CHAPTER

11 Thermodynamics

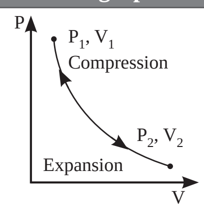
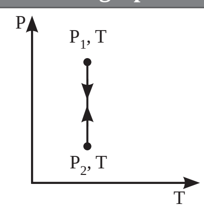
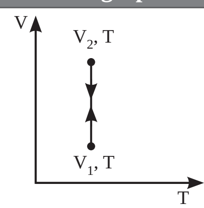
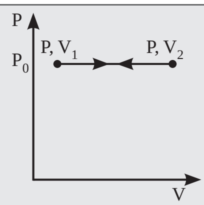
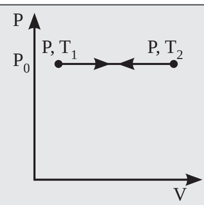
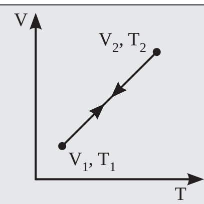
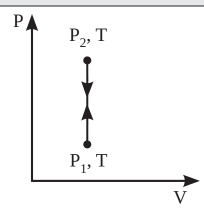
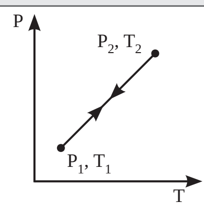
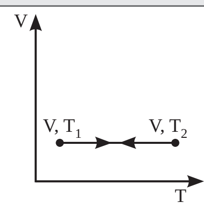
- First law of themodynamics
  $\Delta Q = \Delta U + \Delta W$
- Work done.
  $\Delta W = P\Delta V$
  $\therefore \Delta Q = \Delta U + P\Delta V$
- Relation between specific heats for a gas
  $C_p - C_v = R$

Polytropic Process

It is a thermodynamic process that can be expressed as follows:

$$PV^x = \text{Constant}$$

x (Polytropic exponent)	Type of standard process	Expression
0	Isobaric (dP = 0)	P = Constant
1	Isothermal (dT = 0)	PV = Constant
γ	Adiabatic (dQ = 0)	PV^γ = Constant
∞	Isochoric (dV = 0)	V = Constant

Process	Definition	P-V graph	P-T graph	V-T graph
Isothermal	Temperature constant			
Isobaric	Pressure constant			
Isochoric	Volume constant			

For any General Process

$$\Delta Q = \Delta U + W$$

$$\Rightarrow \quad nC\Delta T = \frac{f}{2}nR\Delta T + \frac{nR\Delta T}{1-x}$$

[$\because$ Work done in a general polytropic process = [$nR\Delta T/(1-x)$]

$$\Rightarrow \quad C = \frac{f}{2}R + \frac{R}{1-x}$$

For infinitesimal changes in Q, U, and W, we ca write,

$$dQ = dU + dW$$

$$\Rightarrow \quad nCdT = \frac{f}{2}nRdT + PdV$$

$$\Rightarrow \quad C = \frac{f}{2}R + \frac{P}{n}\frac{dV}{dT}$$

Process	Equation of State	W	ΔU
Isobaric (dP = 0)	$\frac{V}{T} = c$	$P(V_f - V_i) = nR(T_f - T_i)$	$\frac{f}{2}nR(T_f - T_i) = \frac{f}{2}P(V_f - V_i)$
Isochoric (dV = 0)	$\frac{P}{T} = c$	0	$\frac{f}{2}nR(T_f - T_i) = \frac{f}{2}V(P_f - P_i)$
Isothermal (dT = 0)	$PV = c$	$nRT\ln\left(\frac{V_f}{V_i}\right) = nRT\ln\left(\frac{P_i}{P_f}\right)$	0
Adiabatic (dQ = 0)	$PV^\gamma = c$	$\frac{f}{2}nR(T_i - T_f)$ $= \frac{f}{2}(P_iV_i - P_fV_f)$	$\frac{f}{2}nR(T_f - T_i)$

Process	ΔQ
Isobaric (dP = 0)	$\left(\frac{f}{2}+1\right)nR\Delta T = \left(\frac{f}{2}+1\right)P(V_f - V_i)$
Isochoric (dV = 0)	$\frac{f}{2}nR(T_f - T_i) = \frac{f}{2}V(P_f - P_i)$
Isothermal (dT = 0)	$nRT\ln\left(\frac{V_f}{V_i}\right) = nRT\ln\left(\frac{P_i}{P_f}\right)$
Adiabatic (dQ = 0)	0

- Slope of adiabatic = γ (slope of isotherm)
- **Carnot engine**

$$\eta = 1 - \frac{Q_2}{Q_1} = 1 - \frac{T_2}{T_1}$$

$$\frac{Q_1}{Q_2} = \frac{T_1}{T_2}$$

$$W = Q_1 - Q_2$$

(efficiency) $\eta = \frac{W}{Q_1}$

- **Refrigerator**

Coefficient of performance is β

$$\beta = \frac{Q_2}{Q_1 - Q_2} = \frac{Q_2}{W}$$

$$\beta = \frac{1-\eta}{\eta}$$

- Heat pump

$$\alpha = \frac{Q_1}{W} = \frac{Q_1}{Q_1 - Q_2} = \frac{1}{\eta}$$