13-Sept (2)

{SIL}

$\boxed{\text{1MERC3}}$

L T P → A block (205)
3 1 1 = 5C

→ Eng. Thermod (PK. Nag) (1)
→ (4) → (3)
→ (2) →

A Choudhary

THERMODYNAMICS

Thermodynamics is the ~~facilitating~~ fascinating branch of sc dealing with energy transfer, and its effects on the state or cond. (condition) of a system.

It relates the ~~system~~ chge which undergoes energy interconversion into form of heat and work
↳ transformation

mechanical en ⇄ Heat en. (James Watt

→ Applications in field of Heat & work { Energy Dev.

→ Power producing devices → ① I.C. engines { car, bikes, me
↳ int. combust.
→ ② Gas turbines { steam & nuclear PP
→ ③ Water turbines

→ Power Consuming Devices → fans, blowers, compressors, pumps, and RAC plants

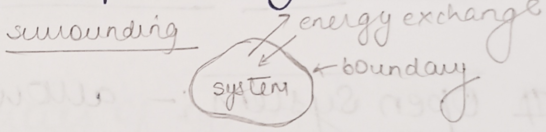
→ Direct energy conversion devices → solar panels,

→ Laws of thermodynamics   20 sept (3)

Thermodynamics systems

→ A system is said to be t.s., prescribed ~~as~~ region or space of finite quantity of matter surrounded by an envelope which is known as boundary.

→ system can be any mix^T of gases, piston-cylinder ass., etc.



Surrounding

→ The matter & space external to the system, that may be influenced by the changes in the system.

Boundary

→ The system and surr. are ~~surrounded~~ separated by an envelope ....

→ it represents limit of system

→ can be real or

→ can change volm, position, orientation and size relative to the observer.

→ can be diathermic and/or adiabatic

→ walls & bound. which d.n. allow energy exc. in form of heat ⇒ adiabetic (work can be transferred)

→ ~~diane~~ diathermic ⇒ allow heat transfer

System + Surr = Universe

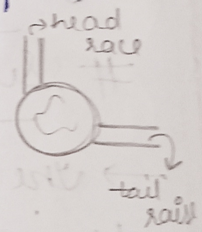
Closed System :- does not allow ↳ mass transfer

within the boundary of system remains constant and same and only energy, heat and work can be exchanged with its surroundings.

→ physical nature & chemical composition can be changed of mass within the system.

→ eg: piston-cylinder assembly, gas/vapour within a soun bomb-calorimeter, pressure cooker, RAC plants

Open System :- allows mass, energy and heat exchange



→ eg: water/turbine wheel, gas/steam turbine, steam/nuclear powerplants, steam generator/boiler.

Isolated system :- neither mass nor energy exchanged
↳ doesn't exist (ideal)

Adiabetic System :- walls/boundaries which do not alow heat transfer to take place across them.

→ but can exchange energy in form of work.

→ When in a series of state changes such that the final state is identical with the initial state. this it is called a thermodynamic cycle.

point functions : depends not on path, but the end points

Intensive & Extensive Properties

(i) Does not depend on mass, it's value remains const. throughout the system ⇒ Intensive ($P = P_1 = P_2 = P_3$)

eg: P, T, viscosity, elec. potential, thermal cond.

(ii) Extensive ⇒ depends on mass of system

eg: energy, enthalpy, volume, etc. ($P = P_1 + P_2 + P_3$)

Equilibrium

~~AA~~ Thermodynamic Equilibrium

→ system is said to be in t.eq when there is no change in any macroscopic property is registered or observed if the system is isolated from its surroundings.

→ In the absence of any unbalanced force within the sys. & also the sys & surr ⇒ mechanical equib.

→ chemical equib ⇒ no chemical rxn & or transfer of matter from one part of system to another.

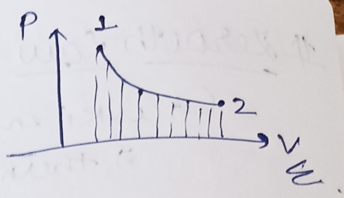
→ Thermal equib ⇒ when a system exists in both mechanical + ~~thermal~~ chemical equib. if separated from its surroundings by a ~~the~~ diathermic wall, no spontaneous change in properties of system ⇒ it

$\therefore dW = F \times dx$

$\Rightarrow dW = (P \cdot A)\, dx$

$\Rightarrow dW = P \times dV$

$\therefore \int_1^2 dW = \int_1^2 P \times dV$



$$\Rightarrow \boxed{W_{1-2} = \int_1^2 P\,dV}$$

{system must be in t. eq. b/w states 1 & 2}

does not depend on end condition.

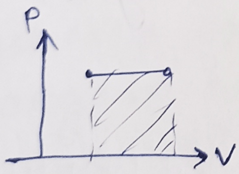
☆☆ $W_{1-2} = {}_1W_2 \neq W_2 - W_1$!

