Chapter-2.

Basic Concepts of Thermodynamics

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* **Thermodynamics** :- It is the branch of energy interaction and its effect on system and surroudings.

* **System** :- It is a fixed mass or a region in space where an study is focused.

* **Surrounding** :- Everything except the system is called.

* **Boundary** :- A real or imaginary surface thats separates the system with surrounding (Fixed and moveble)

$\frac{1}{2}mv^2$

* Type of systems :-

System	Mass	Energy	Example
(i) Closed sys.	x	✓ interaction	Piston Sylender without volve
(ii) Open Sys.	✓	✓	Piston sylender
(iii) Isolated Sys.	x	x	A perfectly insuleted thermpal flask

* **Properties of a system** :- Any characterstic of the system is called property of the system.

Intensive (Intrinsic)	Extransive (Extensive)
→ Independent of mass of the System	→ The properties which depends on mass of the system under consideration Ex. Volum., Enthalpy, Internal Energy
Ex. - Presure, temp, density	
* All specific properties are intensive property Ex. Speci. volu. Speci. IE, Enthlopy	

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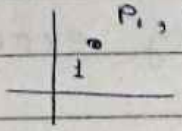
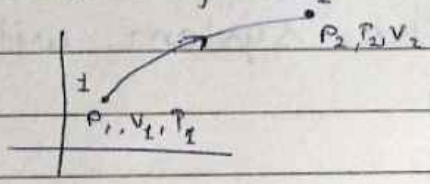
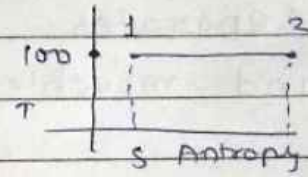
→ Keypoints :- ① They are exact properties
② They are point functions
③ They are indepent of past history.

* State of the system :-
① The condition of the system is know as state of system.



② The state of the system is specified by it properties





③ The change in the state of process

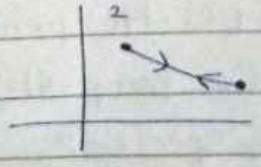
* Path :- The infinite states through which the system passes its called path.

* Quasistatic or non Quasistatic :- The process which is carried out vary slowly so that the system can be assumed to be in equilibirum anywhere between Initial and final State.
Non-Quasistatic → which is not slowly.

Quasistatic(=)

* Reversible process :- A reversible process is one which can be taken from its initial state to anothed state without and change either to system or surrou.

Ex. ① Friction less motion



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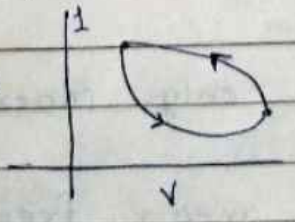
* Irreversible process :- An irreversible process is what counter in reality almost all the time. The system and environment cannot be restored to its original state at the same time.

Ex: ① When the heat flows one obj to another
② burning of paper.

	Reversible process	Irreversible process
(i)	This process carried out infinate slowly	→ It is carried out rapidly.
(ii)	At any stage equilibirium is not disturbed.	→ Equilibirium is maintain only after completion of process
(iii)	It is ideal process	→ inideal
(iv)	Same path	→ diff. path
(v)	Maximum work	→ Minimum work
(vi)	Physical process	→ chemical process

* All reversible process are Quasistatic but all quasi-static process are not reversible

* Cyclic process :- A process consist of a series of changes which return the system back to its initial state.



u = internal energy
w = area in the curve

① $u_F = u_i$ $\Delta u = u_F - u_i = 0$

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⑤ $\Delta Q = \Delta U + \Delta W$
$\Delta Q = \Delta W \quad \because \Delta U = 0$

* Non-cyclic process :- when the system doesn't return to its original state due to irreversibilities present in system (like friction) Ex. - boiling water

* Thermodynamic Equilibrium :- A system is said to be in therm. equ. if following equlib. are satisfied :-

① Thermal equ. → Same temp. for the system
② Machanical equ. → (force) Pressure at a point shouldn't change with time.
③ Chemical equ. → chemical composition shouldn't change with time
④ Phase equ. → The mass of each plase should remain constant with time

* Macroscopic Approch :- In macroscopic approch the individual molecular behaviour is not taken int account rather average molecular behaviour is studied
* Macroscopic app. is valid till the continuum concent is application
* Pressur, Density applicable only macroscopic app is valid

It remains valid till the mean free path is much much less than system direction

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Mean free path :- It is the avg distance travelled by the molecular between two successive collision.

* Microscopic Approch :- In this app individual molecular behaviour is taken into consideration (This app is used when density is very less)
In microscopic system there are large num of minute particales positioned randomly and moving with random momentum
Thus position and momentumm of individual partical are known as microscopic parameters

* Gas laws :- Ideal Gas :- ① Intermolecular force are negligible
② Volume occupied by the molucular is themselves is neligible in compared to container vol.
③ Fav condition → low pressure, high temp.
* All normal Gas at STP are ideal Ex: O_2, N_2, SO_2, CO_2, NO_2 (metioned)
* Water vapour will always be considered ideal gas
* Steam will never be considered as ideal gas.

* Ideal gas equation :- $PV = mRT$
m → mass, R → Characterstic Gas Constant KJ/Kg K
m / molucular mass

Number of mols :-
$PV = n\bar{R}T$ → Universal Gass Constant 8.314 KJ/Kmol
$R = \frac{\bar{R}}{M}$ → molecular mass

$O_2 = 32$ $R = \frac{8.314}{32} = 0.26$
Water 18 $R = \frac{8.314}{18} = 0.461$
Air = 29 $\frac{8.314}{29} = 0.287$

$\bar{R} = 8.314$ KJ/K mol K

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* Gas Laws

① Pressure & temp
② Pressure & Volume
③ Pressure & amount of gas
④ Temp & Vol.
⑤ Volume & Amount gas

Boyle's law :- If temp. is constant, pressure of gas ↑, Vol ↓

$$\frac{1}{PV} = K$$

$$\boxed{P_1 V_1 = P_2 V_2}$$

Charle's law :- If temp. of gas ↑, vol ↑, If pressure is constant

$$\frac{V}{T} = K \qquad \frac{V_1}{T_1} = \frac{V_2}{T_2}$$

Gay Lussac's law :- As the temp. of enclosed gas ↑ pressure ↑

$$\frac{P}{T} = K \qquad \boxed{\frac{P_1}{T_1} = \frac{P_2}{T_2}}$$

Combined gas law :- When amount of gas is constant

$$\frac{PV}{T} = K \qquad \boxed{\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}}$$

FIRST LAW OF THERMODYNAMICS :- A Thermodynamic system is a collection of objects we can regard as a unit that can exchange energy with surrounding

