Standing Air Waves;
Resonance

Objective:

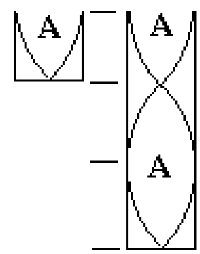
To illustrate resonance in a pipe closed at one end, and determine the speed of sound in air.

Apparatus:

Vertical water/air column, metric scale, tuning forks (with at least 350 cycles/sec), a rubber mallet.

Theory:

In this experiment a section of a transparent tube is partially filled water. The air at the open end of the pipe is set in motion by the periodic vibrations of a tuning fork. A given air pulse from the lower prong of the fork, (a compression), travels back up. If the length of the air column (height of the water) is adjusted so that a succession of pulses is reflected at the top, in phase with the pulse generator (prong of the fork) the amplitude of the pulses (oscillations of the air molecules) will become large and the air column is said to be "in resonance" with the pulse generator i.e. tuning fork.



(a) (b)

At resonance, the air column has the properties of "standing waves"; the air molecules vibrate with an amplitude that varies from zero (at a node) to a maximum (at an antinode), at intervals of one-quarter wavelength, i.e. half wavelength intervals between consecutive antinodes (or node) . It is characteristic of such standing waves in a tube that there must be a node at the fixed water surface (which vibrates only a negligible amount) and an antinode at (actually a little beyond) the open end of the tube. The first possible resonant node is shown at (a) in the figure; here the distance NA is one-quarter wavelength. The next case is shown at (b).

The "end correction" is the distance from the open end of the pipe to the antinode just above it. If this correction is constant, the difference of the pipe lengths at (a) and (b) is seen to be one-half wavelength. Successive resonance points should show this same difference. If tube lengths are plotted against the numbers 1/4, 3/4, 5/4..., what will the slope represent? The end correction may be found from the same graph.

Operation of the Pipette filler Pump:

The pipette filler consists of a rubber bulb and three rubber valves. The valves are normal closed; squeezing the round pad of the valve between the thumb and forefinger opens the valve. The first or top valve (the "**A**" valve) allows outside air into the bulb. The **S**econd valve (the "**S**" valve) is below the bulb and allows air from the bulb into the reservoir for the water column. The third valve is an **E**xhaust valve (the "**E**" valve) which allows air from the reservoir to escape to the outside.

Filling the column with water:

Squeeze the bulb to pressurize the air inside.
Keeping the bulb squeezed. Open valve **S.**
Release valve **S.**
Release the bulb, open valve **A** to re-inflate bulb.
Release valve **A**
Repeat until you reach the desired water level.

Lower the water level in the column:

Open valve E to allow the air in the reservoir to escape.

Fine tuning the water level:

When you are close to a resonance you can "hover" the water level up and down by a few millimeters to find the exact resonance.

Make sure the bulb is full of air.
Squeeze the bulb halfway.
While maintaining your "squeeze" on the bulb, open the S valve.
Holding the S valve open, you can change the water level by changing your "squeeze" on the bulb.
Release valve S when you have the best resonance point.

Procedure and Report:

Caution: Strike the tuning forks **only** with a rubber mallet or "ping" them with your fingers. This is done in order to avoid introducing overtones in the forks as well as to prevent damaging them. When determining resonance listen for the tone of lowest pitch, as overtones may be present. The source of sound (tuning fork) is held about an inch above the open end of the vertical tube, which initially is filled to the 10 cm mark with water. The water level is slowly lowered until the first resonance point is reached, as shown by an audible increase in intensity of the sound. The height of the water surface is then recorded.

Caution: The water level is now lowered further until the next resonance point is found, and the pipe length above the water is again noted. This procedure is continued until the tube is nearly out of the water. The wavelength of the standing airwaves in the pipe can be found from this data, and the speed of the waves may be computed from this wavelength and the frequency of the tuning fork.

1) Determine the resonance points; measure and tabulate the corresponding tube lengths. Take care not to miss the first resonance, which occurs at a tube length of only a few centimeters. Record the frequency of the sound source, the room temperature, and the current barometric pressure. Repeat the procedure for a second frequency.

2) Plot tube lengths at resonance against the appropriate fractions as suggested above, and use the slope to find the wavelength of the airwaves in the tube.

3) Find the end correction from the graph. If differences were used, find the end correction from the wavelength and the first point of resonance.

4) Find the speed of the sound waves from their wavelength and the frequency ($\lambda = v/f$).

5) Compute the speed from the approximate relation: $V(t)$ **= 331 + 0.6 t** meter/sec, where "t" is the air temperature, in ^{o}C.

Questions

1) Are the airwaves in the pipe "longitudinal" or "Transverse"? Do the air molecules vibrate parallel or perpendicular to the pipe length? Are these vibrations of constant amplitude along the pipe length? (Briefly describe)

2) Explain the physical significance of the "end correction." Did the experimental value for the wavelength depend on the end correction? Why?

3) Will the speed of sound change with barometric pressure (P_0), if the temperature remains constant? Explain with reference to the equation:

$$V = \sqrt{\frac{\eta P_0}{\rho_0}}.$$

Where ρ_0 is density and η is the ratio of specific heat.

4) The velocity of sound as computed in step 6 above appears to be independent of the diameter of the tube used. Would you expect this to be true if you had thought about it previously? Under what conditions would you expect the velocity of sound in a pipe to depend upon the diameter of the pipe?

Data table I
Resonance lengths

N^{th} Observation of resonance (For first frequency)	Resonance Length (L)
Location of 1^{st} resonance	
Location of 2^{nd} resonance	
Location of 3^{rd} resonance	
Location of 4^{th} resonance	
Location of 5^{th} resonance	
(For second frequency)	
Location of 1^{st} resonance	
Location of 2^{nd} resonance	
Location of 3^{rd} resonance	
Location of 4^{th} resonance	
Location of 5^{th} resonance	

Data table II
Speed of sound

$\Delta L=(L_f-L_i)$	f(Hz)	$V=2(\Delta L)\ f$	Accepted V	% discrep.