Important Unsteady State Heat Conduction Formulas PDF

Formulas
Examples
with Units

List of 18
Important Unsteady State Heat Conduction Formulas

1) Biot Number given Characteristic Dimension and Fourier Number Formula

Evaluate Formula

Formula

$$Bi = \frac{h \cdot \tau}{\rho_B \cdot c \cdot s \cdot F_o}$$

Example with Units

$$110.0234 = \frac{10\,\text{W/m²*K} \cdot 1937\,\text{s}}{15\,\text{kg/m³} \cdot 1.5\,\text{J/(kg*K)} \cdot 6.9\,\text{m} \cdot 1.134}$$

2) Biot Number given Heat Transfer Coefficient and Time Constant Formula

Evaluate Formula

Formula

$$Bi = \frac{h \cdot A_c \cdot \tau}{\rho_B \cdot c \cdot V \cdot F_o}$$

Example with Units

$$0.9111 = \frac{10\,\text{W/m²*K} \cdot 0.00785\,\text{m²} \cdot 1937\,\text{s}}{15\,\text{kg/m³} \cdot 1.5\,\text{J/(kg*K)} \cdot 6.541\,\text{m³} \cdot 1.134}$$

3) Biot Number using Fourier Number Formula

Evaluate Formula

Formula

$$Bi = \left(-\frac{1}{F_o} \right) \cdot \ln\left(\frac{T - T_\infty}{T_0 - T_\infty} \right)$$

Example with Units

$$0.7651 = \left(-\frac{1}{1.134} \right) \cdot \ln\left(\frac{589\,\text{K} - 373\,\text{K}}{887.36\,\text{K} - 373\,\text{K}} \right)$$

4) Biot Number using Heat Transfer Coefficient Formula

Evaluate Formula

Formula

$$Bi = \frac{h \cdot \ell}{k}$$

Example with Units

$$23.1628 = \frac{10\,\text{W/m²*K} \cdot 4.98\,\text{m}}{2.15\,\text{W/(m*K)}}$$

5) Capacitance of Thermal System by Lumped Heat Capacity Method Formula

Evaluate Formula

Formula

$$C_{Th} = \rho_B \cdot c \cdot V$$

Example with Units

$$147.1725\,\text{J/K} = 15\,\text{kg/m³} \cdot 1.5\,\text{J/(kg*K)} \cdot 6.541\,\text{m³}$$

6) Fourier Number Formula

Evaluate Formula

Formula

$$F_o = \frac{\alpha \cdot \tau_c}{s^2}$$

Example with Units

$$0.293 = \frac{5.58\,\text{m²/s} \cdot 2.5\,\text{s}}{6.9\,\text{m}^2}$$

7) Fourier Number given Characteristic Dimension and Biot Number Formula

Evaluate Formula

Formula

$$F_o = \frac{h \cdot \tau}{\rho_B \cdot c \cdot s \cdot Bi}$$

Example with Units

$$4.5955 = \frac{10\,\text{W/m²*K} \cdot 1937\,\text{s}}{15\,\text{kg/m³} \cdot 1.5\,\text{J/(kg*K)} \cdot 6.9\,\text{m} \cdot 27.15}$$

8) Fourier Number given Heat Transfer Coefficient and Time Constant Formula

Evaluate Formula

Formula

$$F_o = \frac{h \cdot A_c \cdot \tau}{\rho_B \cdot c \cdot V \cdot Bi}$$

Example with Units

$$0.0381 = \frac{10\,\text{W/m²*K} \cdot 0.00785\,\text{m²} \cdot 1937\,\text{s}}{15\,\text{kg/m³} \cdot 1.5\,\text{J/(kg*K)} \cdot 6.541\,\text{m³} \cdot 27.15}$$

9) Fourier Number using Biot Number Formula

Evaluate Formula

Formula

$$F_o = \left(-\frac{1}{Bi} \right) \cdot \ln\left(\frac{T - T_\infty}{T_0 - T_\infty} \right)$$

Example with Units

$$0.032 = \left(-\frac{1}{27.15} \right) \cdot \ln\left(\frac{589\,\text{K} - 373\,\text{K}}{887.36\,\text{K} - 373\,\text{K}} \right)$$

10) Fourier Number using Thermal Conductivity Formula

Evaluate Formula

Formula

$$F_o = \left(\frac{k \cdot \tau_c}{\rho_B \cdot c \cdot \left(s^2 \right)} \right)$$

