RESONANCE LAB (in no particular order)

1) Determine the fundamental node and wavelength for each tuning fork. (Closed pipe)
2) Determine the fundamental and harmonics for 5 tuning forks (long pipe)
Find the speed of sound
Find the frequency of an unknown

3) Calculate beats for 2 different sets of resonant forks. (observations on separate paper)

4) Observe open pipe resonance for at least 3 tuning forks. (observations on separate paper)

5) AT HOME: Experiment with pipes and music (glasses, bottles, shower?) (or observe acoustics at the concert!)

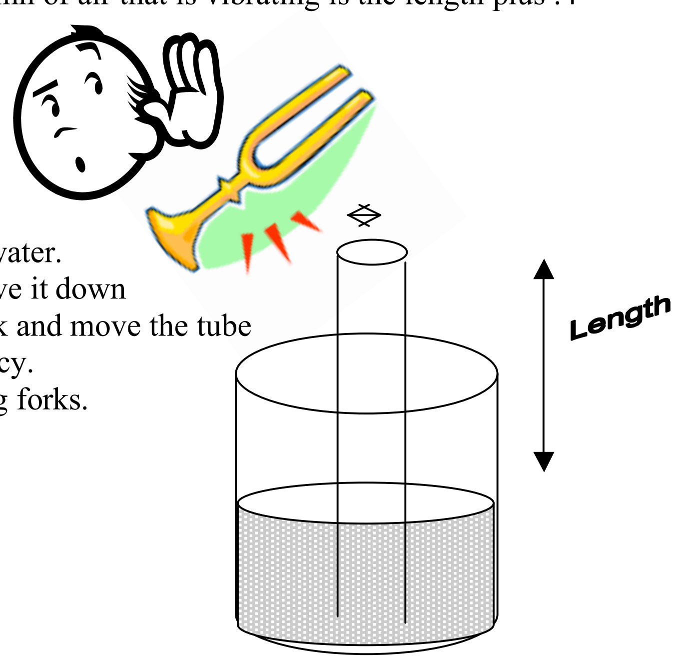
6) AT HOME: Investigate the acoustics of at least two different rooms, preferably with drawings or pictures, and detailed descriptions of the sound/music in them….

PART ONE:

When a tuning fork is vibrating near the open end of a cylinder, sound waves are sent into the column of air inside the cylinder. The waves reflect off the closed end of the cylinder and travel back to the opening. The reflected waves will combine with new waves coming from the tuning fork. Resonance occurs if the reflected waves and the new waves are in step with each other (constructive interference) to create a standing wave. The amplitudes of the reflected and new waves combine and a louder sound with a definite frequency is heard. Musical instruments depend on resonance for their operation. Without resonance, the notes you hear may not be the same. The column of air vibrates at its natural or resonant frequency to produce the sound.

-→ **DO!!:** In the example above draw the simplest part of a wave possible that is open (antinode that is free to move) at one end, and closed (node that is fixed) at the other end.

Notice that you have drawn a quarter of a complete wave, which means that the column of air is resonating a sound whose wavelength is approximately 4 times the length of the column. However, the air also vibrates back and forth across the tube opening as well, so to adjust for this, the effective length of the column of air that is vibrating is the length plus .4 times the diameter.



Set up the apparatus:
Use an 1000 ml cylinder filled about ¾ with water.
Hold the resonant glass tube in the water. Move it down as far as possible. Gently strike the tuning fork and move the tube up until you hear a clear loud definite frequency.
Make at least 4 trials and for 5 different tuning forks.

PART ONE:

Frequency Fork (Hz)	Diameter Tube(m)	Trial 1 Length	Trial 2 Length	Trial 3 Length	Average Length (m)	Effective Length (L+.4d)	Wavelength 4L (m)

Which tuning fork required the shortest air column for resonance?

Do high frequencies need short or long tubes to resonate?

IF four different tuning forks vibrate near the opening of a resonance tube, could you get all four frequencies to resonate at once?

Why does the sound appear louder when the column of air is a certain length?

Repeat this same experiment with at least two tuning forks and some other type of tube (different glass, cardboard, plastic, etc…..). Describe your experiment and results and how it was similar or different from what you expected.

