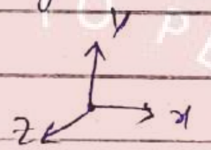
Ch # 1:

Thermodyanamics

Degree of freedom:

No of independent ways on which particle can move.

* Translatory degree of freedom:
  * Three ways motion



* Rotational degree of freedom:
  * Two ways motion
    * clockwise
    * Anti-clockwise

Heat →
- Caloric theory → heat is weightless, invisible small particle
- Mechanical theory → heat is a mechanical work

New Lee

Fun. Heat

→ state change → temp change → expansion

* So heat is the form of energy.

OR

* The total K.E of a molecule of a system is called heat

* Heat produces motion.

$H \propto W$ $\boxed{H = JW}$

J → mechanical equivalent of heat

$$\boxed{J = \frac{H}{W}}$$

1st Law of Thermodynamics

It gives the mathematical relation b/w heat, U & Work

$$\Delta q = \Delta U + \Delta W$$

$$\boxed{\Delta Q = \Delta U + P\Delta V}$$

Small, change, Small

Inferences from 1^{st} law of T.D:

* 1^{st} time related heat energy with other form of energy.
* It is law of conservation of (heat) energy.
* "U" is state function.
* The definition of heat as energy in transmit.

⇓

Thermal (heat) energy can be converted into mechanical work.

* For a cyclic process

$$\boxed{\Delta U = 0} \quad (U_i = U_f)$$

Limitation:

* It doesnot indicate the direction of heat

⇓

1^{st} law doesnot indicate why the heat can't flow a cold body to hot body

* It doesnot tells anything about the condition under which heat can be transformed into work.

⇓

Feasibility of process / spontaneity

* 1^{st} Law of T.D doesnot indicate as to why all work convert into heat & all heat cannot to work
⇓
100% efficient engine

* All natural spontaneous process are irreversible.

(7) Application

a) Isothermal process:

T = constant ⇒ $\Delta T = 0$

U = constant ⇒ $\Delta U = 0$

Q, P, V ⟶ variable

* Conducting wall / Diathermic wall

* According to 1^{st} law of T.D

Isothermal expansion
⇓
$\boxed{\Delta Q = \Delta W}$

Isothermal Compression
⇓
$\boxed{-\Delta Q = -\Delta W}$

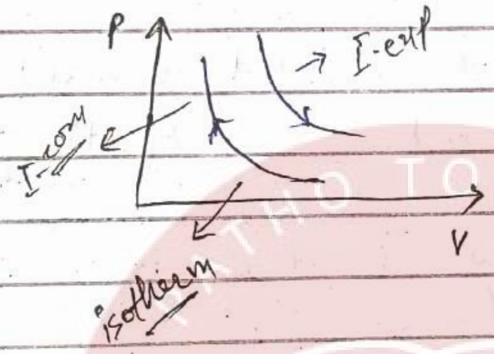
* equation of Isothermal process

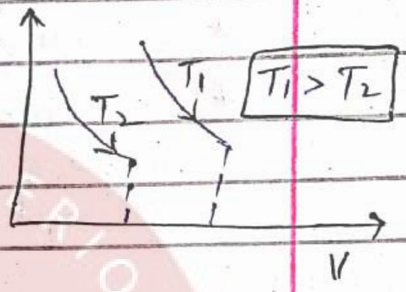
$\boxed{P_1V_1 = P_2V_2}$
⇓
Boyle's Law

* **W. done in Isothermal process:**

$$\boxed{W = nRT \frac{\log V_2}{\log V_1}} \Rightarrow (W \propto T)$$

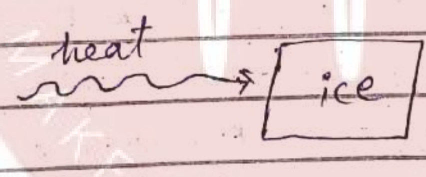
Graph of Isothermal process:





examples:

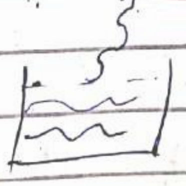
a): Latent heat of fusion → solid — liquid



(melting)

T = constant

b): Latent heat of ~~evo~~ vaporization:



(Boiling)

(T = constant)

New Lec

(d) Adiabatic Process:

*: $\Delta Q = 0$ => No heat enter nor lost => heat content are kept constant.

