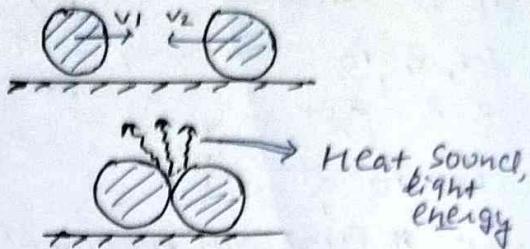


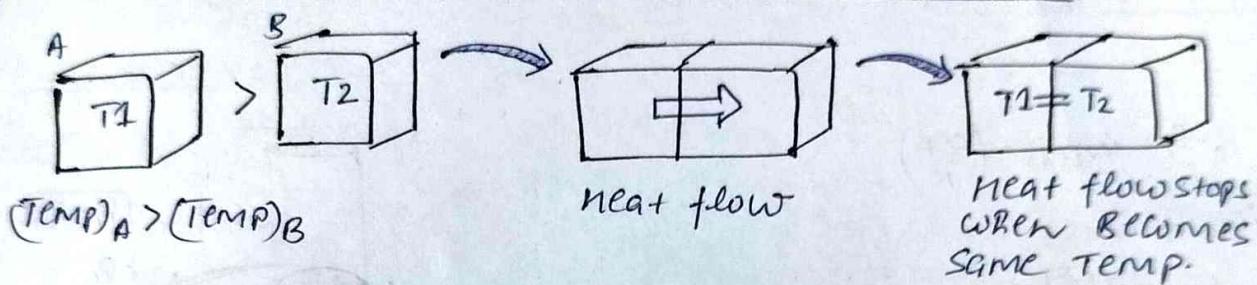
-° HEAT AND TEMPERATURE :-

loss in mechanical energy
results in heat.

Vibrational energy



> HOT-COLD IN CONTACT NO MECHANICAL WORK IS BEING DONE :-



Hence;

Heat is energy transferred from one object to other without any mechanical work.

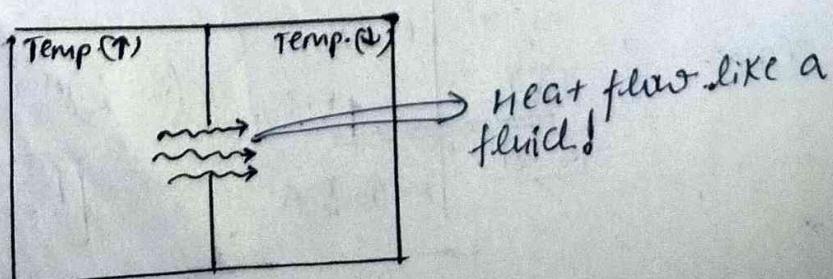
> UNIT OF HEAT :-

Amount of heat req. to raise the temperature of one gram of water by 1°C

$$1 \text{ Cal} = 4.186 \text{ Joule}$$

WHY CALORIE :-

In early days, heat was not recognised as a energy.. heat was thought to be a fluid contained within bodies.



> Mechanical Eq. of Heat :- (J) Conversion factor b/w heat & work.

Mechanical work can also be done to change the temperature of water.

$1 \text{ Cal} = 4.186 \text{ Joule}$; This relation is known as Mechanical Eq. of heat.
 ∵ Heat energy ∵ Mechanical energy.

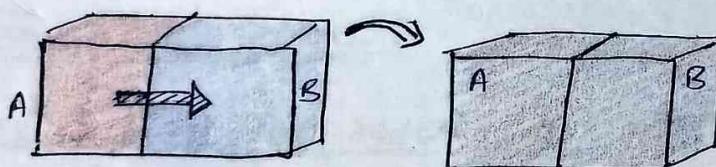
$$J = \frac{W}{n} \equiv J = 4.186 \text{ Joules Calorie}$$

> THERMODYNAMICS :-

Branch of science that deals with refⁿ b/w heat and other forms of energy

> THERMAL EQUILIBRIUM :-

Two bodies are said to be in thermal eq. if no heat transfer takes place b/w them when they are placed in contact!



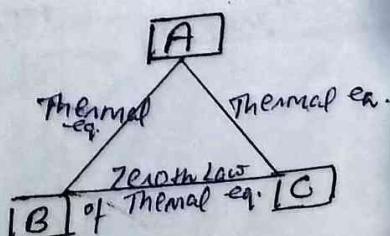
∴ $T_A > T_B$
 $(A \neq B)$

∴ $T_A = T_B$
 $(A \rightleftharpoons B) \rightarrow A \text{ and } B \text{ are in thermal equilibrium}$

> ZEROTH LAW :-

If two bodies A & B are in thermal eq. and A and C are in thermal eq. then
 A and C are in thermal eq.

If; $A \rightleftharpoons B \wedge B \rightleftharpoons C$
 $\swarrow \quad \searrow$
 $B \rightleftharpoons C$



#KILLER VISUALIZATION :-

$$A \rightleftharpoons B \quad A \rightleftharpoons C$$

$(T_A = T_B) \quad (T_A = T_C)$

$\downarrow \quad \downarrow$

$$B \rightleftharpoons C$$

$(T_B = T_C)$

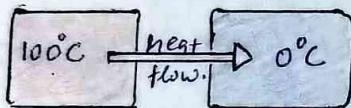
> UNDERSTANDING ZEROTH LAW.

\because It is important because it introduces the concept of Temp.

> TEMPERATURE :-

> Measures of hotness or coldness of an object.

> Gives the direction of heat flow.



> Object in thermal eq. are assigned equal temperature.



> QUANTIFYING TEMP. :-

\because length of Hg \propto temp.

To measure temp. mercury is kept in contact with obj. until it achieves thermal eq. length of column tells about temperature.

