the water by means of an electromechanical vibrator driven by a digital function generator driving either a single or double point wave-source or a long straight wave-source. Increasing the frequency of the digital function generator increases the frequency of the generated wave. Pieces of plastic and metal of various shapes and sizes are provided to facilitate the demonstration of reflection, diffraction, and interference of waves.

Experiments Using the Ripple Tank

1. Observe and sketch the wave generated by a single point source.
   What happens to the wavelength when the frequency of the wave is increased?

2. Observe and sketch the waves generated by a double point source. Notice the result of the different sets of waves interfering with each other
   How does the "interference pattern" change when the frequency of the source is increased?

How is the interference pattern affected by a change in the phase (from 0 to 180°) of one point source relative to the other? To change the phase of one source relative to the other, interchange the red and black leads of one driver at the frequency generator terminals.

3. Observe and sketch the waves generated by a straight ripple generator.

4. Observe and sketch the reflection of plane waves from a plane surface. Use a straight ripple generator and use a long straight piece of aluminum standing on its longest edge as the reflector. Position the reflector so that it is at some angle other than parallel to the incoming plane waves. Note: For this part and for parts 5 and 6, try launching just a couple of waves by turning on the vibrator for about one second and then turning it off. It is sometimes easier to watch the results of reflection and focusing without the interference of the incident waves.

5. Observe and sketch the focusing of incident plane waves by a concave reflector. You may have to experiment somewhat to see this effect in the clearest way.

6. Try manually launching a single circular wave from the focus observed in part 5 above by poking your finger in the water at that focus, and see if you observe a plane wave after your circular wave reflects off the concave surface used in part 5.

7. See if you can observe and sketch diffraction effects of plane waves around the edge (or edges) of an obstacle.

8. Using the straight ripple generator, observe the pattern obtained when plane waves pass through a single slit. Investigate how this pattern depends on the slit width for a particular wavelength. Repeat this for a double slit.

A Visual Demonstration of Beats

9. Set up two separate ripple generators and insert just one point source in each generator. Now you can vary the frequency of one point source relative to the other and you can change the distance between the two point sources.

Adjust the frequencies of the two generators to be as close to the same as you can (i.e., try to achieve a "zero-beat" situation) with the point sources about 5 to 8 centimeters apart. This should result in a non-rotating interference pattern similar to that which you obtained using the double point source in part 2 above. Sketch what you observe below.

Change the frequency of one point source relative to the other by a very small amount. First make it a slightly higher frequency than the other. Then make it a slightly lower frequency than the other. Sketch (and describe) what you observe in the space below. Imagine yourself as a miniature person standing in the ripple tank 25 or 30 cm away from the point sources and experiencing the "beat frequency".

What happens to the interference pattern when the difference between the frequencies of the point sources is made larger?

What happens to the beat frequency in this case**?**