Important Governing Equations and Sound Wave Formulas PDF

Formulas
Examples
with Units

List of 18
Important Governing Equations and Sound Wave Formulas

1) Critical Density Formula

Evaluate Formula

Formula

$$\rho_{cr} = \rho_o \cdot \left(\frac{2}{\gamma+1}\right)^{\frac{1}{\gamma-1}}$$

Example with Units

$$0.7734\,\text{kg/m}^3 = 1.22\,\text{kg/m}^3 \cdot \left(\frac{2}{1.4+1}\right)^{\frac{1}{1.4-1}}$$

2) Critical Pressure Formula

Evaluate Formula

Formula

$$p_{cr} = \left(\frac{2}{\gamma+1}\right)^{\frac{\gamma}{\gamma-1}} \cdot P_0$$

Example with Units

$$2.6414\,\text{at} = \left(\frac{2}{1.4+1}\right)^{\frac{1.4}{1.4-1}} \cdot 5\,\text{at}$$

3) Critical Temperature Formula

Evaluate Formula

Formula

$$T_{cr} = \frac{2 \cdot T_0}{\gamma+1}$$

Example with Units

$$250\,\text{K} = \frac{2 \cdot 300\,\text{K}}{1.4+1}$$

4) Flow Velocity Downstream of Sound Wave Formula

Evaluate Formula

Formula

$$u_2 = \sqrt{2 \cdot \left(\frac{a_1^2 - a_2^2}{\gamma-1} + \frac{u_1^2}{2}\right)}$$

Example with Units

$$45.0772\,\text{m/s} = \sqrt{2 \cdot \left(\frac{12\,\text{m/s}^2 - 31.90\,\text{m/s}^2}{1.4-1} + \frac{80\,\text{m/s}^2}{2}\right)}$$

5) Flow Velocity Upstream of Sound Wave Formula

Evaluate Formula

Formula

$$u_1 = \sqrt{2 \cdot \left(\frac{a_2^2 - a_1^2}{\gamma-1} + \frac{u_2^2}{2}\right)}$$

Example with Units

$$79.9566\,\text{m/s} = \sqrt{2 \cdot \left(\frac{31.90\,\text{m/s}^2 - 12\,\text{m/s}^2}{1.4-1} + \frac{45\,\text{m/s}^2}{2}\right)}$$

6) Isentropic Change across Sound Wave Formula

Evaluate Formula

Formula

$$dpd\rho = a^2$$

Example with Units

$$117649\,\mathrm{m^2/s^2} = 343\,\mathrm{m/s}^2$$

7) Isentropic Compressibility for given Density and Speed of Sound Formula

Evaluate Formula

Formula

$$\tau_s = \frac{1}{\rho \cdot a^2}$$

Example with Units

$$0.0694\,\mathrm{cm^2/N} = \frac{1}{1.225\,\mathrm{kg/m^3} \cdot 343\,\mathrm{m/s}^2}$$

8) Mach Angle Formula

Evaluate Formula

Formula

$$\mu = asin\left(\frac{1}{M}\right)$$

Example with Units

$$30° = asin\left(\frac{1}{2}\right)$$

9) Mach Number Formula

Evaluate Formula

Formula

$$M = \frac{V_b}{a}$$

Example with Units

$$2.0408 = \frac{700\,\mathrm{m/s}}{343\,\mathrm{m/s}}$$

10) Mayer's Formula Formula

Evaluate Formula

Formula

$$R = C_p - C_v$$

Example with Units

$$273\,\mathrm{J/(kg*K)} = 1005\,\mathrm{J/(kg*K)} - 732\,\mathrm{J/(kg*K)}$$

11) Ratio of Stagnation and Static Density Formula

Evaluate Formula

Formula

$$\rho_r = \left(1 + \left(\frac{\gamma - 1}{2}\right) \cdot M^2\right)^{\frac{1}{\gamma - 1}}$$

Example

$$4.3469 = \left(1 + \left(\frac{1.4 - 1}{2}\right) \cdot 2^2\right)^{\frac{1}{1.4 - 1}}$$

12) Ratio of Stagnation and Static Pressure Formula

Evaluate Formula

Formula

$$P_r = \left(1 + \left(\frac{\gamma - 1}{2}\right) \cdot M^2\right)^{\frac{\gamma}{\gamma - 1}}$$

Example

$$7.8244 = \left(1 + \left(\frac{1.4 - 1}{2}\right) \cdot 2^2\right)^{\frac{1.4}{1.4 - 1}}$$

13) Ratio of Stagnation and Static Temperature Formula

Evaluate Formula

Formula

$$T_r = 1 + \left(\frac{\gamma - 1}{2}\right) \cdot M^2$$

Example

$$1.8 = 1 + \left(\frac{1.4 - 1}{2}\right) \cdot 2^2$$

14) Speed of Sound Formula

Evaluate Formula

Formula

$$a = \sqrt{\gamma \cdot [\text{R-Dry-Air}] \cdot T_s}$$

Example with Units

$$344.9012\,\text{m/s} = \sqrt{1.4 \cdot 287.058 \cdot 296\,\text{K}}$$

15) Speed of Sound Downstream of Sound Wave Formula

Evaluate Formula

Formula

$$a_2 = \sqrt{(\gamma - 1) \cdot \left(\frac{u_1^2 - u_2^2}{2} + \frac{a_1^2}{\gamma - 1} \right)}$$

