1st Law of Thermodynamics

Ist Law For a Closed System:

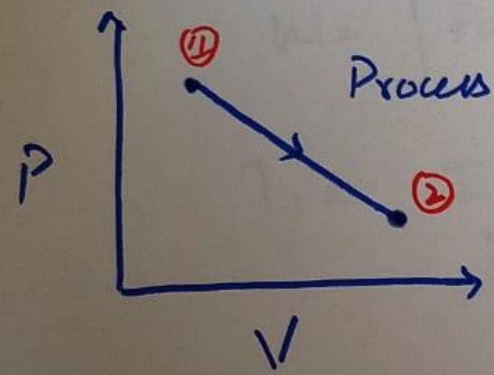
Examples: Sun, Piston Cylinder arrangement without valves

Thermodynamic Cycle:

=> Set of processes so arranged that initial and final state are the same points

-> The change in a thermodynamic property is zero in a thermodynamic cycle

=> Initial and Final state are same.

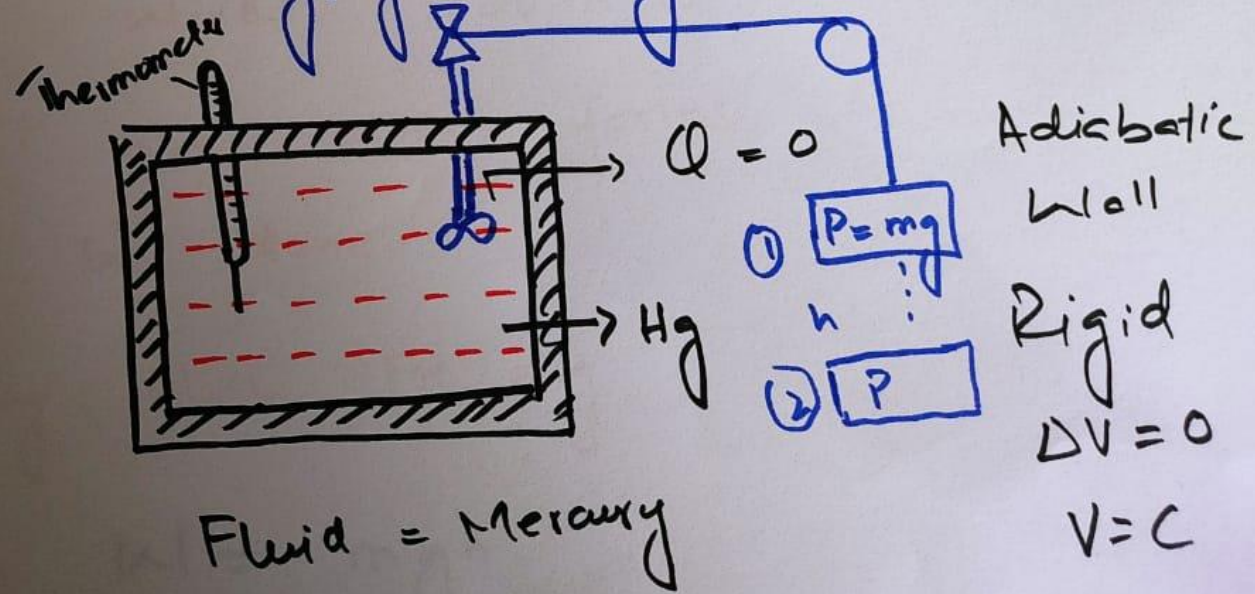


Thermodynamic Process

I st Law For a Closed System undergoing a cycle

Joule's Experiment

Conservation of Energy Proof



$W = \int P dV = 0$

$T_1 =$ Initial temperature of Hg

$T_1 = T_{atm}$ (atmospheric temperature)

