GATE 2024

प्रचण्ड Batch

HMT

MODES OF HEAT TRANSFER

TIME- 4:30PM

YOGESH SIR

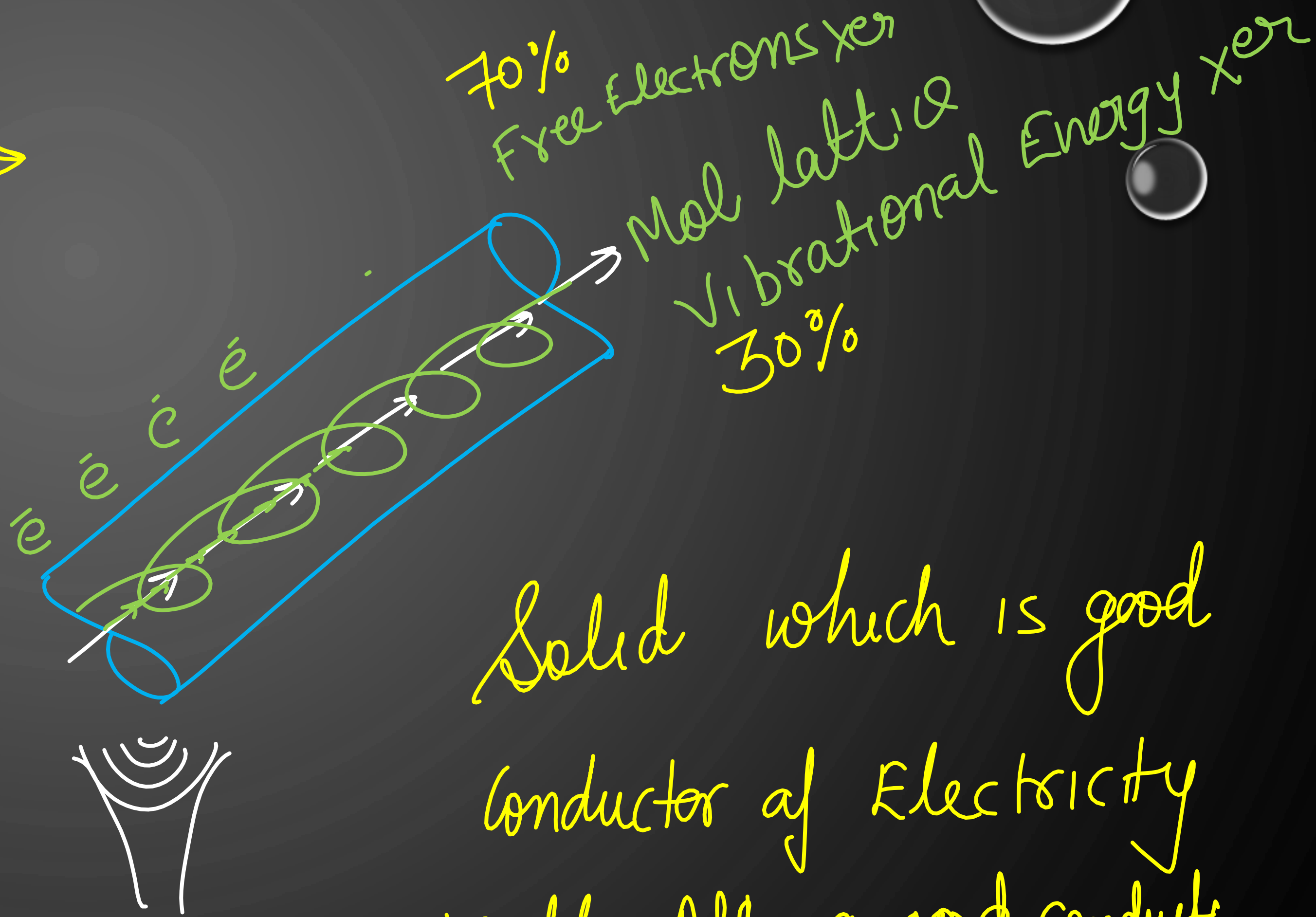
Modes of Heat xer :→

① Conduction

② Convection

③ Radiation

Conduction :→



$K_{Diamond} = 2300 \frac{W}{m\text{-}K}$

Solid which is good conductor of Electricity well Also a good conductor of Heat

Exception → Diamond

Conduction

30/

Mol lattice Vibrational Energy xer

↓

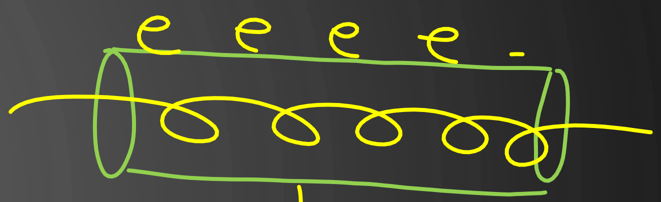