Hence;

$$x \propto T$$

Some property temperature

$$x = aT + b$$

where, a, b are constant

$$\text{at } T=0$$

$$> x_0 = a \times 0 + b$$

$$\text{at } T=100$$

$$> x_{100} = a \times 100 + b$$

$$x_0 = ax_0 + b \quad (1)$$

$x_{100} = ax_{100} + b$ where x_0 & x_{100} denote value of property at 0°C and 100°C resp.

Solving eq 1

$$x_0 = b \quad a = \left(\frac{x_{100} - x_0}{100} \right)$$

then; $x_t = aT + b$

$$x_t \Rightarrow \left(\frac{x_{100} - x_0}{100} \right) T + x_0 \rightarrow$$

$$T = \frac{(x_t - x_0) \times 100}{(x_{100} - x_0)}$$

Platinum resistance Thermo.

$$T = \frac{(R_t - R_0) \times 100}{(R_{100} - R_0)}$$

where;

R_0, R_{100} denotes the value of } resistance at 0°C & 100°C

Mercury Thermo.

$$T = \frac{(l_t - l_0) \times 100}{(l_{100} - l_0)}$$

where;

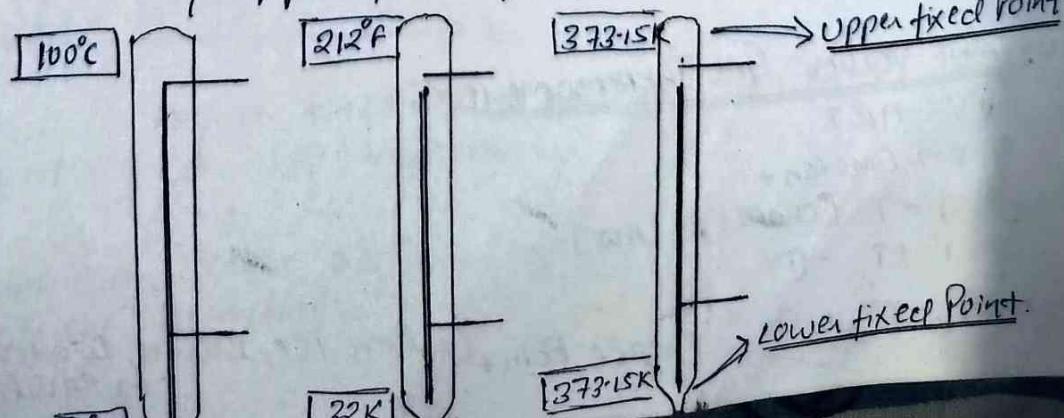
l_0, l_{100} denotes the length } of ing at 0°C & 100°C

TEMPERATURE SCALES :-

(i) Celsius or Centigrade :- {lower fixed Point:- 0°C } {upper fixed Point:- 100°C }

(ii) Fahrenheit Scale :- {lower fixed point:- 32°F } {upper fixed point:- 212°F }

(iii) Kelvin Scale :- {lower fixed point:- 273.15 K } {upper fixed point:- 373.15 K }



> CONVERSION B/w TEMP. SCALES :-

x may be $^{\circ}\text{C}$, $^{\circ}\text{F}$, K .

$$\left(\frac{x - \text{F.P}}{\text{B.P} - \text{F.P}} \right) = \left(\frac{C - 0}{100 - 0} \right) = \left(\frac{F - 32}{212 - 32} \right) = \left(\frac{K - 273.15}{373.15 - 273.15} \right)$$

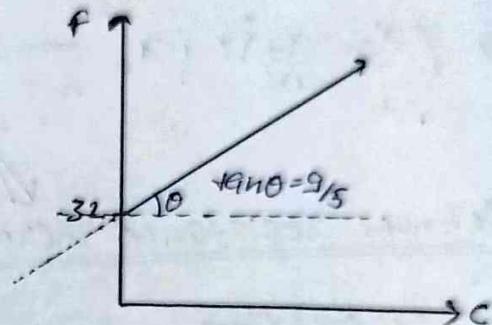
Celsius Scale Fahrenheit Scale Kelvin Scale

NOW;

$$\left(\frac{C - 0}{100 - 0} \right) = \left(\frac{F - 32}{212 - 32} \right)$$

$$\frac{C}{100} = \frac{F - 32}{180}$$

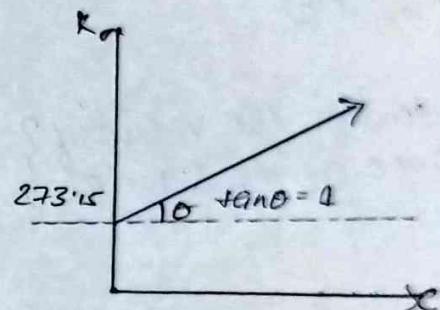
$$\frac{5C}{5} = F - 32 \Rightarrow F = \frac{9C}{5} + 32$$



Also;

$$\left(\frac{C - 0}{100 - 0} \right) = \left(\frac{K - 273.15}{373.15 - 273.15} \right)$$

$$\Rightarrow K = C + 273.15$$



KELVIN SCALE IS ALSO KNOWN AS ABSOLUTE TEMP. SCALE.



> ABSOLUTE ZERO TEMP. (0K) :-

The Gas is supposed to have no molecular motion at $T=0$.
This Temp is known as absolute zero temperature or ideal gas scale.

$$V_{\text{rms}} = \sqrt{\frac{3RT}{M}} ; \quad [T=0K] \Rightarrow V_{\text{rms}} = 0$$

> CONSTANT VOLUME GAS THERMOMETER :-

$$PV = NRT$$

If $V \rightarrow \text{Constant}$

$$\Rightarrow P \propto T \quad [\text{CHARLES LAW}]$$

$$\Rightarrow P = kT \quad \text{--- (1)}$$

$$\Rightarrow P_{\text{tri}} = kT_{\text{tri}} \quad \text{--- (2)}$$

(When ice, liquid, water are in equilibrium)

