EXPERIMENT

AIM

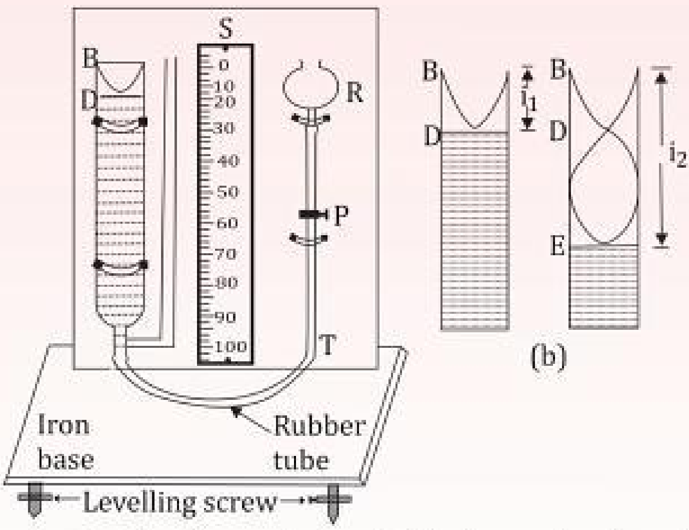
To find the speed of sound in air at room temperature using a resonance tube by two resonance positions.

MATERIAL REQUIRED

A rubber pad, resonance tube, two tuning forks of known 480 Hz and 512 Hz frequencies, water in a beaker, plumbline, a set square and one thermometer.

DIAGRAM

The resonance tube apparatus consists of a cylindrical tube CD about one meter long and 5 cm in diameter which is made of metal, fixed on a vertical wooden plank. A glass tube of small bore is fixed along the meter scale and is connected to metallic tube near its lower end.



To keep the level of water column fixed in the tube, a pinch cock P is clamped on the rubber tube. The tube and part of reservoir are filled with water. The metallic tube forms air column BD over the water surface. The length of the air column can be changed by changing the water level in the tube. If is done by raising or lowering the reservoir and loosening the pinch cock.

The position of the meter scale should be in such manner that the zero of scale coincides with the mouth of the tube CD. This experimental set up stands vertically on a heavy iron base supported on levelling screws.

THEORY

If a vibrating tuning fork of known frequency (say v) is held over the mouth of an air column in the glass tube CD, then a standing wave pattern is formed in the tube. Instantaneously, a superposition between a forward moving wave and a reflected wave takes place in the tube to cause the resonance. Thus, it leads to a noticeable increase in the amplitude of the sound.

Therefore, for resonance to occur, a node (i.e., a point having zero amplitude) must be formed at the closed end and an anti-node (i.e., a point having maximum amplitude) must be formed at the open end.

To Determine the Speed of Sound in Air

Consider at length a of the air column, the first loud sound is heard that means the air column of length a having the natural frequency equals to the natural frequency of the tuning fork, then the vibration of air column with maximum amplitude starts. Since, the length of vibrating air column is little longer than the length of air column in tube CD.

$$\frac{\lambda}{4} = a + e \qquad \text{............ (1)}$$

where, e = 0.6r (where, r radius of glass tube) is the end correction for resonance tube and λ is wavelength of sound produced by tuning fork.

On lowering the closed end of tube CD, consider that the resonance position listens at the length b of the air column in the tube. In this condition, the length of the air column in the tube approximately equals to the three quarters of the wavelength of sound produced by the tuning fork.

i.e.

$$\frac{3\lambda}{4} = b + e \qquad \text{............ (2)}$$

On subtracting Eq (1) from Eq (2), we get:

$$\lambda = 2(b - a)$$

Therefore, the speed of sound in air is given by:

$$v = 2v(b - a)$$

Where, v = frequency of the tuning fork

b = length of air column in second resonance with tuning fork a = length of air column at the first resonance

PROCEDURE

ADJUSTMENT OF RESONANCE TUBE

1. First, fix the resonance tube vertically with the help of levelling screws and test it with plumbline.
2. Note the room temperature with the help of thermometer.
3. Note the frequency of the tuning fork.
4. Fix the reservoir to the highest point of the vertical rod with the help of clamp.

DETERMINATION OF FIRST RESONANCE POSITION

5. Open the pinch cock and then fill the reservoir with water in such a way that it rises to the top in the pipe.
6. It is to be confirmed that the water does not spill out even if the reservoir attains the lowest position.
7. For the first resonance position, initiate with the zero length of air column in pipe.
8. Close the pinch cock and lower down the position of reservoir on the vertical rod.
9. Now, set the tuning fork into vibration by striking it on a rubber pad and then take the vibrating tuning fork to just above (about 1cm above) the mouth of the tube.
10. It should be ensured that the prongs of the tuning fork remain parallel to the ground and lying one above the another thereby the prongs can vibrate vertically.
11. Simultaneously, make the reservoir in lower position which will lead to the lowering of water level in the pipe.

12. Try to listen the sound being produced in the tube. It may not be audible in this position because of dying out of vibration of tuning fork.
13. Now, set the tuning fork into vibration mode again by striking it on the rubber pad and bring the tuning fork near to the free opening of pipe and listen the sound again.
14. By slowly loosen the pinch cock, lower the level of water continuously till the sound of maximum intensity is heard.
15. Now, increase and decrease in the water level by 1 mm to confirm that loudness falls sharply on any side of the resonance position.
16. Fix the position of the tube where the intensity of sound is maximum.
17. Note the length x_1 of the air column in the glass tube from with the help of meter scale and set squares. This corresponds to the first resonance position or fundamental node.