PART TWO: RESONANCE: THE VELOCITY OF SOUND- Student Guide

Background

A closed tube (one open end, one closed end) will *resonate* with a tuning fork when the frequency of the tube is related to that of the tuning fork. Since the closed end of the tube must be a node (N) and the open end an anti-node (A), the first position of resonance (L_1) occurs when the tube is approximately one quarter (1/4) of a wavelength (λ) . (See Figure One) The next resonance position will occur when the length is three quarters (3/4) of a wavelength ($\lambda/4 + \lambda/2$ – see Figure 2), the next at five quarters (5/4) of a wavelength $5\lambda/4$, and so on.

The differences of these positions will always be exactly one-half wavelength because they are the distances between two nodes. (NOTE: the first position is not exactly one quarter of a wavelength because the anti-node does not exist exactly at the end of the tube, but rather slightly above it.) By recording the points at which the nodes occur, you can determine the length of the average half wavelength produced by the tuning fork. This average number is then doubled, to determine the length of the average full wavelength produced by the tuning fork. This number is then multiplied by the frequency number stamped on the tuning fork (Hz) to determine the velocity of a sound wave.

The known velocity for sound waves in air at a temperature of 0 ° C is 33,100 cm/s or 331 m/s. For every 1 ° C increase in air temperature, sound travels 60 cm/s (.6 m/s) faster. Thus in a classroom with a temperature of 20 ° C, the velocity of sound should be approximately 34,300 cm/s or 343 m/s . Also keep in mind that humidity affects the speed of sound.

If you have an unmarked tuning fork you can determine its frequency by measuring its wavelength on the apparatus and dividing this number by the value you calculated for the velocity of sound.

In the following exercise, you will use the Velocity of Sound apparatus to prove that the points of greatest resonance are indeed the points that are noted above. You will also use this data to determine the frequency of an unmarked tuning fork.

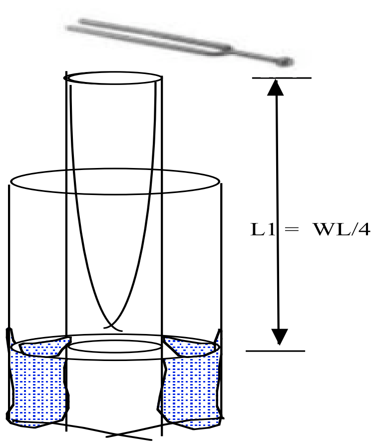


Fig 1.

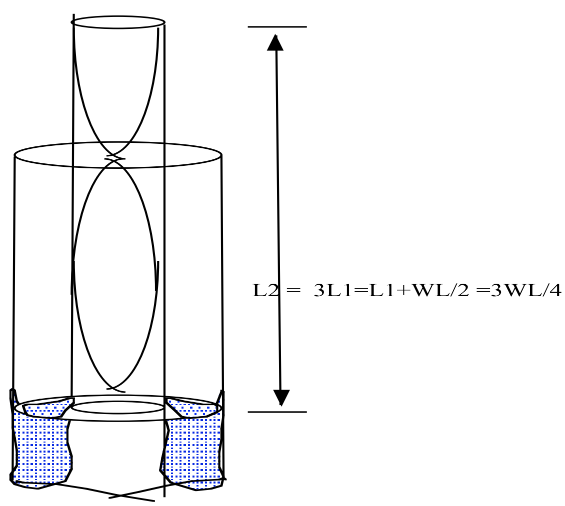


Fig 2.

