Thermodynamics and Governing Equations Formulas

List of 19 Thermodynamics and Governing Equations Formulas

Thermodynamics and Governing Equations

1) Choked Mass Flow Rate

Open Calculator

fx $$\dot{m}_{choke} = \frac{m \cdot \sqrt{C_p \cdot T}}{A_{throat} \cdot P_o}$$

ex $$1.278959 = \frac{5kg/s \cdot \sqrt{1005J/(kg*K) \cdot 298.15K}}{21.4m^2 \cdot 100Pa}$$

2) Choked Mass Flow Rate given specific heat ratio

Open Calculator

fx $$\dot{m}_{choke} = \left(\frac{\gamma}{\sqrt{\gamma - 1}}\right) \cdot \left(\frac{\gamma + 1}{2}\right)^{-\left(\frac{\gamma+1}{2 \cdot \gamma - 2}\right)}$$

ex $$1.281015 = \left(\frac{1.4}{\sqrt{1.4 - 1}}\right) \cdot \left(\frac{1.4 + 1}{2}\right)^{-\left(\frac{1.4+1}{2 \cdot 1.4 - 2}\right)}$$

3) Efficiency of cycle

Open Calculator

fx $$\eta_{cycle} = \frac{W_T - W_c}{Q}$$

ex $$0.467213 = \frac{600KJ - 315KJ}{610KJ}$$

4) Efficiency of Joule cycle

Open Calculator

fx $$\eta_{\text{joule cycle}} = \frac{W_{\text{Net}}}{Q}$$

ex $$0.5 = \frac{305\text{KJ}}{610\text{KJ}}$$

5) Enthalpy of Ideal Gas at given Temperature

Open Calculator

fx $$h = C_p \cdot T$$

ex $$299.6408\text{kJ/kg} = 1005\text{J/(kg*K)} \cdot 298.15\text{K}$$

6) Heat Capacity Ratio

Open Calculator

fx $$\gamma = \frac{C_p}{C_v}$$

ex $$1.34 = \frac{1005\text{J/(kg*K)}}{750\text{J/(kg*K)}}$$

7) Internal Energy of Perfect Gas at given Temperature

Open Calculator

fx $$U = C_v \cdot T$$

ex $$223.6125\text{kJ/kg} = 750\text{J/(kg*K)} \cdot 298.15\text{K}$$

8) Mach Angle

Open Calculator

fx $$\mu = a\sin\left(\frac{1}{M}\right)$$

ex $$30^\circ = a\sin\left(\frac{1}{2}\right)$$

9) Mach Number

Open Calculator

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

ex $$2.040816 = \frac{700\text{m/s}}{343\text{m/s}}$$

10) Max work output in Brayton cycle

fx

Open Calculator

$$(W_p\text{max}) = \left(1005 \cdot \frac{1}{\eta_c}\right) \cdot T_{B1} \cdot \left(\sqrt{\frac{T_{B3}}{T_{B1}} \cdot \eta_c \cdot \eta_{turbine}} - 1\right)^2$$

ex $$102.8266\text{KJ} = \left(1005 \cdot \frac{1}{0.3}\right) \cdot 290\text{K} \cdot \left(\sqrt{\frac{550\text{K}}{290\text{K}} \cdot 0.3 \cdot 0.8} - 1\right)^2$$

11) Pressure Ratio

Open Calculator

fx $$P_R = \frac{P_f}{P_i}$$

ex $$3.984615 = \frac{259\text{Pa}}{65\text{Pa}}$$

12) Specific Heat of mixed out gas

Open Calculator

fx $$C_{p,m} = \frac{C_{pe} + \beta \cdot C_{p,\beta}}{1 + \beta}$$

ex $$1043.344\text{J}/(\text{kg*K}) = \frac{1244\text{J}/(\text{kg*K}) + 5.1 \cdot 1004\text{J}/(\text{kg*K})}{1 + 5.1}$$

13) Speed of Sound

Open Calculator

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

ex $$344.9012\text{m/s} = \sqrt{1.4 \cdot [\text{R-Dry-Air}] \cdot 296\text{K}}$$

14) Stagnation enthalpy

Open Calculator

fx $$h_0 = h + \frac{U_{fluid}^2}{2}$$

ex $$301.0125\text{kJ/kg} = 300\text{kJ/kg} + \frac{(45\text{m/s})^2}{2}$$

15) Stagnation Temperature

Open Calculator

fx $$T_0 = T_s + \frac{u_2^2}{2 \cdot C_p}$$

ex $$297.0075\text{K} = 296\text{K} + \frac{(45\text{m/s})^2}{2 \cdot 1005\text{J/(kg*K)}}$$

