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Boundary Layer Equations for Hypersonic Flow Formulas

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List of 20 Boundary Layer Equations for Hypersonic Flow Formulas

Boundary Layer Equations for Hypersonic Flow

Dimensionless Quantities

1) Nusselt's Number with Reynolds Number, Stanton Number and Prandtl Number

Open Calculator

fx $$\mathrm{N_u} = \mathrm{Re} \cdot \mathrm{St} \cdot \mathrm{Pr}$$

ex $$1400 = 5000 \cdot 0.4 \cdot 0.7$$

2) Prandtl Number with Reynolds Number, Nusselt's Number, and Stanton Number

Open Calculator

fx $$\mathrm{Pr} = \frac{\mathrm{N_u}}{\mathrm{St} \cdot \mathrm{Re}}$$

ex $$0.7 = \frac{1400}{0.4 \cdot 5000}$$

3) Reynolds Number for given Nusselt's Number, Stanton Number and Prandtl Number

Open Calculator

fx $$\mathrm{Re} = \frac{\mathrm{N_u}}{\mathrm{St} \cdot \mathrm{Pr}}$$

ex $$5000 = \frac{1400}{0.4 \cdot 0.7}$$

4) Stanton Number with Reynolds Number, Nusselt's Number, Stanton Number and Prandtl Number

Open Calculator

fx $$\mathrm{St} = \frac{\mathrm{N_u}}{\mathrm{Re} \cdot \mathrm{Pr}}$$

ex $$0.4 = \frac{1400}{5000 \cdot 0.7}$$

Hypersonic Flow Parameters

5) Dynamic Viscosity around Wall

Open Calculator

fx $$\mu_{\mathrm{viscosity}} = \mu\mathrm{e} \cdot \left(\frac{\mathrm{Tw}}{\mathrm{T_{static}}} \right)^{\mathrm{n}}$$

ex $$11.16478\mathrm{P} = 11.2\mathrm{P} \cdot \left(\frac{15\mathrm{K}}{350\mathrm{K}} \right)^{0.001}$$

6) Local Shear Stress at Wall

Open Calculator

fx $$\tau = 0.5 \cdot C_f \cdot \rho_e \cdot \mu e^2$$

ex $$0.9408\text{Pa} = 0.5 \cdot 0.00125 \cdot 1200\text{kg/m}^3 \cdot (11.2\text{P})^2$$

7) Local Skin-Friction Coefficient

Open Calculator

fx $$C_f = \frac{2 \cdot \tau}{\rho_e \cdot u_e^2}$$

ex $$0.001313 = \frac{2 \cdot 61\text{Pa}}{1200\text{kg/m}^3 \cdot (8.8\text{m/s})^2}$$

8) Skin Friction Coefficient for Incompressible Flow

Open Calculator

fx $$c_f = \frac{0.664}{\sqrt{Re}}$$

ex $$0.00939 = \frac{0.664}{\sqrt{5000}}$$

9) Static Density Equation using Skin Friction Coefficient

Open Calculator

fx $$\rho_e = \frac{2 \cdot \tau}{C_f \cdot u_e^2}$$

ex $$1260.331\text{kg/m}^3 = \frac{2 \cdot 61\text{Pa}}{0.00125 \cdot (8.8\text{m/s})^2}$$

10) Static Velocity Equation using Skin Friction Coefficient

Open Calculator

$$u_e = \sqrt{\frac{2 \cdot \tau}{C_f \cdot \rho_e}}$$

$$9.0185\text{m/s} = \sqrt{\frac{2 \cdot 61\text{Pa}}{0.00125 \cdot 1200\text{kg/m}^3}}$$

11) Static Viscosity Relation using Temperature of Wall

Open Calculator

$$\mu e = \frac{\mu_{viscosity}}{\left(\frac{Tw}{T_{static}}\right)^n}$$

$$10.23218\text{P} = \frac{10.2\text{P}}{\left(\frac{15\text{K}}{350\text{K}}\right)^{0.001}}$$

Local Heat Transfer for Hypersonic Flow

12) Adiabatic Wall Enthalpy using Stanton Number

Open Calculator

$$h_{aw} = \frac{q_w}{\rho_e \cdot u_e \cdot St} + h_w$$

$$102.0409\text{J/kg} = \frac{12000\text{W/m}^2}{1200\text{kg/m}^3 \cdot 8.8\text{m/s} \cdot 0.4} + 99.2\text{J/kg}$$

