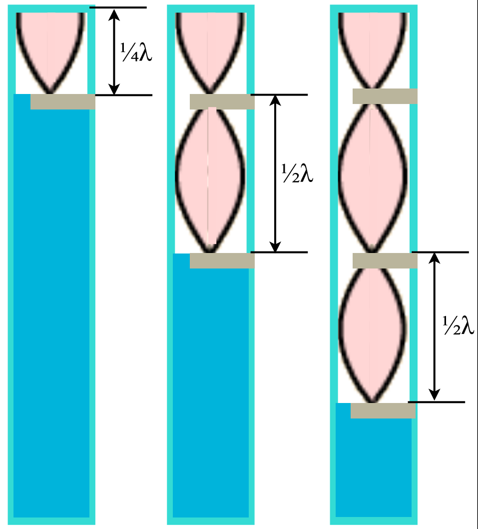


The water line is always a node, the open top is always an anti-node.

Lab 06: Speed of Sound in Air

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 $\frac{1}{4}\lambda$ or $\frac{1}{2}\lambda$.

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 experimental technique on the accuracy of your results

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

EXPERIMENTAL EQUIPMENT

- Thermometer
- Tuning forks
- Rubber strike plate
- Masking tape
- Glass resonance tube
- Overflow pan

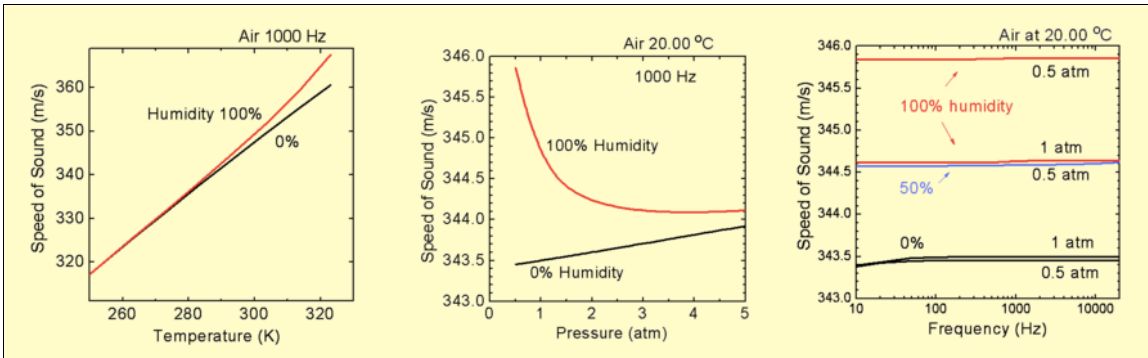
PROCEDURE

- 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.
- Gradually lower the water level by lowering the reservoir. Use masking tape to mark the water levels where the sound resonates the 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 ($\frac{1}{4}\lambda$) 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 ($\frac{1}{2}\lambda$). 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.
- Select a third tuning fork with an unknown frequency. Repeat the experiment one more time. If you have selected a low frequency fork, you may only be able to hear and mark two resonances.
- Make sure you remove every molecule of masking tape from the glass column when you finish.

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									
512		$\lambda_1=4y_1$		$\lambda_2=2y_2$		$\lambda_3=2y_3$	$\lambda_{avg}=\dfrac{(\lambda_1+\lambda_2+\lambda_3)}{3}$	$v=(\lambda_{avg})f$	
unknown									



The speed of sound depends on temperature. But it also depends on the air pressure and the relative humidity.

Relative Humidity (%)	Speed of Sound at T = 21°C
0	343.95
10	344.08
20	344.22
30	344.35
40	344.49
50	344.62
60	344.75
70	344.89
80	345.02
90	345.15
100	345.29

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:

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

5. Use the predicted value for the speed of sound to find the frequency of your unmarked tuning fork, and calculated the percent error as compared to the known frequency of the fork.

QUESTIONS

6. 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?
7. Notice that adding water vapor to the air increases the speed of sound. Do your experimental values (calculated for dry air) support this? That is, are they higher than expected because of the humidity? Given the size of effect increasing humidity has at room temperature (less than 1%), would you actually expect to be able to see it in your data? Was it reasonable to neglect the effect of humidity when calculating our predicted value?
8. 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.
9. 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.)
10. 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?
11. Suggest two ways to improve your measurements or your technique to achieve more accurate results. (Remember, accuracy is about technique, and your measuring tools determine the precision!)