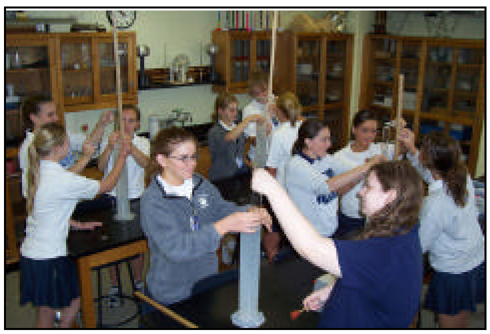
MND Physics

The Speed of Sound

Standing longitudinal waves form in open and closed tubes resulting in the production of sound.

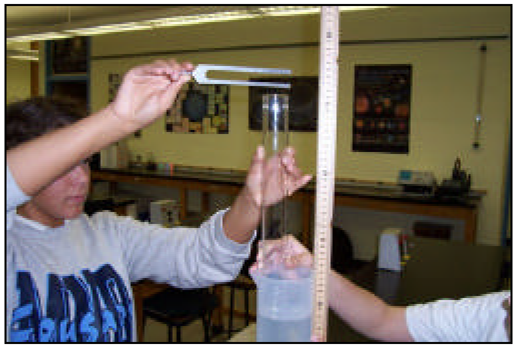


RESONANCE IN OPEN PIPES:

The fundamental harmonic of an open pipe resonates when a pressure node forms at each end of the pipe with an anti-node in between. The length of the pipe *"L"* is ideally equal to half of the wavelength of the sound wave. We say "ideally" because in practice, a small correction factor for the pipe length must be applied. This correction factor accounts for both the location of the tuning fork (not exactly at the mouth of the tube) and the diameter of the pipe itself.

RESONANCE IN CLOSED PIPES:

The fundamental harmonic of a closed pipe resonates when a pressure node forms at the open end of the pipe with an anti-node at the closed end. In the case of closed pipes, the length of the pipe *"L"* is ideally equal to one-fourth of the wavelength of the sound wave. As in the open pipe experiment, a correction factor for the pipe length must be applied.



CALCULATIONS AND FORMULAS:

For the accepted value for the speed of sound in air, use:
$v_{\text{ACCEPTED}} = (331 + 0.60T)$ m/s , where T is the numerical value of the room temperature in Celsius (but with no units).

OPEN PIPE CALCULATIONS:

L = actual measured pipe length in meters
$L_{\text{CORRECTED}} = L + 0.8\,d$, where d = diameter of the open pipe in meters
$l = 2\,L_{\text{CORRECTED}}$
$v = f\,l$

CLOSED PIPE CALCULATIONS:

L = actual measured pipe length in meters
$L_{\text{CORRECTED}} = L + 0.8\,d$, where d = diameter of the closed pipe in meters
$l = 4\,L_{\text{CORRECTED}}$
$v = f\,l$

EQUIPMENT:

Tuning fork set (one C 512 Hz, one G 384 Hz, one E 320 Hz, one C 256 Hz), open tube set (2 paper adjustable length tubes), closed tube set (2000ml plastic cylinder filled with water almost to the top, glass tube open at both ends), cool tap water, meter stick, CBL temperature probe.

PROCEDURE:

OPEN TUBE EXPERIMENT

1. Set up the adjustable open tube on the end of the table top as shown.

2. Strike the C 512 Hz fork sharply with the rubber mallet; NEVER STIKE A HARD OBJECT WITH THE FORK ITSELF!

3. With one person holding the larger of the 2 tubes firmly on the desktop, place the fork very close to the opening of the tube (but do not make contact with the tube) and adjust the inner tube back and forth until you hear the greatest intensity of resonating sound.