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Energy transfer into and out of system can be through

① Energy work done (W)
② Heat (Q)

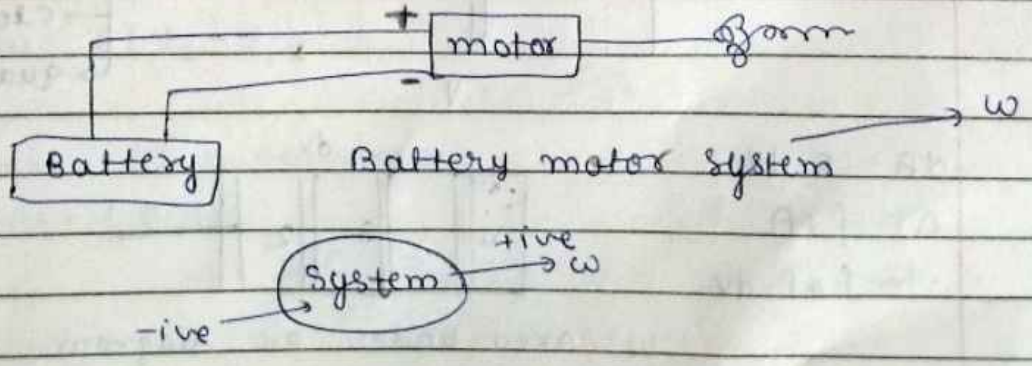
SIGN CONVENTION

For work (W)	Heat (Q)
→ Work done by system is (+ive). Ex. Turbine	Q_{in} = (+ive)
→ Work done on the system is (-ive)	Q_{out} = (-ive)
Ex. - Pump, compressor	

ENERGY AND ENERGY INTERACTION

- work
- Heat
- mass

Ex. ①



Ex. ② Work is said to ~~be~~ we done by system, if the Soul effect on things external to the system can be reduced to the raising of a weight

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(1) Energy

microscopic + macroscopic

↓ ↓

I.E K.E, P.E

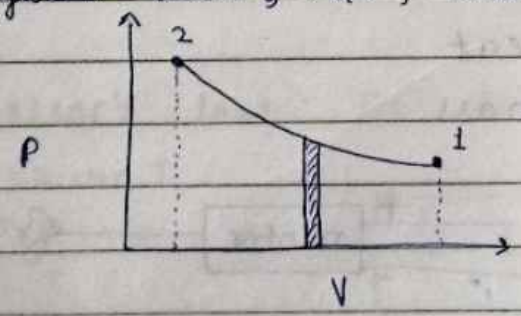
↳ Sensible Energy + latent heat + chemical Energy + Nuclear Energy

0°c —L— 100°c
Sensible

* Macroscopic is the energy possessed by bulk molecules
* Microscopic energy is the energy possessed by substance at molecular level

Close system Analysis

1 Close system work, Pdv, boundary work



$\delta w = P \cdot A \cdot dx$ (Unit)

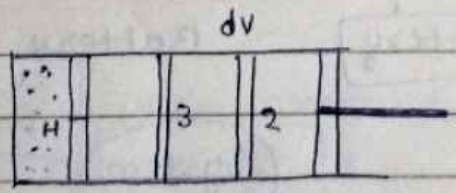
$w = \int P \cdot dV$

↳ Closed
↳ quasistatic process

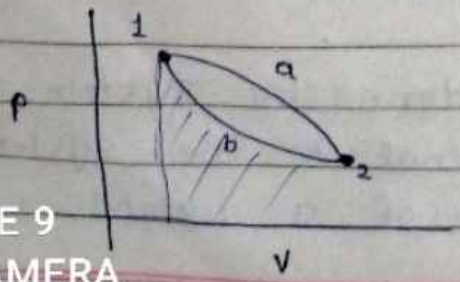
$dA = P \cdot dV$

$A = \int dA$

$= \int P \cdot dV$



W = Area under PV diagram



$W_{1a2} \neq W_{1b_2}$

↓

Path function

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* Important point w.r.t. work.

① It is a path function :- Path function are properties or quantities whose value depend on transition of system from initial state to final state Heat is also path function.

② It is a boundary function

③ Work is not a property

④ It is an inexact differential equation.

PdV work in various process

① Const. vol. process (Isochoric)

$$W = \int_1^2 P \cdot dV$$

Volume constant

$$= P(V_2 - V_1)$$

$$\boxed{W = 0}$$

② Isobaric (P = constant)

$$W = \int_1^2 P \cdot dV$$

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

③ Isothermal (T = constant)

$$W = \int P \cdot dV \qquad PV = mRT$$

$$W = \int_1^2 \frac{C}{V} \cdot dV \qquad P_1V_1 = \text{const.}$$

$$W = C \int \frac{1}{V} \cdot dV = C [\log V]_1^2$$

$$\boxed{W = C \ln \frac{V_2}{V_1}}$$

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$$\boxed{w = C \ln \frac{P_1}{P_2}}$$

$$\boxed{w = mRT \ln \frac{P_1}{P_2}}$$

$$\boxed{w = mRT \ln \frac{V_2}{V_1}}$$

④ Adiabatic Process :- (Heat flow → $Q_s = 0$)

$$\boxed{PV^\gamma = C}$$

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

air → 1.4

$C_p - C_v = R$

$$w = \int_1^2 P \cdot dV$$

$$= \int_1^2 \frac{C}{V^\gamma} \cdot dV$$

$$= C \int_1^2 \frac{1}{V^\gamma} \cdot dV$$

$$\Rightarrow C \left[\frac{V^{-\gamma+1}}{-\gamma+1} \right]_1^2 = \frac{C}{1-\gamma} \left[V_2^{-\gamma+1} - V_1^{-\gamma+1} \right]$$

$$\Rightarrow w = \frac{P_2V_2 - P_1V_1}{-\gamma+1}$$

$$\boxed{w = \frac{P_1V_1 - P_2V_2}{\gamma - 1}}$$

$$PV^\gamma = C$$

$$P_1V_1^\gamma = P_2V_2^\gamma$$

$$\frac{P_1}{P_2} = \left(\frac{V_2}{V_1} \right)^\gamma$$

$$\frac{P_2}{P_1} = \left(\frac{V_1}{V_2} \right)^\gamma$$

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

$$\because \left(\frac{V_1}{V_2}\right)^{\gamma} = \frac{P_2}{P_1}$$

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}}$$

Polytropic Process :- $(PV^n = C)$

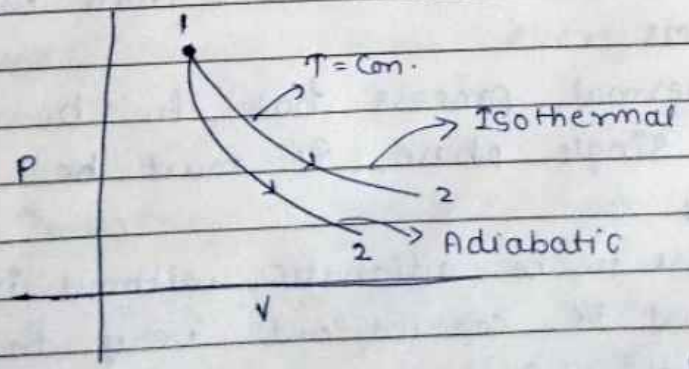
$$W = \int P \cdot dV \qquad C_p - C_v = R$$

$$= \int \frac{C}{V^n} \cdot dV \qquad \frac{C_p}{C_v} = \gamma$$

$$W = \frac{P_1V_1 - P_2V_2}{n-1} \longrightarrow \text{For general process}$$

n Value lies b/w 1 to 1.4

Representation of isothermal & Adiabatic curves on P-V diagrams for an ideal gas.



