# Kundt's Tube Experiment

BS192: Undergraduate Science Laboratory (Physics)

**Group 7 (Lab No. 3, Experiment No. 4)**

**A laboratory report by**


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Experiment No. 4

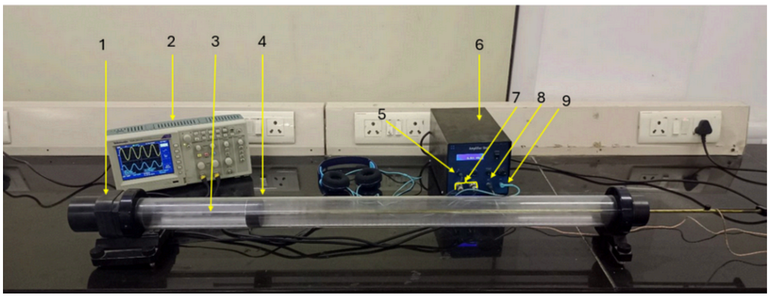
# Kundt's Tube Experiment

## I. Aim:

To determine the speed of sound in air using Kundt's tube apparatus.

## II. Apparatus:

Transparent tube with 1000 mm length and 59 mm diameter with a reading scale. At one end of the tube, a loudspeaker is attached and at the other end, a movable piston with a reflector and a microphone is connected. Kundt's tube amplifier with oscillator unit. Support blocks to hold the tube horizontally up from the workbench.



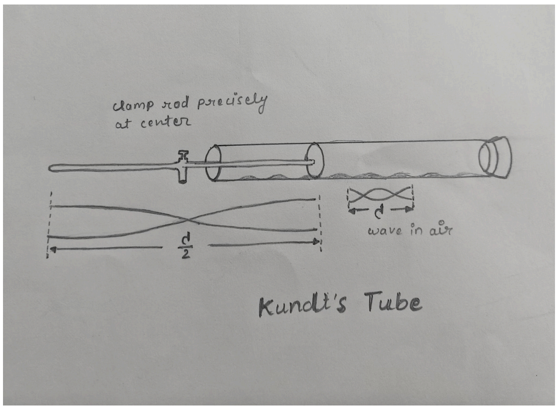

## III. Theory:

In this experiment, we will deal with the longitudinal nature of sound waves. Sound travels as longitudinal waves in the air and can propagate as longitudinal and transverse waves in solids like metal rods. In a longitudinal wave, the motion of the particles is parallel to the direction of propagation of the wave, whereas, in a transverse wave, the motion of the particles is perpendicular to the direction of propagation of the wave. It is also a compression wave since the longitudinal displacement of the gas molecules is caused by the changing pressure. The propagation speed of the wave depends on the elasticity of the medium. In turn, the elasticity depends on the temperature. Thus, the sound velocity is a function of the temperature.

$$v = f \times \lambda$$

where $\lambda$ is the wavelength and $f$ is the frequency. Transverse waves aren't feasible in gaseous and fluidic substances due to the absence of perpendicular interlinking. The wavelength is the distance between two consecutive compressions or rarefactions while the frequency is the number of compressions or rarefactions that pass any point in the medium per second.

In Kundt's tube the sound wave from the speaker and the reflected wave from the other end of the tube results in the formation of the standing waves. Standing waves are produced when two waves of nearly equal wavelength and amplitude propagate in opposite directions in the same medium. These waves exhibit nodes and antinodes. Nodes are the points where the amplitude is minimum, and antinodes are the points where the amplitude is maximum. Distances between the nodes or antinodes are used to determine sound wavelength, which allows us to find the speed of sound.




## IV. Procedure:

• Place the Kundt's tube apparatus on a flat vibration-free surface.

• Connect the speaker, headphones and microphone to the Amplifier-Oscillator Unit and set the oscillator at some specific frequency (any value between 0.200 kHz to 5kHz). Record the value as f.

• Start moving the piston slowly outward while listening carefully to the headphones.

• Find a position of the piston where you hear maximum loudness in the tube to get the resonance condition.

• Measure the length from the speaker to the reflector and note it down as the tube length "L".

• Starting with the microphone close to the speaker, gradually pull it back to the reflector.

• When the loudness is maximum/minimum, note down the distance as $X_1$.

• Pull back the microphone slowly and count the number of points with maximum/minimum (antinodes/nodes) sound being heard. Note this as "n". Also, note down the position of the nth point where maximum/minimum is heard as $X_2$.

• Then ( $X_2$-$X_1$/n) gives half the wavelength in millimetres i.e. $\lambda/2$. With this data find the velocity of sound by using the relation $v = f \times \lambda$.

