

Sum  
Piston cyl.  
(without valve)

First Law of Thermodynamics

① For closed system undergoing a Thermodynamic Cycle

- \* The change in a thermodynamic property of a system will be zero

- \* Initial & Final states are same

② 1<sup>st</sup> law for a process.

[When a system undergoes a thermodynamic cycle then the net heat supplied to the system from the surrounding is equal to net work done by the system on its surrounding]

1<sup>st</sup> Law of Thermo. for a closed system undergoing a cycle

$T_1$  = Initial Temp. of Hg.

[ $T_1 = T_{atm}$  (Atm temp.)]

Heat and Work are mutually convertible but since energy can neither be created nor destroyed.  
"Energy Conversion Remains Constant"

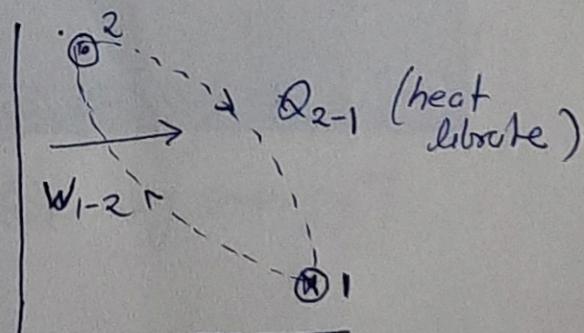
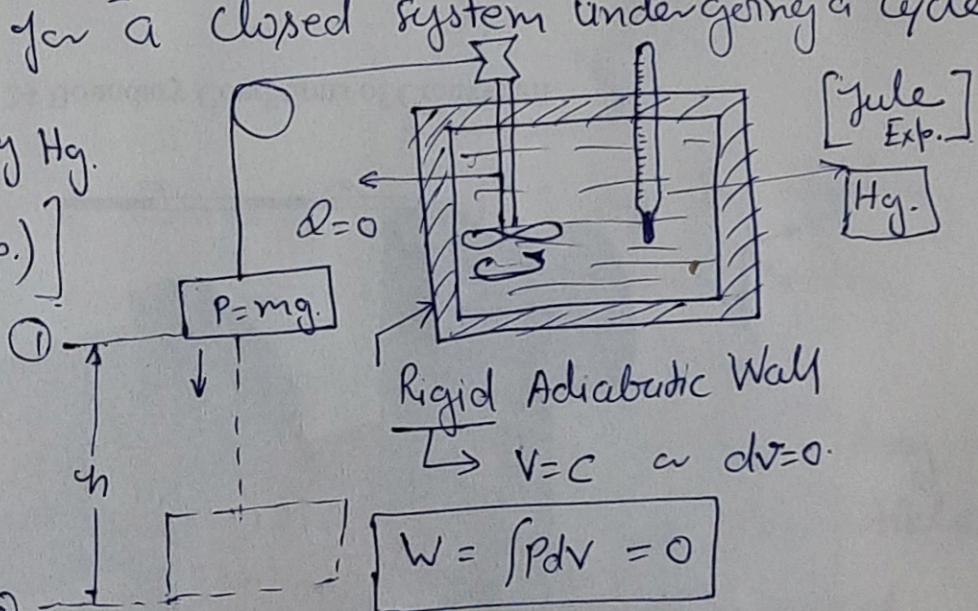
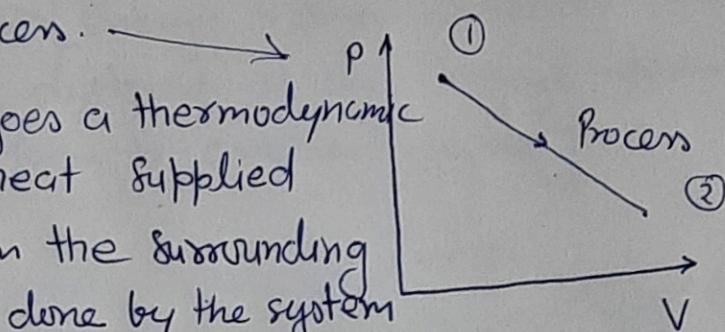
$$W = mgh.$$

$$W = T \cdot Q \quad (\text{Shift Work})$$

$$W = TQ = mgh$$

$$\text{Final Temp} = T_2$$

$$T_2 > T_1$$



Stirring work is very much spontaneous so it will not find a equilibrium intermediate stages. So the process will be non reversible]

$$W_{1-2} \propto Q_{2-1}$$

[NOTE - irreversible work denoted by dotted line]

$$\sum W \propto \sum Q$$

$$\sum W = J \sum Q$$

[ $J$  = Joule equivalent or mechanical equivalent of heat]