* P, V, T → variable

* quick process (Rapid change)

* Non-conducting wall (adiabatic wall)

1st Law of T.D

A. expansion ($\Delta Q = 0$)

⇓

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

⇓

*work is done at cost of Internal energy

* System used its own I.E for work.

I.E = ↓

T = ↓

* cooling

A. compression

⇓

$\boxed{-\Delta W = \Delta U}$

⇓

* w.done is converted into I.E.

I.E ↑

T ↑

* heating is produced

* Equation of Adiabatic process

$PV^{\gamma} = const$

$\boxed{P_1V_1^{\gamma} = P_2V_2^{\gamma}}$

⇓

poisson's equation

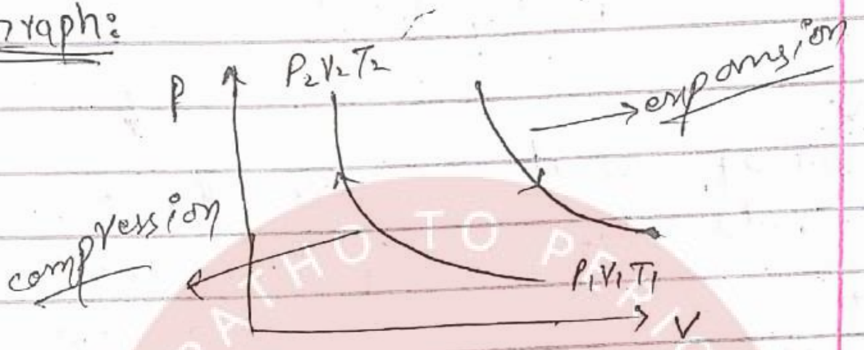
$P \propto \frac{1}{V^{\gamma}}$

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

(*) **Wk done in A process:**

$$\boxed{W = nR(T_1 - T_2)} \qquad \omega \propto T_1 - T_2$$

Graph:



* Graph of A process is called Adiabat. Adiabat is hyperbola in shape.

* Adiabat is steeper than isotherm

MCQs:

The ratio of slope of adiabatic to isothermal graph is.

(a) $1 : \gamma$ (b) $\gamma : 1$ (c) $\sqrt{\gamma} : 1$ (d) $1 : \sqrt{\gamma}$

* isothermal process slope $= P/V$ $\quad \frac{P}{V\gamma} \times \frac{\gamma}{P}$

* Adiabatic process slope $= P/V\gamma$

e.g

* Rapid escape of air from a burst tyre.

* The rapid expansion & compression of air through which sound waves is passing

* ~~seta~~ clouds formation in atmosphere

② Isochoric process or Isometric process

* Volume = Constant
* Q, P, T, = variable

$$\boxed{\Delta Q = \Delta U + \cancel{\Delta W}^{\,0}}$$

Conversion of heat energy into I.E of system

⇓

P ↑
T ↑
U ↑

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

Removal of heat & equivalent decrease in the I.E

⇓

P ↓
T ↓
U ↓

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

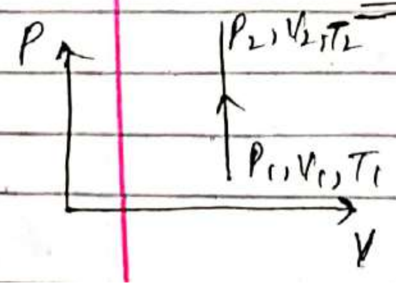
* Its indicator is temp
* $\boxed{P \propto T}$ $\frac{P}{T}$ = constant