Isothermal

$PV = C$

$P \cdot dV + V \cdot dP = 0$

$$\frac{dP}{dV} = -\frac{P}{V}$$

Adiabatic

$PV^{\gamma} = C$

$P \cdot \gamma V^{\gamma-1} \cdot dV + V^{\gamma} \cdot dP = 0$

$$\frac{dP}{dV} = -\gamma \frac{P}{V}$$

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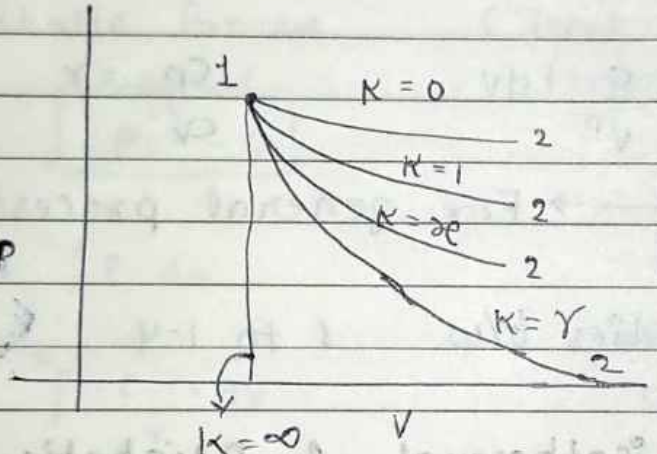
* Adiabatic curve is more steeper that isothermal curve

Isochoric	Isobaric	Isothermal	Adiabatic
$\frac{P_1}{T_1} = \frac{P_2}{T_2}$	$\frac{V_1}{T_1} = \frac{V_2}{T_2}$	$P_1V_1 = P_2V_2$	$P_1V_1^{\gamma} = P_2V_2^{\gamma}$

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}}$$



Practical Realisation of process :-

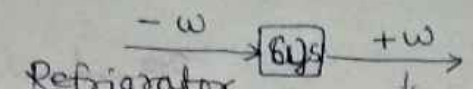
① If free piston is free to move than we can assume prosess

② If an isothermal process has to be carried out in a single phase, It must be carried out very slowly.

③ For a process to be adiabatic without insulation than it must be carried out very fastly. If with insulation It can be fast or slow.

* Free expansion :- $w = 0$ Work is identified at boundaries.

① Let the partition remove - The expansion of



Refrigrator

Ex. Turbain work give

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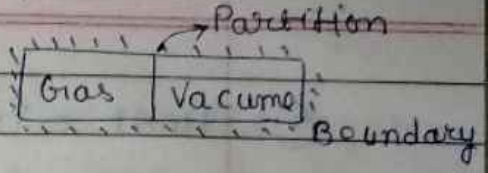
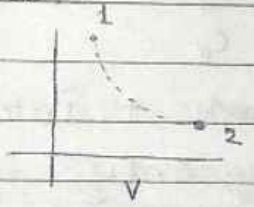


gas against vaccume is known as free expansion

② $\int_1^2 dw = 0$

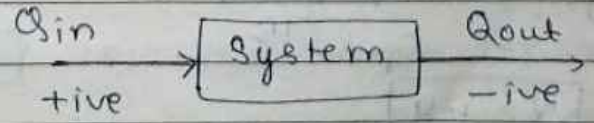
③ If only Gas is taken on system, when the partition is removed, there is change in the vol. of gas. $w = \int_1^2 P \cdot dv$

The two end states can be located at P-V and a joined by doted line and the processon can be occure



* However it vacum is spaces divided in large number of small vacum and partition removed slowely then every state pass by the system equ.

Heat Transfer :- Heat :- Sign convation



Heat is a form of energy that is transmitted across a boundary by virtue of temp. diffrens.

① It is also a (Boundry phenomenan.)

② It is also not a property

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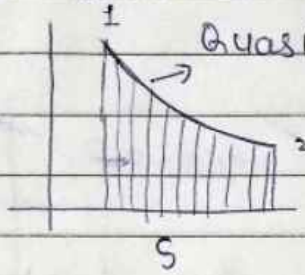
③ Heat is also a path function.



Quasistatic $\int_1^2 dQ = Q_{12}$

Area - Heat transfer

Heat:-

$Q \propto dT$

$Q \propto m$

$Q = mc\,dT$ (c = Specific heat)

$c = \frac{Q}{m \cdot dT}$ $\left(\frac{KJ}{kg \cdot K}\right)$ or $\frac{KJ}{kg \cdot C}$

Specific heat (c) → $\frac{c_p}{c_v}$ $c_p > c_v$

c_p → boundary work + internal energy

c_v → internal energy only

$\frac{c_p}{c_v} = \gamma$

$c_p - c_v = R$

For Monoatomic gas ⇒ $c_v = 3 \times R/2$

$c_p = R + 3R/2 = 5R/2$

$\boxed{\gamma = 1.67}$

Diatomic gas ⇒ $c_v = 5R/2$

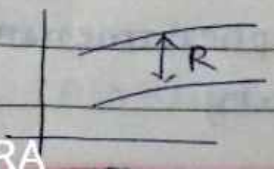
$c_p = 7R/2$

$\boxed{\gamma = 1.4}$

Triatomic

$\boxed{\gamma = 1.3}$

④ As the tem.↑ both c_p and c_v ↑ by equal amount



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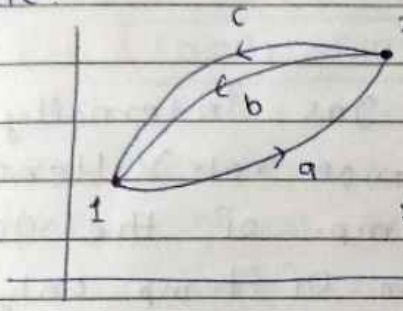
* **First law of Thermodynamic** :- For a closed system (Joule's laws) undergoing a cycle net heat transfer is equal to net work transfer.
It is also called as law of consv. of energy
It is valid for both rever. as well as irreversible cycle



