MPESB Sub Engineer 2026

Thermodynamics Notes

Mechanical Engineering

Important Topics

1. Basic Concepts and Definitions
2. Properties of Pure Substances
3. Ideal Gas and Real Gas
4. First Law of Thermodynamics
5. Thermodynamic Processes
6. Second Law of Thermodynamics
7. Entropy and Availability
8. Third Law of Thermodynamics
9. Thermodynamic Cycles
10. Air Standard Cycles
11. Vapor and its Properties
12. Steam Power Cycles
13. Gas Power Cycles
14. Refrigeration and Heat Pumps
15. Psychrometrics (Properties of Moist Air)

Exam Focus

- Concepts + Numerical based MCQs
- Important formulas
- Diagrams and processes
- Previous year trends

Useful For

- MPESB Sub Engineer
- AE/JE exams
- State PSC exams
- Other technical exams

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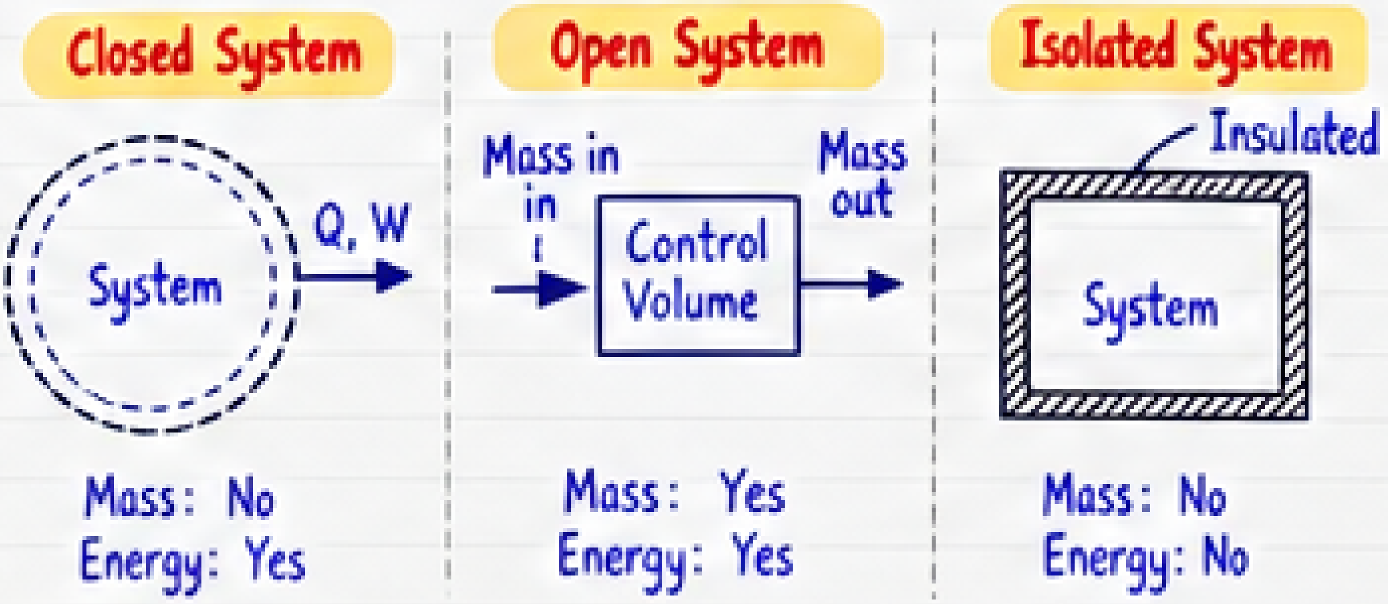
Thermodynamics Notes

1. Basic Concepts and Definitions

- **Thermodynamics:** study of energy, its transformations and the effect of these transformations on properties of matter.
- **System:** fixed quantity of matter or a region in space.
- **Surroundings:** everything outside the system.
- **Boundary:** real or imaginary surface separating system and surroundings.

- **Types of Systems:**
  1. Closed system – no mass transfer, only energy.
  2. Open system – both mass and energy transfer.
  3. Isolated system – neither mass nor energy transfer.