DETERMINATION OF SECOND RESONANCE POSITION

18. Now, lower the position of the reservoir R and clamp it to the near position of the tube and opening of the pinch cock till the length of air column in the tube increases about three times of the length x_1.
19. Next find the second resonance position by repeating the steps 9 to 17 and then determine the length of air column x_2 in the glass tube. It is to be ensured that the tuning fork must be of same frequency (v_1) as used in finding the first resonance position.
20. Take at least four readings (i.e., two for when the level of water is falling and two for when the level of water is rising in the tube) to confirm the lengths x_1 and x_2.
21. Now, repeat the steps 9 to 20 with the second tuning fork of different frequency (v_2) and determine the respective first and second resonance positions.
22. Calculate the speed of sound by using formula, $v = 2v(x_2 - x_1)$ for each frequency.

OBSERVATIONS

1. Temperature of the room, T = ________ °C
2. Frequency of the first tuning fork, v_1 = ________ Hz
3. Frequency of the second tuning fork, v_2 = __________ Hz

TABLE FOR THE DETERMINATION OF RESONATING LENGTH FOR DIFFERENT FREQUENCIE

Frequency of tuning fork used.	S. No.	length x_1 for the first resonance position of the tube			Length x_2 for the second resonance position of the tube		
		Water level is falling (cm)	Water level is raising (cm)	Mean length, X_1 (cm)	Water level is falling (cm)	Water level is raising (cm)	Mean length, x_2 (cm)
V_1 = 512 Hz	1						
	2						
V_2 = 480 Hz	1						
	2						

CALCULATIONS

1. Frequency of first tuning fork, v_1 = ________ Hz.
2. Therefore, speed of sound in air, $v_i = 2v_1(x_2 - x_1)$ _________ ms^{-1} .... (1)
3. The frequency of second tuning fork, v_2 = _______ Hz

4. Therefore, speed of sound in air, $v_{ii} = 2v_2 (x_2 - x_1)$ = ______ ms^{-1} .... (2)
5. Therefore, mean speed of sound in air eq. (1) + eq. (2), $v = \frac{v_i + v_{ii}}{2}$ = ______ ms^{-1}

NOTE: Applying the end correction when you will be going to take the observations of second resonance position, then be clear that the loudness of sound in second resonance position must be lower than the loudness in the first resonance. So, in case you find different results, then they must be corrected at the same time by applying end correction.

RESULT

The speed of sound in air at room temperature is $\frac{v_i + v_{ii}}{2}$ = __________ ms^{-1}

PRECAUTIONS

1. The vibrating tuning fork should not touch the walls of the resonance tube and should be kept just above the top of the resonance tube.
2. The tuning fork must be striked on the rubber pad very gently.
3. Second resonance position must be accurately identified as the loudness of sound is very low.
4. Increasing and decreasing of water level in the resonance tube should be done very slowly.
5. The resonance tube should be kept vertically by using the levelling screws and plumbline.
6. The experiment should be performed in a quiet atmosphere, so that the resonance positions may be identified properly.
7. The choice of frequencies of the tuning forks being used should be such that the two resonance positions may be achieved in the air column of the resonance tube.
8. The prongs of the vibrating tuning fork must be kept parallel to the ground and keeping one over the other, so that the vibrations reaching the air inside the tube are vertical.
9. At the time of experiment, room temperature should be measured continuously so that its mean value can be taken.

SOURCES OF ERROR

1. Resonance tube may not have uniform cross-sectional area.
2. The pressure of water vapor in the air column may exhibit a higher value of speed of sound.
3. Rising and lowering of water level in resonance tube may not be slow.
4. The prongs of the vibrating tuning fork may touch the tube.

VIVA VOCE

Q1. Define the resonance of air column.

Ans. Resonance of air column can be defined as the phenomenon in which the frequency of air column becomes equal to the frequency of the tuning fork.

Q2. Mention the principle of the working of the resonance tube.

Ans. The resonance tube works on the principle of the air column with the tuning fork.

Q3. Define the term end error.

Ans. End error can be defined as the error in the measurement of resonating length due to the non-rigidity of reflecting surfaces.

Q4. What is the reason of lying of anti-node just above the edge of the open end of tube?

Ans. The anti-node lies just above the edge of the open end of tube because the sound wave reflects in the air column from a region slightly above the edge because the tube medium continues up to that region.

Q5. Can you specify the position of nodes and anti-nodes in the air column?

Ans. The node lies at the surface of the water level while the anti-node lies at the open end of the metallic tube.

Q6. Name the phenomenon responsible for resonance in this experiment.

Ans. In this experiment, for resonance to occur, a node must be formed at the closed end and on anti- node must be formed at the open end of tube. So, due to this reason, the frequency of the air column becomes equal to the natural frequency of the tuning fork.

Q7. Write two other examples of resonance of sound from day-to-day life.

Ans. If we consider the musical instruments, then there can be the examples like strings of violin, length of the tube in a flute. While, in the case of mechanical resonance, example the breaking of the wine glass with sound at precise resonant frequency of the glass.

Q8. What would happen if the resonant tube is vertical?

Ans. According to the experimental procedure, the resonant tube should be set vertical firstly because the whole experimental apparatus and its procedure depend upon its position. Moreover, if it is not vertical, then it would lead an error in the result.

Q9. Which state of medium has maximum has maximum and minimum speed of sound?

Ans. The speed of sound is maximum in solids, minimum is gases and zero in vacuum.

Q10. Do you find the velocity of sound in air column or in water column?

Ans. The velocity is found in air column above the water surface.