1 - a - 2 - b - 1

1 - a - 2 - c - 1

* 1 - a - 2 - b - 1

$$(\delta Q)_{1a2} + (\delta Q)_{2b1} = (\delta W)_{1a2} + (\delta W)_{2b1} \quad \text{—— (1)}$$

* 1 - a - 2 - c - 1

$$(\delta Q)_{1a2} + (\delta Q)_{2c1} = (\delta W)_{1a2} + (\delta W)_{2c1} \quad \text{—— (2)}$$

eq. (1) - eq. (2)

$$(\delta Q)_{2b1} - (\delta Q)_{2c1} = (\delta W)_{2b1} - (\delta W)_{2c1} \quad \text{— (A)}$$

from eq. (A) $(\delta Q)_{2b1} - (\delta W)_{2b1} = (\delta Q)_{2c1} - (\delta W)_{2c1}$

$(\delta Q - \delta W)_{2b1} = (\delta Q - \delta W)_{2c1}$

Though path b and c are different but the Quantity $(\delta Q - \delta W)$ is same for both the path and this must ~~property~~ represent a change in property.

$$\boxed{\delta Q - \delta W = \delta E} \rightarrow \text{Energy}$$

It is first law of Thermo. for a process.

* **First law of a process** :- When a heat is transferred to a gas then a part of it is taken by the gas itself and the remaining is converted into useful work. This is equal to dw.

$W = \int P\,dV = \frac{P_1V_1 - P_2V_2}{\gamma - 1}$ 17-9 20-C A b a 18-d one 3-300 -10 kJ

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The energy taken by the gas internally is known as change in internal energy (dU)

$dQ = dU + dW$ for a process

$dU \rightarrow dE$

$dQ = dU + dW$

E = 56.25 kJ

W = -56.25 kJ

The energy taken by the gas internally has no external work (no change vol.), Hence, dU will only change the temp. of the gas.

Internal energy is function of temp. only

$dU \propto dT$ C_v = Volum. constant

$dU = mC_v\,dT$

* First law for a closed system :- $\Delta Q = \Delta W$

$dW \rightarrow dW_{P.dV} + dW_{shaft} + dW_{electri.}$

$dE \rightarrow E_K + E_P + U$ ($E_K + E_P$: macro, U : micro)

$dQ = dU + dW = dE + P\,dV = dU + P\,dV$

Interegal form

$Q = \Delta E + \int P\,dV$

$Q = \Delta U + \int P\,dV$

Enthalpy :- (h) → Specific (H - Total enthalpy)

It is thermodynamic quantity equivelent to the total heat content of the system.

$U \rightarrow mC_v\,dT + P\,dV$

$h = U + PV$ (U : micro, PV : macro)

c, 1-82, d, c, a, b, a, a, c, c, c, a

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It is the total heat content at constant.
h → It is an intensive property

$dQ = dU + P \cdot dV$

At constant pressure $P \cdot dV = d(PV)$

$(dQ)_p = dU + d(PV)$

$(dQ)_p = d(U + PV)$

$\boxed{(dQ)_p = dh}$

Heat transferred at constant pressure of the enthalpy of a system.

$\boxed{dh = mC_p dT}$

$$H = \dot{m} C_p \int_{T_1}^{T_2} dT$$

* Energy of Isolated System :- No interaction of system with surrounding

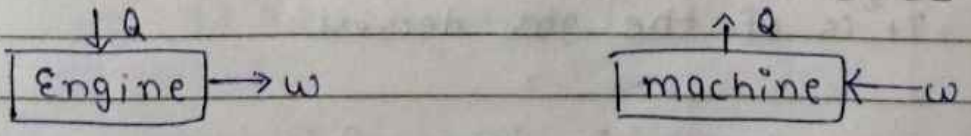
$dQ = 0$

$dw = 0$

$\boxed{dE = 0}$ $\boxed{E = \text{constant}}$

* The Energy of an isolated system is always constant.

* Perpetual motion machine of first kind (PMM$_1$) :-



First law :- There can be no machine which would continuosly supply mech. work without some other form of energy disappearing simoultaneously.

(S) ← H +ive

(S) → H -ive

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Such a fictions m/c machine is called PMM, (The PMM, is impossible)

* Numerical Question :-

(S) ① A Stationary mass of gas is compressed without friction from an initial state 0.3 m^3 and 0.105 m pascal to a final state of 0.15 m^3 and 0.105 m pascal. The pressure remaining constant during the process there is a Heat transfered of 37.6 KJ of heat from the gas during the process. How much does the internal energy of the gas.

⇒ $V_1 = 0.3$ $P_1 = 0.105$

$V_2 = 0.15$ $P_2 = 0.105$

$Q = \Delta U + \Delta W$

$Q_{12} = U_2 - U_1 + W_{12}$

$W_{12} = \int_{V_1}^{V_2} P \cdot dV$

$\Rightarrow P(V_2 - V_1) = 0.105\ (0.15 - 0.30)$

$\Rightarrow -15.75$ KJ

$Q_{12} = -37.6$ KJ

$-37.6 = \Delta U - 15.75$

$\Delta U = -21.85$ KJ

It is of the gas decress

Q ② when a system is taken from state a to b, in figu. given along path, acb, 84 KJ of heat flows into the system and system does 32 KJ of work.

Heat $Q = \Delta U + W$

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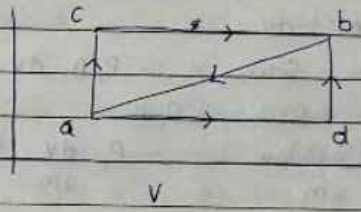
(a) How much will the heat flow into the system along path adb. If the work done is 10.5 KJ.

(b) When the system is return from b to a along the curved path the work done on the system is 21 KJ. Does the system absored or liberete and How much heat absored?