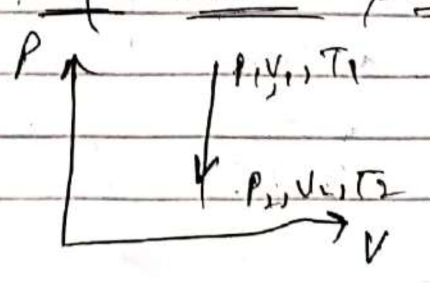
$$\boxed{\frac{P_1}{T_1} = \frac{P_2}{T_2}}$$

e.g

pressure cooker is the example of isochoric process

Graph of isochoric process





(4) Isobaric Process:

* P= constant
* V, T, ΔQ = variable
* In isobaric process, heat is divided into two parts. Some energy is used in W.done & rest of the heat energy is changed of temperature.

$$\Delta Q = \Delta U + \Delta W$$

$$(\Delta Q = \Delta U + \underbrace{P}_{\text{constant}}\Delta V)$$

equation:

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

W.done:

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

(5) Isolated process:

$$\Delta Q = 0$$

$$\Delta W = 0$$

$$\Delta U = 0$$

New lec

Heat Capacity

Amount of heat required to raise the temp of substances by 1°C or 1F.

Heat capacity of an obj | Specific heat of a material | Molar specific heat

heat required to raise the temper by 1°C.

Specific heat → Mass " "
Specific heat → Molar spe " "

a) Mass specific heat:

$\Delta Q \propto m$

$\Delta Q \propto \Delta T$

$\Delta Q \propto m \Delta T \qquad \Delta Q = C m \Delta T$

$\boxed{C = \frac{\Delta Q}{\Delta T m}}$ or $\boxed{C = S/m}$ $\therefore S = \frac{\Delta Q}{\Delta T}$

b): Molar specific heat:

$\Delta Q \propto n$

$\Delta Q \propto \Delta T$

$\Delta Q \propto n\Delta T$ or

$\Delta Q = Cn\Delta T$ $\boxed{C = \frac{\Delta Q}{n\Delta T}}$ $\boxed{C = S/n}$

Molar Specific heat Capacity

isobaric — Molar specific heat at const pressure

isochoric — Molar specific heat at const volume

$C_p = \frac{\Delta Q_p}{n\Delta T}$

$\boxed{C_p = \frac{W + \Delta U}{n\Delta T}}$

$C_v = \frac{\Delta Q_v}{n\Delta T} = \boxed{\frac{\Delta U}{n\Delta T}}$

$Q_p > Q_v$ or $C_p > C_v$

$Q_p = W + \Delta U$

$Q_p = W + Q_v \Rightarrow \boxed{W = Q_p - Q_v}$

$\boxed{C_p - C_v = R}$ $\boxed{\gamma = \frac{C_p}{C_v}}$ $\left(\gamma = 1 + \frac{2}{f}\right)$

(3) Isothermal process:

$T =$ const

$\Delta T = 0$

$C = \frac{\Delta Q}{n \times 0}$

$\boxed{C = \infty}$

(4) Adiabatic process

$Q =$ const

$\Delta Q = 0$

$C = \frac{\Delta Q}{n\Delta T}$

$C = \frac{0}{n\Delta T}$

$\boxed{C = 0}$

Gas	C_p	f	C_v	γ
* Monoatomic	$\frac{5}{2}R$	3	$\frac{3}{2}R$	$\frac{5}{3}=1.67$
* Diatomic	$\frac{7}{2}R$	5	$\frac{5}{2}R$	$\frac{7}{5}=1.4$
* polyatomic	$\frac{9}{2}R$	6 or 7	$\frac{7}{2}R$	$\frac{9}{7}=1.29$

Mayer's Relation

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

MCQs: $\frac{R}{C_p} = \frac{\gamma - 1}{\gamma}$ $\qquad \frac{C_p}{\gamma} = \frac{R}{\gamma - 1}$

