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# Thermodynamics and Governing Equations Formulas

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# List of 19 Thermodynamics and Governing Equations Formulas

## Thermodynamics and Governing Equations

### 1) Choked Mass Flow Rate

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

[Open Calculator !\[\]\(a870788d6ed9b8fd294b7654a8c8526b\_img.jpg\)](#)

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

### 2) Choked Mass Flow Rate given specific heat ratio

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

[Open Calculator !\[\]\(c50c8b7b2cc2cf9ff925edec0ee94c0d\_img.jpg\)](#)

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

### 3) Efficiency of cycle

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

[Open Calculator !\[\]\(f60b7a900783ac3fd531bfd9c111be6d\_img.jpg\)](#)

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



#### 4) Efficiency of Joule cycle

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

[Open Calculator !\[\]\(cbe80b694ebd74fcfe136a095b608235\_img.jpg\)](#)

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

#### 5) Enthalpy of Ideal Gas at given Temperature

$$fx \quad h = C_p \cdot T$$

[Open Calculator !\[\]\(3e2231b1ad3ca8da8658228c00dd08e0\_img.jpg\)](#)

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

#### 6) Heat Capacity Ratio

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

[Open Calculator !\[\]\(0d5ec72f61334709c3fc9450209b754f\_img.jpg\)](#)

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

#### 7) Internal Energy of Perfect Gas at given Temperature

$$fx \quad U = C_v \cdot T$$

[Open Calculator !\[\]\(b64b40baaee5acddc1eab8538ba84754\_img.jpg\)](#)

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




8) Mach Angle 

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

[Open Calculator !\[\]\(e78f798d4ea5c530c9db49e7d26e6b95\_img.jpg\)](#)


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

9) Mach Number 

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

[Open Calculator !\[\]\(05be7c7a8995decd503647c99211f7c2\_img.jpg\)](#)

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

10) Max work output in Brayton cycle 


fx

[Open Calculator !\[\]\(fe3aebe81acea8d45108cd2768939da7\_img.jpg\)](#)

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

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




11) Pressure Ratio 

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

[Open Calculator !\[\]\(e2376d476d06eb31946dc01a69a4403a\_img.jpg\)](#)


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

12) Specific Heat of mixed out gas 

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

[Open Calculator !\[\]\(0b5e7e25e8775f7e7e80906ada4f0021\_img.jpg\)](#)


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

13) Speed of Sound 

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

[Open Calculator !\[\]\(bd3b31712ad9bab5a241210fa6925cdd\_img.jpg\)](#)

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

14) Stagnation enthalpy 

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

[Open Calculator !\[\]\(7bc43b319a082987e20f7bf78f4bab80\_img.jpg\)](#)

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



## 15) Stagnation Temperature

[Open Calculator !\[\]\(eafc244b53721dd1ec133f0772f70fc7\_img.jpg\)](#)

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

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

## 16) Stagnation Velocity of Sound

[Open Calculator !\[\]\(10f8862fc183b400327470ea85afe9ae\_img.jpg\)](#)

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

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

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

[Open Calculator !\[\]\(35dc653d59570f8f891c312eeece91a2\_img.jpg\)](#)

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

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


## 18) Stagnation Velocity of Sound given Stagnation Enthalpy

[Open Calculator !\[\]\(b538fe54c1f3a7343e37e85cc2d00497\_img.jpg\)](#)

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

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



19) Work ratio in practical cycle [Open Calculator](#) 

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

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



## Variables Used

- **a** Speed of Sound (Meter per Second)
- **a<sub>0</sub>** Stagnation Velocity of Sound (Meter per Second)
- **A<sub>throat</sub>** Nozzle Throat Area (Square Meter)
- **C<sub>p</sub>** Specific Heat Capacity at Constant Pressure (Joule per Kilogram per K)
- **C<sub>p</sub>** Specific Heat Capacity at Constant Pressure (Joule per Kilogram per K)
- **C<sub>p,m</sub>** Specific Heat of Mixed Gas (Joule per Kilogram per K)
- **C<sub>p,β</sub>** Specific Heat of Bypass Air (Joule per Kilogram per K)
- **C<sub>pe</sub>** Specific Heat of Core Gas (Joule per Kilogram per K)
- **C<sub>v</sub>** Specific Heat Capacity at Constant Volume (Joule per Kilogram per K)
- **h** Enthalpy (Kilojoule per Kilogram)
- **h<sub>0</sub>** Stagnation Enthalpy (Kilojoule per Kilogram)
- **m** Mass Flow Rate (Kilogram per Second)
- **M** Mach Number
- **m<sub>choke</sub>** Choked Mass Flow Rate
- **P<sub>f</sub>** Final Pressure (Pascal)
- **P<sub>i</sub>** Initial Pressure (Pascal)
- **P<sub>o</sub>** Throat Pressure (Pascal)
- **P<sub>R</sub>** Pressure Ratio
- **Q** Heat (Kilojoule)
- **T** Temperature (Kelvin)
- **T<sub>0</sub>** Stagnation Temperature (Kelvin)
- **T<sub>0</sub>** 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)
- $W_{pmax}$  Maximum Work done in Brayton Cycle (Kilojoule)
- $W_T$  Turbine Work (Kilojoule)
- $\beta$  Bypass Ratio
- $\gamma$  Heat Capacity Ratio
- $\gamma$  Specific Heat Ratio
- $\eta_c$  Compressor Efficiency
- $\eta_{cycle}$  Efficiency of Cycle
- $\eta_{joule\ cycle}$  Efficiency of Joule Cycle
- $\eta_{turbine}$  Turbine Efficiency
- $\mu$  Mach Angle (Degree)



## Constants, Functions, Measurements used

- **Constant:** **[R-Dry-Air]**, 287.058 Joule / Kilogram \* Kelvin  
*Specific Gas Constant for Dry Air*
- **Constant:** **[R]**, 8.31446261815324 Joule / Kelvin \* Mole  
*Universal gas constant*
- **Function:** **asin**, asin(Number)  
*Inverse trigonometric sine function*
- **Function:** **sin**, sin(Angle)  
*Trigonometric sine function*
- **Function:** **sqrt**, sqrt(Number)  
*Square root function*
- **Measurement:** **Temperature** in Kelvin (K)  
*Temperature Unit Conversion* 
- **Measurement:** **Area** in Square Meter (m<sup>2</sup>)  
*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* 



## Check other formula lists

- [Rocket Propulsion Formulas](#) 
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