> dividing eq 1 and 2

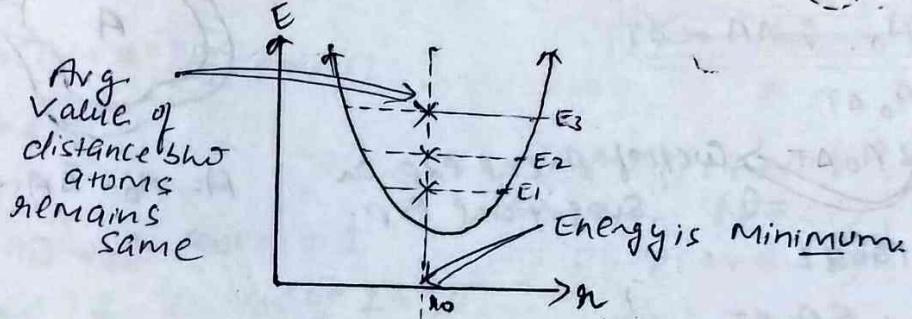
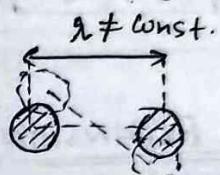
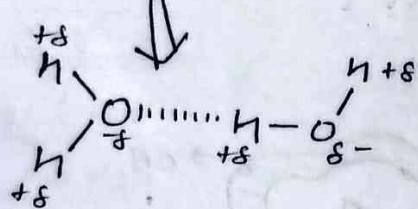
$$\frac{P}{P_{tr}} = \frac{T}{T_{tr}} ; \text{ where } T_{tr} = 273.16 \text{ K}$$

So,

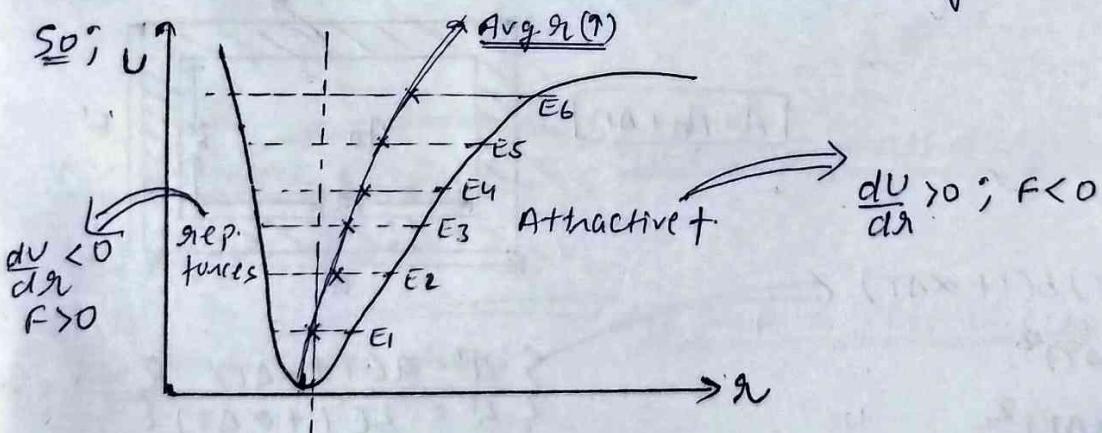
$$T = \frac{P}{P_{tr}} \times 273.16$$

> INTERACTION B/w MOLE:-

Internal interaction H-Bonds, Intergatomic forces are attractive and Spring like force.



> If (↑) Temp. Means (↑) vibration then why shouldn't avg. distance b/w atoms remains same? why expansion?

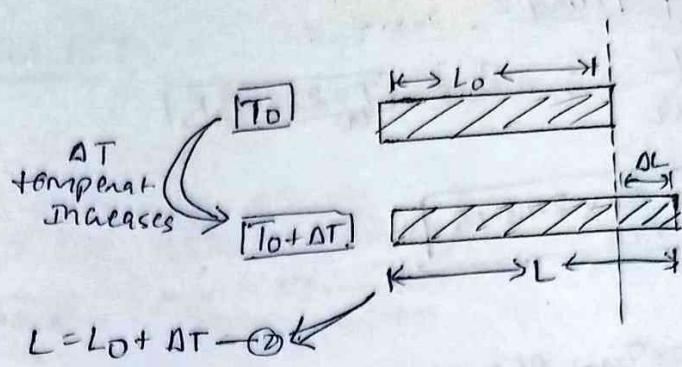


On (↑) Temp. Avg. distance b/w atoms increases due to (↑) amplitude on (↑) vibrations

"Hence Expansion occurs because of unsymmetrical Potential Curve!"

> LINEAR EXPANSION :-

$$\begin{aligned} \Delta L &\propto \Delta T \\ \Delta L &\propto L_0 \\ \Delta L &\propto L_0 \Delta T \end{aligned}$$



$$\therefore L = L_0 + \alpha L_0 \Delta T \quad \text{--- (2)}$$

Hence from eq 1 and 2;

α = Coeff of linear expansion

$$\begin{aligned} L &= L_0 + \alpha L_0 \Delta T \\ L &= L_0 (1 + \alpha \Delta T) \end{aligned}$$

> AREALE EXPANSION :-

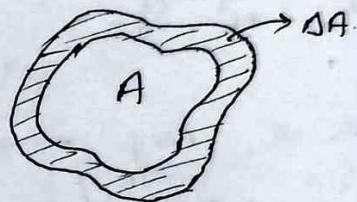
$$\Delta A \propto A_0 ; \Delta A \propto \Delta T$$

$$\Delta A \propto A_0 \Delta T$$

$$\Delta A = B A_0 \Delta T \quad \text{Coeff of Area exp. on superficial exp.}$$

from eq 1 and 2

$$\begin{aligned} A &= A_0 + B A_0 \Delta T \\ A &= A_0 (1 + B \Delta T) \end{aligned}$$