$\frac{R}{C_p} = \left(\frac{\gamma-1}{\gamma}\right)$

MCQs: $\frac{R}{C_v} = \gamma - 1$

Note:

* $C_p - C_v = R$ $\qquad \gamma = \frac{C_p}{C_v} \Rightarrow C_v = \frac{C_p}{\gamma}$

$\gamma C_v - C_v = R$

$C_v(\gamma - 1) = R$ imp

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

$C_p - C_v = R$

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

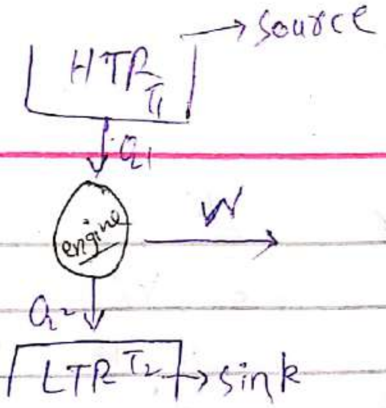
$C_p\left(1 - \frac{1}{\gamma}\right) = R$

imp

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

Heat engine

convert heat energy to mechanical energy



$$Q_1 = W + Q_2$$

$$\boxed{W = Q_1 - Q_2}$$

$$\eta = \frac{\text{output}}{\text{input}} \times 100\% \qquad \eta = \frac{W}{Q_1} \times 100$$

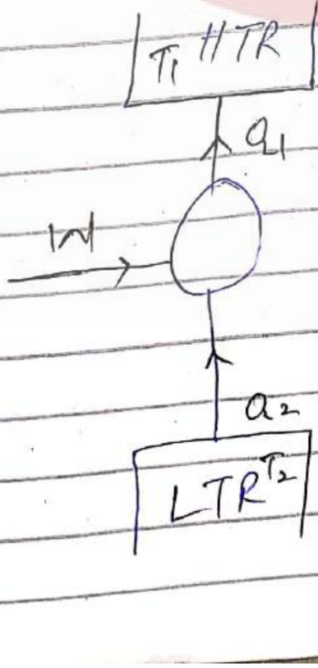
$$\eta = \frac{Q_1 - Q_2}{Q_1} \times 100$$

$$\eta = \frac{\cancel{Q_1}}{\cancel{Q_1}} - \frac{Q_2}{Q_1} \times 100$$

if $\boxed{Q_2 \uparrow \quad \eta \downarrow}$ ← $\boxed{\eta = 1 - \frac{Q_2}{Q_1} \times 100}$ → if $\boxed{Q_1 \uparrow \quad \eta \uparrow}$

MQ: if $Q_2 = 0$ then $\eta = 1$ or 100%
⇓
No sink

Refrigerator / Reverse heat engine / Heat pump



(*) For Cooling:

Roo = LTR

Surroun = HTR

~~For heating~~

$\eta = \frac{output}{input}$ $\eta = \frac{Q_2}{W}$ $\boxed{\eta = \frac{Q_2}{Q_1 - Q_2}}$

$\boxed{\eta = \frac{Q_2}{T_1 - T_2}}$

(*) For heating

Room = HTR

Surr = LTR

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

Carnot Engine

* Ideal engine
* can't be constructed practically
* Most efficient heat engine
* Sadi Carnot
* η - depend upon tempera of → Source (HTR), → Sink (LTR)

* independant of Nature of working substances.