4. Measure the total length of the tube assembly and record this value.

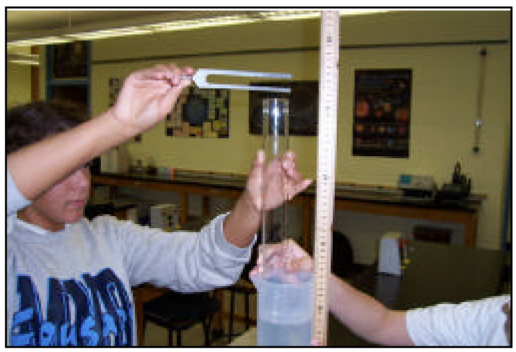
5. Measure the diameter of the inner tube (the one closest to the fork).

6. Record the room temperature with the CBL temperature probe.

7. Calculate the speed of sound making sure to apply the correction factor.

CLOSED TUBE EXPERIMENT

1. Set up the adjustable closed tube apparatus on the table top as shown. Fill the plastic 2000ml graduated cylinder almost up to the top with cool tap water. Carefully insert the glass tube into the water. Note that the water inside the glass tube remains at the same level regardless of how much you move the glass tube up or down; this feature allows you to adjust the tube length for a closed pipe system.



2. Strike the C 384 Hz fork sharply with the rubber mallet; NEVER STIKE A HARD OBJECT WITH THE FORK ITSELF!

3. With one person loosely holding the glass tube to the inside wall of the plastic cylinder (a loose grip is needed to be able to move the glass tube up and down), place the fork very close to the opening of the glass tube (but do not make contact) and adjust the inner glass tube up and down until you hear the greatest intensity of resonating sound. IMPORTANT: Make sure you are hearing the FUNDAMENTAL FREQUENCY! Harmonics are easy to mistake as fundamental frequencies especially when using this apparatus.

4. Once you are sure you have determined the proper tube height for the fundamental frequency, gently secure the glass tube to the inside wall of the plastic cylinder with your hand so that a measurement can be made. This is a two person process: one holds the assembly, another will make the measurement.

5. Measure the total length of the tube assembly and record this value. The total length of the resonating tube is measured from the top of the water to the top of the glass tube.

6. Measure the diameter of the glass tube (the correction factor is applied to the glass tube, not to the plastic cylinder).

7. Record the room temperature with the CBL temperature probe.

8. Calculate the speed of sound making sure to apply the correction factor.

9. Repeat steps 2-8 for the closed pipe procedure using the 320 Hz and 256 Hz forks (you will not be using the 512 Hz fork with the closed tube apparatus).

DATA:

Table 1 - Open Pipe Data	
1. Tuning fork frequency	512 Hz
2. Measured pipe diameter (m)	
3. Measured pipe length (m)	
4. Corrected pipe length (m) **(#3) + [0.8 (#2)]**	
5. Calculated wavelength (m) **2 x (#4)**	
6. Calculated speed of sound (m/s) **(#1) x (#5)**	
7. Room temperature (^{o}C)	
8. Accepted value for speed (m/s) **331 + [0.60 (#7)]**	
9. % error **[[|(#8) – (#6)|] / (#8)] x 100**	

Table 2 - Closed Pipe Data			
1. Tuning fork frequency	384 Hz	320 Hz	256 Hz
2. Measured pipe diameter (m)			
3. Measured pipe length (m)			
4. Corrected pipe length (m) **(#3) + [0.8 (#2)]**			
5. Calculated wavelength (m) **4 x (#4)** **NOTE: Closed tube wavelength is 4 x the length!**			
6. Calculated speed (m/s) **(#1) x (#5)**			
7. Room temperature (^{o}C)			
8. Accepted speed value (m/s) **331 + [0.60 (#7)]**			
9. % error **[[|(#8) – (#6)|] / (#8)] x 100**			

ANALYSIS:

Discuss all sources of error.

QUESTIONS:

1. Does a fork used in a given trial produce a sound at another length? Explain.

2. Does the temperature of the water have any effect on the results for the closed tube trials? Explain.

3. An open pipe, 3.0 m long and 0.15 m in diameter resonates when air at 20 degrees C is blown against its opening. What is the frequency of the note produced? What is the letter designation for this note?