(c) If $U_a = 0$ and $U_d = 42$ KJ find the heat absorbed in the process ad and db



⇒ (a) ⇒ $Q_{acb} = 84$ KJ

$W_{acb} = 32$ KJ

$Q_{acb} = (U_b - U_a) + W_{acb}$

$U_b - U_a = 52$ KJ

$Q_{adb} = (U_b - U_a) + W_{adb}$

$Q_{adb} = 52 + 10.5 = 62.5$

(b) $W = -21$ KJ

$Q_{ba} = U_a - U_b + W_{ba}$

$= -52 - (-21)$

$= -73$ KJ liberete

(c) $U_a = 0$ $U_d = 42$

$W_{acb} = W_{ad} + W_{db} = 10.5$ KJ

$Q_{ad} = U_d - U_a + W_{ad}$

$= 42 - 0 + 10.5 = 52.5$ KJ

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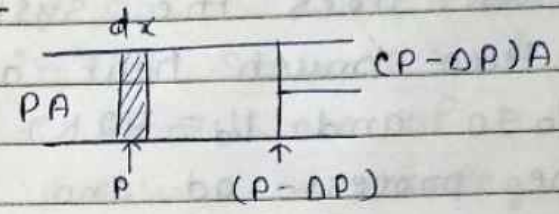
$Q_{adb} = 62.5\ KJ = Q_{ad} + Q_{db}$

$Q_{db} = 62.5 - 52.5 = 10\ KJ$

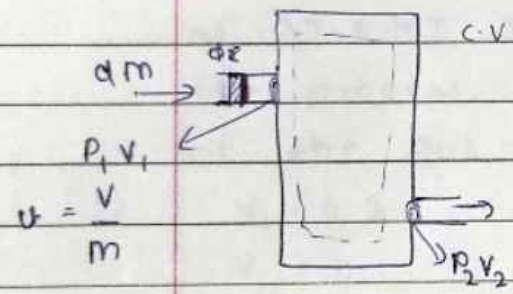
* First law for an open system :-

* Displacement work :-



$W = PA \cdot dx = P \cdot dV$

$W = (P - \Delta P)A \cdot dx = (P - \Delta P) \cdot dV$



$\delta W_{C.V} = -P_1 A \cdot dx$

$\delta W = -P_1 dV$

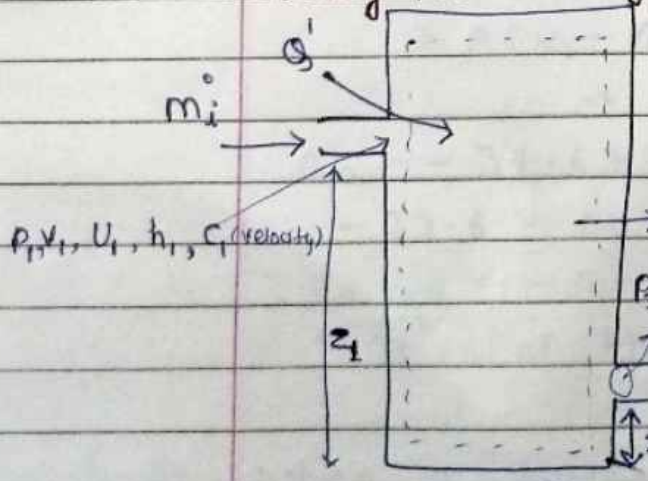
$\frac{(\delta W)_{C.V}}{\partial m} = -P_1 \frac{dV}{\partial m}$ (Per kg bases)

$= -P_1 V_1$

$\boxed{W_{CV} = -P_1 V_1}$

$W_{exit} = P_2 V_2$

Steady Flow Energy equation (SFEE) :-



① Steady State :-

Conservation of mass

$\dot{m}_i = \dot{m}_e = \dot{m}$

Energy conservation

$Energy_{in} = Energy_{out}$

$\rightarrow \dot{m}_i\left(U_1 + \frac{C_1^2}{2} + gZ_1 + P_1V_1\right) + Q = \dot{m}_e\left(U_2 + \frac{C_2^2}{2} + gZ_2 + P_2V_2\right) + W$

$\rightarrow \dot{m}_i\left(h_1 + \frac{C_1^2}{2} + gZ_1\right) + Q = \dot{m}_e\left(h_2 + \frac{C_2^2}{2} + gZ_2\right) + W_{CV}$

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ex: $q = \frac{Q}{m}$

Divided by m

$$h_1 + \frac{C_1^2}{2} + gz_1 + q = h_2 + \frac{C_2^2}{2} + gz_2 + w_{cv}$$

This is first law of thermodynamics for open system.

→ $U_1 + P_1V_1 + \frac{C_1^2}{2} + gz_1 + q = U_2 + P_2V_2 + \frac{C_2^2}{2} + gz_2 + w_{cv}$

(i) $U_1 = U_2$

(ii) $q = 0$ $w_{cv} = 0$

(iii) In compressible

Bernoulis eq.

$$P_1V_1 + \frac{C_1^2}{2} + gz_1 = P_2V_2 + \frac{C_2^2}{2} + gz_2$$

- Steady flow energy equ. applied to common engine. Devies :-

① Turbine :-

$$h_1 + \frac{C_1^2}{2} + gz_1 + q = h_2 + \frac{C_2^2}{2} + gz_2 + w_{cv}$$

(0 over $\frac{C_1^2}{2}$, 0 over gz_1, 0 over q, 0 over $\frac{C_2^2}{2}$, 0 over gz_2)

→ Steady State, Adiabatic $\Delta K_e = 0$ $\Delta P_e = 0$

$$h_1 = h_2 + w_{cv}$$

$$\boxed{w_{cv} = h_1 - h_2}$$

② Compressure :- $h_1 = h_2 - w_{cv}$

$$\boxed{w_{cv} = h_2 - h_1}$$

Imp. formula's

→ $\delta Q - \delta E = \delta w$ → F law for a process

$\delta Q = \delta w$ → 1st law for a cycle

Enthalpy $h = U + pV$ or $mC_p\Delta T$

$$mC_p \int_{T_1}^{T_2} \Delta T \qquad h = mC_p(T_2 - T_1)$$

Internal Energy - $U = mC_v\Delta T = mC_v(T_2 - T_1)$

$\frac{C_p}{C_v} = \gamma$ $C_p - C_v = R$ $C_v = \frac{R}{\gamma - 1}$ $C_p = \frac{\gamma R}{\gamma - 1}$

Chapter: 2

Second Law of Thermodynamics

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Thermal Energy reservoir :-

Source :- It is a TER which can supply large amount of energy without undergoing any temp. change Sum. (∞ energy receive but T constant)

Sink :- It is an TER which can receive large amount of thermal energy without undergoing any temp. change.

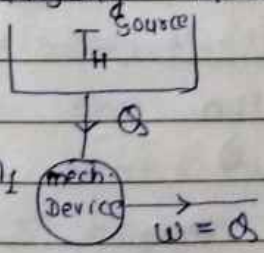
Low grade Energy ⇒ Unorganized form of energy Ex Heat

High grade Energy ⇒ Organized form of energy ⇒ work.