→ $dW \Rightarrow$ inexact / imperfect differential

→ $dV =$ exact / perfect

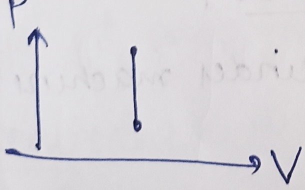
PdV work-processes :-

① const. pressure process (Isobaric)



$$W_{12} = \int_1^2 P\,dV = P(V_2 - V_1)$$

② const. vol^m process (Isochoric)

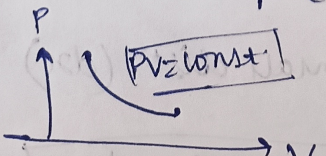


$$W_{12} = 0$$

③ const. temp (Isothermal)

$\because P_1V_1 = P_2V_2$

$\Rightarrow P = \dfrac{P_1V_1}{V}$



$$W = \int \frac{P_1V_1}{V}\, dV$$

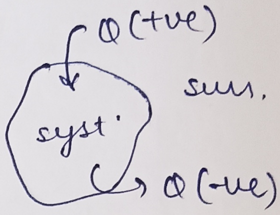
$$= \boxed{P_1V_1 \ln\left(\frac{V_2}{V_1}\right)}$$

27 Sept

Heat : defined as energy associated with random motion of atoms and molecules.

→ dirⁿ of heat transfer

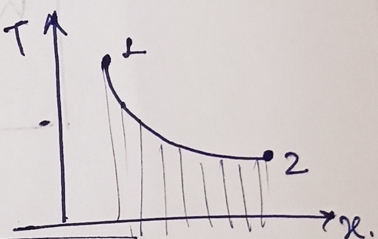
Heat Transfer v/s Work Transfer
↳ due to temp. difference



Three modes of Heat transfer

① conduction : when two bodies in direct contact
② convection : b/w wall & fluid system in motion
eg
↳ empty space
b/w two bodies thru E.M. waves ⇒ radiation ③

Heat transfer ⇒ path funcⁿ



Just like W.T.,
heat T can be written as,

$$\boxed{Q = \int_1^2 T\,dx}$$

$$\boxed{Q_{1-2} = \int_1^2 T x\, dx}$$ → pdt of intensive T and

$$dQ = T \cdot dx$$

$$\boxed{dx = \frac{dQ}{T}}$$

$$\boxed{\oint dW = \oint dQ}$$

∴ Energy cannot be created or destroyed, only conver[ted]

∴ Heat and work are mutually convertible.

∴ When a sys. undergoes thermodynamic cycle, the net heat supplied to system from its sur[roundings]

= net work done by the system on its surroundings.

∴ First Law ⇒ Total Energy of an isolated sys in all its forms remains const.

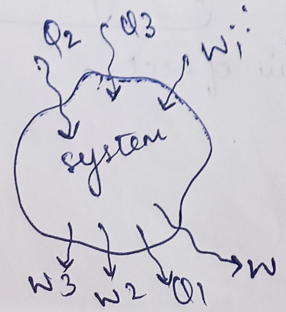
⇒ No machine can produce energy w/o corresponding expenditure of energy.

Energy stored → A property of system

⇒ algebraic sum of all energy transfer across system boundaries is zero,

but if a system undergoes a change of state during/ b/w which heat transfer and work transfer are involved,

then the net energy transfer will be stored or accumulated within the system



$(Q-W)$ - will be stored

↪ internal energy of the system

∴ $\boxed{(Q-W) = \Delta E}$ → increase in energy of system

→ due to moment of molecules

Internal energy :-

→ body has potentialenergy and kinetic energy,

→ matter of a body is composed of molecules, these molecules move continuously and randomly.

→ matter possesses internal kinetic energy due to motion of molecules and internal potential energy due to relative position of their molecules.

→ sum of these two energies is known as internal energy.

∴ Total Stored Energy of substance/mass/body : $T = U + E_K + E_P$

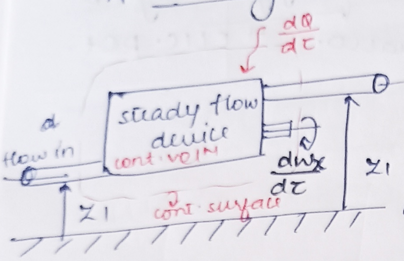
$\downarrow$ total internal

⇒ Total $E = \underbrace{U}_{\text{micro energy}} + \underbrace{KE + PE + \text{chem}E + \text{elec}E + \text{Mg}E + \text{Poten}}_{\text{macro energies}}$

$$\therefore \quad E = U + \frac{1}{2}mv^2 + \rho gh +$$

Steady flow ⇒ rate of flow of mass and energy across the controlled surface are const.

