Important Aero Thermal Dynamics Formulas PDF

Formulas
Examples
with Units

List of 16
Important Aero Thermal Dynamics Formulas

1) Aerodynamic Heating to Surface Formula

Evaluate Formula

Formula

$$q_w = \rho_e \cdot u_e \cdot St \cdot \left(h_{aw} - h_w \right)$$

Example with Units

$$14.4261\,\text{W/m}^2 = 98.3\,\text{kg/m}^3 \cdot 8.8\,\text{m/s} \cdot 0.005956 \cdot \left(102\,\text{J/kg} - 99.2\,\text{J/kg} \right)$$

2) Chapman-Rubesin Factor Formula

Evaluate Formula

Formula

$$C = \frac{\rho \cdot \nu}{\rho_e \cdot \mu_e}$$

Example with Units

$$0.75 = \frac{997\,\text{kg/m}^3 \cdot 7.25\,\text{St}}{98.3\,\text{kg/m}^3 \cdot 0.098043\,\text{P}}$$

3) Coefficient of Friction using Stanton Equation for Incompressible Flow Formula

Evaluate Formula

Formula

$$C_f = \frac{St}{0.5 \cdot Pr^{-\frac{2}{3}}}$$

Example

$$0.0094 = \frac{0.005956}{0.5 \cdot 0.7^{-\frac{2}{3}}}$$

4) Density Calculation using Chapman-Rubesin Factor Formula

Evaluate Formula

Formula

$$\rho = C \cdot \rho_e \cdot \frac{\mu_e}{\nu}$$

Example with Units

$$996.9959\,\text{kg/m}^3 = 0.75 \cdot 98.3\,\text{kg/m}^3 \cdot \frac{0.098043\,\text{P}}{7.25\,\text{St}}$$

5) Internal Energy for Hypersonic Flow Formula

Evaluate Formula

Formula

$$U = H + \frac{P}{\rho}$$

Example with Units

$$1.5128\,\text{KJ} = 1.512\,\text{KJ} + \frac{800\,\text{Pa}}{997\,\text{kg/m}^3}$$

6) Non Dimensional Internal Energy Parameter Formula

Evaluate Formula

Formula

$$e' = \frac{U}{C_p \cdot T}$$

Example with Units

$$0.0752 = \frac{1.51\,\text{KJ}}{4.184\,\text{kJ/kg*K} \cdot 4.8\,\text{K}}$$

7) Non Dimensional Internal Energy Parameter using Wall-to-Freestream Temperature Ratio Formula

Evaluate Formula

Formula

$$e' = \frac{Tw}{T_\infty}$$

Example with Units

$$0.075 = \frac{15\,K}{200\,K}$$

8) Non Dimensional Static Enthalpy Formula

Evaluate Formula

Formula

$$g = \frac{h_o}{he}$$

Example with Units

$$3.001 = \frac{1500\,J/kg}{499.8347\,J/kg}$$

9) Stanton Equation using Overall Skin Friction Coefficient for Incompressible Flow Formula

