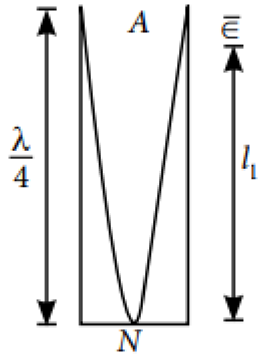
Experiment - 8 : Speed of sound in air at room temperature using a resonance tube.

Theory



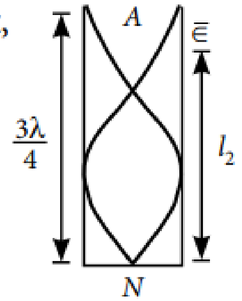
A resonance tube is a tube open on one-side and closed at the other end by a water surface. The tube is made to resonate with a turning fork for two different positions. The first position is for the first harmonic of the tube. So

$$\frac{\lambda}{4} = l_1 + \epsilon \qquad \ldots(i)$$

The second position is for the first overtone of the tube.

$$\frac{3\lambda}{4} = l_2 + \epsilon \qquad \ldots(ii)$$

'∈' is the end-correction, since the anti-node of the displacement wave is formed slightly above the mouth of the tube. Subtracting (i) from (ii) we get,



$$\frac{3\lambda}{4} - \frac{\lambda}{4} = (l_2 - l_1) \Rightarrow \lambda = 2(l_2 - l_1)$$

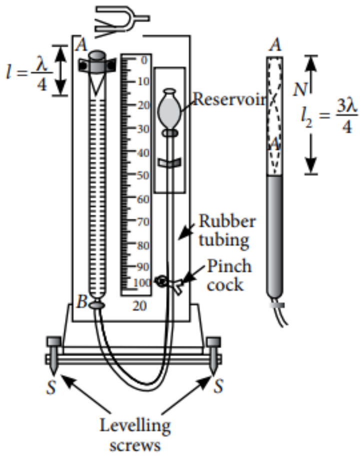
If υ is the frequency of the tuning fork, then $v = \upsilon\lambda = 2\upsilon(l_2 - l_1)$

where v is the velocity of the sound wave at the room temperature.

Also, from (i) and (ii), by eliminating λ, we get, $\epsilon = \frac{l_2 - 3l_1}{2}$

Procedure

For the experiment, we use a resonance tube apparatus, tuning fork, set square, beaker and water. Once the apparatus is set, the tuning fork is struck and placed above the upper end A of the resonance tube, so that the prongs of the tube are in vertical plane. Then the pinchcock is opened and the water-level is allowed to fall slowly. At some position, a loud sound is heard. This corresponds to the 1st resonance position. Similarly, a 2nd resonance position is attained and calculations are performed.


A
$l = \frac{\lambda}{4}$
Reservoir
Rubber tubing
Pinch cock
B
20
S
S
Levelling screws
A
N
$l_2 = \frac{3\lambda}{4}$

MCQs Corner

Experiment – 8

34. In the first overtone position of the resonance tube, the pressure anti-node is present at (L is the length of the tube) which positions from the closed end.

(a) $\frac{L}{3}, L$ (b) $0, \frac{2L}{3}$

(c) $\frac{L}{3}, \frac{2L}{3}$ (d) $0, L$

35. A tuning fork having frequency of 340 Hz is vibrated just above a cylindrical tube. The height of the tube is 120 cm. Water is slowly poured in. The minimum height of water for resonance is (v = 340 m/s)

(a) 25 cm (b) 45 cm (c) 75 cm (d) 95 cm

36. A resonance tube is old and has jagged end. It is still used in the laboratory to determine velocity of sound in air. A tuning fork of frequency 512 Hz produces first resonance when the tube is filled with water to a mark 11 cm below a reference mark, near the open end of the tube. The experiment is repeated with another fork of frequency 256 Hz which produces first resonance when water reaches a mark 27 cm below the reference mark. The velocity of sound in air, obtained in the experiment, is close to

(a) 335 m s^{-1} (b) 322 m s^{-1} (c) 328 m s^{-1} (d) 341 m s^{-1}

37. While measuring the speed of sound by performing a resonance column experiment, a student gets the first resonance condition at a column length of 18 cm during winter. Repeating the same experiment during summer, she measures the column length to be x cm for the second resonance. Then

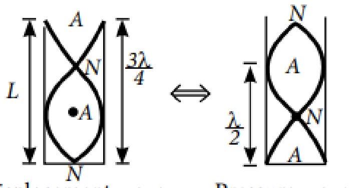
(a) $36 > x > 18$ (b) $18 > x$ (c) $x > 54$ (d) $54 > x > 36$

Answer Key

34. (b) 35. (b) 36. (c) 37. (c)

Hints & Explanation

34. **(b) :**



Displacement wave   Pressure wave

In case of a pressure wave, the nodes and anti-nodes are swapped as compared to a displacement wave. As $L = \frac{3\lambda}{4}$ here, $\lambda = \frac{4L}{3}$

The pressure anti-nodes are formed at 0, $\frac{\lambda}{2}$ distance from the closed end or they are formed at 0, $\frac{2L}{3}$ from the closed end.

35. **(b) :** For resonance, $\upsilon = \frac{nv}{4L}$ where $n = 1, 3, 5\ldots$

or $L = \left(\frac{nv}{4\upsilon}\right)\text{m} = n\left(\frac{340}{4\times 340}\right) \times 100$ cm

$L = 25n$ cm, $n = 1, 3, 5\ldots$

$\Rightarrow$ $L = 25$ cm, 75 cm, 125 cm…

Height of the water column = $(120 - L)$ = 95 cm, 45 cm, $(120 - 125)$cm is not possible.

So, the minimum height of water is 45 cm.

36. **(c) :** Due to jagged end

$\frac{v}{4(11-x)\times 10^{-2}} = 512$ ...(i); $\frac{v}{4(27-x)\times 10^{-12}} = 256$ ...(ii)

From eqn. (i) and (ii), $2(11 - x) = (27 - x) \Rightarrow x = -5$ cm

From eqn. (i), $\frac{v}{4\times 16\times 10^{-2}} = 512 \Rightarrow v \simeq 328 \text{ m s}^{-1}$

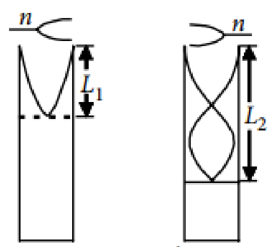
37. **(c) :** $v_1 = \sqrt{\frac{\gamma RT}{M}}$ assuming M is the average molar mass of the air (*i.e.*, nitrogen)

and γ is also for nitrogen.

$v_1 = \sqrt{\frac{\gamma RT_1}{M}}$; $v_2 = \sqrt{\frac{\gamma RT_2}{M}}$

where T_1 and T_2 stand for winter and summer temperatures.

$L_1 = \frac{v_1}{n} = \frac{\lambda}{4} = 18$ cm



1st resonance   2nd resonance

at temperature T_1.

At T_2, summer, $v_2 > v_1$.

$L_2 = \frac{v_2}{n} = \frac{3\lambda}{4} > 3\times 18.$ $\therefore$ $L_2 > 54$ cm