Example with Units

$$0.005 = \left(\frac{2.15\,\text{W/(m*K)} \cdot 2.5\,\text{s}}{15\,\text{kg/m³} \cdot 1.5\,\text{J/(kg*K)} \cdot \left(6.9\,\text{m}^2 \right)} \right)$$

11) Initial Internal Energy Content of Body in Reference to Environment Temperature Formula

Evaluate Formula

Formula

$$Q_o = \rho_B \cdot c \cdot V \cdot \left(T_i - T_{amb} \right)$$

Example with Units

$$21781.53\,\text{J} = 15\,\text{kg/m³} \cdot 1.5\,\text{J/(kg*K)} \cdot 6.541\,\text{m³} \cdot \left(600\,\text{K} - 452\,\text{K} \right)$$

12) Initial Temperature of Body by Lumped Heat Capacity Method Formula

Evaluate Formula

Formula

$$T_0 = \frac{T - T_\infty}{\exp\left(\frac{-h \cdot A_c \cdot \tau}{\rho_B \cdot c \cdot V} \right)} + T_\infty$$

Example with Units

$$979.9524\,\text{K} = \frac{589\,\text{K} - 373\,\text{K}}{\exp\left(\frac{-10\,\text{W/m²*K} \cdot 0.00785\,\text{m²} \cdot 1937\,\text{s}}{15\,\text{kg/m³} \cdot 1.5\,\text{J/(kg*K)} \cdot 6.541\,\text{m³}} \right)} + 373\,\text{K}$$

13) Temperature of Body by Lumped Heat Capacity Method Formula

Evaluate Formula

Formula

$$T = \left(\exp\left(\frac{-h \cdot A_c \cdot \tau}{\rho_B \cdot c \cdot V} \right) \right) \cdot \left(T_0 - T_\infty \right) + T_\infty$$

Example with Units

$$556.0486\,\text{K} = \left(\exp\left(\frac{-10\,\text{W/m²*K} \cdot 0.00785\,\text{m²} \cdot 1937\,\text{s}}{15\,\text{kg/m³} \cdot 1.5\,\text{J/(kg*K)} \cdot 6.541\,\text{m³}} \right) \right) \cdot \left(887.36\,\text{K} - 373\,\text{K} \right) + 373\,\text{K}$$

14) Temperature Response of Instantaneous Energy Pulse in Semi Infinite Solid Formula

Evaluate Formula

Formula

$$T = T_i + \left(\frac{Q}{A \cdot \rho_B \cdot c \cdot \left(\pi \cdot \alpha \cdot \tau \right)^{0.5}} \right) \cdot \exp\left(\frac{-x^2}{4 \cdot \alpha \cdot \tau} \right)$$

Example with Units

$$600.0201\,\text{K} = 600\,\text{K} + \left(\frac{4200\,\text{J}}{50.3\,\text{m}^2 \cdot 15\,\text{kg/m}^3 \cdot 1.5\,\text{J/(kg*K)} \cdot \left(3.1416 \cdot 5.58\,\text{m}^2\text{/s} \cdot 1937\,\text{s} \right)^{0.5}} \right) \cdot \exp\left(\frac{-0.02\,\text{m}^2}{4 \cdot 5.58\,\text{m}^2\text{/s} \cdot 1937\,\text{s}} \right)$$

15) Temperature Response of Instantaneous Energy Pulse in Semi Infinite Solid at Surface Formula

Evaluate Formula

Formula

$$T = T_i + \left(\frac{Q}{A \cdot \rho_B \cdot c \cdot \left(\pi \cdot \alpha \cdot \tau \right)^{0.5}} \right)$$

Example with Units

$$600.0201\,\text{K} = 600\,\text{K} + \left(\frac{4200\,\text{J}}{50.3\,\text{m}^2 \cdot 15\,\text{kg/m}^3 \cdot 1.5\,\text{J/(kg*K)} \cdot \left(3.1416 \cdot 5.58\,\text{m}^2\text{/s} \cdot 1937\,\text{s} \right)^{0.5}} \right)$$

16) Thermal Conductivity given Biot Number Formula

Evaluate Formula

Formula

$$k = \frac{h \cdot \ell}{Bi}$$

Example with Units

$$1.8343\,\text{W/(m*K)} = \frac{10\,\text{W/m}^2\text{*K} \cdot 4.98\,\text{m}}{27.15}$$

