Speed of sound - temperature matters, not air pressure

Die Schallgeschwindigkeit, die Temperatur ... und nicht der Luftdruck http://www.sengpielaudio.com/DieSchallgeschwindigkeitLuftdruck.pdf

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Tutorium

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

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

c_0 = speed of sound in air at 0°C = 331 m/s

p_0 = atmospheric air pressure 101,325 Pa (standard)

ρ_0 = density of air at 0°C: 1.293 kg/m³ = Z_0 / c_0

ρ = lower-case Greek letter "rho"

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"

Speed of sound at 20°C (68°F) is c_{20} = 343 m/s

Specific acoustic impedance at 20°C is Z_{20} = 413 N · s /m³

Air density at 20°C is ρ_{20} = 1.204 kg/m³

Specific acoustic impedance at 0°C is Z_0 = 428 N · s /m³

Sound resistance = Specific acoustic impedance $Z = \rho \cdot c$

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

$$c_0 = \sqrt{\frac{p_0}{\rho_0} \cdot \kappa} = \sqrt{\frac{101325}{1{,}2935} \cdot 1{,}402} = 331.4 \text{ m/s} \qquad \text{Eq. 2}$$

The last accepted measure shows the value 331.3 m/s.

And from this one gets the speed of sound:

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

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:

$$c = 331.3 + 0{,}6 \cdot \vartheta \qquad \text{Eq. 4}$$

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:

$$c_\vartheta \sim \sqrt{\vartheta} \qquad \text{Eq. 5}$$

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