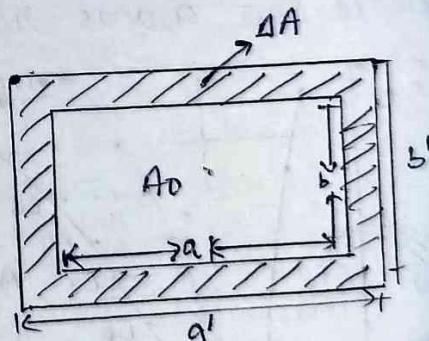
$$A = A_0 + \Delta A \quad \text{--- (3)}$$

$$\frac{B}{A_0} = 2\alpha$$

$$A_0 = ab$$

$$A = a'b'$$

$$A = A_0 + \Delta A$$



$$A = a(1 + \alpha \Delta T) b(1 + \alpha \Delta T)$$

$$\Rightarrow abc(1 + \alpha \Delta T)^2$$

$$A \Rightarrow A_0 (1 + \alpha \Delta T)^2$$

By Binomial approx.; $\alpha \Delta T \ll 1$

$$A = A_0 (1 + 2\alpha \Delta T) \approx A_0 (1 + 2\alpha \Delta T)$$

$$\therefore B = 2\alpha$$

> VOLUME EXPANSION :-

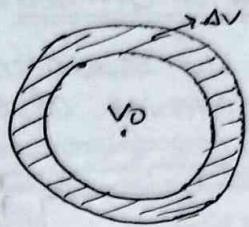
$$\begin{aligned} \Delta V &\propto \alpha \Delta T \\ \Delta V &\propto V_0 \\ \Delta V &\propto V_0 \alpha \Delta T \end{aligned}$$

$$\Delta V = \gamma V_0 \alpha \Delta T \rightarrow \text{Coef. of volume exp.}$$

$$V = V_0 + \Delta V$$

$$V = V_0 + V_0 \gamma \alpha \Delta T$$

$$\boxed{V = V_0 (1 + \gamma \alpha \Delta T)}$$



$$\sum l \circ : \gamma = 3\alpha$$

$$V_0 = l b R$$

$$V' = l' b' R'$$

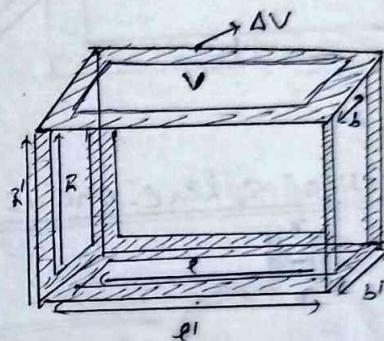
$$V = l(1 + \alpha \Delta T) b(1 + \alpha \Delta T) R(1 + \alpha \Delta T)$$

$$V = l b R (1 + \alpha \Delta T)^3$$

$$V = V_0 (1 + \alpha \Delta T)^3$$

By Binomial approx, $\alpha \Delta T \ll 1$
 $V = V_0 (1 + 3\alpha \Delta T)$ & $V = V_0 (1 + \gamma \alpha \Delta T)$

$$\boxed{\gamma = 3\alpha}$$



$$\left. \begin{aligned} l' &= l(1 + \alpha \Delta T) \\ b' &= b(1 + \alpha \Delta T) \\ R' &= R(1 + \alpha \Delta T) \end{aligned} \right\}$$

> FOR ISOTROPIC PROPERTIES :- Same prop. in all direction.

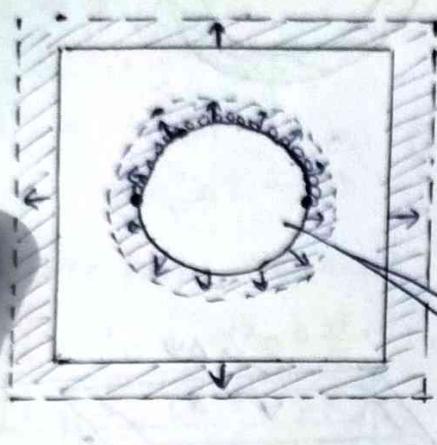
$$\alpha \approx \beta \approx \gamma = 1 \circ 2 \circ 3$$

> FOR ANISOTROPIC PROPS :- diff prop. in diff direction.

$\therefore \beta = \alpha_1 + \alpha_2$; where $\alpha_1, \alpha_2, \alpha_3$ are coef. of linear expansion
 $\therefore \gamma = \alpha_1 + \alpha_2 + \alpha_3$ in X, Y, Z directions.

> EXPANSION IN CAVITIES :-

As distance b/w each atom (r), distance b/w any two points in material also increase.

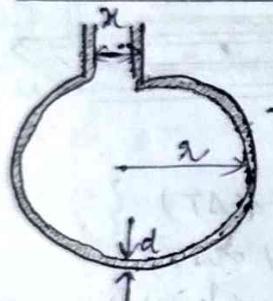


Hence, dimension of a cavity always increases.

Treat expansion in cavities as magnification rather than swelling up!

> NOTE :-

Identical sphere one is hollow & one is solid expands equally.



clearly;
 x, r_1, d all increases.

> CHANGE IN DENSITY :-

Since, mass remains constant;

$$(M)_0 = (M)_f$$

$$S_0 V_0 = S V$$

$$S_0 V_0 = S V_0 (1 + \gamma \Delta T)$$

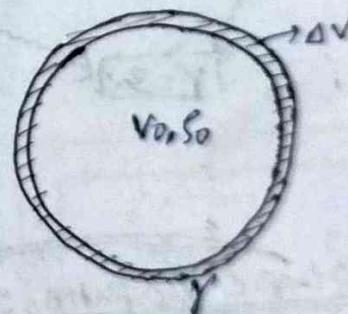
$$\boxed{S = \frac{S_0}{1 + \gamma \Delta T}}$$