* W. substances = ideal gas

* Cycle → 2 isothermal process, → 2 adiabatic process

* $\eta = 1 - \frac{T_2}{T_1}$ or $\eta = \left(1 - \frac{T_2}{T_1}\right) \times 100\%$

or

$\eta = \left(1 - \frac{Q_2}{Q_1}\right) \times 100\%$

$\eta = \frac{T_1 - T_2}{T_1}$ $\eta = \frac{\Delta T}{T_1}$

* $\boxed{\frac{Q_1}{Q_2} = \frac{T_1}{T_2}}$ → carnot theorm,

MCQs: if $T_2 = 0$

then $\boxed{\eta = 100\%}$

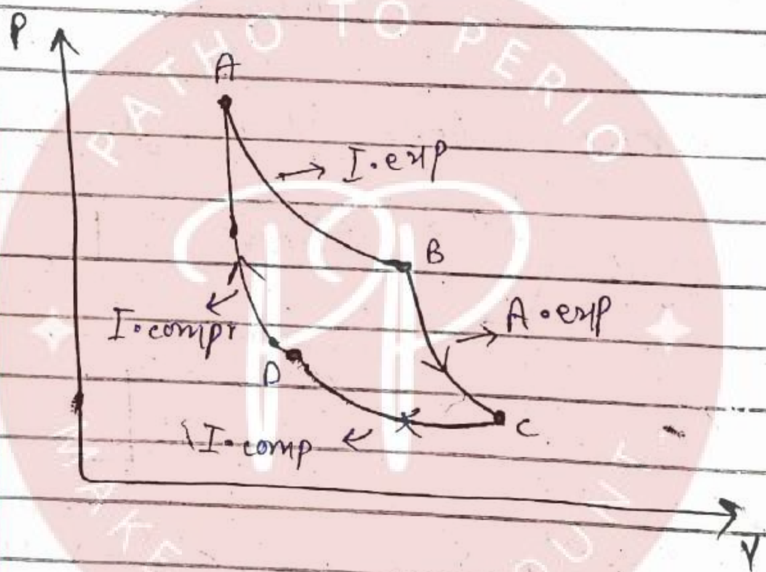
isothe exp
Adi ~~exp~~ exp
adia ~~exp~~ comp
adi comp

if $\frac{T}{273.16} = \frac{Q_{21}}{Q_{23}}$

$$\boxed{T = 273.16 \frac{Q_{21}}{Q_{23}}}$$

→ HTR
→ LTR

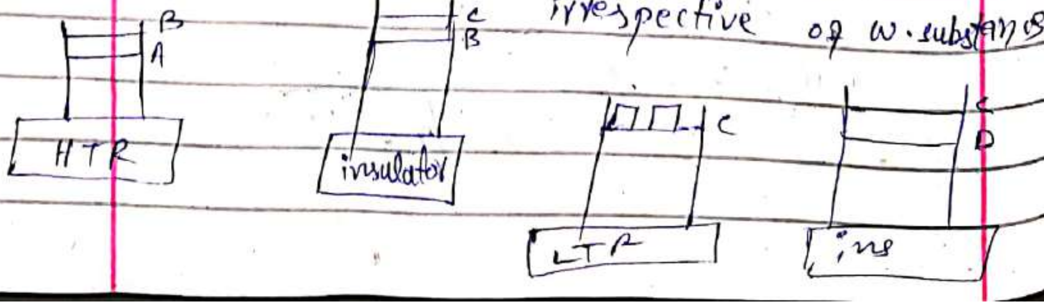
273.16 → Triple point of water = 0°C
→ at which three states of H_2O exist.



Carnot theorm

No engine can be more efficient than carnot engine.

All C. engine working b/w same temp have same η irrespective of w.substance



MCQs

(isotherl)

(+) During Carnot cycle, heat is given to the system, its temperature must ______.

a) ↑ b) ↓ (c) Same d) None

(+) During Carnot cycle, heat is given out from the system, its temper must ______.

a) ↑ b) ↓ (c) Same d) None

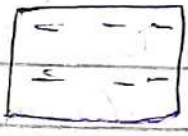
T change ← (adiabatic)

(+) During Carnot heat, no heat is provided or taken out of the system, then temp of system must be ______.