Phononic Conduction

70%

Free Electrons xer

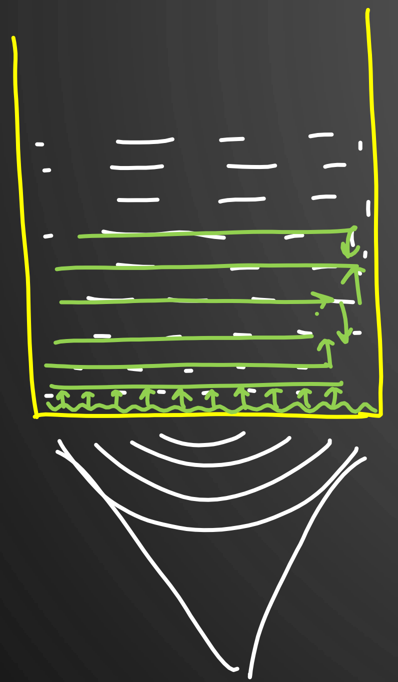
↓

Electronic Conduction



→ Conduction is a Microscopic Phenomenon

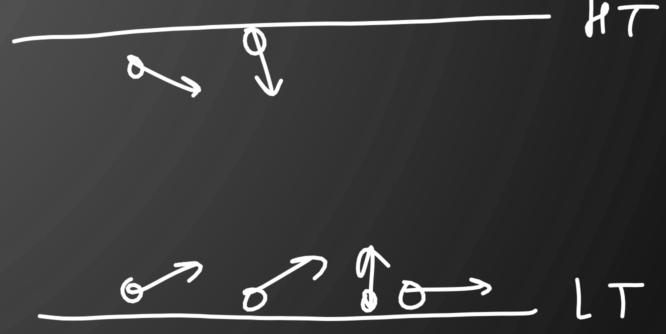
Conduction in Liquids :→



Condⁿ Also Occurs in liquids When high Velocity high temp Molecule Comes in contact with Low Vel, Low temp Mol

They exchanges their heat & this Phenomenon is known as Condⁿ in Liquids.