$$\downarrow$$

$$S = S_0 (1 + \gamma \Delta T)^{-1}$$

By Binomial Approx; when $\gamma \Delta T \ll 1$

$$\underline{\underline{S = S_0 (1 - \gamma \Delta T)}}$$



$$\boxed{V = V_0 (1 + \gamma \Delta T)}$$

MEASUREMENT BY METALLIC SCALE

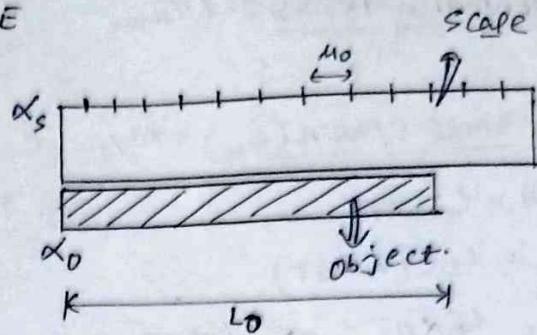
length of object changes as;

$$L = L_0(1 + \alpha_o \Delta T)$$

reference of scale changes as;

$$l = l_0(1 + \alpha_s \Delta T)$$

also; Reading = $\frac{\text{length}}{\text{Unit}}$



$$\text{Reading} = \frac{l}{l_0} = \frac{L_0(1 + \alpha_o \Delta T)}{l_0(1 + \alpha_s \Delta T)}$$

$$\text{Initial Reading } (R_0) = L_0/l_0 \quad \text{--- (1)}$$

$$\text{New Reading } (R) = \frac{l}{l_0} = \frac{L_0(1 + \alpha_o \Delta T)}{l_0(1 + \alpha_s \Delta T)} \quad \text{--- (2)}$$

from eq 1 and 2 :-

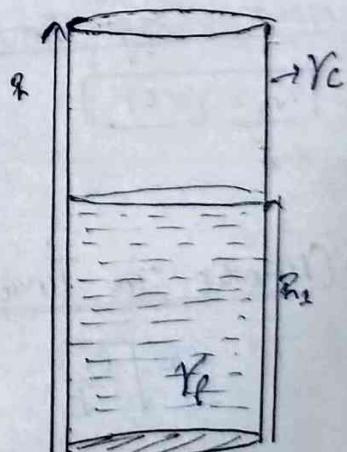
$$R = R_0 (1 + \alpha_o \Delta T) (1 + \alpha_s \Delta T)^{-1}$$

$$R = R_0 [1 + (\alpha_o - \alpha_s) \Delta T]$$

EXPANSION OF A LIQ. IN A CONTAINER :-

$$\therefore V = V_0 (1 + \gamma_{\text{liq}} \Delta T)$$

$$\text{But } V = V_0 [1 + (\gamma_e - \gamma_c) \Delta T]$$



> Thermal Stress :- ($\sigma_{\text{therm}} = F_a / \text{Area}$)

Thermal strain (ϵ_{th}) = $\Delta L / L$

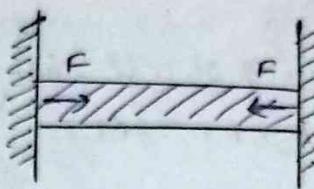
$$\Delta L = L_0 \alpha \Delta T$$

$$L = L_0(1 + \alpha \Delta T)$$

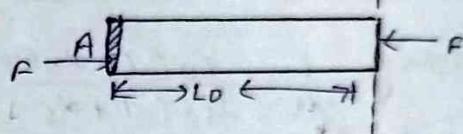
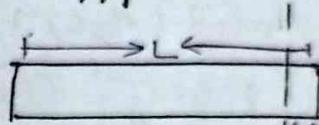
$$\epsilon_{\text{th}} = \frac{L_0 \alpha \Delta T}{L_0(1 + \alpha \Delta T)} \Rightarrow \left(\frac{\alpha \Delta T}{1 + \alpha \Delta T} \right)$$

Using Binomial Approx.: - $\alpha \Delta T \ll 1$

$$[\epsilon_{\text{th}} = \alpha \Delta T]$$



III



$$\Delta L = L_0 \alpha \Delta T \quad \text{--- (1)}$$

Thermal Stress :-

$$\gamma = \frac{\sigma}{\epsilon} = \frac{F/A}{\Delta L / L}$$

$$\frac{F}{A} = (\gamma \times \frac{\Delta L}{L})$$

$$\sigma_{\text{th}} = \gamma \times \epsilon_{\text{th}} = \frac{\gamma \alpha \Delta T}{1 + \alpha \Delta T}$$

$$\boxed{\sigma_{\text{th}} = \frac{\gamma \alpha \Delta T}{1 + \alpha \Delta T}}$$

Now, Using Binomial approx; $\alpha \Delta T \ll 1$

$$\boxed{\sigma_{\text{th}} = \gamma \alpha \Delta T}$$

> Change in Time Period :- (of a simple pendulum)

$$T_0 = 2\pi \sqrt{l_0/g} \quad \text{--- (1) [Original time period]}$$

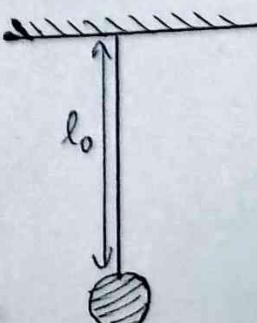
$$T = 2\pi \sqrt{\frac{L_0(1 + \alpha \Delta \theta)}{g}} \quad \text{--- (2) [New time period when temp. increases by } \Delta \theta \text{]}$$

$$\underline{\text{eq 1 / eq 2 :-}}$$

$$T = \sqrt{1 + \alpha \Delta \theta} \Rightarrow (1 + \alpha \Delta \theta)^{1/2}$$

Using Binomial approx:-

$$\frac{T}{T_0} = (1 + \frac{\alpha \Delta \theta}{2})$$



$$\frac{T}{T_0} = \left(1 + \alpha \frac{\Delta \theta}{2}\right)$$

$$\Rightarrow \frac{T - T_0}{T_0} = \frac{\alpha \Delta \theta}{2}$$

$$\Rightarrow \frac{\Delta T}{T_0} = \frac{\alpha \Delta \theta}{2} \quad \text{"fractional change in time period"}$$

Case I

when; $\Delta \theta < 0$
(Temp. decreases)

$$T = 2\pi \sqrt{\frac{L}{g}} \quad T_0 = 2\pi \sqrt{\frac{L_0}{g}}$$

$$L = L_0(1 + \alpha \Delta \theta) \quad \text{when, } \Delta \theta < 0 \\ L < L_0$$

$\Rightarrow T < T_0$
clocks run faster.