16) Stagnation Velocity of Sound

Open Calculator

fx $$a_o = \sqrt{\gamma \cdot [R] \cdot T_0}$$

ex $$58.89647\text{m/s} = \sqrt{1.4 \cdot [R] \cdot 298\text{K}}$$

17) Stagnation Velocity of Sound given Specific Heat at Constant Pressure

Open Calculator

fx $$a_o = \sqrt{(\gamma - 1) \cdot C_p \cdot T_0}$$

ex $$346.1156\text{m/s} = \sqrt{(1.4 - 1) \cdot 1005\text{J/(kg*K)} \cdot 298\text{K}}$$

18) Stagnation Velocity of Sound given Stagnation Enthalpy

Open Calculator

fx $$a_o = \sqrt{(\gamma - 1) \cdot h_0}$$

ex $$346.987\text{m/s} = \sqrt{(1.4 - 1) \cdot 301\text{kJ/kg}}$$

19) Work ratio in practical cycle

Open Calculator

fx $$W = 1 - \left(\frac{W_c}{W_T} \right)$$

ex $$0.475 = 1 - \left(\frac{315KJ}{600KJ} \right)$$

Variables Used

- **a** Speed of Sound *(Meter per Second)*
- **a_o** Stagnation Velocity of Sound *(Meter per Second)*
- **A_{throat}** Nozzle Throat Area *(Square Meter)*
- **C_p** Specific Heat Capacity at Constant Pressure *(Joule per Kilogram per K)*
- **C_p** Specific Heat Capacity at Constant Pressure *(Joule per Kilogram per K)*
- **$C_{p,m}$** Specific Heat of Mixed Gas *(Joule per Kilogram per K)*
- **$C_{p,\beta}$** Specific Heat of Bypass Air *(Joule per Kilogram per K)*
- **C_{pe}** Specific Heat of Core Gas *(Joule per Kilogram per K)*
- **C_v** Specific Heat Capacity at Constant Volume *(Joule per Kilogram per K)*
- **h** Enthalpy *(Kilojoule per Kilogram)*
- **h_0** Stagnation Enthalpy *(Kilojoule per Kilogram)*
- **m** Mass Flow Rate *(Kilogram per Second)*
- **M** Mach Number
- **$\dot{m}_{choke}$** Choked Mass Flow Rate
- **P_f** Final Pressure *(Pascal)*
- **P_i** Initial Pressure *(Pascal)*
- **P_o** Throat Pressure *(Pascal)*
- **P_R** Pressure Ratio
- **Q** Heat *(Kilojoule)*
- **T** Temperature *(Kelvin)*
- **T_0** Stagnation Temperature *(Kelvin)*
- **T_0** Stagnation Temperature *(Kelvin)*

- **T_{B1}** Temperature at Inlet of Compressor in Brayton *(Kelvin)*
- **T_{B3}** Temperature at Inlet to Turbine in Brayton Cycle *(Kelvin)*
- **T_s** Static Temperature *(Kelvin)*
- **U** Internal Energy *(Kilojoule per Kilogram)*
- **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)*
- **W** Work Ratio
- **W_c** Compressor Work *(Kilojoule)*
- **W_{Net}** Net Work Output *(Kilojoule)*
- **$W_{p}max$** Maximum Work done in Brayton Cycle *(Kilojoule)*
- **W_T** Turbine Work *(Kilojoule)*
- **β** Bypass Ratio
- **γ** Heat Capacity Ratio
- **γ** Specific Heat Ratio
- **η_c** Compressor Efficiency
- **η_{cycle}** Efficiency of Cycle
- **$\eta_{joule\ cycle}$** Efficiency of Joule Cycle
- **$\eta_{turbine}$** Turbine Efficiency
- **μ** Mach Angle *(Degree)*

Constants, Functions, Measurements used

- Constant: **[R-Dry-Air]**, 287.058
  Specific Gas Constant for Dry Air
- Constant: **[R]**, 8.31446261815324
  Universal gas constant
- Function: **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.
- Function: **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.
- Function: **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: **Area** in Square Meter (m²)
  Area 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: **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: **Mass Flow Rate** in Kilogram per Second (kg/s)
  Mass Flow Rate Unit Conversion
- Measurement: **Specific Energy** in Kilojoule per Kilogram (kJ/kg)
  Specific Energy Unit Conversion

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