13) Enthalpy of Wall using Stanton Number

Open Calculator

$$h_w = h_{aw} - \frac{q_w}{\rho_e \cdot u_e \cdot St}$$

$$99.15909\text{J/kg} = 102\text{J/kg} - \frac{12000\text{W/m}^2}{1200\text{kg/m}^3 \cdot 8.8\text{m/s} \cdot 0.4}$$

14) Local Heat Transfer Rate Calculation using Stanton Number

Open Calculator

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

$$11827.2\text{W/m}^2 = 0.4 \cdot 1200\text{kg/m}^3 \cdot 8.8\text{m/s} \cdot (102\text{J/kg} - 99.2\text{J/kg})$$

15) Local Heat Transfer Rate using Nusselt's Number

Open Calculator

$$q_w = \frac{N_u \cdot k \cdot (T_{wall} - Tw)}{x_d}$$

$$16041.67\text{W/m}^2 = \frac{1400 \cdot 0.125\text{W/(m*K)} \cdot (125\text{K} - 15\text{K})}{1.2\text{m}}$$

16) Nusselt Number for Hypersonic Vehicle

Open Calculator

$$N_u = \frac{q_w \cdot x_d}{k \cdot (T_{wall} - Tw)}$$

$$1047.273 = \frac{12000\text{W/m}^2 \cdot 1.2\text{m}}{0.125\text{W/(m*K)} \cdot (125\text{K} - 15\text{K})}$$

17) Stanton Number for Hypersonic Vehicle

Open Calculator

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

$$0.405844 = \frac{12000 W/m^2}{1200 kg/m^3 \cdot 8.8 m/s \cdot (102 J/kg - 99.2 J/kg)}$$

18) Static Density Equation using Stanton Number

Open Calculator

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

$$1217.532 kg/m^3 = \frac{12000 W/m^2}{0.4 \cdot 8.8 m/s \cdot (102 J/kg - 99.2 J/kg)}$$

19) Static Velocity using Stanton Number

Open Calculator

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

$$8.928571 m/s = \frac{12000 W/m^2}{0.4 \cdot 1200 kg/m^3 \cdot (102 J/kg - 99.2 J/kg)}$$

20) Thermal Conductivity at Edge of Boundary Layer Equation using Nusselt's Number

Open Calculator

$$k = \frac{q_w \cdot x_d}{N_u \cdot (T_{wall} - Tw)}$$

$$0.093506 W/(m*K) = \frac{12000 W/m^2 \cdot 1.2 m}{1400 \cdot (125 K - 15 K)}$$

Variables Used

- c_f Skin friction coefficient
- C_f Local Skin-Friction Coefficient
- h_{aw} Adiabatic Wall Enthalpy *(Joule per Kilogram)*
- h_w Wall Enthalpy *(Joule per Kilogram)*
- k Thermal Conductivity *(Watt per Meter per K)*
- n Constant n
- N_u Nusselt Number
- Pr Prandtl Number
- q_w Local Heat Transfer Rate *(Watt per Square Meter)*
- Re Reynolds Number
- St Stanton Number
- T_{static} Static Temperature *(Kelvin)*
- T_{wall} Adiabatic Wall Temperature *(Kelvin)*
- Tw Wall Temperature *(Kelvin)*
- u_e Static Velocity *(Meter per Second)*
- x_d Distance from Nose Tip to Required Base Diameter *(Meter)*
- $\mu_{viscosity}$ Dynamic Viscosity *(Poise)*
- μe Static Viscosity *(Poise)*
- ρ_e Static Density *(Kilogram per Cubic Meter)*
- τ Shear Stress *(Pascal)*

Constants, Functions, Measurements used

- Function: **sqrt**, sqrt(Number)
  Square root function
- Measurement: **Length** in Meter (m)
  Length Unit Conversion
- Measurement: **Temperature** in Kelvin (K)
  Temperature Unit Conversion
- Measurement: **Speed** in Meter per Second (m/s)
  Speed Unit Conversion
- Measurement: **Thermal Conductivity** in Watt per Meter per K (W/(m*K))
  Thermal Conductivity 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: **Density** in Kilogram per Cubic Meter (kg/m³)
  Density Unit Conversion
- Measurement: **Specific Energy** in Joule per Kilogram (J/kg)
  Specific Energy Unit Conversion
- Measurement: **Stress** in Pascal (Pa)
  Stress Unit Conversion

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