Case II

when; $\Delta \theta > 0$

(Temp. Increases)

$$T = 2\pi \sqrt{\frac{L}{g}} \quad T_0 = 2\pi \sqrt{\frac{L_0}{g}}$$

$$L = L_0(1 + \alpha \Delta \theta) \quad \text{--- (1)}$$

when, $\Delta \theta > 0$

$L > L_0$ from eq (1)

$\Rightarrow T > T_0$

Clocks run slower.

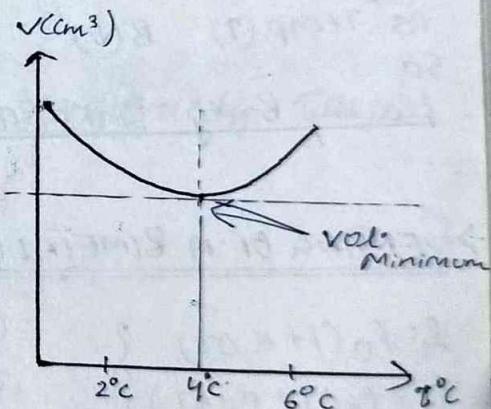
> EXPANSION OF WATER :-

Upon heating water.

" $0^\circ - 4^\circ C$ Vol. decreases }

" After $4^\circ C$ Vol. increases }

At $4^\circ C$ Vol. is Minimum and
hence ρ is Maximum



> VARIATION OF BUOYANT FORCE WITH TEMP :-

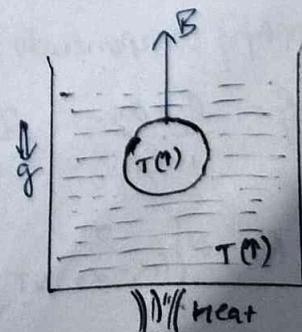
$$B_0 = \rho_e V g \quad \text{--- (1) [original]}$$

when $\downarrow \Delta T > 0$

New Buoyant force

$$B = (\rho_e)_{\text{new}} (V)_{\text{new}} \times g$$

$$B = \left(\frac{\rho_e}{1 + \gamma_p \Delta T} \right) \times V_0 (1 + \gamma_{\text{obj}} \Delta T) \times g \quad \text{--- (2)}$$



$\uparrow B$
 $\downarrow g$
 $T(M)$
 $\uparrow B$
 $\downarrow g$
 $T(M)$
 $\uparrow B$
 $\downarrow g$
 $T(M)$

$$\frac{B}{B_0} = \frac{(1 + \gamma_{\text{obj}} \Delta T)}{(1 + \gamma_e \Delta T)}$$

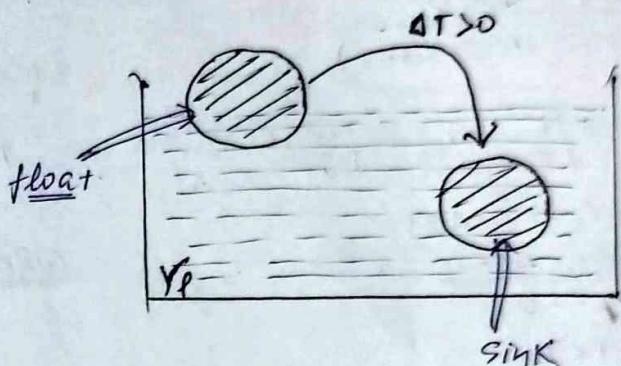
$$B = B_0 \frac{(1 + \gamma_0 \Delta T)}{(1 + \gamma_e \Delta T)}$$

$$B = B_0 (1 + \gamma_0 \Delta T) (1 + \gamma_e \Delta T)^{-1}$$

$$B = B_0 (1 + \gamma_0 \Delta T) (1 - \gamma_e \Delta T)$$

$$B = B_0 \left\{ 1 + (\gamma_0 - \gamma_e) \Delta T - \gamma_0 \gamma_e^2 \Delta T^2 \right\}$$

$$B = B_0 \left\{ 1 + \frac{(\gamma_0 - \gamma_e) \Delta T}{\gamma_{\text{relax}}} \right\}$$



for same ΔT ; $(\gamma_e > \gamma_0) \Rightarrow (\gamma_0 - \gamma_e) < 0 \Rightarrow \gamma_{\text{relax}} < 0$

Hence;

as Temp (T) $B(N)$

so,

Floating Body sinks as Temp. (\uparrow)

> BENDING OF A BI-METALLIC STRIP :-

$$\begin{cases} l_1 = l_0 (1 + \alpha_1 \Delta T) \\ l_2 = l_0 (1 + \alpha_2 \Delta T) \end{cases}$$

$$\begin{cases} \textcircled{1} \quad (R+d)\theta = l_1 \\ \textcircled{2} \quad (R-d)\theta = l_2 \end{cases}$$