a) ↑ b) ↓ (c) may rise or fall d) None

Entropy

Statistical entropy → always ↑	Thermal entropy
The measure of randomness (disorderness) is called statistical entropy.	The unavailibility of useful thermal energy is called Thermal entropy.
$\boxed{S = K \ln W}$	$\boxed{\Delta S = \frac{\Delta Q}{\Delta t}}$
K = Boltzman const	S → is a state variable (~~II Law T.D~~)
W = probability of order/disorder	J/K



$W = 1$

$S = k \ln 1 \Rightarrow S = k(0)$ $\boxed{S=0}$

$* \; W \neq 1$

$* \; S \neq 1$

Entropy

- For a System
- At body level
- At engine

For a System:

a): For a process as $\Delta Q = 0$

so $\Delta Q = 0$

$S =$ const

$\boxed{\Delta S = 0}$

b): For all reversible process

$\Delta S = 0$

c): For all irreversible process

$\Delta S \neq 0$

$\Delta S \neq +ve$ $\quad S = \Uparrow$

d): ΔS for universe is always +ve.

$\Delta S \geq 0$ → $\Delta S = 0$ (Reverse)

$\Delta S \geq 0$ → $\Delta S > 0$ (irreversie)

At body level:

a): Hot body — Reject heat

* $S\downarrow$ * $\Delta S = -ve$ * $\Delta S_1 = -\frac{Q}{T_1}$

b): At cold body (LTR):

* $S\uparrow$ * $\Delta S = +ve$ * $\Delta S = +\frac{Q}{T_2}$

New lec

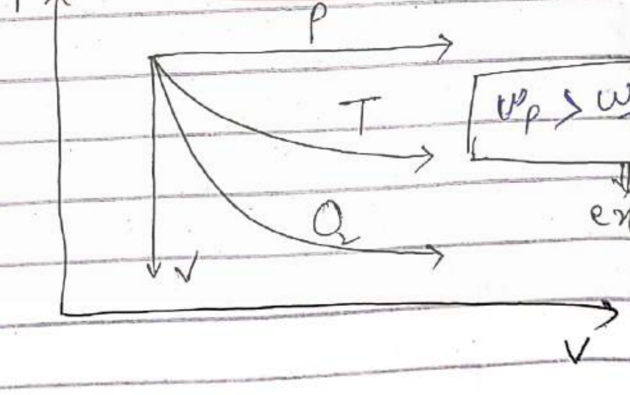
At engine level:

$\Delta S = +ve$, $S\uparrow$

$\Delta S = \Delta S_2 + \Delta S_1$

$$\boxed{\Delta S = \frac{Q}{T_2} - \frac{Q}{T_1}}$$

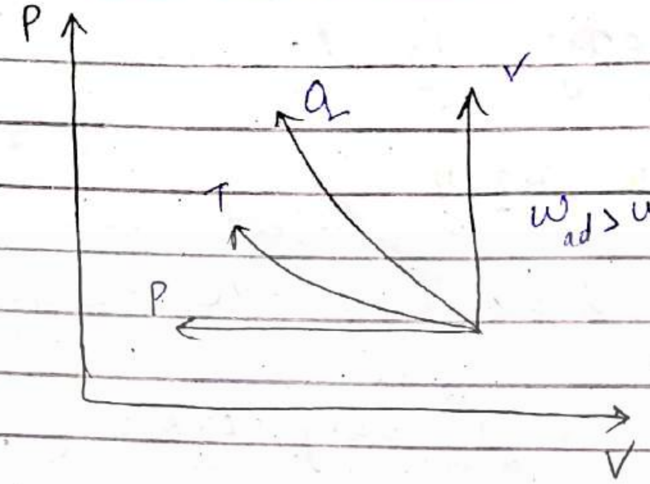
$\Delta S = +ve\ (T_1 > T_2)$



$\boxed{W_P > W_T > W_Q > W_V}$

⇓

expansion



$W_{ad} > W_{isoth} > W_T > W_P$

Zeroth Law:

gives definition of Temperature