• Now, repeat the experiment for different frequencies and different tube lengths.

## V. Results and Discussion

**Observations:**

Given the $A_1$(mm), $A_2$(mm) and $n$, the wavelength (λ) can be calculated as follows

$$\frac{\lambda}{2} = Distance\ between\ any\ 2\ consecutive\ nodes/antinodes\ (in\ mm)$$

$$\frac{\lambda}{2} = \frac{A_2 - A_1}{n \times 1000}$$

The λ calculated from here can then be multiplied by the taken frequency to get the speed of sound

$$V = f \times \lambda$$

Here,

$A_1$ = Position of the first node/antinode

$A_2$ = Position of the last node/antinode

$n$ = Number of nodes/antinodes between $A_1$ and $A_2$

| Frequency (*f*) (Hz) | Tube length (L) (mm) | $A_1$ (mm) | $A_2$ (mm) | $n$ | Velocity (*v*) *(m/s)* |
|---|---|---|---|---|---|
| 400 | 800 | 150 | 595 | 1 | 356 |
| 500 | 800 | 340 | 680 | 1 | 340 |
| 700 | 400 | 40 | 280 | 1 | 336 |
| 900 | 400 | 115 | 310 | 1 | 351 |
| 900 | 500 | 30 | 410 | 2 | 342 |
| 1000 | 800 | 200 | 715 | 3 | 343.33 |
| 1200 | 700 | 55 | 630 | 4 | 345 |
| 1500 | 800 | 50 | 750 | 6 | 350 |
| 1500 | 700 | 75 | 650 | 5 | 345 |
| 2000 | 600 | 40 | 560 | 6 | 346.67 |

We can use the least square fitting method to predict a linear relation between ν and $\frac{1}{\lambda}$ based on our readings

We want to obtain a relation

$$y = A + Bx$$

where $x = \frac{1}{\lambda}, y = f, B = V$

$f = V \times \frac{1}{\lambda}$

$\Delta = N\Sigma x^2 - \Sigma x^2$

$A = \frac{\Sigma x^2 \Sigma y - \Sigma x \Sigma xy}{\Delta}$

$B = \frac{N\Sigma xy - \Sigma x \Sigma y}{\Delta}$

$N$ = number of readings = 10

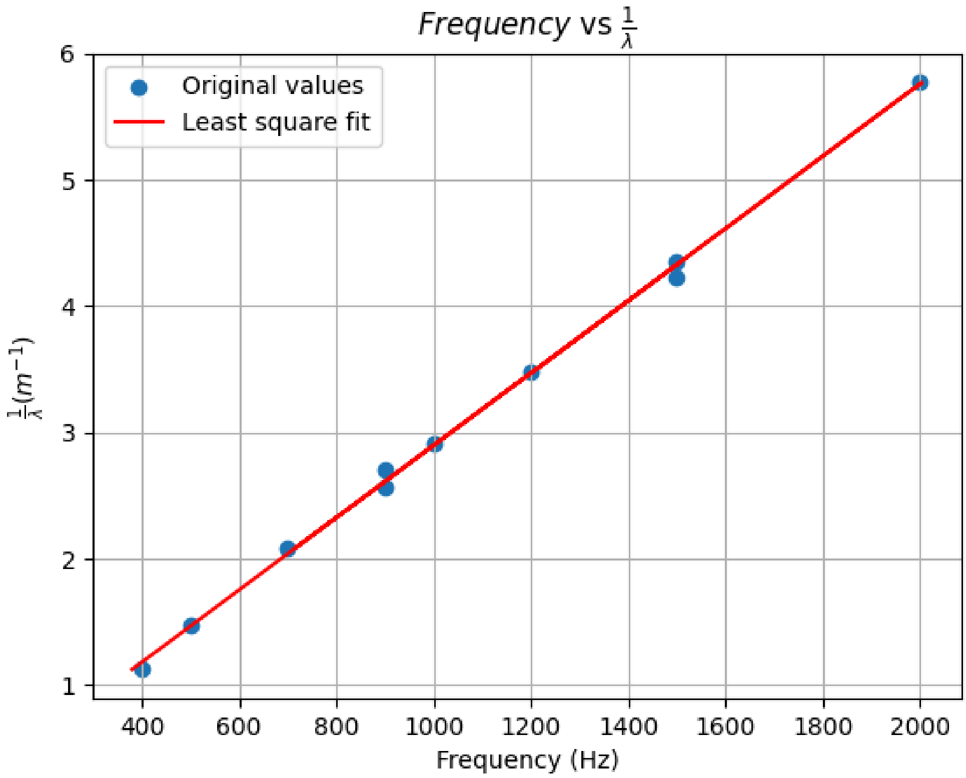
Below are the calculations carried out to get the equation and the graph.

