Name: _____

Partners: _____

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PHYSICS 221 LAB #2: STANDING WAVES & RESONANCE

The picture above is the Tacoma Narrows Bridge shortly before it collapsed. A moderate wind initially excited small ripples that grew into violent oscillations. Eventually, these tore the bridge apart. This was a spectacular case of resonance.

OBJECTIVES

1. To observe the phenomenon of resonance and standing waves on strings and for sound waves.

2. To understand how the wave properties of speed, wavelength, and frequency are related.

3. To experimentally determine the speed of sound in air.

OVERVIEW

The speed of a traveling wave is the rate at which a crest travels. It is related to its frequency and wavelength by $v = f\lambda$. This speed depends on the medium in which the wave is traveling.

The theoretical value for the speed of a wave transmitted along a string is $v = \sqrt{\dfrac{T}{m/L}}$, where T is the tension and (m/L) is its mass per length.

The speed of sound in air depends most strongly on the temperature. Factors such as changes in humidity don't affect it as much. If the temperature is measured in Kelvin, the theoretical value of the speed of sound in a gas is $v=\sqrt{\dfrac{gkT}{m}}$, where k = 1.38 x 10^{-23} J/K and m is the mass of a gas molecule. Air is mostly diatomic molecules, so $\gamma = c_p/c_v = 7/5$.

A standing wave is when the wave crests don't appear to travel along the medium (string, or air). Instead, points of no displacement, a.k.a. nodes, stay put and the crests, a.k.a. antinodes, oscillate between maximum and minimum. A simple example is people swinging a jump rope: the ends in the people's hands hardly go anywhere (nodes) while the rope in the middle swings around (antinode). Standing waves occur when the right number of wavelengths "fit" into the available length of medium. For sound waves in a pipe, a closed end will be a node of displacement (the air can't be pushed *through* the pipe's capped end.) and an open end will be an antinode. When the conditions for a standing wave are met, there will be a resonance and the amplitude of the wave will become large. For sound waves this means a louder sound.

PART ONE: Waves on a String

1. The setup of the string and driver will be similar to that pictured below. The length of the string between the post and the pulley should be about 1 meter. Set the function generator to produce a sinusoidal wave. **Be very careful not to turn the amplitude too high or the wave driver may be damaged!**
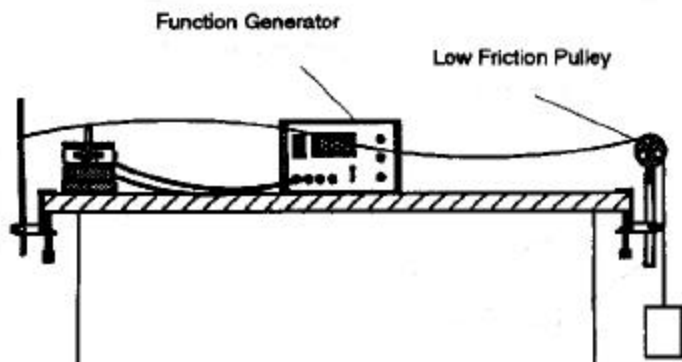
2. Hang 200 grams on the end of the string and start with a very low frequency. Gradually increase the frequency until the amplitude of the wave on the string increases dramatically indicating that you have reached a resonance. You should increase and decrease the frequency to find the value that gives the largest amplitude.

3. Find four resonances and measure the distances between consecutive nodes to fill in the first two columns below. Also draw the shape of each standing wave below

	Frequency (Hz)	Distance between nodes (m)	Wavelength (m)	Speed of wave (m/s)
1				
2				
3				
4				

1

2

3

4

4. Calculate the wavelength and speed for each of the standing waves to complete the table above. Show your first calculation.

5. Take the average of the speeds that you have found.

$$v_{avg} = \underline{\hspace{3cm}}$$

6. Determine the mass per unit length of the string <u>while it is stretched by a 200 gram mass</u>.

$$m/L = \underline{\hspace{3cm}}$$

Question: How does the average measured speed compare to the theoretically predicted value? Show your work.

PART TWO: Sound Waves

1. The apparatus you will use is pictured to the right. Slide the reservoir as high up as it will go. Slowly fill the reservoir until the glass tube is nearly full (within about 10 cm). Be sure that there are no kinks in the rubber tubing. The water level in the glass tube can be adjusted by raising or lowering the supply tank.

2. Position the speaker over the glass tube and connect it to the function generator. Make sure the function generator is set to produce a sinusoidal wave. Set the frequency between 500 and 1000 Hz and turn the speaker on at a <u>low</u> volume. Record the frequency selected below.