→ steady state process {steady flow energy eqⁿ (SFEE)}



→ A_1, A_2 ⇒ cross section of stream (m^2)

→ w_1, w_2 ⇒ mass flow rate (kg/s) ↳ $dm/d\tau$

→ p_1, p_2 ⇒ absolute pressure (N/m^2)

→ v_1, v_2 ⇒ specific volm (m^3/kg)

→ u_1, u_2 ⇒ specific internal energy (J/kg)

→ C_1, C_2 ⇒ inlet & outlet velocity (m/s)

→ Z_1, Z_2 ⇒ height above an arbitrary datum (m)

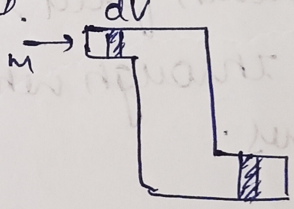
→ $\frac{dQ}{d\tau}$ ⇒ net rate of heat transfer (J/s)

→ $\frac{dW_x}{d\tau}$ ⇒ net rate of work transfer (J/s)

→ τ ⇒ time in seconds

Mass Balance: eqⁿ of continuity

⇒ mass of rate inside the controlled volm is equal to mass flow rate outside.



⇒ $w_1 = w_2 = w_3$

→ $dW_{flow} = P \cdot dV$

$= P \cdot v\, dm$ $\quad \{dV = v\, dm$ ↳ specific volm

⇒ mass flow rate ⇒ $\boxed{\frac{A_1 C_1}{v_1} = \frac{A_2 C_2}{v_2} = w}$

→ $dW_{2flow} = P_2 V_2 dm_2$

$\because h = u + PV$

$$\therefore \boxed{w_1\left[h_1 + \frac{c_1^2}{2} + z_1 g\right] + \frac{dQ}{d\tau} = w_2\left[h_2 + \frac{c_2^2}{2} + z_2 g\right] + \frac{dw_x}{d\tau}}$$

steady flow energy eqⁿ per unit time

$$\because \boxed{w_1 = w_2 = w}$$

$$\Rightarrow w\left[\quad\right] + \frac{dQ}{d\tau} = w\left[\quad\right] + \frac{dw_x}{d\tau}$$

$$\Rightarrow \left[\quad\right] + \frac{dQ}{w\,d\tau} = \left[\quad\right] + \frac{dw_x}{w\,d\tau}$$

$$\because \boxed{w = \frac{dm}{d\tau}}$$

$$\Rightarrow \boxed{\left[\quad\right] + \overbrace{\frac{dQ}{dm}}^{Q} = \left[\quad\right] + \overbrace{\frac{dw_x}{dm}}^{W}}$$

SFEE per unit mass.

$$\Rightarrow \boxed{Q - W = (h_2 - h_1) + \left(\frac{c_2^2 - c_1^2}{2}\right) + g(z_2 - z_1)}$$

<u>applications</u>: pipeline flow, all heat transfer processes, all mech. power gen. process in engines, turbines, combustion proc., flow through nozzles, diffusers, etc.

$\because$ pipe velocities are often small $\Rightarrow C_1 \simeq C_2 \simeq 0$

$$\boxed{h_1 = h_2}$$

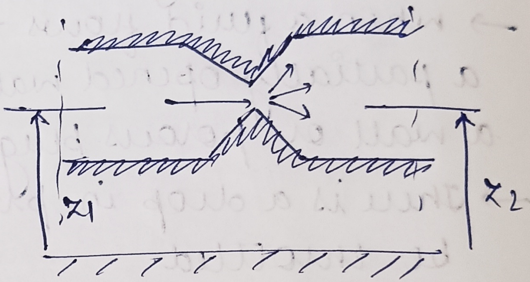
↳ for any throttling device

enthalpy before throttling $\Rightarrow$ enthalpy afterwards

Nozzles and Diffusers :-

→ Nozzle is a device which increases velocity or the KE of a fluid at the expense of its pressure drop.

→ SFEE for nozzles :-



→ insulated $\Rightarrow \frac{dQ}{dm} = 0$

→ no shaft $\Rightarrow \frac{dw}{dm} = 0$

→ $z_1 = z_2$

$$\Rightarrow \boxed{h_1 + \frac{C_1^2}{2} = h_2 + \frac{C_2^2}{2}}$$

→ $C_1 <<<< C_2 \Rightarrow C_1 \simeq 0$

$$\Rightarrow \boxed{h_1 = h_2 + \frac{C_2^2}{2}}$$

$$\Rightarrow \boxed{C_2 = \sqrt{2(h_1 - h_2)} \text{ m/s}}$$

→ Application: airplane / jet propulsions

→ Diffuser is a device which increases the pressure of of a fluid at the expense of its kinetic energy.