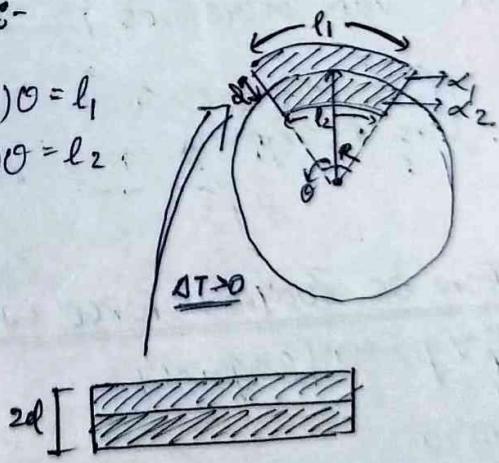
dividing eq1 and 2^o-

$$\frac{R+d}{R-d} = \frac{l_1}{l_2} = \frac{l_0(1 + \alpha_1 \Delta T)}{l_0(1 + \alpha_2 \Delta T)}$$

applying Componendo & dividendo :-

$$\frac{R}{d} = \frac{l_1 + l_2}{l_1 - l_2} = \frac{2 + (\alpha_1 + \alpha_2) \Delta T}{(\alpha_1 - \alpha_2) \Delta T}$$

$$R = d \left\{ \frac{2}{(\alpha_1 - \alpha_2) \Delta T} + \frac{(\alpha_1 + \alpha_2)}{(\alpha_1 - \alpha_2)} \right\}$$



SPECIFIC HEAT CAPACITY :- (S) → MATERIAL SPECIFIC

Heat gained or released by a unit mass substance to raise or fall its Temp. by 1°C .

$$S = \frac{\Delta Q}{M \Delta T} \quad \therefore$$

$$Q = m s \Delta T$$

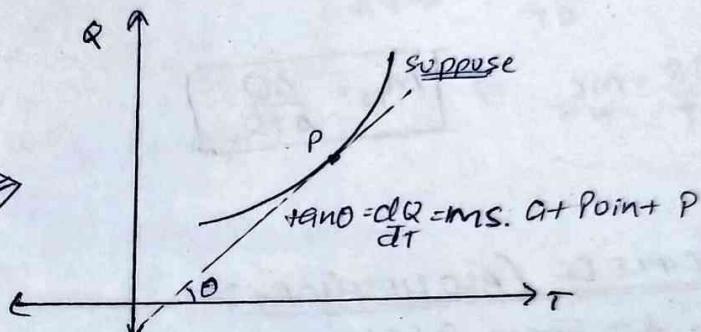
↓ ↓ ↓
 Heat Supplied Mass Specific Heat
 change in temperature.

$$Q = m s \Delta T$$

$$dQ = (m s) dT$$

$$\frac{dQ}{dT} = m s$$

graph



MOLAR HEAT CAPACITY :-

Heat req. to raise Temp. of 1 mole of a substance by 1°C

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

HEAT CAPACITY :- (CS) → OBJECT SPECIFIC.

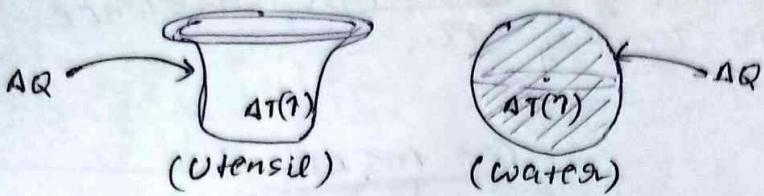
{ Heat Capacity or Thermal Capacity of a Body or }
 Object is equal heat req to raise temp. by 1°C .

$$S = \frac{\Delta Q}{\Delta T}$$

$$\Rightarrow \frac{m s \Delta T}{\Delta T} = m s \Rightarrow \boxed{S = m s} \quad \therefore$$

"two diff Aluminium utensils have same specific heat capacity But diff. heat capacity".

WATER EQUIVALENT :- " If thermal capacity is expressed in terms of mass of water it is called equivalent of body!"



$$\frac{(\text{Heat Capacity})_{\text{utensil}}}{(\text{Heat Capacity})_{\text{water}}} = \frac{\Delta Q}{\Delta T}$$

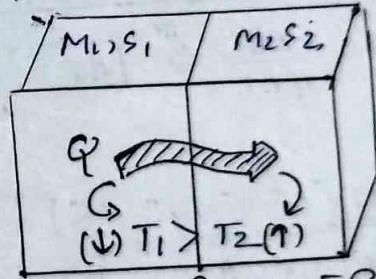
$$S_{\text{utensil}} = \frac{\Delta Q}{\Delta T} = S_{\text{water}}$$

$$\frac{\Delta Q}{\Delta T} = m s_w \Rightarrow M_w = \frac{\Delta Q}{\Delta T s_w}$$

PRINCIPLE OF CALORIMETRY :-

When two Temp. substance at diff. Temp are mixed together then exchange of heat takes place till Temp. of both substance become equal.

This Temp. is known as "final temp. of mixture" or "equilibrium Temp."



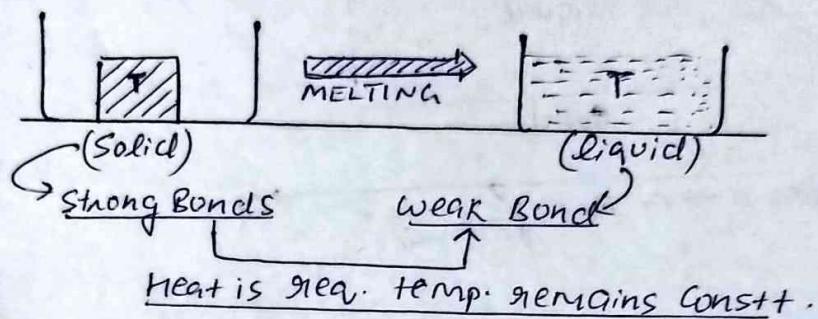
→ HEAT GIVEN BY ONE SUBSTANCE = HEAT TAKEN BY ANOTHER. !!

$$Q_{\text{given by 1}} = Q_{\text{gained by 2}}$$

$$[M_1 s_1 (T_1 - T) = M_2 s_2 (T - T_2)]$$

> LATENT HEAT :-
 Heat req. to change the phase } { Solid \rightarrow liq. ?
 { liq. \rightarrow gas } of Unit Mass of subst.

