Speed of sound - temperature matters, <u>not air pressure</u>

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Tutorium

The expression for the speed of sound c_0 **in air** is:

$$c_0 = \sqrt{\frac{p_0}{\rho} \cdot \kappa}$$ **Eq. 1**

c_0 = speed of sound in air at 0 °C = 331 m/s   <u>Speed of sound</u> at 20 °C (68 °F) is c_{20} = 343 m/s

p_0 = atmospheric air pressure 101,325 Pa (standard)   Specific acoustic impedance at 20°C is Z_{20} = 413 N · s /m³

ρ_0 = density of air at 0 °C: 1.293 kg/m³ = Z_0 / c_0 Air density at 20 °C is ρ_{20} = 1.204 kg/m³

ρ = lower-case Greek letter "rho"   Specific acoustic impedance at 0 °C is Z_0 = 428 N · s /m³

κ = adiabatic index of air at 0 °C: 1.402 = c_p / c_v = ratio of the specific warmth

κ = lower-case Greek letter "kappa"   Sound resistance = Specific acoustic impedance $Z = \rho \cdot c$

Calculating from these values, the speed of sound c_0 **in air** at 0 °C:

$$c_0 = \sqrt{\frac{p_0}{\rho_0} \cdot \kappa} = \sqrt{\frac{101325}{1,2935} \cdot 1,402} = 331.4 \text{ m/s}$$ **Eq. 2**   The last accepted measure shows the value **331.29 m/s**.

And from this one gets the speed of sound:

$c_\vartheta = c_0 \cdot \sqrt{1 + \alpha \cdot \vartheta}$ in m/s   **Eq. 3**

α = coefficient of expansion 1 / 273.15 = 3.661 · 10⁻³ in 1 / °C

–273.15°C (Celsius) = absolute zero = 0 °K (Kelvin), all molecules are motionless.

ϑ = temperature in °C = lower-case Greek letter "theta"

c_0 = speed of sound in air at 0 °C

The speed of sound c_{20} in **air of 20 °C** is:

c_{20} = **343 m/s**   This value of c is usually used in formulas.

This following formula has sufficient accuracy for sound engineers - the speed of sound in air (m/s) is a function of the temperature ϑ in °C:

c = **331.5 + 0,6 · ϑ**   **Eq. 4** You can get the speed of sound easily using this formula.

With Eq. 3 it is clear that the speed of sound increases with rising temperature:

$$c_\vartheta \sim \sqrt{\vartheta}$$ **Eq. 5**

Note: The speed of sound c in air is only dependent on the temperature ϑ. It is completely independent of the air pressure p.

Reason: The air pressure and the air density are proportional to each other at the same temperature.

This means in Eq. 1: The ratio p_0 / ρ_0 **is always constant**.

The speed of sound in air depends on the density of air and the density of air depends on the temperature.

Therefore the speed of sound is the same on a mountain peak as it is at sea level, provided that the temperature is the same.

Questions:

1. What is the speed of sound c_{15} at 15 °C?

2. What is the speed of sound c_{25} at 25 °C?

3. At 20 °C, a **1 m sound path** gives a time-of-arrival difference of Δt = 2.915 ms, **approximately 3 ms**. Thus, for a 10 m path it will be 29.15 ms. Which time-of-arrival differences result for 10 meters of sound path if the temperature is 15 °C, and 25 °C?

A request: If you find in technical books the speed of sound in air indicated as a function of temperature then disregard or cross out any additional misleading reference to it being also a function of air pressure. Any qualification of the speed of sound being "at sea level" is also irrelevant.

A frequent question is "**What is the speed of sound?**" The reply should be **"At what temperature?"**

Calculation: Speed of sound in air - temperature   http://www.sengpielaudio.com/calculator-speedsound.htm