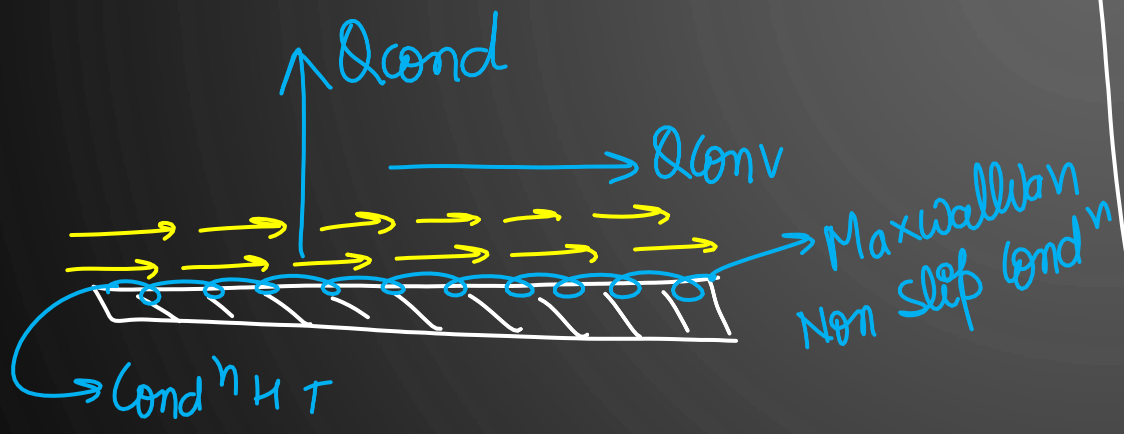
****

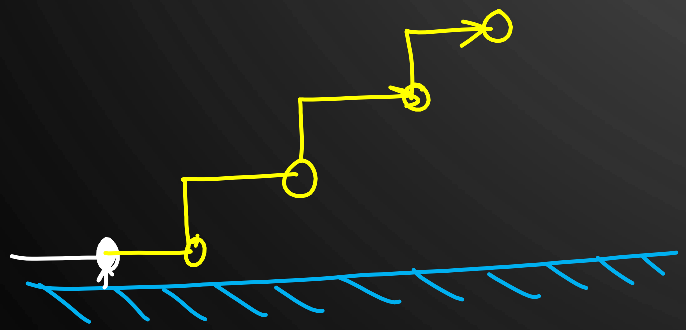


High Vel & High Temp Mol called with Low Vel Low temp Mol

→ Conduction in GASSES.

Convection:→





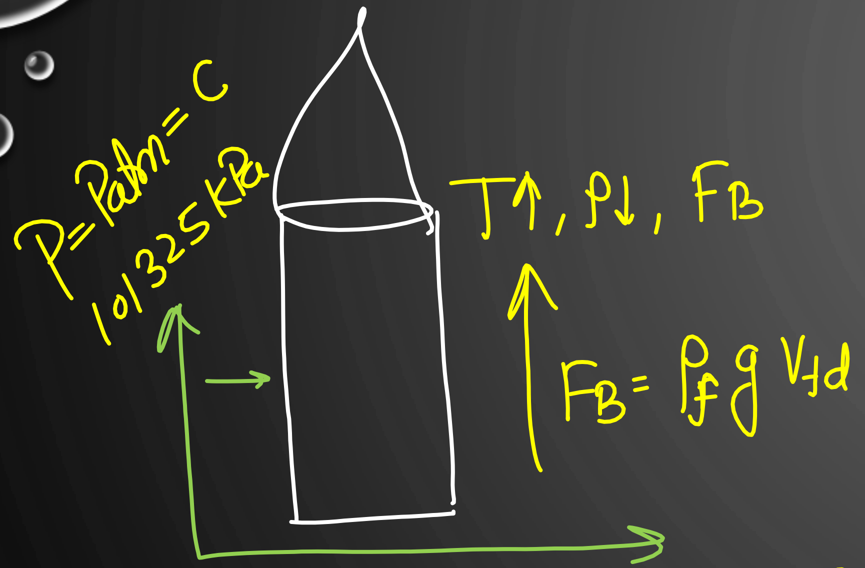
In Convection HT, HT by Condⁿ is Transported by fluid (flowing)

* Convection is a Transport Phenomenon.