17) Time Constant of Thermal System Formula

Evaluate Formula

Formula

$$\tau = \frac{\rho_B \cdot c \cdot V}{h \cdot A_c}$$

Example with Units

$$1874.8089\,\text{s} = \frac{15\,\text{kg/m}^3 \cdot 1.5\,\text{J/(kg*K)} \cdot 6.541\,\text{m}^3}{10\,\text{W/m}^2\text{*K} \cdot 0.00785\,\text{m}^2}$$

18) Time Taken by Object for Heating or Cooling by Lumped Heat Capacity Method Formula

Evaluate Formula

Formula

$$\tau = \left(\frac{-\rho_B \cdot c \cdot V}{h \cdot A_c} \right) \cdot \ln\left(\frac{T - T_\infty}{T_0 - T_\infty} \right)$$

Example with Units

$$1626.6686\,\text{s} = \left(\frac{-15\,\text{kg/m}^3 \cdot 1.5\,\text{J/(kg*K)} \cdot 6.541\,\text{m}^3}{10\,\text{W/m}^2\text{*K} \cdot 0.00785\,\text{m}^2} \right) \cdot \ln\left(\frac{589\,\text{K} - 373\,\text{K}}{887.36\,\text{K} - 373\,\text{K}} \right)$$

Variables used in list of Unsteady State Heat Conduction Formulas above

- **A** Area *(Square Meter)*
- A_c Surface Area for Convection *(Square Meter)*
- **Bi** Biot Number
- **c** Specific Heat Capacity *(Joule per Kilogram per K)*
- C_{Th} Capacitance of Thermal System *(Joule per Kelvin)*
- F_o Fourier Number
- **h** Heat Transfer Coefficient *(Watt per Square Meter per Kelvin)*
- **k** Thermal Conductivity *(Watt per Meter per K)*
- **Q** Heat Energy *(Joule)*
- Q_o Initial Energy Content *(Joule)*
- **s** Characteristic Dimension *(Meter)*
- **T** Temperature at Any Time T *(Kelvin)*
- T_0 Initial Temperature of Object *(Kelvin)*
- T_∞ Temperature of Bulk Fluid *(Kelvin)*
- T_{amb} Ambient Temperature *(Kelvin)*
- T_i Initial Temperature of Solid *(Kelvin)*
- **V** Volume of Object *(Cubic Meter)*
- **x** Depth of Semi Infinite Solid *(Meter)*
- **α** Thermal Diffusivity *(Square Meter Per Second)*
- ρ_B Density of Body *(Kilogram per Cubic Meter)*
- ℓ Thickness of Wall *(Meter)*
- τ Time Constant *(Second)*
- τ_c Characteristic Time *(Second)*

Constants, Functions, Measurements used in list of Unsteady State Heat Conduction Formulas above

- constant(s): **pi**, 3.14159265358979323846264338327950288 *Archimedes' constant*
- Functions: **exp**, exp(Number) *n an exponential function, the value of the function changes by a constant factor for every unit change in the independent variable.*
- Functions: **ln**, ln(Number) *The natural logarithm, also known as the logarithm to the base e, is the inverse function of the natural exponential function.*
- Measurement: **Length** in Meter (m) *Length Unit Conversion*
- Measurement: **Time** in Second (s) *Time Unit Conversion*
- Measurement: **Temperature** in Kelvin (K) *Temperature Unit Conversion*
- Measurement: **Volume** in Cubic Meter (m^3) *Volume Unit Conversion*
- Measurement: **Area** in Square Meter (m^2) *Area Unit Conversion*
- Measurement: **Energy** in Joule (J) *Energy Unit Conversion*
- Measurement: **Thermal Conductivity** in Watt per Meter per K (W/(m*K)) *Thermal Conductivity Unit Conversion*
- Measurement: **Specific Heat Capacity** in Joule per Kilogram per K (J/(kg*K)) *Specific Heat Capacity Unit Conversion*
- Measurement: **Heat Transfer Coefficient** in Watt per Square Meter per Kelvin ($W/m^{2}*K$) *Heat Transfer Coefficient Unit Conversion*
- Measurement: **Density** in Kilogram per Cubic Meter (kg/m^3) *Density Unit Conversion*
- Measurement: **Diffusivity** in Square Meter Per Second (m^2/s) *Diffusivity Unit Conversion*
- Measurement: **Entropy** in Joule per Kelvin (J/K) *Entropy Unit Conversion*

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