Example with Units

$$31.9218\,\text{m/s} = \sqrt{(1.4 - 1) \cdot \left(\frac{(80\,\text{m/s})^2 - (45\,\text{m/s})^2}{2} + \frac{(12\,\text{m/s})^2}{1.4 - 1} \right)}$$

16) Speed of Sound given Isentropic Change Formula

Evaluate Formula

Formula

$$a = \sqrt{dpd\rho}$$

Example with Units

$$343\,\text{m/s} = \sqrt{117649\,\text{m}^2/\text{s}^2}$$

17) Speed of Sound Upstream of Sound Wave Formula

Evaluate Formula

Formula

$$a_1 = \sqrt{(\gamma - 1) \cdot \left(\frac{u_2^2 - u_1^2}{2} + \frac{a_2^2}{\gamma - 1} \right)}$$

Example with Units

$$11.9419\,\text{m/s} = \sqrt{(1.4 - 1) \cdot \left(\frac{(45\,\text{m/s})^2 - (80\,\text{m/s})^2}{2} + \frac{(31.90\,\text{m/s})^2}{1.4 - 1} \right)}$$

18) Stagnation Temperature Formula

Evaluate Formula

Formula

$$T_0 = T_s + \frac{U_{fluid}^2}{2 \cdot C_p}$$

Example with Units

$$297.0119\,\text{K} = 296\,\text{K} + \frac{(45.1\,\text{m/s})^2}{2 \cdot 1005\,\text{J/(kg*K)}}$$

Variables used in list of Governing Equations and Sound Wave Formulas above

- **a** Speed of Sound *(Meter per Second)*
- **a_1** Sound Speed Upstream *(Meter per Second)*
- **a_2** Sound Speed Downstream *(Meter per Second)*
- **C_p** Specific Heat Capacity at Constant Pressure *(Joule per Kilogram per K)*
- **C_v** Specific Heat Capacity at Constant Volume *(Joule per Kilogram per K)*
- **dpdρ** Isentropic Change *(Square Meter per Square Second)*
- **M** Mach Number
- **P_0** Stagnation Pressure *(Atmosphere Technical)*
- **p_{cr}** Critical Pressure *(Atmosphere Technical)*
- **P_r** Stagnation to Static Pressure
- **R** Specific Gas Constant *(Joule per Kilogram per K)*
- **T_0** Stagnation Temperature *(Kelvin)*
- **T_{cr}** Critical Temperature *(Kelvin)*
- **T_r** Stagnation to Static Temperature
- **T_s** Static Temperature *(Kelvin)*
- **u_1** Flow Velocity Upstream of Sound *(Meter per Second)*
- **u_2** Flow Velocity Downstream of Sound *(Meter per Second)*
- **U_{fluid}** Velocity of Fluid Flow *(Meter per Second)*
- **V_b** Speed of Object *(Meter per Second)*
- **γ** Specific Heat Ratio
- **μ** Mach Angle *(Degree)*
- **ρ** Density *(Kilogram per Cubic Meter)*
- **ρ_{cr}** Critical Density *(Kilogram per Cubic Meter)*
- **ρ_0** Stagnation Density *(Kilogram per Cubic Meter)*
- **ρ_r** Stagnation to Static Density

Constants, Functions, Measurements used in list of Governing Equations and Sound Wave Formulas above

- constant(s): **[R-Dry-Air]**, 287.058
  Specific Gas Constant for Dry Air
- Functions: **asin**, asin(Number)
  The inverse sine function, is a trigonometric function that takes a ratio of two sides of a right triangle and outputs the angle opposite the side with the given ratio.
- Functions: **sin**, sin(Angle)
  Sine is a trigonometric function that describes the ratio of the length of the opposite side of a right triangle to the length of the hypotenuse.
- Functions: **sqrt**, sqrt(Number)
  A square root function is a function that takes a non-negative number as an input and returns the square root of the given input number.
- Measurement: **Temperature** in Kelvin (K)
  Temperature Unit Conversion
- Measurement: **Pressure** in Atmosphere Technical (at)
  Pressure Unit Conversion
- Measurement: **Speed** in Meter per Second (m/s)
  Speed Unit Conversion
- Measurement: **Angle** in Degree (°)
  Angle Unit Conversion
- Measurement: **Specific Heat Capacity** in Joule per Kilogram per K (J/(kg*K))
  Specific Heat Capacity Unit Conversion
- Measurement: **Density** in Kilogram per Cubic Meter (kg/m^3)
  Density Unit Conversion
- Measurement: **Specific Energy** in Square Meter per Square Second (m^2/s^2)
  Specific Energy Unit Conversion
- Measurement: **Compressibility** in Square Centimeter per Newton (cm^2/N)
  Compressibility Unit Conversion

- τ_s Isentropic Compressibility *(Square Centimeter per Newton)*

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