Convection
- → Natural Convection (Free convection)
- → Forced Convection

If the Flow takes place Naturally due density Density Diffrence i e due to

Buoyancy Forces arising by change In density



$$PV = mRT$$

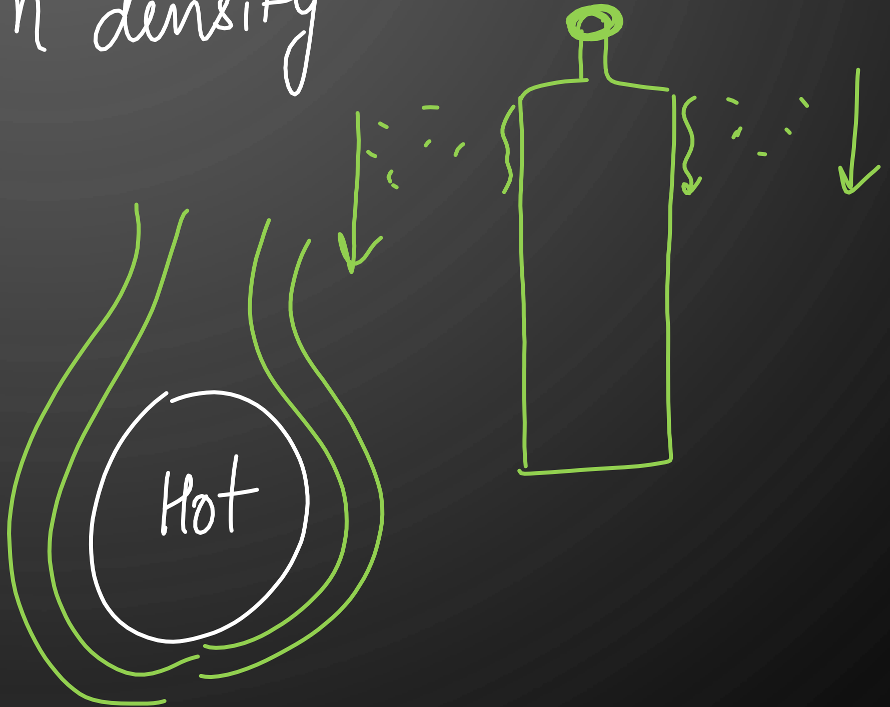
$$P = \frac{m}{V} RT$$

$$P = \rho RT$$

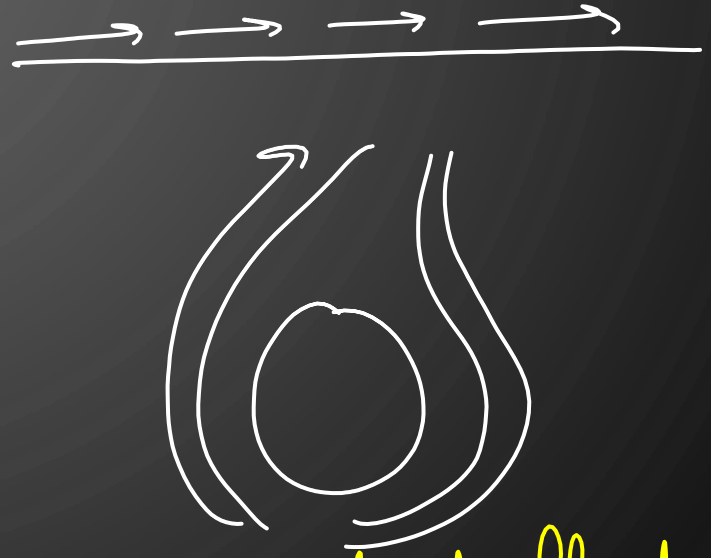
$$\rho \propto \frac{1}{T}$$

$T\uparrow, \rho\downarrow$

$T\downarrow, \rho\uparrow$



When Convection H T Takes place with the help of Some external Agent i.e forcefully then it is known as forced $Conv^n$.



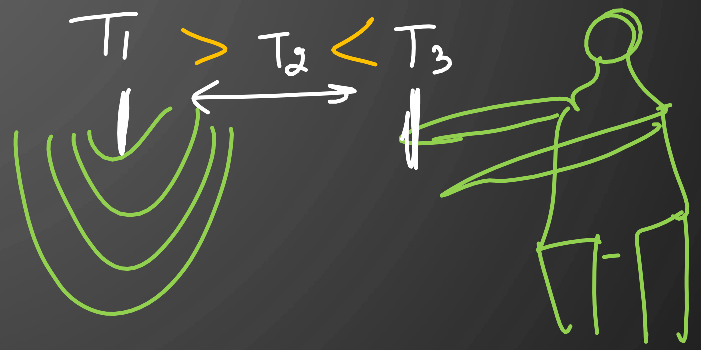
Bulk Displacement of fluids Particle

→ Macroscopic phenomenon

Radiation :→

Radiation is the Mode of HT which do not require Any Material Medium, and hence Radiation Heat Transfer take place with the help of EMT, wave Propagation, which Travel with the speed of light.

