

# Thermodynamics Formulas - Chapters 19 and 20

## 1 First Law of Thermodynamics

**Energy Conservation:**

$$\Delta E_{\text{th}} = W + Q \quad (1)$$

where:

- $\Delta E_{\text{th}}$  = Change in thermal energy (J)
- $W$  = Work done on the system (J)
- $Q$  = Heat added to the system (J)

### 1.1 Work Done on an Ideal Gas

$$W = - \int_{V_i}^{V_f} P dV \quad (2)$$

### 1.2 Calorimetry Equation (Heat Transfer)

$$Q = mc\Delta T \quad (3)$$

where:

- $Q$  = Heat energy transferred (J)
- $m$  = Mass (kg)
- $c$  = Specific heat capacity (J/kg·K)
- $\Delta T$  = Temperature change (K)

### 1.3 Heat of Transformation (Phase Change)

$$Q = \pm mL \quad (4)$$

where:

- $L$  = Latent heat (J/kg)
- $L_f$  = Heat of fusion (solid  $\leftrightarrow$  liquid)
- $L_v$  = Heat of vaporization (liquid  $\leftrightarrow$  gas)

## 2 Heat Transfer Mechanisms

### 2.1 Conduction

$$\frac{dQ}{dt} = kA \frac{\Delta T}{L} \quad (5)$$

### 2.2 Radiation

$$\frac{dQ}{dt} = e\sigma AT^4 \quad (6)$$

## 3 Ideal Gases and Heat

### 3.1 Ideal Gas Law

$$PV = nRT \quad (7)$$

### 3.2 Internal Energy of an Ideal Gas

$$E_{\text{th}} = \frac{f}{2}nRT \quad (8)$$

### 3.3 Root-Mean-Square (RMS) Speed

$$v_{\text{rms}} = \sqrt{\frac{3k_B T}{m}} \quad (9)$$

## 4 Thermodynamic Processes

**Isothermal Process:**

$$W = -nRT \ln \left( \frac{V_f}{V_i} \right) \quad (10)$$

**Adiabatic Process:**

$$PV^\gamma = \text{constant} \quad (11)$$

$$TV^{\gamma-1} = \text{constant} \quad (12)$$

**Heat Capacities:**

$$C_P = C_V + R \quad (13)$$

For a monatomic gas:

$$C_V = \frac{3}{2}R, \quad C_P = \frac{5}{2}R \quad (14)$$

For a diatomic gas:

$$C_V = \frac{5}{2}R, \quad C_P = \frac{7}{2}R \quad (15)$$