Evaluate Formula

Formula

$$St = C_f \cdot 0.5 \cdot Pr^{-\frac{2}{3}}$$

Example

$$0.006 = 0.009391 \cdot 0.5 \cdot 0.7^{-\frac{2}{3}}$$

10) Stanton Number for Incompressible Flow Formula

Evaluate Formula

Formula

$$St = 0.332 \cdot \frac{Pr^{-\frac{2}{3}}}{\sqrt{Re}}$$

Example

$$0.006 = 0.332 \cdot \frac{0.7^{-\frac{2}{3}}}{\sqrt{5000}}$$

11) Static Density Calculation using Chapman-Rubesin Factor Formula

Evaluate Formula

Formula

$$\rho_e = \frac{\rho \cdot \nu}{C \cdot \mu_e}$$

Example with Units

$$98.3004\,kg/m^3 = \frac{997\,kg/m^3 \cdot 7.25\,St}{0.75 \cdot 0.098043\,P}$$

12) Static Enthalpy Formula

Evaluate Formula

Formula

$$he = \frac{H}{g}$$

Example with Units

$$499.8347\,J/kg = \frac{1.512\,KJ}{3.025}$$

13) Static Viscosity Calculation using Chapman-Rubesin Factor Formula

Evaluate Formula

Formula

$$\mu_e = \frac{\rho \cdot \nu}{C \cdot \rho_e}$$

Example with Units

$$0.098\,P = \frac{997\,kg/m^3 \cdot 7.25\,St}{0.75 \cdot 98.3\,kg/m^3}$$

14) Thermal Conductivity using Prandtl Number Formula

Evaluate Formula

Formula

$$k = \frac{\mu_{viscosity} \cdot C_p}{Pr}$$

Example with Units

$$6096.6857\,\text{W/(m*K)} = \frac{10.2\,\text{P} \cdot 4.184\,\text{kJ/kg*K}}{0.7}$$

15) Viscosity Calculation using Chapman-Rubesin Factor Formula

Evaluate Formula

Formula

$$\nu = C \cdot \rho_e \cdot \frac{\mu_e}{\rho}$$

Example with Units

$$7.25\,\text{St} = 0.75 \cdot 98.3\,\text{kg/m}^3 \cdot \frac{0.098043\,\text{P}}{997\,\text{kg/m}^3}$$

16) Wall Temperature Calculation using Internal Energy Change Formula

Evaluate Formula

Formula

$$Tw = e' \cdot T_\infty$$

Example with Units

$$15\,\text{K} = 0.075 \cdot 200\,\text{K}$$

Variables used in list of Aero Thermal Dynamics Formulas above

- **C** Chapman–Rubesin factor
- C_f Overall Skin-friction Drag Coefficient
- C_p Specific Heat Capacity at Constant Pressure *(Kilojoule per Kilogram per K)*
- e' Non-Dimensional Internal Energy
- **g** Non Dimensional Static Enthalpy
- **H** Enthalpy *(Kilojoule)*
- h_{aw} Adiabatic Wall Enthalpy *(Joule per Kilogram)*
- h_o Stagnation Enthalpy *(Joule per Kilogram)*
- h_w Wall Enthalpy *(Joule per Kilogram)*
- **he** Static Enthalpy *(Joule per Kilogram)*
- **k** Thermal Conductivity *(Watt per Meter per K)*
- **P** Pressure *(Pascal)*
- **Pr** Prandtl Number
- q_w Local Heat Transfer Rate *(Watt per Square Meter)*
- **Re** Reynolds Number
- **St** Stanton Number
- **T** Temperature *(Kelvin)*
- T_∞ Free Stream Temperature *(Kelvin)*
- **Tw** Wall Temperature *(Kelvin)*
- **U** Internal Energy *(Kilojoule)*
- u_e Static Velocity *(Meter per Second)*
- μ_e Static Viscosity *(Poise)*
- $\mu_{viscosity}$ Dynamic Viscosity *(Poise)*
- **v** Kinematic Viscosity *(Stokes)*
- **ρ** Density *(Kilogram per Cubic Meter)*
- ρ_e Static Density *(Kilogram per Cubic Meter)*

Constants, Functions, Measurements used in list of Aero Thermal Dynamics Formulas above

- 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 Pascal (Pa)
  Pressure Unit Conversion
- Measurement: **Speed** in Meter per Second (m/s)
  Speed Unit Conversion
- Measurement: **Energy** in Kilojoule (KJ)
  Energy Unit Conversion
- Measurement: **Thermal Conductivity** in Watt per Meter per K (W/(m*K))
  Thermal Conductivity Unit Conversion
- Measurement: **Specific Heat Capacity** in Kilojoule per Kilogram per K (kJ/kg*K)
  Specific Heat Capacity Unit Conversion
- Measurement: **Heat Flux Density** in Watt per Square Meter (W/m²)
  Heat Flux Density Unit Conversion
- Measurement: **Dynamic Viscosity** in Poise (P)
  Dynamic Viscosity Unit Conversion
- Measurement: **Kinematic Viscosity** in Stokes (St)
  Kinematic Viscosity Unit Conversion
- Measurement: **Density** in Kilogram per Cubic Meter (kg/m³)
  Density Unit Conversion
- Measurement: **Specific Energy** in Joule per Kilogram (J/kg)
  Specific Energy Unit Conversion

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