Radiation HT Dominates over Conduction & Convection When temp diff is very high



All bodies at All temperatures emit thermal Radiation except the body is a 0 K

at 0K → Mol Become Motionless

Steady State Conduction-1

4:30 PM

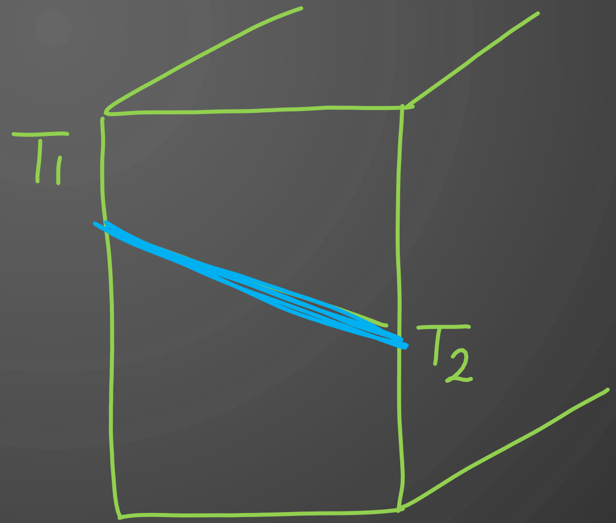
<u>Note</u>:→ Liquids are better conducter of heat as compare to gasses

K_{water} = ~~0.69~~ 0.61 to 0.69 W/m-k

K_{Air} = 0.023 W/m-k

Governing Law for Cond^n is Fourier Law of Conduction H T.

→ B/W two Isothermal Surface



****

$$\boxed{\frac{dT}{dy} = 0}, \quad \boxed{\frac{dT}{dx} \neq 0}$$

$$\boxed{\frac{dT}{dt} = 0}$$

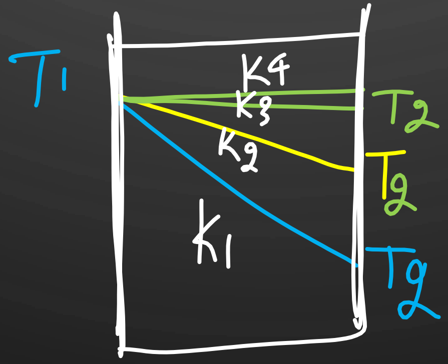
$$Q = -KA\frac{dT}{dx}$$

$$K = \frac{Q}{-A\left(\frac{dT}{dx}\right)}, \quad A = 1, \ \frac{dT}{dx} = 1, \quad \boxed{K = Q}$$

$K = Q$

* Conductivity defined as the Rate of HT Per unit Area, Per unit temp Gradient, (in the Dirn of Motion), b/w two Isothermal Walls

* It is thermophysical Property of Material which Allows the heat to get conducted through it



$K_4 > K_3 > K_2 > K_1$

Metals :→

- K_{silver} → 405 W/m-K
- K_{copper} → 385 W/m-K
- K_{gold} → 260 W/mK
- K_{Al} → 205 W/m-K
- K_{Iron} → 110 W/m-K
- K_{steel} → 17 to 45 W/m-K

Non-Metal

- → Crystline (Perfect Crystline Structure)
  - → $K_{Diamond} = 2300$ W/m-K
  - → $K_{grafite} = 1100$ W/m-K
  - → $K_{copper\ Crystal} = 8000$ W/m-K
- → Amorphus
  - $K_{glass} = 1\,5 \frac{W}{m\text{-}K}$

Material which have Low thermal Conductivity are known as Insulators → Used to Prevent Rate of H T

$K_{metals} > K_{liquids} > K_{gases}$

$K_{Asbestos} = 0.2$ W/m-K

PUF / $K_{glass\ wool} = 0.032$ W/m-K

↳ Poly Urethene Foam

$K_{refractory\ Bricks} = 0.9$

↓

$K_{freon\ Gas} = 0.0083$ W/m-K

Note-1 K vary with dirn

& it does not vary with Dirn Materi

is known as Isotropic

$K \neq f(x, y, z)$

Isotropic

Conductivity Varies with Location in a given dirn →

$\longrightarrow k_1 \longrightarrow k_2 \longrightarrow k_3 \ldots$

→ hetrogeneous Material

In General

$$K = f(T, P, \rho, \text{Porosity}, \text{Moisture})$$

Solids

Variation of Conductivity in Metals :→

$$K = k_0 + k_1 T + k_2 T^2 + k_3 T^3 + \dots$$

$$K = k_0\left[1+\frac{k_1}{k_0}T\right] + k_2 T^2\left[1+\frac{k_3}{k_2}T\right] + \dots$$

$$\boxed{K = K_0[1+\alpha T]}$$

$\alpha \rightarrow$ Constt

$\alpha \rightarrow$ −ve (Pure Metals)