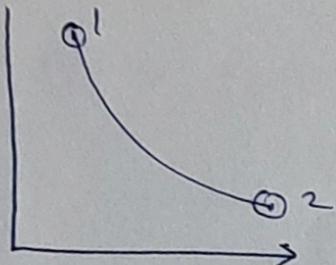
$$\sum W = \sum Q$$

$$\left[ J = 1 \frac{\text{N}\cdot\text{m}}{\text{J}} \right]$$

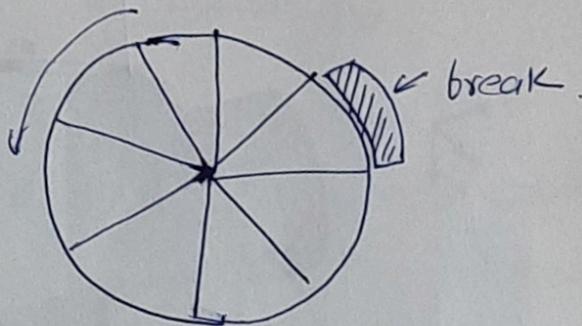
$$W_{\text{net}} = Q_{\text{net}}$$

$$\oint dW = \oint dQ$$

$\rightarrow$  [Energy neither created nor destroyed it can change from one form to another form]



Exp - 2



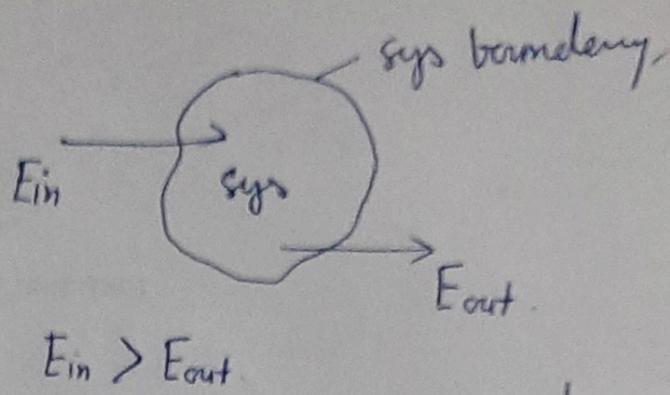
When a high speed rotating wheel stopped by applying a break then break get heated means work transferred into heat. but When a heated break put on the wheel then wheel not moving. It concluded that work can be completely convertible into heat but heat can't be completely converted into work so work is a high grade energy and heat is a low grade energy.

[heat is a more distributed form of energy]

