Transverse and Longitudinal Standing Waves

Physics 110 Laboratory

Introduction:

Since an object has mass, when the object travels it carries along with it energy and momentum. In a traveling wave energy and momentum are made to travel in space, in the absence of transmission of any mass. This is because in wave motion it is the "disturbance" that moves. But like objects (particles) waves exhibit many physical phenomena such as transmission, reflection, energy loss, etc. They also exhibit phenomenon very different from particles. One of these is that of interference: two waves that travel in opposite directions pass through each other so that at every point in space the net disturbance is an effective sum of their individual disturbances.

In this laboratory we will study two examples of standing waves, waves created when two traveling waves interfere in just the right way ("resonance") to produce a stationary pattern of nodes (places of zero wave disturbance) and antinodes (places of maximal disturbance. The two examples are standing **transverse** waves on a string and standing **longitudinal** waves formed in a column of air driven by a small acoustic speaker.

For one dimensional systems we will study in this lab, a simple relation exists among the distance between successive nodes, the frequency of the driving mechanism, and the speed of wave propagation in the medium of interest:

$$v_{\text{wave}} = \lambda f \qquad (1)$$

where v_{wave} is the wave propagation speed, λ is the wavelength of the standing wave (which equals twice the distance between successive nodes, why?), and f is the (resonant) frequency of the standing wave.

Part I. Longitudinal waves in a variable length air column

- Set the audio oscillator, to which your speaker is connected, to 1000 Hz. Position the moveable piston head within the resonator tube near the tube opening. BE CAREFUL. THE SPEAKERS ARE FRAGILE. DO NOT TOUCH THEM WITH THE PISTON HEAD. Gradually draw the piston into the tube until you hear a clear resonance. Keep the input amplitude to the speaker low so as to not burn out the speaker.
- Continue drawing the piston head further into the tube and record the lengths of the air column at subsequent resonances. A resonance occurs when the piston head coincides with a node. Thus the distance between successive resonances equals $\lambda/2$. From your data obtain a best estimate of λ. Calculate the speed of sound (with uncertainty) for a wave of frequency equal to 1000 Hz.
- Repeat the above steps for f = 2000 Hz. Compare the two speeds you have calculated. How do your values compare with the value for the speed of sound at the temperature of the air in the room? You can find this value tabulated in a handbook in the lab, or better yet, check the web.

Part II. Transverse waves on a string

- Plot the resonant frequency versus 1/l and determine the velocity (with uncertainty) of the wave. The wave velocity can also be found from the equation (2) where F_T is the tension in the string and μ is the linear mass density of the string (mass/length). Measure μ, compute a velocity from Eq. 2 (with uncertainty), and compare your two values of the velocity.

$$v_{wave} = \sqrt{F_T/\mu} \qquad (2)$$

- Set up the elastic string with a 250 g mass hung over the pulley and measure and record the length (with uncertainty) of string between the two fixed nodes (that at the pulley and that at the mechanical oscillator). Carefully adjust the frequency of the driver so that resonances are formed with 1 to at least 7 loops. Record the frequencies (make two measurements at each resonance and report the average- half the difference of your two independent measurements is an estimate of the uncertainty) and sketch the loop structure in each case. Are the resonant frequencies equally spaced?