Displacement work $\int P dV = 0$

But there are other forms of work that can be done

Stirring work For e.g

$W = mgh$

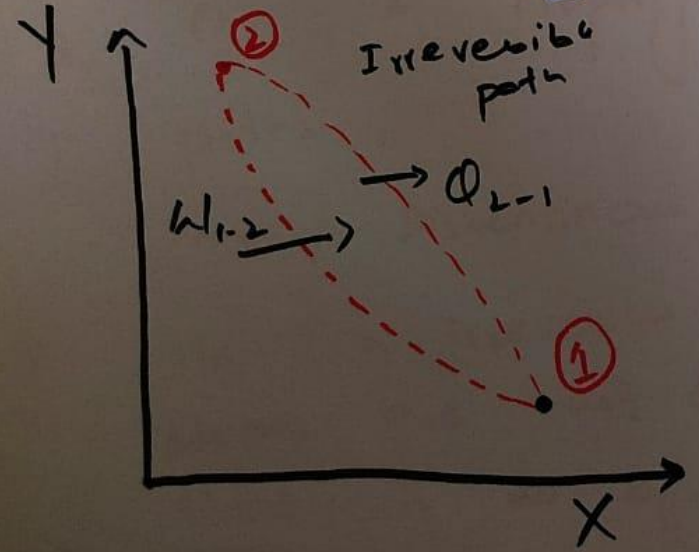
Shaft work $|W| = \tau\theta$

$$|W| = mgh = \tau\theta$$

Work done on the system

Final temperature $= T_2$

$T_2 > T_1$



Mechanical work gave rise in K.E of the system which in turn has increased the temperature of the system. (4

Remember:

=> Stirring Work is a rapid / spontaneous process.

=> That is why b/w Final and initial states are not in equilibrium.

=> Intermediate states are not in equilibrium

=> Irreversible Process

=> On a Property Diagram Irreversible paths are represented in dotted lines / Discontinous lines

=> In a irreversible process intermediate states are not easily determined because there is no equilibrium.

Joule did this experiment with different setups. By using fluids, Mechanical work setups, Electric work setups.

He found out the amount of work he puts into a system it is recieved back in the amount of heat. Irrespective of process either reversible & irreversible.

$W_{1-2} \propto Q_{2-1}$ ✓

$Q_{1-2} \propto W_{2-1}$ (Not exact amount)

The concept of high grade energy & low grade energy was devised.

$$\Sigma |W| \propto \Sigma Q$$

$$\oint d|W| = \oint dQ$$

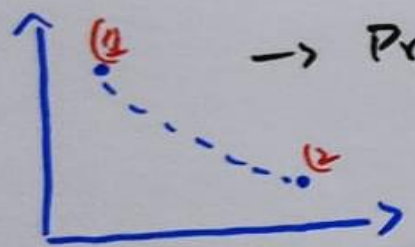
$|W|_{net} = Q_{net}$ In a cycle.

$$\boxed{\oint d|W| = \oint dQ}$$

Only valid for a cycle

First law of thermodynamics for a closed system undergoing a process.