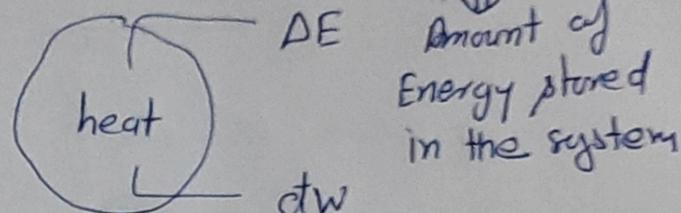
## Energy balance

$$Q_{1-2} = W_{2-1} + \Delta E$$

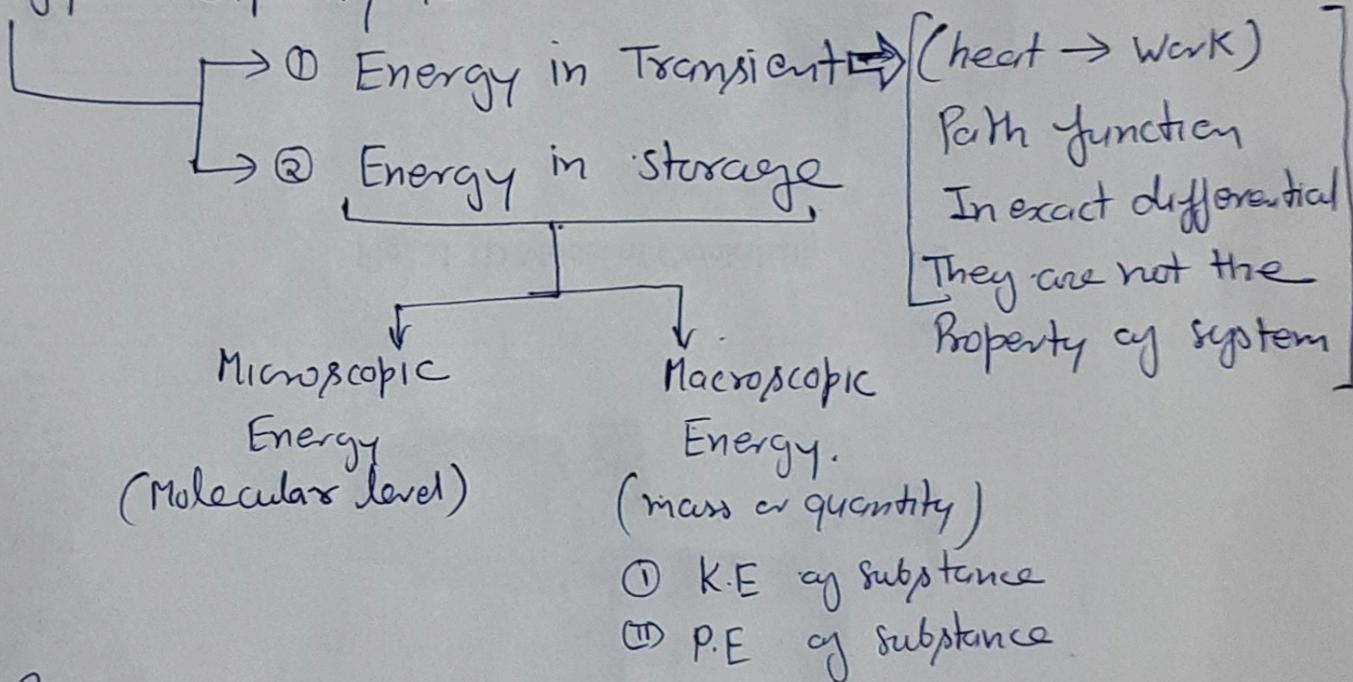
↳ Total Energy  
 of the system  
 ↳ [Property]



$$E_{in} - E_{out} = \boxed{\Delta E}$$



Energy  $\rightarrow$  Capacity to do Work



$$Q_{1-2} = W_{1-2} + \Delta E$$

↳ microscopic  
 ↳ Internal  
 Energy.

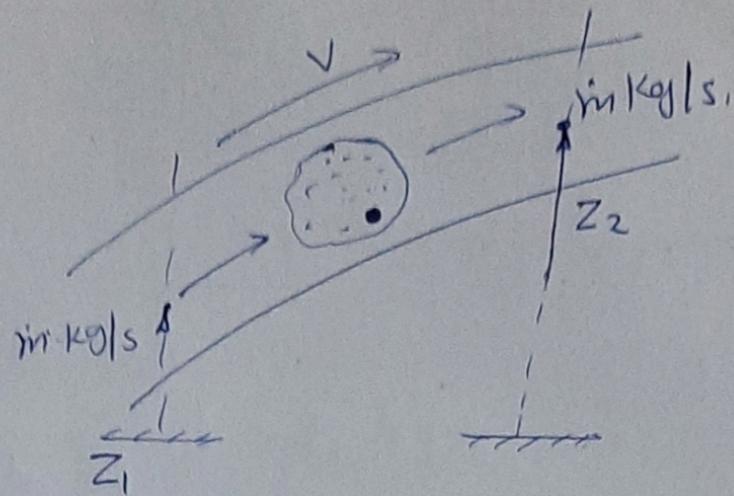
Total Energy  
of system

$$\boxed{E = E_k + E_p + U}$$

Total energy of  
substance at molecular  
level.

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

$$\Delta PE = mg(z_2 - z_1)$$



If at any instant we neglect the K.E & PE  
then

$$\boxed{\Delta E = \Delta U}$$

So

$$Q_{1-2} = W_{2-1} + \Delta E$$

in differential form

$$\boxed{dQ = dE + dW}$$

$$\begin{aligned} E &= E_{\text{translational}} + E_{\text{rotational}} \\ &+ E_{\text{chem}} + E_{\text{electron}} + E_{\text{nucleon}}. \end{aligned}$$

→ This eqn is valid for  
Open as well as Closed system

For a closed system [no mass interaction]

$$\boxed{\Delta E = \Delta U} \rightarrow \text{will be valid.}$$

[Total energy of a system equal to internal energy  
of a system]

Internal Energy of a substance

$$\boxed{U = \epsilon \cdot N} \text{ no. of molecules.}$$

$$dQ = dE + dw$$

True for open system &  
closed systems /  
rev. as well as irreversible  
processes

