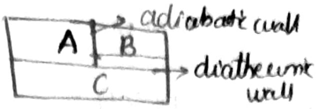
THERMODYNAMICS

① Zeroth law of thermodynamics



$A = C,\ B = C$

A & B must be in thermal equilibrium

② First law of thermodynamics

$\boxed{dQ = dU + dW}$

heat — internal energy — work done external

$\uparrow dW = PdV \uparrow$

$dV = A\,dx$

$dU = \frac{f}{2} nRdT$

→ Amount of heat given to system dQ is +ve

→ Heat liberated from system dQ is −ve

→ Work done on system. dW is −ve.

→ Work done by system dW is +ve.

③ Cyclic process

→ Heat & work are path functions

Process in which initial state & final state are same.

$\boxed{\Delta U = 0}$

→ work done in clockwise direction (cyclic process) is +ve

→ work done in anti c.w direction is −ve.

Work done = area of loop

④ Molar heat capacity:

$dQ = nCdT$

C → C_p: $dQ = nC_p dT$

C → C_v: $dU = nC_v dT$

$C_p - C_v = R$

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

$C_p = MC_p$

$C_v = MC_v$

$C_p \rightarrow SI = J/mol \cdot K$

$C_p = SI = J/kg\,K$

$C_p - C_v = r$ — specific gas const (varies from gas to gas)

⑤ Adiabatic constant (γ):

$\gamma = \frac{C_p}{C_v}$ $\quad C_p = \frac{\gamma R}{\gamma - 1}$ $\quad C_v = \frac{R}{\gamma - 1} = \frac{dU}{ndT} = \frac{fR}{2}$

⑥ Mixture of gases

$$C_{P(mix)} = \frac{n_1 C_{P_1} + n_2 C_{P_2} + \cdots}{n_1 + n_2 + n_3 + \cdots}$$

$$\gamma_{(mix)} = \frac{C_{P(mix)}}{C_{V(mix)}}$$

$$\gamma_{mix} = 1 + 2/f_{(mix)}$$

$$C_{V(mix)} = \frac{n_1 C_{V_1} + n_2 C_{V_2} + \cdots}{n_1 + n_2 + n_3 + \cdots}$$

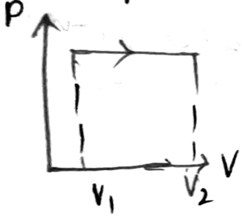
⑦

	γ	$\frac{dU}{dQ} = \frac{1}{\gamma}$	$\frac{dW}{dQ}$
Mono	$5/3$	60%	40%
di	$7/5$	70%	30%
tri	$4/3$	75%	25%

⑧ Different process of thermodynamics

(i) Isobaric process

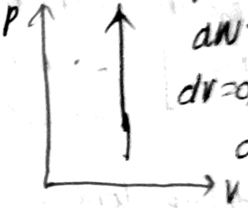
$P = const$



$$(dQ)_P = dU + dW$$

$$dW = P(V_2 - V_1)$$

(ii) Isochoric process



$V = const$

$dW = PdV$

$dV = 0,\ dW = 0$

$dQ = dU$

(iii) Isothermal process

$T = const$

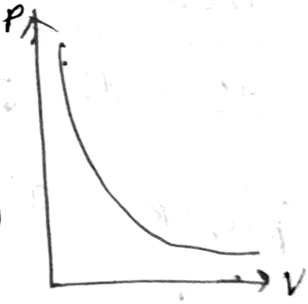
$dU = 0$

$dW = dQ$

$PV = const$

$$W = nRT \ln\left(\frac{V_2}{V_1}\right)$$

$$W = 2.303\, nRT \log_{10}\left(\frac{V_2}{V_1}\right)$$



$$\frac{dQ}{m\,dT} = S = \infty$$

(iv) adiabatic process:

$dQ = 0$

$C = 0$

$0 = dU + dW$

$dU = -dW$

$$dW = -n\frac{R}{\gamma - 1}[T_2 - T_1] = \frac{P_2V_2 - P_1V_1}{1-\gamma}$$

$PV^{\gamma} = k$

$$\frac{\Delta P}{\Delta V} = -\gamma\, P/V$$

$TV^{\gamma-1} = k$

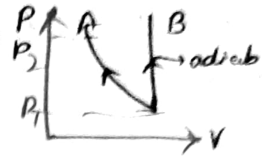
$P^{1-\gamma}T^{\gamma} = k$

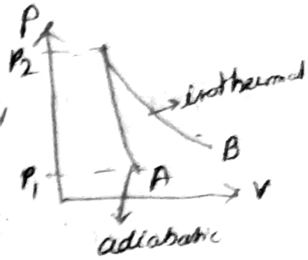
$\frac{\Delta V}{\Delta T} = \frac{-1}{\gamma-1}\frac{V}{T}$, $\frac{\Delta P}{\Delta T} = -\left[\frac{\gamma}{1-\gamma}\right]\frac{P}{T}$

(9) Isothermal vs adiabatic:

$\frac{\Delta P}{\Delta V} = -\gamma P/V \leftarrow PV^{\gamma} = K$ $\quad \left|\frac{\Delta P}{\Delta V}\right|_{adia} > \left|\frac{\Delta P}{\Delta V}\right|_{isothermal}$

$\frac{\Delta P}{\Delta V} = -P/V \leftarrow PV = K$





→ Steeper curve indicates adiabatic process.

(10) Reversible polytropic process:

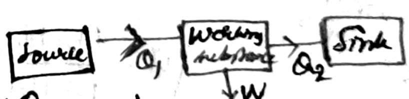
Reversible process is a quasistatic process. (very slow process)

$PV^{\gamma} = const.$, $C = C_v + R/1-x$ $\quad x =$ polytropic process

- $x = \infty$, $C = C_v$ (Isochoric process)
- $x = 0$, $C = C_v + R$, $C = C_p$ (Isobaric process)
- $x = 1$, $C = \infty$ (temp is const) isothermal process
- $x = \gamma$, $C = C_v + R/1-\gamma = \frac{R}{\gamma-1} - R/\gamma-1$, $\boxed{C=0}$ (adiabatic process)

Kelvin-Planck statement: It is impossible 100% of heat is converted into work.

Clausius statement: Heat cannot flow from colder body without doing external work.



(11) Carnot engine:

$Q_1 = W + Q_2 \Rightarrow W = Q_1 - Q_2$ $\quad \eta = \frac{W}{Q_1} = 1 - \frac{Q_2}{Q_1} = 1 - \frac{T_2}{T_1}$

[Use temp in kelvin]

(12) Refrigerator: Reverse process of heat engine

$W = Q_1 - Q_2$, $\beta = \frac{T_2}{T_1 - T_2}$

$\beta = \frac{Q_2}{Q_1 - Q_2} = \frac{1-\eta}{\eta}$

Entrophy $(S) = \ln\left(\frac{T_2}{T_1}\right)$