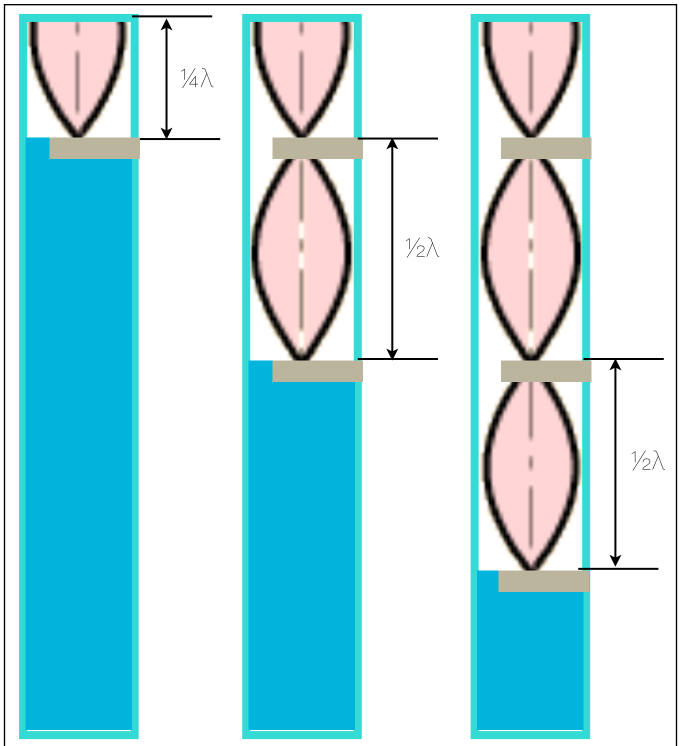
Lab 07: The Speed of Sound in Air



Always measure top to tape, tape to tape, tape to tape.

Introduction

It is possible to investigate sound waves by creating standing waves in a column of air. If the air column is driven by a sound wave of the right frequency, a standing wave will be produced in the column which results in an audible tone. The process is closely related to what happens in a wind instrument like a flute, clarinet, trombone, or organ.

We will use a glass tube partially filled with water. The water level represents a closed end of the air column, and can be varied in order to adjust the length of the column. If we hold a vibrating tuning fork over the column and vary the water level, we will hear a louder sound whenever the column length is right for standing waves at the frequency of the tuning fork.

The water line is always a node, having zero amplitude. When the sound is the loudest, the amplitude of the wave is greatest at the mouth of the tube. The actual position of the node will depend on the wavelength, but the relative spacing of the resonances will always be the same fraction of a wavelength, either ¼**λ** or ½**λ**.

Set your apparatus in the overflow pan, just in case.

Objectives

- Create a standing wave in an air column
- Observe the change in the wave pattern when the column length is changed
- Use these observations to calculate the speed of sound
- Calculate the amount of error in an experimental value
- Evaluate the effect of a change in experimental technique on the accuracy of your results

Experimental Equipment

- Thermometer
- Two tuning forks of known frequency
- Rubber strike plate
- Masking tape
- Glass column connected to a water reservoir
- Overflow pan

Procedure

- Work in groups of four; you will need that many people cooperating simultaneously to use the apparatus correctly and record accurate measurements.
- Make sure that the column and stand are on the floor, in the overflow pan.
- Adjust the reservoir on the stand until it is at the top of the glass column. Fill the reservoir until the water level in the column is within about 10cm of the top (no need to measure, just eyeball it). This should give you enough water to work with and avoid overflows.
- Strike a known tuning fork on the rubber strike plate to make it vibrate. Do not strike the fork against the glass tube or the lab table or your lab partner's forehead. Hold the fork over the open end of the glass tube.
- Starting with the water in the tube at its highest level, gradually lower the water level by lowering the reservoir. Use masking tape to mark the water levels where the sound is loudest as you increase the length of air in the column.
- You should have a long enough tube to hear three resonances with each fork. However, the third resonance for the lower frequency fork is very difficult to hear. If you are not able to locate this resonance, use the top two resonances which you have measured with greater confidence.

- The highest water level (shortest air column) is approximately (¼λ) below the top of the tube. Use the meter stick to measure this distance (y_1) from the **top of the tube to the first tape mark**.
- The distance between successive resonances is (½λ). Measure the distances (y_2 and y_3) between successive resonances and record them. **Measure from tape to tape**.
- Repeat the measurements for the second tuning fork.
- Make sure you remove every molecule of masking tape from the glass column before you leave.

DATA

If you have not already, make sure you have arranged your data into a neat table. Use the formulas provided in the example table below to complete the calculations.

Frequency (Hz)	y_1 (m)	λ_1 (m)	y_2 (m)	λ_2 (m)	y_3 (m)	λ_3 (m)	λ_{av} (m)	v (m/s)	% error
384		$\lambda_1=4y_1$		$\lambda_2=2y_2$		————	$\lambda_{avg}=\frac{(\lambda_1+\lambda_2)}{2}$	$v=(\lambda_{avg})f$	
512		$\lambda_1=4y_1$		$\lambda_2=2y_2$		$\lambda_3=2y_3$	$\lambda_{avg}=\frac{(\lambda_1+\lambda_2+\lambda_3)}{3}$	$v=(\lambda_{avg})f$	

CALCULATIONS

1. The speed of sound waves in gases depends on the type of gas and on the temperature. For air it is:

$$v=(331+0.6T)\text{ m/s}$$

where T is the temperature in °C. Record the air temperature, and use it to calculate the **actual value** for the speed of sound.

2. Calculate the average wavelength for each of the two tuning forks using the formulas given in the example table above.
3. Use the formula in the table above to calculate the average speed of sound for each of the two tuning forks, using the average value for each wavelength.
4. Calculate the percent error for each of your average values:

$$\%error=\left(\frac{actual\ \ value-average\ \ value}{actual\ \ value}\right)\times 100$$

QUESTIONS

5. How do the average speeds compare the the theoretical value calculated? Are your values high or low? Are the errors in each value similar? Is one value noticeably more accurate?
6. Why is it typically more accurate to calculate the speed using the higher frequency fork? There are several reasons, and you should be able to think of at least two, even if your values don't happen to match this trend.
7. You measured each resonance with respect to the previous one (tape–to–tape). If you measured each resonance with respect to the top of the tube, would this increase or decrease your accuracy? Why? (Note that you would have to calculate the wavelength a little differently, but it could be done.)
8. If the temperature in the room suddenly increased, what would happen to the speed of the wave? Does the wave frequency change? How would this affect the wavelength?
9. Would you expect the speed of sound to be greater through air or water? Explain.
10. Suggest two ways to improve your measurements or your technique to achieve more accurate results. (Remember, accuracy is about technique–your measuring tools are definitely precise enough!)