For closed system

$$dQ = du + dw$$

[but  $E$  is the Property of system]  $dt$  = inexact differential  
(because  $Q$  &  $w$  is a  
Path function & not a  
Property of system)

### Energy as Property of the system

$$Q_A = \Delta E_A + W_A$$

$$Q_B = \Delta E_B + W_B$$

$$\sum W = \sum Q$$

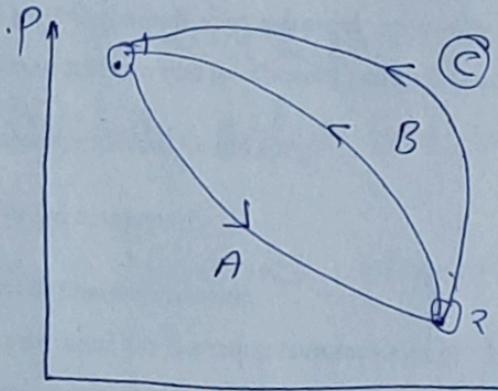
$$W_A + W_B = Q_A + Q_B$$

$$Q_A - W_A = W_B - Q_B$$

$$\begin{cases} \Delta E_A = Q_A - W_A \\ \Delta E_B = Q_B - W_B \end{cases}$$

$$\Delta E_A = -\Delta E_B \quad \text{--- (1)}$$

$$Q_C = \Delta E_C + W_C$$



now for Path C

$$\sum W = \sum Q.$$

$$W_A + W_C = Q_A + Q_C$$

$$W_C - Q_C = Q_A - W_A$$

$$W_C - Q_C = -\Delta E_A$$

$$-\Delta E_C = \Delta E_A \quad \text{--- (2)}$$

$$\begin{array}{|c|} \hline \Delta E_A = \Delta E_B = \Delta E_C \\ \hline \end{array}$$

From eqn (1) & (2)

$$+\Delta E_B = \Delta E_C \Rightarrow \boxed{\Delta E_B = \Delta E_C}$$

The change in total Energy for each Path is same so it indicates that the stored energy is Point Function not a path function. The stored energy is a Point Function.

So For closed system

$$dW = dW_{pdv} + dW_{shaft} + dW_{elect} \dots$$

If all other types of work like mech. elect etc are neglected then

$$\boxed{dW = dW_{pdv}}$$

$$\boxed{dQ = du + Pdv}$$

I<sup>st</sup> law -

For Closed system

Involving only Pdv Work.

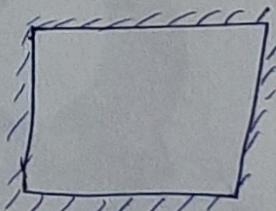
Now Case - I

For a system whose Volume remain const.

$$\boxed{V=c}$$

$$dV = 0$$

$$dQ = du + 0.$$



[If there is no work other than Pdv work].

~~du~~

$$\boxed{Q_{1-2} = \Delta U}$$

↳ [Heat transfer is equal to Change in Internal Energy for an Isochoric Process.]

## Specific Internal Energy

$U/\text{kg}$  of substance =  $u \cdot \text{KJ/kg}$  or  $J/\text{kg}$ .

$$Q_{1-2} = \Delta U$$

KJ/kg or J/kg

NOTE - Specific Property  
denoted by small letter  
like 'U' Internal Energy  
as 'u' - specific Internal  
Energy ]

## Specific Heat at Const. Volume

Heat required to cause unit change in temp.  
in a unit quantity of substance at const. Volume

$$C_V$$

$$dQ = dU$$

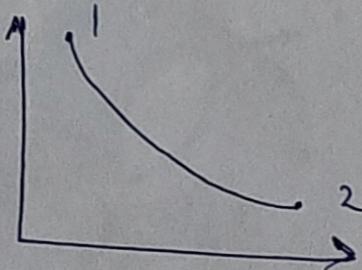
change in sp. internal Energy.

$$C_V = \left( \frac{dQ}{dT} \right)_V$$

$$\text{Sp. heat at } C_V = \left( \frac{dU}{dT} \right)_V \quad \text{For const Volume}$$

const volume.  $\frac{du}{dt} = C_V dT$

$$\int_1^2 du = \int_1^2 C_V dT$$



$$U_2 - U_1 = C_V (T_2 - T_1)$$

$$\Delta U = C_V \Delta T$$

For m kg of mass

$$\Delta U = m C_V \Delta T$$

$$Q = \Delta U \quad \text{For Isochoric process}$$

so for Isochoric Process  
heat transfer is

$$Q_{1-2} = m C_V \Delta T$$