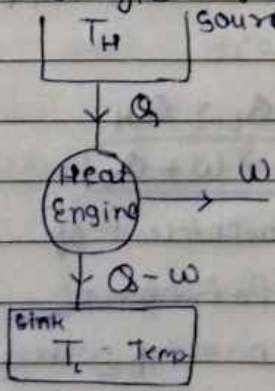
"According to second law of therm. complete conversion of low grade energy into high grade energy in a cycle is impossible without any lose."

STATMENTS OF II^nd law :-

① Kelvin - Planck :- It is impossible to developed a device operating on a cycle that produces work by exchanging heat with single reservoir.



(not possible)

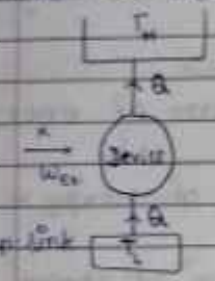


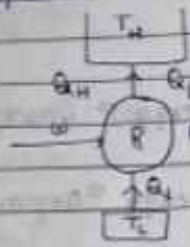
② Concept of Heat engine is derived from Kelvin-plank 2nd law

(ii) No heat engine can have η of 100%.

* PMM$_2$ - It is a device which veilat Kelvin Plank's PMM$_2$ is impossible.

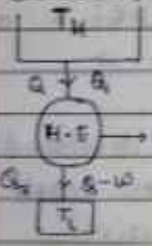
② Clausius Statement :- It is impossible to develop a device which works on a cycle and transfer heat from lower temp to higher temp. without and external work input.





$Q_H = Q_L + W$

* Efficiency :-



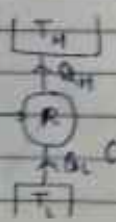
$\eta = \frac{\text{output}}{\text{input}} = \frac{W}{Q}$

$W = Q$, $Q_1 = W + Q_2$

$W = Q_1 - Q_2$

$\eta = \frac{\text{work done}}{\text{Heat Supplied}} = \frac{W}{Q_1} = \frac{Q_1 - Q_2}{Q_1}$

Refrigerator :-



$W + Q_1 = Q_H$

$Q_H = W + Q_2$

COP → Coefficient of performance

$COP = \frac{\text{desired effect}}{\text{required input}} = \frac{Q_L}{W} = \frac{Q_L}{Q_H - Q_L}$

$(COP)_R = \frac{Q_L}{Q_H - Q_L}$ — ①

Heat pump

$(COP)_{H.P} = \frac{Q_H}{Q_H - Q_L}$ — ②

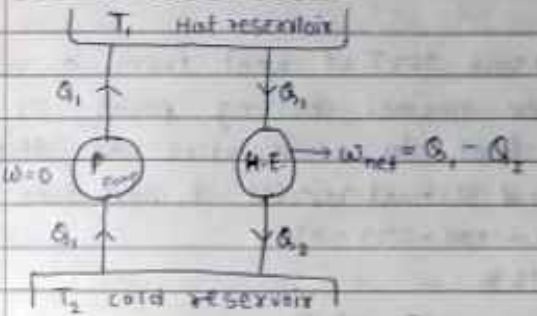
eq ② - ①

$(COP)_{H.P} - (COP)_R = \frac{Q_H}{Q_H - Q_L} - \frac{Q_L}{Q_H - Q_L} = 1$

$(COP)_{H.P} = 1 + (COP)_R$

* Equivalance of Kelvin plank and clausius Statement :-

① Violation of Clausius :-



Let us assume a cyclic heat engine (E) operating between the same energy reservoir producing work in one cyclic. The rate of working of H.E is such that it draws an amount of heat Q_1 from hot reservoir equal to that dischanged by heat pump. Then the hot reservior may be eliminated and the heat Q_1 discharged by heat pump is fed to heat engine. So we see that heat pump (P) and heat engine (E) acting to gether constitude a heat engine operating in cycle and produces net work while exchanging heat with single reservior. This voilate Kelvin Plank.

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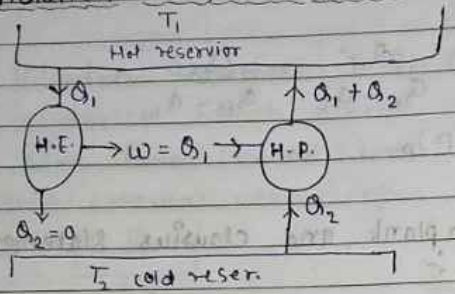
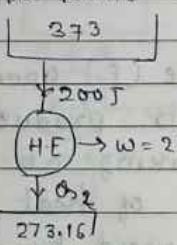
② Violation of Kelvin Plank :-



Q.① A carnot Engine absorb 200J of heat from a reservior at the temp of the normal boiling point of water and rejects heat to a reservior at the triple point of water. Find (a) Heat rejected (b) work done (c) Therm' eff.

⇒ * Boiling point → 100°C = 100 + 273 = 373K

* Triple point ⇒ 273.16 K



$Q_1 = 200$

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

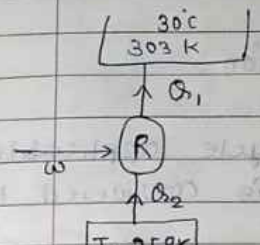
$\frac{Q_2}{Q_1} = \frac{T_2}{T_1}$

$Q_2 = \frac{200 \times 273.16}{373} = 146.4\ J$

$W = Q_1 - Q_2 = 200 - 146.4 = 53.6\ J$

$\eta = \frac{W}{Q} = \frac{53.6}{200} = 26.8\ \%$ Ans.

Q.② A domestic food freezer maintain a temp of −15°C. The ambient air temp is 30°C. If heat leaks into the freezer at continuous rate 1.75 KJ/s. what is the heat power necessary to pump this heat out continuously.



$Q_2 = 1.75$

$T_2 = -15°C = 258\ K$

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

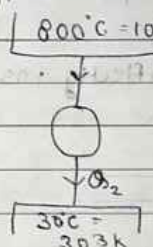
$Q_1 = \frac{1.75 \times 303}{258}$

$Q_1 = 2.056$

$W = Q_1 - Q_2 = 0.31\ KJ/s = KW$

Q.③ A cyclic heat engine between a source temp of 800°C and a sink temp 30°C. what is the least rate of heat rejection per KW net output of the engine.

$T_1 = 1073\ K$



$T_2 = 303\ K$

$W = 1\ KW$

$W = Q_1 - Q_2$

$1 = Q_1 - Q_2$

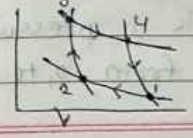
$\frac{Q_1 - Q_2}{Q_1} = 1 - \frac{T_2}{T_1}$

$\frac{1}{Q_1} = 1 - 0.282 = 0.718$

$Q_1 = 1.392\ KJ/sec.$

$Q_2 = Q_1 - 1 = 0.392\ KJ/sec.$

* Carnot cycle :- It is a reversible cycle in which all process constituting the cycle are reversible.