$$\oint dW = \oint dQ \rightarrow \text{Cycle}$$

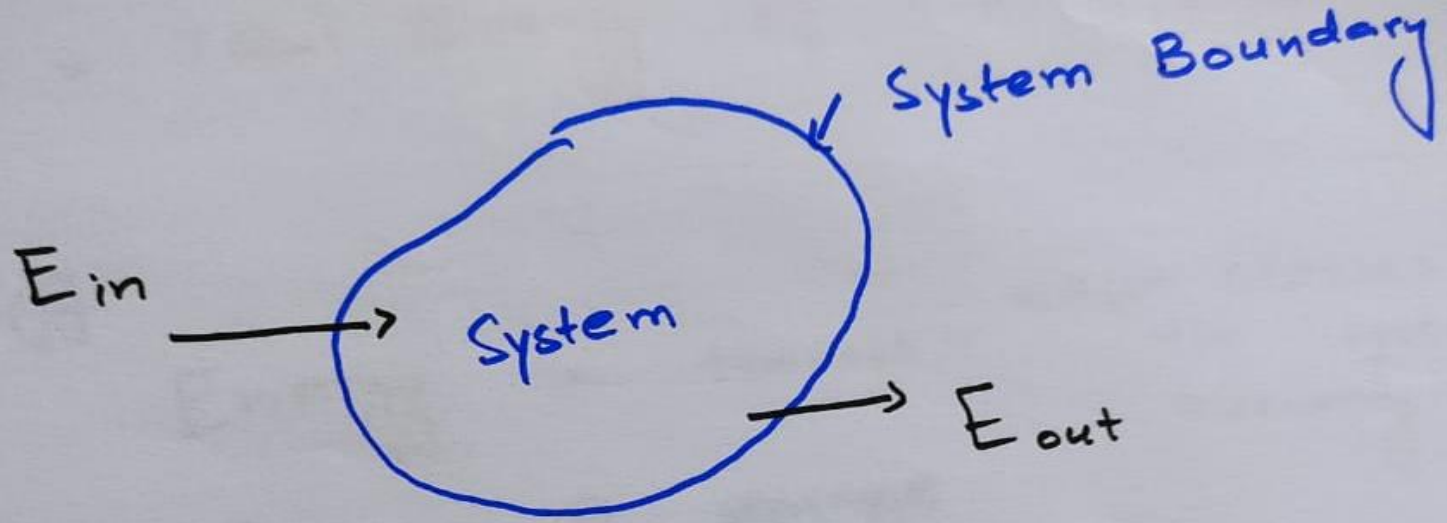


→ Process → change of state

By Joule's Experiment : Conclusion

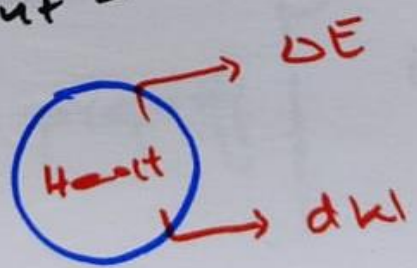
Work can be completely converted to heat, but heat cannot be completely converted to work.

Energy Balance



$E_{in} > E_{out}$?

$E_{in} - E_{out} = \Delta E$ ← Stored Energy



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

ΔE = Total Energy of the system : Property

Energy :

Energy in transit → which crosses the system's boundary

Energy of storage

→ Path Function
→ Inexact Differential
→ They are not property of system

} Energies in transit

Heat

Work

Stored Energy

Microscopic Energy

(Energy at molecular level)

Macroscopic

(K.E of substance
P.E of substance)

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

ΔE → Microscopic, Macroscopic

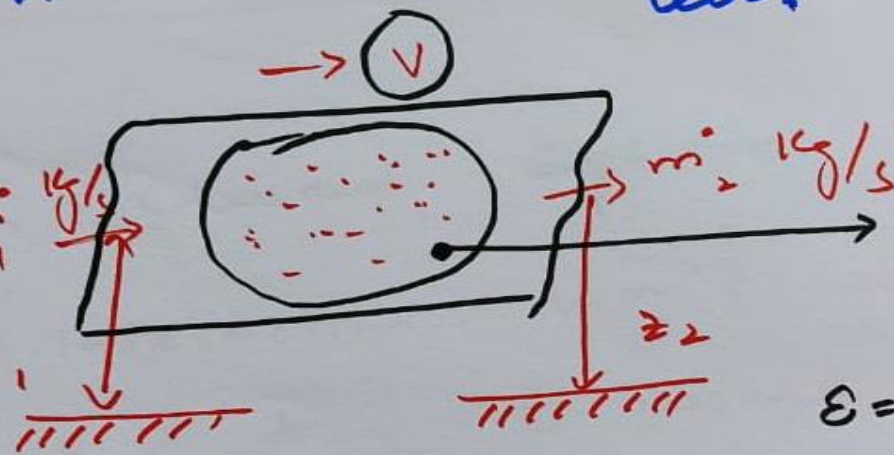
Microscopic → Internal Energy

★ K.E exist in both in microscopic stored energies as well as macroscopic stored energies.

$$E = E_k + E_p + U$$

→ Total Energy of substance at molecular level

Total Energy of system



$K.E = \frac{1}{2} m v^2$

$P.E = mg(z_2 - z_1)$

ε = Energy of one molecule

$\varepsilon = \varepsilon_{tran} + \varepsilon_{rot} + \varepsilon_{chem} + \varepsilon_{electron} + \varepsilon_{nuclear}$

if system's P.E & K.E are neglected

$$\Delta E = \Delta U$$

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

In differential form

Process $\boxed{dQ = dE + dW}$ → This equation is valid for open as well as closed system.

For a closed system

Mass interaction won't exist

So K.E & P.E would be zero

So :- $\Rightarrow \Delta E = \Delta U$

$$\boxed{dQ = \Delta U + dW}$$

For a closed system

if there are "N" number of molecules

$$U = N\varepsilon$$

Internal energy of the substance

so $$dQ = dU + dW$$ → Open & Closed ✓ system

↳ Reversible as well as Irreversible process

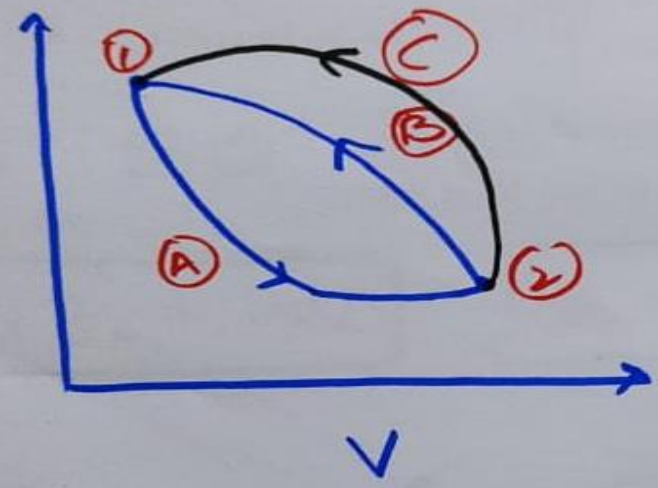
$$dQ = dU + dW$$ → For a closed system

U (For an Ideal gas)