Properties of a System

- **Extensive properties:** depend on mass (V, U, H, S, m)
- **Intensive properties:** independent of mass (P, T, ρ, μ)

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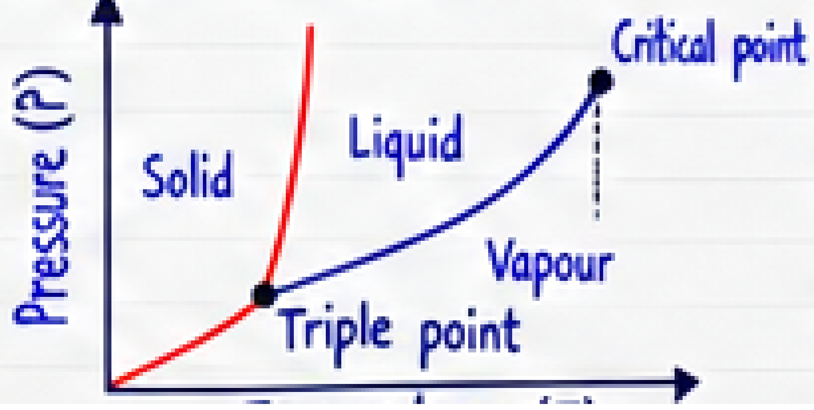
2. Properties of Pure Substances

- A pure substance has a fixed chemical composition.
- It can exist in solid, liquid or vapour phase.
- Important properties: Pressure (P), Temperature (T), Specific volume (v), Internal energy (u), Enthalpy (h), Entropy (s)

Property Relations

- Specific volume: $v = \frac{V}{m}$ (m^3/kg)
- Density: $\rho = \frac{1}{v}$ (kg/m^3)
- Specific internal energy: $u = \frac{U}{m}$ (kJ/kg)
- Specific enthalpy: $h = \frac{H}{m}$ (kJ/kg)
- Enthalpy relation: $h = u + Pv$
- Specific heat: $c = \frac{\delta Q}{m dT}$

3. Phase Diagram



Triple point: solid, liquid and vapour coexist.

Critical point: beyond this, liquid and vapour are indistinguishable.

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4. Ideal Gas and Real Gas

Ideal Gas Equation

$$\boxed{PV = mRT \text{ or } Pv = RT}$$

P = Pressure (kPa)
V = Volume (m^3)
m = Mass (kg)
R = Gas constant (kJ/kg·K)
T = Temperature (K)
v = Specific volume (m^3/kg)

Gas Constant (R)

Substance	R (kJ/kg·K)
Air	0.287
Oxygen (O_2)	0.259
Nitrogen (N_2)	0.296
Carbon dioxide (CO_2)	0.188
Steam (H_2O)	0.4615

Other Relations

$$R = \frac{R_u}{M}$$

R_u = 8.314 kJ/kmol·K
M = Molecular weight (kg/kmol)

Real Gas

- Follows van der Waals equation: $\left(P + \frac{a}{v^2}\right)(v - b) = RT$
- At high pressure and low temperature, real gas deviates from ideal behavior.
- Compressibility factor: $Z = \frac{Pv}{RT}$

  $Z = 1$ for ideal gas
  $Z \neq 1$ for real gas

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5. First Law of Thermodynamics

- It is a statement of conservation of energy.
- Energy can be converted from one form to another, but cannot be created or destroyed.

General Form

$$\boxed{Q - W = \Delta U}$$

Q = Heat supplied (kJ)
W = Work done by system (kJ)
ΔU = Change in internal energy (kJ)

For a Closed System (Finite Process)

$$Q_1 - W_{12} = U_2 - U_1 = m(u_2 - u_1)$$

For a Steady Flow System (Open System)

$$q - w = (h_2 - h_1) + \frac{V_2^2 - V_1^2}{2} + g(z_2 - z_1)$$

q = heat transfer per unit mass (kJ/kg)
w = work transfer per unit mass (kJ/kg)
h = specific enthalpy (kJ/kg)
V = velocity (m/s)
z = elevation (m)
g = 9.81 m/s^2

• Intensive properties: independent of mass (P, T, ρ, v)

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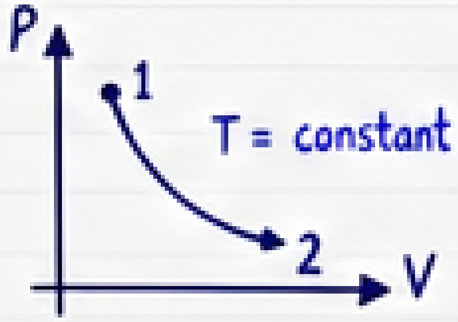
6. Thermodynamic Processes

1. Isothermal Process (T = constant)

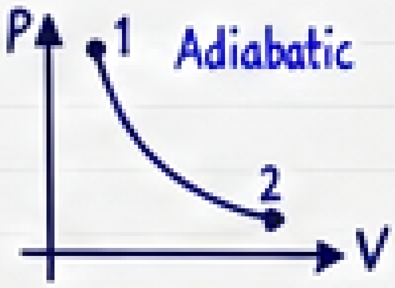
- For ideal gas: $PV = \text{constant}$
- Work done: $W = mRT \ln\left(\frac{V_2}{V_1}\right)$



