

Speed of Sound in Air

1. Newton's Formula

Newton assumed that when a sound wave travels in air, the **compression and rarefaction are isothermal** (temperature remains constant).

For sound in a gas,

$$v = \sqrt{\frac{P}{\rho}} = \sqrt{\frac{P}{\rho}}$$

where

- P = pressure of air
- ρ = density of air

Using standard values at 0°C ,

$$v = 1.01 \times 10^5 \cdot 1.293 \approx 280 \text{ m/s} = \sqrt{\frac{1.01 \times 10^5}{1.293}} \approx 280 \text{ m/s}$$

Problem with Newton's Formula

- Experimental value $\approx 331 \text{ m/s}$
 - Newton's value is **too low**
 - Reason: Sound propagation is **too fast** for heat exchange \rightarrow process is **not isothermal**
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2. Laplace Correction (Adiabatic Process)

Laplace corrected Newton's assumption by stating that the changes are **adiabatic**, not isothermal.

For an adiabatic process:

$$P = K \rho^\gamma$$

where

- $\gamma = \frac{C_p}{C_v}$ (adiabatic index)
- For air, $\gamma = 1.4$

Corrected speed of sound:

$$v = \sqrt{\frac{\gamma P}{\rho}} \quad v = \sqrt{\gamma P / \rho}$$

Numerical Value

At 0°C to 0°C :

$$v = 1.4 \times 1.01 \times 10^5 / 1.293 \approx 331 \text{ m/s} \quad v = \sqrt{\frac{1.4 \times 1.01 \times 10^5}{1.293}} \approx 331 \text{ m/s}$$

✓ Matches experimental value

Final Temperature Formula (Very Important)

$$v = \sqrt{\frac{\gamma R T}{M}} \quad v = \sqrt{\gamma R T / M}$$

or approximately,

$$v = 331 + 0.6T \text{ (m/s)} \quad v = 331 + 0.6T \text{ (m/s)}$$

where T is in $^\circ\text{C}$.

Comparison Table

| Newton | Laplace |
|----------------------|----------------------------|
| Isothermal process | Adiabatic process |
| $v = \sqrt{P/\rho}$ | $v = \sqrt{\gamma P/\rho}$ |
| Gives low value | Gives correct value |
| Neglects heat effect | Includes heat effect |