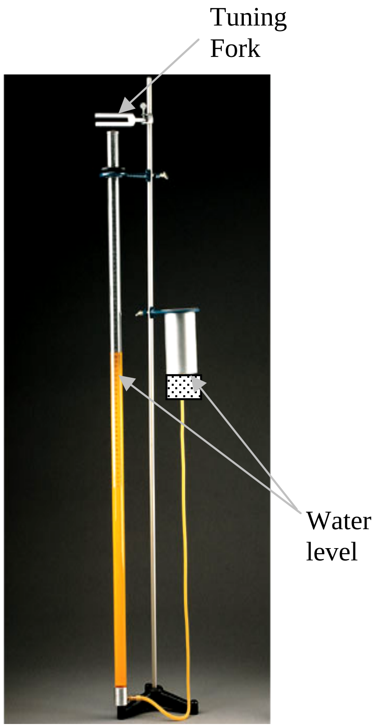
Finding the Speed of Sound Using a Resonant Air Column

Purpose: To measure the speed of sound in air by determining the wavelength of resonant sound waves in an air column of variable length.

Equipment: Resonance air column apparatus, 1000, 2000, 4000 Hz tuning forks.

Introduction:



Resonance Apparatus

In this part sound waves (longitudinal waves) will be generated by a vibrating tuning fork. The medium is room temperature air enclosed in a glass tube, sealed at the lower end by a column of water (see figure). When the tuning fork is set into vibration, a train of waves consisting of alternate compressions and rarefactions in air is sent down the tube. This wave train is reflected at the water surface with a phase change of 180^o and passes back up the tube. At the open end of the tube, it is again reflected, but with no phase change in this case. The resultant waves in the tube are a combination of incident and reflected wave trains and may be very complex, just as in the case of transverse waves in a wire. But just as in the case of the wire, it is possible to produce standing waves under the proper conditions in an air column. The air column will then vibrate strongly in segments, with a frequency equal to the frequency of the tuning fork. This phenomenon occurs when the length of the air column is such value that an odd multiple of quarter-waves “fits” into the air column, since there must be a node at the lower end of the air column (at the surface of the water) and an antinode near the open end of the tube. Under these conditions, the air column resonates with the tuning fork and the intensity of sound from the system is considerably increased. This phenomenon of resonance enables us to determine when standing waves are being produced in the air column.

The length of the air column may be varied, by changing the level of the water in the tube. Thus the positions of the water surface at which resonance occurs may be determined. Careful analysis shows that the position of the antinode at the top of the air column is slightly above the top of the tube (about 0.6 the radius of the tube). If the water level in the tube is gradually lowered from the top of the tube, resonance will occur when the position of the water level corresponds with the position of the first node. This position is sharply defined and may be accurately determined by listening for an extra intense sound. As the water level is further lowered, a second resonance point may be found that corresponds to the second node. In some cases additional nodes may be found, depending upon the relation between the wavelength and the tube length. The inter-nodal distance is just a half wavelength.

Procedure:

1. From the selection of tuning forks available, find three frequencies that will provide wavelengths such that at least three or more nodes can be found in the glass tube. Raise the water level in the glass tube until it is near the top of the tube. Start the tuning fork vibrating by striking it gently with a soft rubber hammer. **Hit the tuning fork when it is away from the glass tube and then quickly bringing it into position over the top of the tube.** Slowly lower the water level while listening for resonance to occur. The amplification of the sound at resonance is quite pronounced, even though the fork itself is emitting a scarcely audible sound. Once you have determined the approximate position of the resonance point, make several trials by running the water surface up and down. When the point of maximum intensity is located, mark its position with a rubber band on the tube. Then lower the water surface and, in a similar manner, locate and mark the next resonance point. Continue this process to the bottom of the tube. In each case make an estimate of the error involved in locating the resonance point.

2. Record the positions of the resonance points to the nearest millimeter and determine the distance between successive resonance points and thus find an average wavelength. Make a diagram that shows the nodes and antinodes of your standing wave and show clearly the wavelength on your diagram.
3. Repeat for the two other tuning forks selected.
4. Determine the velocity of sound in air at room temperature by using the rated frequency of the fork and the wavelength ($v = \lambda f$). Compare this experimental value of v with the theoretical value given (in m/sec) by:

   $$V = 331.5 + 0.61\ T_c$$

   where T_c is the temperature of the air in ^oC.