2. Adiabatic Process (Q = 0)

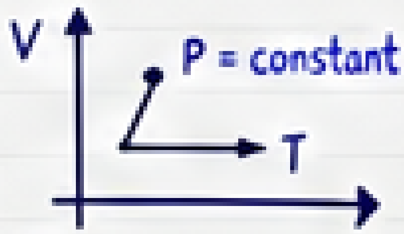
- $PV^{\gamma} = \text{constant}$
- Work done: $W = \frac{P_1V_1 - P_2V_2}{\gamma - 1}$

$$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma - 1}$$



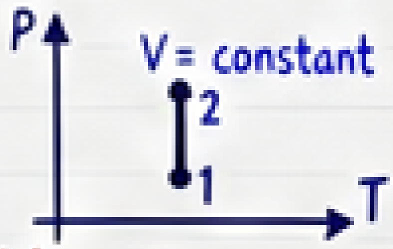
3. Isobaric Process (P = constant)

- $W = P(V_2 - V_1) = mR(T_2 - T_1)$



4. Isochoric Process (V = constant)

- $W = 0$
- $Q = mc_v(T_2 - T_1)$



Polytropic Process ($PV^n = \text{constant}$)

$$W = \frac{P_2V_2 - P_1V_1}{1 - n} \quad (n \neq 1)$$

Special cases:

- $n = 0$ (Isobaric)
- $n = 1$ (Isothermal)
- $n = \gamma$ (Adiabatic)
- $n \to \infty$ (Isochoric)

Temperature (T)

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7. Second Law of Thermodynamics

- No heat engine can convert all the heat supplied into work.
- Heat flows naturally from higher temperature to lower temperature.

Kelvin – Planck Statement

- It is impossible to construct a heat engine which, operating in a cycle, produces no effect other than the absorption of heat from a single reservoir and the production of an equivalent amount of work.

Clausius Statement

- It is impossible to construct a device which will transfer heat from a low temperature body to a high temperature body without some external work.

Entropy

- Measure of disorder or randomness.
- For a reversible process: $$dS = \frac{\delta Q_{rev}}{T}$$
- For a finite process: $$\Delta S = \int_1^2 \frac{\delta Q_{rev}}{T}$$
- Units: kJ/kg·K

Entropy Change in Common Processes

- Isothermal: $\Delta S = mR \ln\left(\frac{V_2}{V_1}\right)$
- Adiabatic (reversible): $\Delta S = 0$
- Isochoric: $\Delta S = mc_v \ln\left(\frac{T_2}{T_1}\right)$
- Isobaric: $\Delta S = mc_p \ln\left(\frac{T_2}{T_1}\right)$

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8. Thermodynamic Cycles (Air Standard Cycles)

1. Otto Cycle (SI Engine)

- Processes: 1-2 Isentropic compression
  - 2-3 Constant volume heat addition
  - 3-4 Isentropic expansion
  - 4-1 Constant volume heat rejection

Otto Cycle

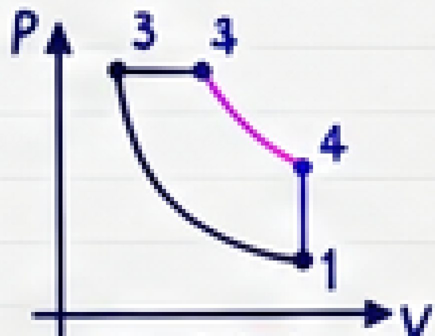
Thermal efficiency:

$$\eta_O = 1 - \frac{1}{r^{\gamma-1}}$$

r = Compression ratio = V_1/V_2

2. Diesel Cycle (CI Engine)

- 1-2 Isentropic compression
- 2-3 Constant pressure heat addition
- 3-4 Isentropic expansion
- 4-1 Constant volume heat rejection



Diesel Cycle

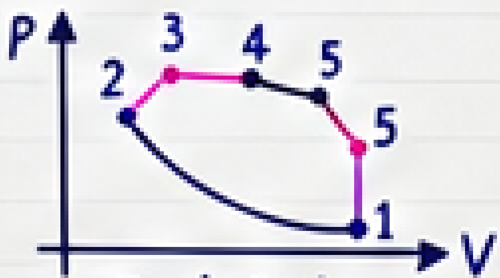
Thermal efficiency:

$$\eta_D = 1 - \frac{1}{r^{\gamma-1}} \cdot \frac{\rho^{\gamma}-1}{\gamma(\rho-1)}$$

ρ = Cut-off ratio = V_3/V_2

3. Dual Cycle

- Combination of Otto and Diesel cycles.



Dual Cycle