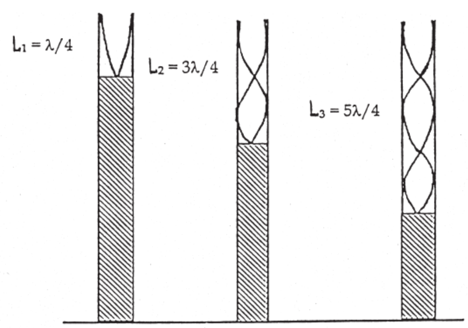
Sound Resonance in a Tube

OVERVIEW

Sound waves are considered longitudinal waves. That is, the molecules (air molecules for instance) will oscillate about their equilibrium positions in the direction of the wave (disturbance). If a tuning fork vibrates and held over an open ended tube, which is closed at the bottom, it will send a sound wave down the tube. This wave will be reflected at the tube's closed end, interference between the reflected wave and the next wave traveling down the tube thus creating the possibility of a standing wave being set up in the air column in the tube. The figure below shows three such standing waves.



The relationship between the (variable) lengths of the air column in the tube

L and the wavelengths of the standing waves λ are:

$$\lambda = 4(L + L_{corr}), \qquad \lambda = (4/3)[L + L_{corr}], \qquad \lambda = (4/5)[L + L_{corr}], \ldots \qquad (1)$$

The first value is the shortest length of tube for resonance of sound with fixed frequency. The second value corresponds to the second shortest length and so forth. In the above equation, L_{corr} is a correcting factor (due to the fact that the maximum amplitude has to occur just outside the tube).

Whenever the tube has one of the lengths satisfying these relations, the tube and the sound source are in resonance, or in other words, the tube resonates at the source's frequency. The condition of resonance is indicated by an increase in the loudness of the sound heard when the air column has the proper resonant- length. The wavelength λ depends in this experiment on the frequency f of the tuning fork used as

$$\lambda = v/f, \qquad (2)$$

where v is the speed of sound.

In this experiment, λ is measured and then the speed of sound is found from

$$v = f\lambda. \qquad (3)$$

A closed tube has a displacement node at the closed end and a displacement antinode at the open end. This antinode is not located exactly at the open end but rather slightly above it. A short distance is required for the equalization of pressure to take place. This distance of the antinode above the end of the tube is called the end correction and it is given by $L_{corr} = 0.3D$, where D is the diameter of the pipe. Therefore, to be exact, one has to add this correction factor to the length of the tube at resonance in order to derive the wavelength from equation (1).

The speed of sound in air is 331.5 m/s at 0^o C. At higher temperatures the speed is slightly greater than this and is given by the equation

$$v = [331.5 + (0.6/^oC)T_C]\ m/s \qquad (4)$$

where T is the room temperature in degrees Celsius. This formula can be used to calculate the theoretical value for the speed of sound which should be compared to your experimental value calculated using equations (1) and (3).

In this experiment, a closed tube of variable length is obtained by changing the level of the water contained in a glass tube. The length of the tube above the water level is the length of the air column in use. The height of the water column in the tube can be easily adjusted via moving up and down a supply tank, which is connected to the tube by a rubber hose.

PROCEDURE

Use only the rubber mallet to strike the tuning fork. Striking it on the lab bench or any other hard object will damage the tuning fork.

Do not at any time let the vibrating fork strike the top of the glass tube.

To feed the water into the system, hold the supply tank higher than the glass pipe and slowly add water into the tank, so that the water flows from the tank into the pipe. End filling water when the level in the pipe reaches its top or somewhat less. After that, one can decrease the water level in the pipe by lowering the tank. Do not overfill the system.

1. Record the frequency of each tuning fork, the temperature of the room and the inside diameter of the tube. **For each tuning fork, note the number of resonances in the tube.**

2. Raise the water level in the tube until it is close to the top. Strike one of the tuning forks and hold it over the open end of the tube. Determine the shortest tube length for which resonance is heard by slowly lowering the water level until you hear a resonance. When the approximate length for resonance has been found, run the water level up and down near this point to determine the position for which the sound is maximum. Measure and record the length of the resonating air column in Table 1 under the L_1 column.

3. Lower the water level until the next position at which resonance occurs is found and repeat Procedure 2 to determine the length of the tube for this case. Record your result under the L_2 column.

4. Repeat Procedures 3 and 4 using the other two tuning forks.

DATA

Table 1

tube diameter D = ________ m, L_{corr} = 0.3D = __________ m

frequency (Hz)	L_1 (m)	L_2 (m)	$L_1 + L_{corr}$ (m)	$L_2 + L_{corr}$ (m)	λ_1 (m)	λ_2 (m)	v_1 (m/s)	v_2 (m/s)

Table 2

frequency	$v_{exp} = (v_1 + v_2)/2$	v_{theor}	% discr

Question

Why does the number of resonances increase with increasing frequency?