Entropy → Work is done by gas

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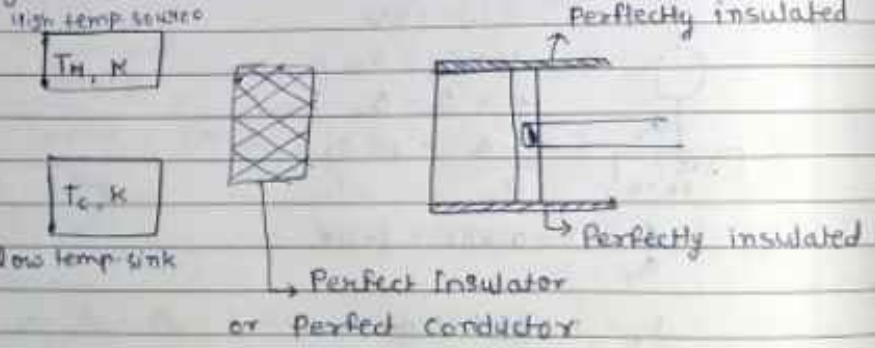
(1-2) Rev. adiabatic compression
(2-3) Rev isothermal heat addition
(3-4) Rev adiabatic expansion
(4-1) Rev isothermal heat rejection.

It is a thermodynamics cycle applicable for perfect gas where efficiency is considered to be minimum.

Carnot cycle consist of
→ Two isothermal process
→ Two adiabatic process

* All 4 process are reversible and therefore it is the most efficiency cycle, as it involves no loses)

The theoritical heat engine that operates on this cycle is called carnot engine.



Process 1-2 ⇒ Reversible Isothermal Expansion

→ Heat is supplied to the system from the T_1 system sources and exp takes once
→ Pressure in exp. there is a pressure from P_1 to P_2
→ Increase in Entropy from S_1 to S_2

② 2-3 (Rev adiabatic expansion) Isentropic :-

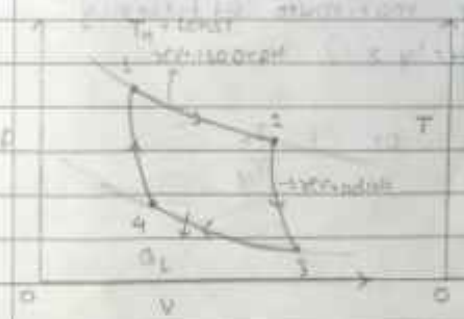
→ Hot reservoir is replaced insulator
→ There is no heat transfer
→ Even though work is done due to internal energy
→ T_2 to T_3 Temp ↓
→ Volu will V_2 to V_3 ↑
→ P_2 to P_3 ↓

③ 3-4 (Rev Isothermal compression) :-

→ Temp will remain constant ($T_3 = T_4$)
→ Q_L Heat will be rejected
→ Pressure ↑ P_3 to P_4
→ Entropy decrease S_3 to S_4
→ V_3 to V_4 ↓

④ 4-1 (Rev adiabatic Compression):-

→ No Heat transfer
→ Tem ↑ T_4 to T_1
→ Press ↑ P_4 to P_1
→ V_4 to V_1 (↓)



Clockwise → +w
Anticlockwise → -w
Area under PV = w
TS = Heat transfer

Work done

$W_{12} = P_1 V_1 \ln \frac{V_2}{V_1}$ (+ive)

$W_{23} = \frac{P_2 V_2 - P_3 V_3}{\gamma - 1}$ (+ive)

$W_{34} = P_3 V_3 \ln \frac{V_4}{V_3}$ (-ive)

$W_{41} = \frac{P_4 V_4 - P_1 V_1}{\gamma - 1}$ (-ive)

Heat transfer

$Q_{12} = W_{12}$

$Q_{23} = 0$

$Q_{34} = W_{34}$

$Q_{41} = 0$

$\eta = \frac{\text{Net work done}}{\text{Heat supplied}} = \frac{W_{12} + W_{23} + W_{34} + W_{41}}{Q_{12} + Q_{34}}$

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

Carnot principle :-

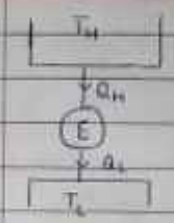
① [$\eta_{irr} < \eta_{rev}$] operating between two cycle.

Efficiency of irr. heat is always less than the η of revers heat engine operating between two same reservoir.

② The efficiencies of all reversible heat engin operating between the ~~same~~ two reservoir are same.

③ Carnot engine has the maximum efficiency (Theoritical ✓, Practicely x)

④ $\eta_c = \frac{W_{net}}{Q_H}$ or $1 - \frac{Q_L}{Q_H}$ or $1 - \frac{T_L}{T_H}$



⑤ For reversible engine

$\eta = \frac{W}{Q_H} = \frac{Q_H - Q_L}{Q_H}$

$\eta = 1 - \frac{Q_L}{Q_H} = 1 - \frac{T_L}{T_H}$

Temp must be in Kelvin

$\eta > \eta_{rev}$ → Impossible

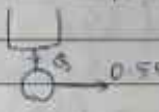
$\eta = \eta_{rev}$ → Reversible Engine

$\eta < \eta_{rev}$ → Irreversible

Q An inventor claims that his new concept of an engine while working between 27°C and 327°C rejects 45% of heat absorbed his new concept of engine is then equivelent to which of the following engine

(a) Carnot (b) ~~Diesel~~ diesel (c) impossible (d) Auto

→ $\eta_{rev} = 1 - \frac{300}{600} = 50\%$



$\eta > \eta_{rev}$: impossible

* Clausius inequality :- $\oint \frac{\delta Q}{T} \leq 0$

The cyclic integral of $\frac{\delta Q}{T} \leq 0$

(1) Reversible Cycle →

$\oint \frac{\delta Q}{T} = \frac{Q_H}{T_H} - \frac{Q_L}{T_L} = 0$

$1 - \frac{Q_L}{Q_H} = 1 - \frac{T_L}{T_H}$

For reversible eng. $\frac{Q_H}{T_H} = \frac{Q_L}{T_L}$

$\frac{Q_H}{Q_L} = \frac{T_H}{T_L}$, $\boxed{\oint \frac{\delta Q}{T} = 0}$ For reversible engine

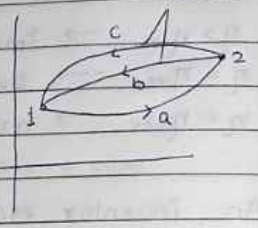
(B) Irreversible Engine (Cycle)