PROCEDURE

1) Set up the velocity of sound apparatus. Make sure it is straight and secure, and make sure the bottom is stoppered.
2) Fill the clear outer tube two thirds full of water.
3) If necessary, insert the white plastic tube into the clear tube, making sure that the zero end of the metric scale on the white tube is at the top and the other end of the white tube is resting on the stopper at the bottom. Now pour more water into the clear tube until it is almost full.
4) Obtain several tuning forks from your teacher. Note that one of the forks has a piece of tape on it to hide the frequency marking. SET THIS TUNING FORK ASIDE. DO NOT REMOVE THE TAPE!
5) From the remaining tuning forks, find the shortest tuning fork in the set. Record the frequency marking (Hz) for this fork (FORK # 1) in the appropriate space in Data Table 1, on the accompanying worksheet.
6) Use a rubber hammer or stopper to strike the tuning fork. (Never strike a tuning fork on a hard surface) Now, hold the vibrating fork with the prongs in a vertical plane near the top of the white plastic tube, as shown in figures 1 and 2.
7) SLOWLY raise the white tube out of the water while you are holding the vibrating fork near the open end of the tube. At one point you will hear a sharp increase in the volume of the tone created by the tuning fork. This point indicates the position of a node in the sound wave.
8) Carefully adjust the height of the tube so that the sound is at maximum intensity. Use the scale on the side of the tube to assign a numerical value to the position of this node. Remember to read this position as the amount of tube above the water level. The position of the top of the clear acetate tube that holds the water has NO significance. In the appropriate space in Data Table 1 (Fork #1, Position #1), record the level of the water at the point where the sound is the loudest.
9) Carefully raise the white tube to a new position that is approximately three times the value of the first position. Adjust the tube around this point until a new position of resonance is found. Record this new height in the appropriate space (Position # 2) of Data Table 1.
10) Carefully raise the white tube to a new position that is approximately five times the value of the first position. Adjust the tube around this point until a new position of resonance is found. Record this new height in the appropriate space (Position # 3) of Data Table 1.
11) Repeat the previous step at least two more times, using position that are seven times greater than the original position of resonance, nine times greater, etc.. until you exceed the length of the tube. Be sure to record your height readings for each node. You must listen carefully! Depending on the frequency, you may only find one or two nodes.
12) Take the next shortest tuning fork and repeat steps 5-11. Be sure to record your data for the position of each node in the appropriate space in Data Table 1.
13) Repeat steps 5-13 for each of the remaining marked tuning forks, in order of their length.
14) Find the unmarked tuning fork that you set aside earlier. Repeat Steps 5-11 for this fork, record all of your data for this fork in the appropriate spaces of the data table.
15) Clean up and complete the remainder of the questions.

PART TWO DATA RECORDING:

FORK f	***Pos 1 node***	***Pos 2 node***	***Pos 3 node***	***Pos 4 node***	***Pos 5 node***		
Hz	***cm***	***cm***	***cm***	***cm***	***cm***		
Dis from		***2^{nd}-1st***	***3^{rd}-2nd***	***4^{th}-3rd***	***5^{th}-4th***	***Avg =λ/2***	***λ =***
last node	***------***	***cm***	***cm***	***cm***	***cm***	***cm***	***cm***
						v=f*λ =	***cm/s***

FORK f	***Pos 1 node***	***Pos 2 node***	***Pos 3 node***	***Pos 4 node***	***Pos 5 node***		
Hz	***cm***	***cm***	***cm***	***cm***	***cm***		
Dis from		***2^{nd}-1st***	***3^{rd}-2nd***	***4^{th}-3rd***	***5^{th}-4th***	***Avg =λ/2***	***λ =***
last node	***------***	***cm***	***cm***	***cm***	***cm***	***cm***	***cm***
						v=f*λ =	***cm/s***

FORK f	***Pos 1 node***	***Pos 2 node***	***Pos 3 node***	***Pos 4 node***	***Pos 5 node***		
Hz	***cm***	***cm***	***cm***	***cm***	***cm***		
Dis from		***2^{nd}-1st***	***3^{rd}-2nd***	***4^{th}-3rd***	***5^{th}-4th***	***Avg =λ/2***	***λ =***
last node	***------***	***cm***	***cm***	***cm***	***cm***	***cm***	***cm***
						v=f*λ =	***cm/s***

FORK f	***Pos 1 node***	***Pos 2 node***	***Pos 3 node***	***Pos 4 node***	***Pos 5 node***		
Hz	***cm***	***cm***	***cm***	***cm***	***cm***		
Dis from		***2^{nd}-1st***	***3^{rd}-2nd***	***4^{th}-3rd***	***5^{th}-4th***	***Avg =λ/2***	***λ =***
last node	***------***	***cm***	***cm***	***cm***	***cm***	***cm***	***cm***
						v=f*λ =	***cm/s***

FORK f unknown	***Pos 1 node***	***Pos 2 node***	***Pos 3 node***	***Pos 4 node***	***Pos 5 node***	***Avg Vel***	***= cm/s***
?? Hz	***cm***	***cm***	***cm***	***cm***	***cm***		
Dis from		***2^{nd}-1st***	***3^{rd}-2nd***	***4^{th}-3rd***	***5^{th}-4th***	***Avg =λ/2***	***λ =***
last node	***------***	***cm***	***cm***	***cm***	***cm***	***cm***	***cm***
						f=v/λ =	***Hz***

PART TWO VELOCITY OF SOUND CALCULATIONS AND DATA ANALYSIS

1) For each fork, calculate the distance between the second and the first node, the third and second node, the fourth and third node, etc… Record your answers in the appropriate space in Data Table 1. If they are not similar, it is possible that you missed recording the first node, so try again.

