

## Physics 110 Lab 7: Transverse and Longitudinal Standing Waves

Name \_\_\_\_\_ Section \_\_\_\_\_ Date \_\_\_\_\_

### Introduction

When an object travels it carries along energy and momentum, because it has mass. 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 phenomena 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 the 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:

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

where  $v_{wave}$  is the wave propagation speed,  $\lambda$  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 1: Longitudinal Waves in a Variable Length Air Column

(a) 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. Gradually draw the piston into the tube until you hear a clear resonance. Move the piston head back and forth slowly to determine the length of the air column for this resonance and record the value in the table below. Continue drawing the piston head further into the tube and record the lengths of the air column at subsequent resonances. Keep the input amplitude to the speaker low so as to not burn out the speaker and be careful not to run the piston into the speaker.

Resonance #	Length of air column (m)	$\lambda/2$ (m)
1		XXXXXX
2		
3		
4		
5		
6		
Average of $\lambda/2$		
Standard deviation of the mean of $\lambda/2$		

(b) A resonance occurs when the piston head coincides with a node. Thus the distance between successive resonances equals  $\lambda/2$ . Calculate the distance between successive resonances and record the results in the table above. Also, calculate the average and standard deviation of the mean (standard deviation divided by the square root of the number of measurements) and enter the results in the table.

(c) From these measurements determine the wavelength  $\lambda$  of the sound waves with frequency 1000 Hz and record the result along with the uncertainty in the space below.

(d) Calculate the speed of sound for a wave of frequency 1000 Hz and record the result along with the uncertainty in the space below.

(e) Repeat the measurements of the length of the air column for successive resonances for  $f = 2000$  Hz and record the results in the table below.

Resonance #	Length of air column (m)	$\lambda/2$ (m)
1		XXXXXX
2		
3		
4		
5		
6		
7		
8		
9		
Average of $\lambda/2$		
Standard deviation of the mean of $\lambda/2$		

(f) Calculate the distance between successive resonances and record the results in the table above. Also, calculate the average and standard deviation of the mean (standard deviation divided by the square root of the number of measurements) and enter the results in the table.

(g) From these measurements determine the wavelength  $\lambda$  of the sound waves with frequency 2000 Hz and record the result along with the uncertainty in the space below.

(h) Calculate the speed of sound for a wave of frequency 2000 Hz and record the result along with the uncertainty in the space below.

(i) Do your two results for the speed of sound in air agree within experimental uncertainty? Explain.

(j) Do your results agree within experimental uncertainties 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 testbook, or better yet, check the web. Explain.

### Part 2: Transverse Waves on a String

(a) Set up the elastic string with a 250 g mass hung over the pulley and measure and record below the length  $L$  (with uncertainty) of string between the two fixed nodes (the pulley and the mechanical oscillator). Also, mark the string at the oscillator and the top of the pulley.

(b) Carefully adjust the frequency of the driver so that a 1 loop resonance is formed along the string. Record the frequency and sketch the loop structure in the table below.

Loop #	f (Hz)	Sketch of loop structure	$\lambda$ (m)
1			
2			
3			
4			
5			
6			
7			

(c) Repeat step (b) for resonances with 2 through 7 loops.

(d) From your sketch and measurement of the length of the string, determine the corresponding wavelength,  $\lambda$ , for each resonant frequency and record the results in the table.

(e) Make a graph of frequency (vertical axis) versus  $1/\lambda$  (horizontal axis) and fit the data to determine the velocity of the wave. Use the regression tool in Excel to determine the uncertainty in

the velocity and record your result in the space below with the appropriate significant figures and units. Also, print a copy of the graph and attach it to the lab write-up.

(f) The wave velocity can also be found from the equation

$$v_{wave} = \sqrt{\frac{T}{\mu}} \quad (2)$$

where  $T$  is the tension in the string and  $\mu$  is the linear mass density of the string (mass/length). Remove the string and measure the total mass of the string  $m_{tot}$ , the total length of the unstretched string  $L_{tot}$ , and the distance between the marks when the string is unstretched  $L_{marks}$ . Record your measurements with estimates of the uncertainties in the space below.

(g) Calculate the linear mass density  $\mu$  for the stretched string from your earlier measurement of the stretched length  $L$  and your measurements above for  $m_{tot}$ ,  $L_{tot}$ , and  $L_{marks}$ . Think carefully about how to do this. Show your calculations and record your final result for  $\mu$  with the appropriate number of significant figures and uncertainty in the space below.

(h) Calculate the velocity of the wave using equation (2) and record the result with the appropriate number of significant figures and uncertainty in the space below.

(i) Do the two values for the velocity of the wave determined in parts (e) and (h) agree within experimental uncertainties? Explain.