WAVELENGTH OF SOUND LAB (Resonance Tube)

**Introduction:** At one time or another you turned a soda bottle into a whistle by blowing across the top of the bottle. When the bottle was fairly full, the pitch you heard was high. As you drank the soda, the level in the bottle went down and so did the pitch of the sound you made. The soda bottle whistled because, of the many tones you made, one of them was just the right frequency to produce a standing wave in the column of air in the bottle. As you drank the soda the level of the liquid went down and the column of air got longer. Then a longer wavelength wave, which had a lower frequency and a lower pitch, formed a standing wave in the air column. This reinforcement of a wave is a form of resonance. The column of air resonated with the source of the sound, which was the air vibrating across the top of the bottle. We can use the idea of changing the level of liquid in a tube to actually measure the wavelength of sound.

**Purpose:** To measure the wavelength of sound using a resonating air column.

**Materials:** Resonance apparatus, tuning forks, rubber block

**Procedure:** Our source of sound today will be a tuning fork. We will hold the tuning fork over the top of a tube that is partially filled with water. Raising or lowering the water reservoir will change the length of the air column in the tube. The idea is to adjust the length of the air column until the loudest tone is heard. Then we can measure the height of the column of air and calculate the wavelength.

Before we begin, examine these drawings of standing waves in the tubes.

 *n* = 1 3 5 7



 *L* = (1/4)λ (3/4)λ (5/4)λ (7/4)λ

Observe how these drawings correspond to what we know about standing waves and reflections from more and less rigid media. A(n) \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ (node/antinode) appears at the bottom because the water is \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ (more/less) rigid than the air in the column. A(n) \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ appears at the top of the column because the air in the room, being unconfined, is slightly less rigid than the air in the column. You can produce a standing wave and thus a loud tone any time you make the air column the right length so that a \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ forms at the top and a \_\_\_\_\_\_\_\_\_\_\_\_\_ forms at the bottom. Since the distance from a node to the adjacent antinode is 1/4 of a wavelength, resonance will occur when the air column is ¼ λ, ¾ λ, λ , etc. wavelengths long (, where *n* = 1, 3, 5, 7…). The shortest air column that resonates is ¼ λ long. The next is ¾ λ long and so on.

**Measuring the Wavelength**

In this lab we will be using tuning forks to generate our tones. DO NOT USE A HARD SURFACE, YOURSELF OR YOUR LAB PARTNER.

Strike the 256 Hz tuning fork on the rubber block. Hold the tuning fork over the top of the tube with a short air column (about 15 cm). **Be careful not to hit the top of the tube**. Slowly increase the length of the air column until the loudest tone is heard. The position at which the loudest sound is heard is the first resonating position or fundamental harmonic. Measure the length of the air column and record in Table 1. Repeat for each tuning fork listed in the data table. Measure the diameter of the tube used and record. (Note that for the 512 Hz you enter the length for the 512 (first) position)

Next, we will try to locate the second resonant length L2 for the 512 Hz tuning fork. Increase the length of the air column past the point where you heard the first loud tone. The air column will be considerably longer and the tone slightly softer. Record the length of the air column in the data table as 512 Hz (second). (Try to find a second resonant length for the other tuning forks. You might not be able to find these, as the length of the air column may be longer than our equipment can measure).

**Calculations**

1. To calculate speed of sound in air:

The velocity of sound in air depends on the temperature of the air, and is given by the following formula:



where T is in °C.

Room Temperature: \_\_\_\_\_\_\_\_\_\_

*vair* = \_\_\_\_\_\_\_\_\_\_\_

1. To calculate Theoretical wavelength, use *vair = f λth*. Algebraically, solve this equation for the wavelength.

*λth*=

1. Calculate the Theoretical Wavelength for each tuning fork and record in Table 1.

To find Measured Wavelength use, where *n* = 1, 3, 5 …. Solve for $λ\_{meas}$ and record this as the Measured Wavelength $λ\_{meas}$

When you find the first resonance length L, *n* = 1.

When you find the second resonance length Lsecond (512 Hz, second), *n* = 3.

 Calculate and record the % error using $\frac{λ\_{th}-λ\_{meas}}{λ\_{th}}×100$

# **Table 1: Data for Fundamental Wavelengths**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Frequency, Hz | Tube diameter, d | Length of Air Column, L | Measured Wavelength$$λ\_{meas}$$ | Theoretical Wavelength$$λ\_{th}$$ | % Error |
| 256 |  |  |  |  |  |
| 320 |  |  |  |  |  |
| 384 |  |  |  |  |  |
| 512 (first) |  |  |  |  |  |
| 512 (second) |  |  |  |  |  |

**SAMPLE CALCULATION:**

**Questions**

1. How close did the measured values of the wavelength come to the theoretical values? Were your results consistently off in one direction? Explain why.
2. The following formula for the wavelength includes the end correction factor for the diameter of the tube:



where *L* is the length of the air column, *d* is the diameter of the air column and *n* = 1, 3, 5…

Copy the following data from Table 1 to Table 2: tube diameter d, length of air column L and theoretical wavelength λth. Calculate the corrected wavelength and record in Table 2. Calculate and record the % error using $\frac{λ\_{th}-λ\_{corrected}}{λ\_{th}}×100$

# **Table 2: Corrected data**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Frequency, Hz | Tube diameter, d | Length of Air Column, L | Corrected Wavelength$$λ\_{corrected}$$ | Theoretical Wavelength$$λ\_{th}$$ | % Error |
| 256 |  |  |  |  |  |
| 320 |  |  |  |  |  |
| 384 |  |  |  |  |  |
| 512 (first) |  |  |  |  |  |
| 512 (second) |  |  |  |  |  |

**SAMPLE CALCULATION:**

1. Does this correction make things better or worse? Explain, how and why.
2. Next, we will find the third resonance length Lthird for the 512 Hz fork using the data from Table 2 and our knowledge of resonance points.
3. Looking at the picture on the first page, what is the fractional wavelength difference between any two consecutive resonance points? \_\_\_\_\_\_\_\_
4. From Table 2, what is the difference in air column lengths for the 512 fork? \_\_\_\_cm

C.) Complete the following relationship: 

D.) Therefore, the Lthird can be found by adding \_\_\_\_\_\_\_ to Lsecond. Write this in equation form.

E.) What is the third resonance length? \_\_\_\_\_\_\_cm

5. Suppose it was cold in the room and the speed of sound was lower, say 330 m/s. The frequency of the tuning fork is unaffected by temperature so it would remain the same. Does this mean the wavelengths will be longer or shorter? Explain.

6. Test your hypothesis in question 5 by calculating the wavelength you would find for the 256 Hz tuning fork at 0 °C. Also calculate the air column height using the tube diameter correction formula. SHOW ALL WORK!