2) For each fork, calculate the average distance between nodes. Record this value for each fork in the appropriate space in Data Table One.

3) For forks # 1-5, calculate the wavelength by multiplying the average distance between nodes by 2.

4) For forks #1-4, calculate the velocity of sound by multiplying the known frequency by the calculated wavelength. Compare them to each other. What do you notice? (You can't do this for fork five since you don't know the frequency).

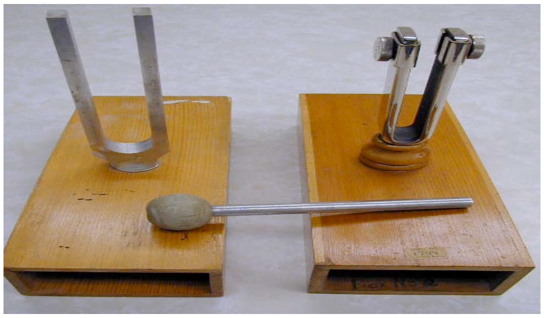
5) Calculate your average velocity of sound. It should be close to 34,300 cm/s at room temperature. Find today's velocity of sound ($v = 331 + 0.6 * °C$), and calculate your percent error. What are sources of error?

6) Using your average velocity of sound, calculate the frequency of the "unknown" fork. SHOW YOUR CALCULATIONS

7) Remove the tape or ask your teacher the real value of the unknown frequency. How close were you? Calculate your percent error.

PART THREE:BEATS:
ANSWER ON SEPERATE PAPER!!!

Obtain two large tuning forks of the same frequency placed on resonator boxes:



Place the open end of the boxes towards each other and gently continuously tap one fork. After a while hold the fork, and make observations on the other one.

Try to find at least one other object that will sympathetically resonate at the same frequency.

Now…. SLIGHTLY change the frequency of one of the forks by adjusting its screws, adding clips or other objects.

Sound both forks together and record your observations.

When you can hear "beats" or wavering sounds, count the number of beats in ten seconds…
The number of beats per second is the beat frequency. Calculate the new frequency you made by using the formula:

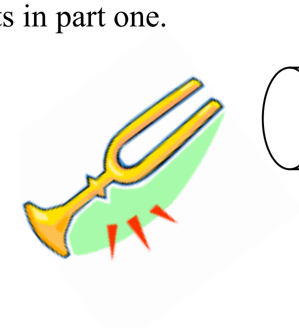
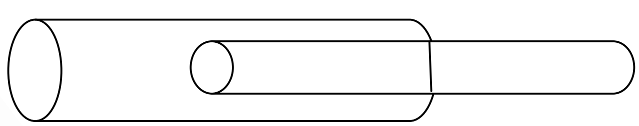
$$f_{\text{beat}} = |f_1 - f_2|$$

Do this several times until you can no longer detect the beats.

PART FOUR OPEN PIPES: ANSWER ON SEPERATE PAPER!!!

Using two known tuning forks…. Find two tubes or pipes as close diameter as possible that fit into each other. Strike the tuning fork close to one end and move it back and forth until you find the resonant length (The total length of both tubes put together).

The resonant length is one half the wavelength, so calculate the wavelength of the note. Compare to the results in part one.

PART 5) Experiment with pipes and music (glasses, bottles, shower?)

Use 5-10 glasses or bottles with different amounts of water. Try blowing across the top, or rubbing the thin edge of the glass and record the sound changes . Explain your observations.

Now tap each glass or bottle with a metallic object and record the sound changes. Explain your observations.

Experiment with open pipes hit against your palm, or metal tubes, or bottles or cardboard to observe the relationship between changes in pitch and changes in materials, diameter, size, and loudness.

****Use a set up to make a song, record your results, or demonstrate to the class!

OR: Why does it sound so good when you sing in the shower?

Different rooms resonate at different frequencies, depending on how large or small they are. Try singing in the shower stall or bathtub (clothed and without water!). Try a high voice and low voice, record observations

Measure the width, length and height of the shower. Each is like a closed pipe, so notes that sound good (resonate) should have a wavelength twice the distance in the shower. Figure out (using 340 m/s) what those notes would be for your shower, and whether it fits your expectations. If you have a musical instrument, try those notes, and record results and conclusions.

6) AT HOME: Investigate the acoustics of at least two different rooms, preferably with drawings or pictures, and detailed descriptions of the sound/music in them….