| $x = \frac{1}{\lambda}$ | $x^2 = \frac{1}{\lambda^2}$ | $y = f$ | $xy$ | $(y - A - Bx)^2$ |
|---|---|---|---|---|
| 1.121 | 1.262 | 400.00 | 449.44 | 396.31 |
| 1.471 | 2.163 | 500.00 | 735.30 | 1.97 |
| 2.913 | 8.483 | 1000.00 | 2912.62 | 30.84 |
| 4.231 | 17.904 | 1500.00 | 6346.97 | 1116.89 |
| 5.769 | 33.284 | 2000.00 | 11538.46 | 18.08 |
| 2.564 | 6.575 | 900.00 | 2307.70 | 265.44 |
| 2.083 | 4.34 | 700.00 | 1458.33 | 244.18 |
| 2.703 | 7.305 | 900.00 | 2432.43 | 1034.50 |
| 4.348 | 18.904 | 1500.00 | 6521.74 | 53.50 |
| 3.478 | 12.098 | 1200.00 | 4173.91 | 10.93 |

$\Delta$ = 181.70

A = -12.73 = y-intercept of the graph

B = 349.61m/s = slope of graph = velocity of sound




# VI. Error Analysis

**Error in linear regression**

$\sigma_y = \sqrt{\frac{1}{N-2}\Sigma\left(y_i - A - Bx_i\right)^2} = 19.92\ Hz$

$\sigma_A = \sigma_y\sqrt{\frac{\Sigma x^2}{\Delta}} = 15.66\ Hz$

$\sigma_B = \sigma_y\sqrt{\frac{N}{\Delta}} = 4.67\ m/s$ = error in velocity

Hence,

$$V = 349.61 \pm 4.67\ m/s$$

**Percentage error in linear fitting:**

$$Error\ \% = \frac{\Delta V}{V} \times 100\%$$

$$= 1.33\ \%$$

| Velocity (m/s) | $x_i - \mu$ | $(x_i - \mu)^2$ |
|---|---|---|
| 356 | 10.5 | 110.25 |
| 340 | -5.5 | 30.25 |
| 343.33 | -2.17 | 4.71 |
| 350 | 4.5 | 20.25 |
| 346.67 | 1.17 | 1.37 |
| 351 | 5.5 | 30.25 |
| 336 | -9.5 | 90.25 |
| 342 | -3.5 | 12.25 |
| 345 | -0.5 | 0.25 |
| 345 | -0.5 | 0.25 |

$$\mu = \frac{\Sigma x_i}{N} = 345.50\ m/s$$

$$\sigma = \sqrt{\frac{\Sigma(x_i - \mu)^2}{N-1}} = 5.77\ m/s$$

**Accuracy error (with respect to the actual value of the speed of sound)**

$$Error\ \% = \frac{|V_{actual} - V_{calculated}|}{V_{actual}} \times 100\ \%$$

$$Error = 0.73\ \%$$

Here, $V_{calculated}$ is taken as the mean of the observed values (345.50 *m/s*) and $V_{actual}$ to be 343 *m/s.*

## Possible Sources of Error

- The frequency on the oscilloscope-amplifier unit fluctuated a lot while taking the measurement.
- The beginning of the length scale was hidden beneath the speaker, so there could be some zero error that could not be accounted for.
- The node is formed instantaneously at a specific position; any deviation from the actual position would be visible in the final calculation.
- The pressure inside the tube could be different than the pressure outside.

# VII. Conclusion

We conducted this experiment to determine the value of sound to be 345.50 *m/s.* We verified the existence of nodes and antinodes by observing the difference in the loudness as we moved the microphone away from the speaker. We also noticed the change in the waveform on the oscilloscope. To get a more accurate reading, we could take the readings at more points and vary each of the variables on a much larger range.

## VIII. Author Contributions

| Name | Roll number | Contribution | Signature |
|---|---|---|---|
| Aksh Kishor Solanki | 24110023 | Creation of pre-report | |
| Akshat Vishal Wandalkar | 24110024 | Error analysis and possible sources of errors | |
| Akshay | 24110025 | Proofreading of reports and elimination of errors, drawing diagrams | |
| Akshit Chhabra | 24110026 | Results and discussion in the lap report, operation of equipment | |
| Akul Gupta | 24110027 | Documenting data during the experiment, sketching of graphs | |