$\alpha \rightarrow$ +ve (Alloys)

$K = K_0(1-\alpha T)$, $T\uparrow$, $K\downarrow$ — Pure Metals

$K = K_0(1+\alpha T)$, $T\uparrow$, $K\uparrow$ — Alloys

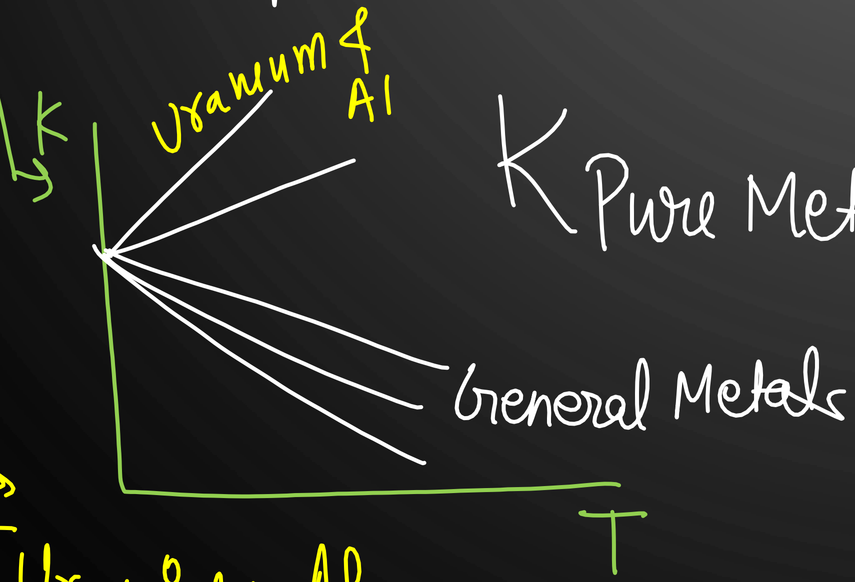
$T\uparrow$, Impurities$\downarrow$

Purity$\uparrow$, $K\uparrow$

Pure Metals :→ T↑, K↓, α (−ve)

Alloys → T↑, Impurities↓, Purity↑, K↑ α(+ve)

$$K = f(\text{Purity of Metal})$$



$K_{\text{Pure Metals}} > K_{\text{Alloys}}$

Exp →
Uranium, Al

$K = K_0(1 \pm \alpha T)$

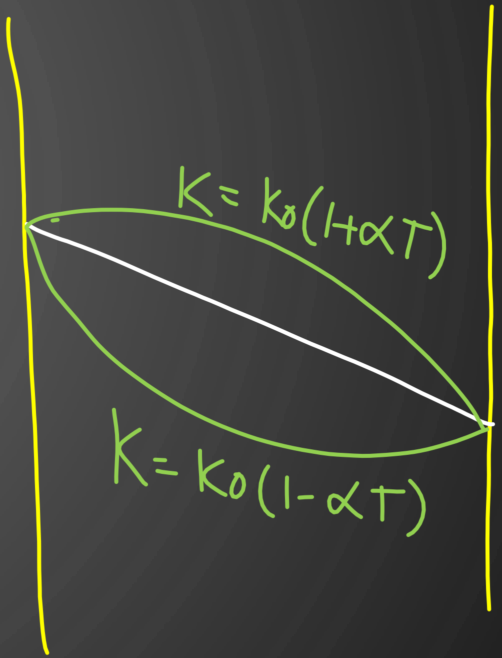
$K_0 \rightarrow K$ at $0^\circ C$

$K_0 = \frac{W}{m^\circ C}$

$T \rightarrow {}^\circ C$

$\alpha \rightarrow 1/K$ or $1/^\circ C$

$K_{Metals} = f(T)$



K vary linearly

$K = \left(\frac{K_1 + K_2}{2}\right)$

Non-Metallic Solids :→

$K = $ (Porosity, Moisture Content)

Porosity ↑, $K \downarrow$, $K \propto 1/\text{Porosity}$

Moisture ↑, $K \uparrow$, $K \propto$ Moisture

→ Red Brick (More Moisture)

→ Refractory Bricks

$K_{avg} \downarrow$, Rate of HT ↓

$K_{Red\ Bricks} > K_{Refractory\ Bricks}$