2.

$$f = \underline{\hspace{3cm}}$$
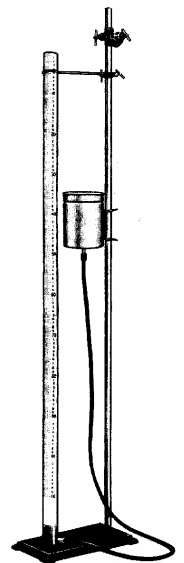
3. Keeping the frequency constant, slowly lower the water level until the first resonance is reached and the sound becomes much louder. Determine the position of the resonance by slightly raising and lowering the water level until you are sure that the sound is at maximum intensity.

4. Repeat the above procedure for the entire length of the glass tube and enter the results in the first column of the table below. Be careful to increase the length of the air column so that you don't miss a resonance! (Note: At some point, you'll need to remove some water.)

	length of air column (m)	wavelengths in column	wavelength (m)	speed of wave (m/s)
1		$\lambda/4$		
2				
3				
4				

5. Sketch the water level and the standing waves for the displacement of the air for each of the resonances. (The first one is done for you.) In the table above, enter the number of wavelengths or fractions of wavelengths are in each standing wave. (The first one is done for you.)
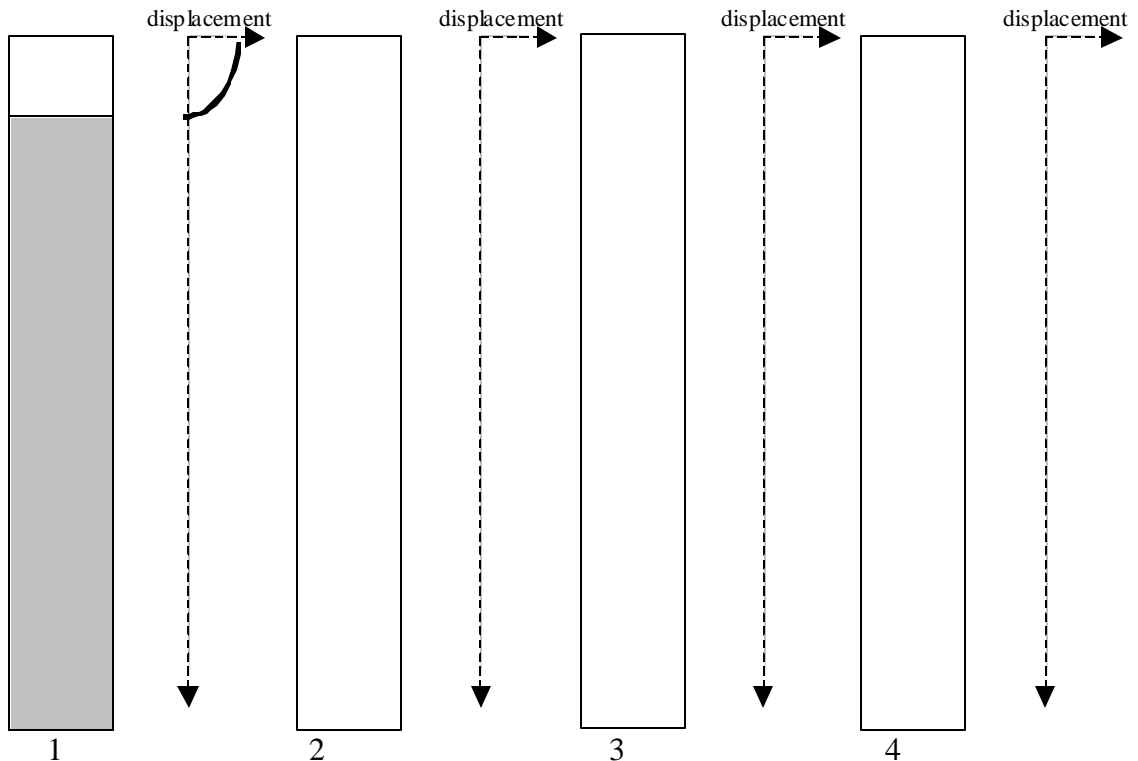
6. For each standing wave, calculate the wavelength and use that to find the speed of the sound wave and enter them in the table above. Show your first calculation below.

7. Take the average of all of your measurements for the speed of sound.

$$v_{avg} = \underline{\hspace{3cm}}$$

8. Measure the temperature of the room in Celsius.

$$T_C = \underline{\hspace{3cm}}$$

Question: How does your experimental measurement of the speed of sound compare with the theoretical value? Show your work. The average mass of a molecule in air is 4.799 x 10^{-26} kg.