Internal Energy of an Ideal gas

$$U = f(T)$$

Energy as property of system



A & B

$$Q_A = \Delta E_A + W_A \Rightarrow Q_A - W_A = \Delta E_A$$

$$Q_B = \Delta E_B + W_B \quad \Sigma W = \Sigma Q$$

$$Q_B - W_B = \Delta E_B (=$$

$$W_A + W_B = Q_A + Q_B \qquad Q_A - W_A = W_B - Q_B$$

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

Process C is involved :17

A & C

$$\Sigma W = \Sigma Q$$

$$\boxed{Q_C = \Delta E_C + W_C} \qquad \boxed{Q_C - W_C = \Delta E_C}$$

$$W_A + W_C = Q_A + Q_C$$

$$W_A - Q_A = Q_C - W_C$$

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

(1) & (2)

$$\boxed{+\Delta E_B = +\Delta E_C} \quad -(3)$$

$$\Delta E_A = \Delta E_B = \Delta E_L$$

it means whatever the path followed b/w state ① & ②.

Change in total energy is emig out to be same.

Stored Energy = $E_K + E_P + U$

A point function

Exact Differential

That's why it is the property of a system.

For a closed system

$$dQ = dU + dW$$

it can be a sum of all type of works.

$$dW = dW_{PdV} + dW_{shaft} + dW_{electric}$$

$$dW = dW_{PdV}$$

if all other types of work are neglected i.e. mechanical or electrical work.

$$\boxed{dQ = dU + PdV}$$

Differential form of 1st law for a closed system involving only PdV word.

For an Isochoric Process

1st Law analysis

$$dQ = dU + P\cancel{dV}^{=0} \qquad V = C$$

$$\boxed{1\ dQ = dU}$$

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

Heat transfer is equal to change in internal energy for an isochoric process.

∴

Specific Internal Energy

Internal energy of 1 kg of substance

U/kg of substance

u → Sp. Internal Energy

unit J/kg

$Q_{1-2} = \Delta u$ kJ/kg or J/kg (Isochoric Process)

Specific Heat at Constant Volume : C_v

Heat required to cause unit change in temperature in a unit quantity of substance at constant volume.

$C_p > C_v$

For constant volume process

$dQ = \Delta u$ change in specific Internal energy

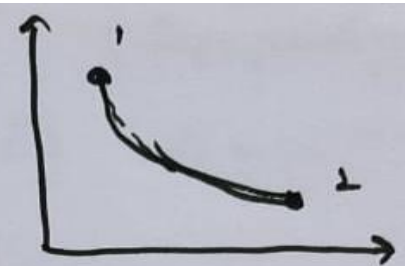
$C_v = \left(\frac{dQ}{\Delta T}\right)_v$ Heat required to cause a unit change in temperature.

$\left(C_v = \frac{du}{dT}\right)_v$

$$dU = C_v dT$$

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

$$\boxed{\Delta u = C_v \Delta T}$$



Specific Internal Energy

For m kg of mass

$$\boxed{\Delta U = m C_v \Delta T}$$

$$\therefore \boxed{Q = \Delta U}$$

$$\boxed{Q = m C_v \Delta T}$$

For an Isochoric process the formula for heat transfer

ENTHALPY "H" (Property of a system)

Total Heat content of a system at a particular state.

