

AP Physics: Lab #10

Standing Waves

Name _____ Hour _____

Lab Partners _____

Purpose:

- * Determine the resonant lengths of a given frequency in a column of air.
- * Calculate an experimental value of the velocity of sound in air and compare it to an accepted value.
- * Determine the resonant frequencies of a given length of string.
- * Calculate an experimental value of the velocity of waves on a string and compare it to an accepted value.

Equipment:

Graduated Cylinder
PVC Pipe
Meter Stick
Assorted Tuning Forks
Rubber Mallet

Mechanical Wave Driver
String
Pulley
Assorted Masses
Electronic Balance

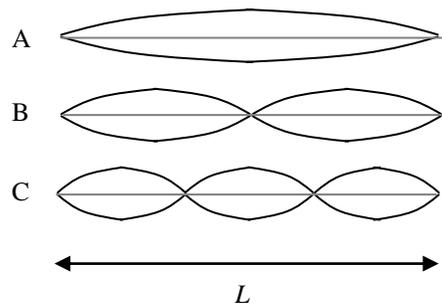
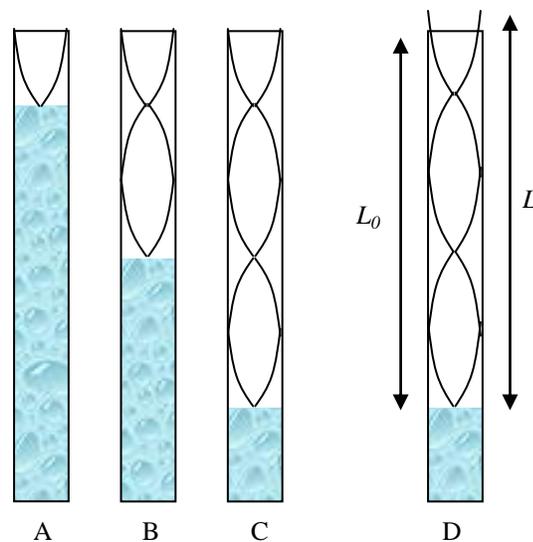
Introduction:

Standing waves occur when two waves of equal wavelength travel in opposite directions through the same medium. This is best observed when a wave is reflected at a boundary, allowing the original wave and the reflected wave to combine to form a standing wave. This experiment will analyze two types of standing waves: those occurring on a string, and those occurring in a column of air.

The air columns in this experiment will be formed in a tube that is open on one end and closed on the other. In this situation, the standing wave can only form with a node at the closed end and an antinode at the open end. In order to satisfy these conditions, standing waves form when the length of the tube corresponds to $\frac{1}{4}\lambda$, $\frac{3}{4}\lambda$, $1\frac{1}{4}\lambda$, etc. These lengths are shown in Diagrams A, B, and C at right.

In addition, the air molecules immediately above the tube also resonate, causing the standing wave to extend slightly above the tube of air, as shown in Diagram D. To compensate for this, the length of the column is extended, depending on the diameter d of the tube. When L_0 is the length of the tube of air, then L is the length of the actual resonating air column, according to the equation:

$$L = L_0 + .4 \cdot d$$

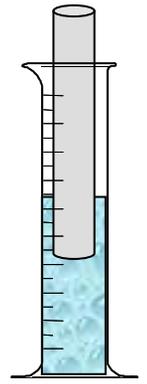


For standing waves formed on strings, both ends of the string are fixed, or unable to vibrate. In this situation, the standing wave must have nodes at both ends of the string. In order to satisfy these conditions, standing waves form when the length of the string corresponds to $\frac{1}{2}\lambda$, 1λ , $1\frac{1}{2}\lambda$, etc. These lengths are shown in Diagrams A, B, and C at left.

Procedures - Air Column:

Fill the graduated cylinder with room temperature water. Place the PVC pipe in the cylinder to form an air column with one end closed by the water level below. If necessary, adjust the water level so that it is close to the top of the PVC pipe when the pipe rests on the bottom of the cylinder.

Choose a tuning fork and record its frequency on Data Table A. Strike the fork with a rubber mallet. (*Do not strike the tuning fork on the lab table or other hard surface.*) Hold the fork over the open end of the air column and adjust the length of the air column until you find a position where the tuning fork resonates loudly. Measure and record the length from the top of the PVC pipe to the water level below. Repeat this step for three additional tuning forks of varying frequencies. Record your measurements on Data Table A. Measure and record the air temperature and the inner diameter of the PVC pipe on Data Table A.



Procedures - String:

Attach the string to a mechanical wave driver, and run the other end over a pulley. Attach a 100 or 200 g mass to the free end of the string, causing tension in the string.

Adjust the frequency of the wave driver until you find the frequency which causes a first harmonic standing wave to form on the string. Record this frequency on Data Table B. Continue to adjust the frequency of the wave driver until you have found additional frequencies for standing waves of the second through fifth harmonics. Record these frequencies on Data Table B.

Measure and record the mass per unit length of the string.

Calculations - Air Column and String:

Calculate and record the adjusted actual length, L , of each air column.

Calculate and record the wavelengths, λ , of the standing waves formed for each trial in the air column and on the string.

Calculate and record experimental values for the velocity of sound in the air column and the velocity of waves on the string.

Use the air temperature to calculate a theoretical value for the velocity of sound in the air column. Use the tension in the string to calculate a theoretical value for the velocity of waves on the string. Calculate the percent error between the experimental and theoretical velocity values for both parts.

Analysis:

To summarize the lab report, answer the application questions below in complete sentences. In addition, include a brief statement of the overall results for the lab.

- Are the standing waves formed in the air column transverse or longitudinal? What about the standing waves formed on the string? Explain the difference between the two types of waves as part of your answer.
- In the air column portion of this experiment, you found only the fundamental frequency of each tuning fork. Choose one of your frequencies from Data Table A and calculate the next 2 air column lengths that would resonate for that tuning fork. Draw diagrams of each wave to accompany your calculations, labeling each node and antinode. Why do you think these harmonics were not used as part of your experimental procedures?
- What effect would warming the air in the PVC pipe have on the resonant length of the air column for a given tuning fork? Explain your answer.
- What effect would adding mass to the end of the string have on the fundamental frequency of the driver for a given length of string? Explain your answer.
- Suppose you found the fundamental frequency that resonates in an air column of adjusted length 1 m. What length of string would be needed to resonate at the same frequency? Draw diagrams of each wave to support your answer, labeling each node and antinode.

Data Table A - Air Column:

Room Temperature = _____

Tube Diameter = _____

Frequency	Length of Air Tube	Adjusted Air Column Length	Wavelength	Experimental Velocity of Sound

Average Experimental Velocity of Sound in Air: _____

Theoretical Velocity of Sound in Air: _____

Percent Error: _____

Data Table B - String:

String Tension = _____

Mass per Unit Length = _____

	Frequency	String Length	Wavelength	Experimental Velocity of Waves
1 st Harmonic				
2 nd Harmonic				
3 rd Harmonic				
4 th Harmonic				
5 th Harmonic				

Average Experimental Velocity of Waves on the String: _____

Theoretical Velocity of Waves on the String: _____

Percent Error: _____

Lab Report:

Title Page, Objectives, & Overall Report – 5 pts

Procedures – 3 pts

Data Table – 6 pts

Calculations – 8 pts

Analysis – 12 pts