$\oint \frac{\delta Q}{T} < 0$ → irreversible

$\oint \frac{\delta Q}{T} > 0$ → impossible cycle

* **Entropy :-** 1-a-2-b-1

$$\oint \frac{\delta Q}{T} = 0$$



$$\left(\frac{\delta Q}{T}\right)_{1a2} + \left(\frac{\delta Q}{T}\right)_{2b1} = 0 \quad \text{— ①}$$

1-a-2-c-1

$$\left(\frac{\delta Q}{T}\right)_{1a2} + \left(\frac{\delta Q}{T}\right)_{2c1} = 0 \quad \text{— ②}$$

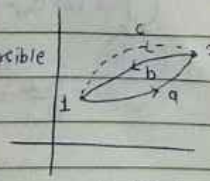
eq ① - eq ②

$$\left(\frac{\delta Q}{T}\right)_{2b1} - \left(\frac{\delta Q}{T}\right)_{2c1} = 0$$

$$\left(\frac{\delta Q}{T}\right)_{2b1} = \left(\frac{\delta Q}{T}\right)_{2c1}$$

$\boxed{\frac{\delta Q}{T} = dS}$ Though path b and c are diff. but end points are same and the quality $\frac{\delta Q}{T}$ is independent of path and depends only on # end points. There $\left(\frac{\delta Q}{T}\right)_{rev}$ must represent a change in property and property is known as entropy.

For irreversible path :-



1-a-2-c-1

$$\oint_{irr.} \frac{\delta Q}{T} < 0$$

$$\left(\frac{\delta Q}{T}\right)_{1a2} + \left(\frac{\delta Q}{T}\right)_{2c1} < 0 \quad \text{— ①}$$

1-a-2-b-1

$$\oint \frac{\delta Q}{T} = 0, \quad \left(\frac{\delta Q}{T}\right)_{1a2} + \left(\frac{\delta Q}{T}\right)_{2b1} = 0$$

$$\left(\frac{\delta Q}{T}\right)_{1a2} = -\left(\frac{\delta Q}{T}\right)_{2b1} \quad \text{— ②}$$

Putting the value of ② in ①

$$-\left(\frac{\delta Q}{T}\right)_{2b1} + \left(\frac{\delta Q}{T}\right)_{2c1} < 0$$

$$\left(\frac{\delta Q}{T}\right)_{2c1} < \left(\frac{\delta Q}{T}\right)_{2b1}$$

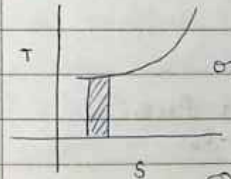
$$\left(\frac{\delta Q}{T}\right)_{irr.} < \left(\frac{\delta Q}{T}\right)_{rev.}$$

$\boxed{\left(\frac{\delta Q}{T}\right)_{irr.} < dS}$, $\boxed{dS > \left(\frac{\delta Q}{T}\right)_{irr.}}$

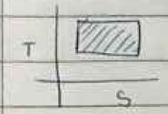
The change in entropy for a process is greater than or equal $\left(\frac{\delta Q}{T}\right)$, the equality exists of the process is reversible.

$$\boxed{dS \geq \frac{dQ}{T}}$$

* **Const. Volum. and Con. pressure on T-S diagram :-**



① Area under T-S diagram when projected on entropy axis gives the heat interaction for a process.



② Net heat interaction

$\Sigma W = \Sigma Q$ (work interaction)

$\delta Q = \delta U + \delta W$ $\quad \frac{dQ}{T} = ds$

$T\,ds = dU + P\,dV$ (constant Vol.)

$T\,ds = C_v\,dT$

$\left(\frac{dT}{ds}\right)_V = \frac{T}{C_v}$

Constant Pressure: $\delta Q = \delta U + \delta W$

$\delta Q = dh - V\,dP$

($\because h = U + PV$, $dh = dU + P\,dV + V\,dP$)

$T\,ds = dh$

$T\,ds = C_p\,dT$

$\frac{dT}{ds} = \frac{T}{C_p}$

* T-S relation for ideal gas :-

$T\,ds = dU + P\,dV$

ideal $dU = C_v\,dT$

$T\,ds = C_v\,dT + P\,dV$

$ds = C_v\frac{dT}{T} + \frac{P}{T}\,dV$

$\frac{P}{T} = \frac{R}{V}$

$\int_1^2 ds = \int_1^2 C_v\frac{dT}{T} + \int_1^2 \frac{R}{V}\,dV$

$\boxed{S_2 - S_1 = C_v \ln\left(\frac{T_2}{T_1}\right) + R\ln\frac{V_2}{V_1}}$ Constant Press.

$R = C_p - C_v$

$T\,ds = dh - V\,dP$

ideal $dh = C_p\,dT$

$ds = \frac{C_p\,dT}{T} - \frac{V\,dP}{T}$ $\quad (\because PV = RT)$

$\frac{V}{T} = \frac{R}{P}$

$\int ds = \int C_p\frac{dT}{T} - \int R\frac{dP}{P}$

$\boxed{S_2 - S_1 = C_p \ln\left(\frac{T_2}{T_1}\right) - R\ln\left(\frac{P_2}{P_1}\right)}$ constant Volum.

* **Entropy Analysis** :- The entropy of the system can change due to three reasons

① Mass interaction } external interaction
② Heat interaction }
③ Entropy Generation } Internal

→ **Entropy Generation** :- It is a major of the magnitude of the irreversibility present during the process $(\delta S)_{gen}$

Total entropy $\boxed{ds = \left(\frac{\delta Q}{T}\right) + (\delta S)_{gen}}$

Adiabatic process :- $\delta Q = 0$ $\quad (\delta S) = +ve$

Isolated system (Universal) $\quad \Delta S = \frac{\delta Q}{T}^{=0} + (\delta S)_{gene}$

$(dS)_{univ} \geq 0$

reversible $= 0$ $\quad$ irreve $dS > 0$

① An adiabatic Vessel contain 2kg of water 25°C. By paddle wheel work transferr, the temp of water is incressed to 30°C. If the specific heat of work 4.187 KJ/kg K find the entropy change of univers

:) $m = 2kg$.

$T_1 = 25 + 273 = 298K$ $\quad T_2 = 30 + 273 = 303K$

$ds = \left(\frac{dQ}{T}\right)^{=0} + (\delta S)_{universe}$

$(\Delta S)_{univ} = (\Delta S)_{system} + (\Delta S)_{surro.}$

$(\Delta S)_{surro.} = 0$

$1\ bar = 10^5\ Pascal$

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$$(\Delta S)_{system} = \int_I^F m c \frac{dT}{T}$$

$$= \int_{298}^{303} 2 \times 4.187 \frac{dT}{T}$$

$$= 2 \times 4.187 \times \ln\left(\frac{T_2}{T_1}\right) = 0.139$$