Unit KJ, J

For one kg of matter

Specific Enthalpy "h" J/kg, KJ/kg

$$H = U + PV$$ → Flow Work

For 1kg & substance

$$h = u + Pv$$ → Flow Work Per kg

Heat transfer for an Isobaric process

For a closed system

$$dQ = dU + dW$$

$dW = dW_{PdV} + dW_{mech} + dW_{elec} \cdots$

if no work other than PdV work

$$dQ = du + Pdv$$

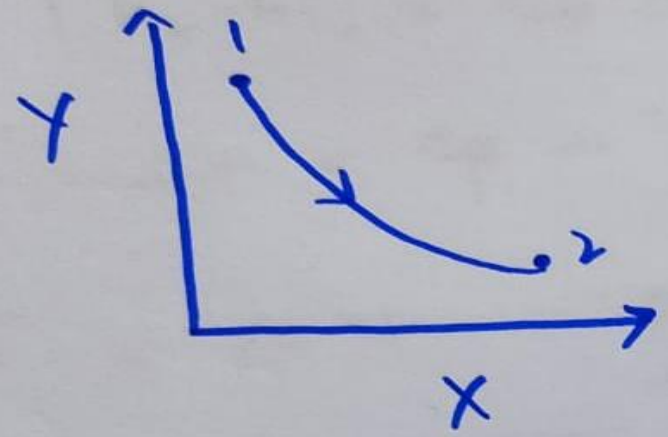
Isobaric Process $P = c$

$$dQ = du + d(Pv)$$

$$dQ = d(u + Pv)$$

$$\boxed{dQ = dh}$$

For one kg of substance undergoing a isobaric process in a closed system.



$Q_{12} = \Delta h$

Heat transfer is equal to change in enthalpy for an isobaric process in a closed system

Specific heat at constant pressure : c_p

Heat required to cause a unit change in temperature for a unit quantity of substance through a constant pressure process.

$$c_p = \left(\frac{dQ}{dT}\right)_p \rightarrow \text{J/kg}$$

$$c_p = \left(\frac{dh}{dT}\right)_p$$

$$dh = c_p dT$$

$$\int_1^2 dh = \int c_p dT \quad (24$$

$$(h_2 - h_1) = c_p \Delta T$$

$$\Delta h = c_p \Delta T$$

$$\boxed{\Delta H = m c_p \Delta T}$$

$$\delta Q = \Delta H$$

For a closed system undergoing a constant pressure process.

$$\boxed{\delta Q = \dot{m} c_p \Delta T}$$

Heat transfer formulas :-

Isobaric Process $\quad \boxed{Q = m c_p \Delta T}$

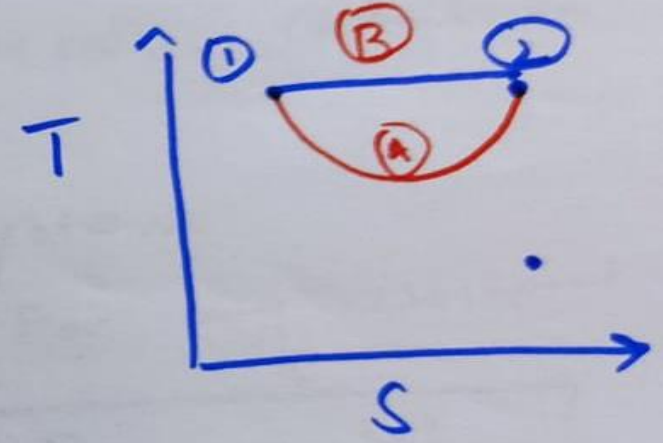
Isochoric Process $\quad \boxed{Q = m c_v \Delta T}$

Isothermal Process :-

$$\boxed{T = C}$$

For an Ideal gas

$\boxed{PV = C}$ → Hyperbolic equation/ relationship



B is isothermal

A is not isothermal path

$PV = C$

→ For ideal gas this relation only represents an Isothermal process.

→ But for pure substances or real gases this $PV = C$ is a hyperbolic relation.

$$Q_{12} = \Delta U + W_{12}$$ closed system

$$\Delta U = m c_v \Delta T$$

$T = C$

$\Delta T = 0$

$\Delta U = 0$

For any isothermal process

Hence, $$Q_{12} = W_{1-2}$$

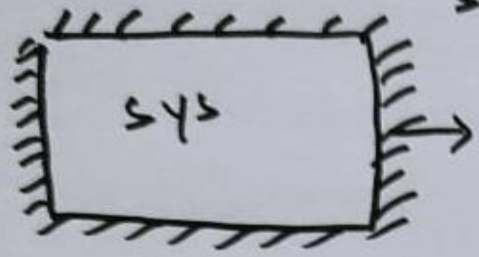
$$W_{1-2} = P_1 V_1 \ln V_2/V_1 = Q_{1-2}$$

or $P_1 V_2 \ln P_1/P_2$

Same formula

(2

Adiabatic Process



$$Q_{1-2} = \Delta U + |W|_{1\to 2}$$

$$Q_{1\to 2} = 0 \qquad \text{Adiabatic}$$

$$0 = \Delta U + |W|_{1-2}$$

$$\boxed{\Delta U = -|W|_{1-2}}$$

In an adiabatic process if work transfer is taking place it will change the internal energy of the system only.

$$|W|_{1-2} = \frac{P_1V_1 - P_2V_2}{\gamma - 1}$$

$$\gamma = C_P/C_V$$