* during change of phase temp. is Constant but Heat is req.
 ↓
 This heat is req. to Break Strong Bonds.



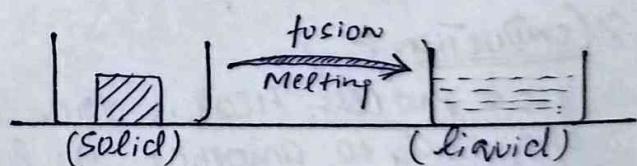
$$L = \frac{\Delta Q}{m} \text{ (By def)}$$

$$\boxed{\Delta Q = mL}$$

> LATENT HEAT OF FUSION :-

"Heat req. to change a Unit Mass of Subst. from Solid to liquid at its Melting Point. and 1 atm Pressure."

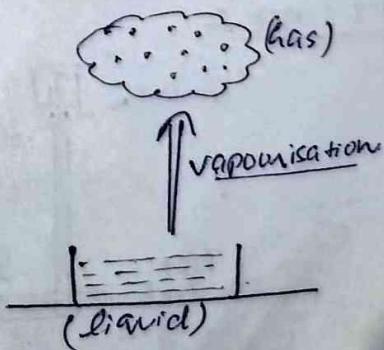
$$\boxed{Q_{\text{fusion}} = mL_{\text{fusion}}}$$



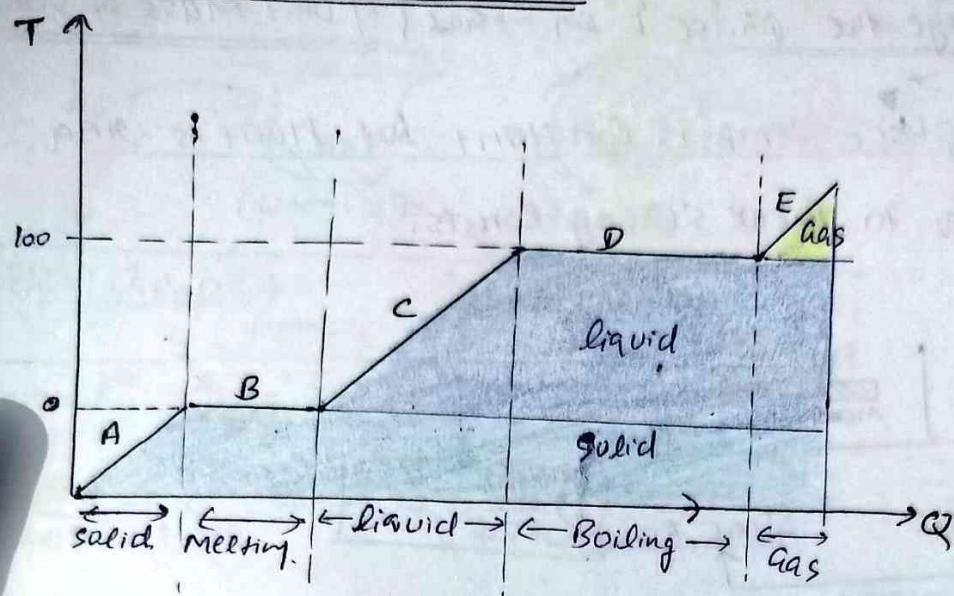
> LATENT HEAT OF VAPOURISATION :-

"Heat req. to change a Unit MASS of substance from liq. to VAPOUR state at its Boiling Point. at 1 atm pressure."

$$\boxed{Q_{\text{vap}} = mL_{\text{vap}}}$$



> HEAT REQ. IN CHANGE OF STATE :-



> HEAT TRANSFER :-

∴ Conduction
(Mainly occurs in solid)

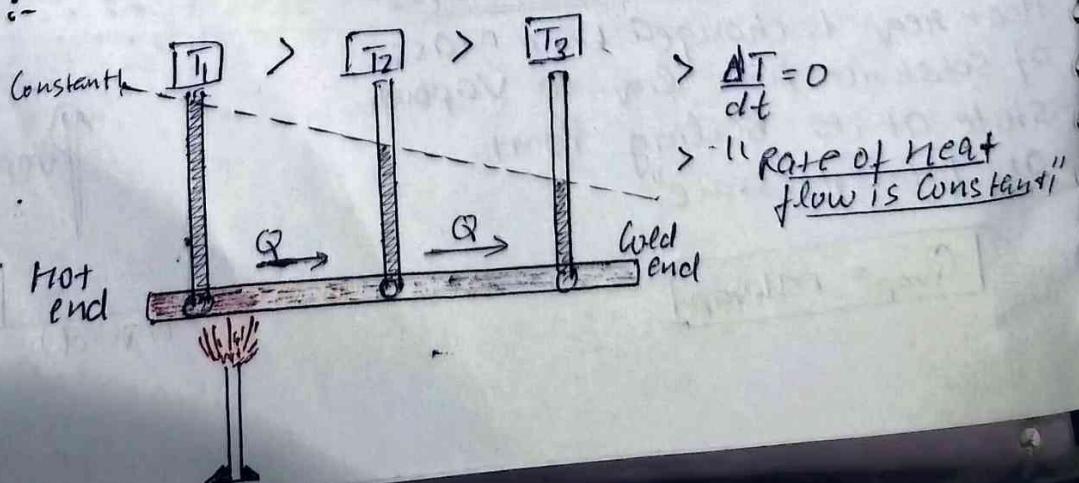
∴ Convection
(Mainly occurs in liquid and gases)

∴ Radiation
(By radiation requires no medium)
[FASTEST MODE]

> CONDUCTION :-

If a process heat is transmitted from one part of a body to another at lower temp. by molecular collisions

STEADY STATE :-

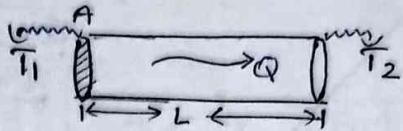


> RATE OF FLOW OF HEAT:-

$$H = \frac{Q}{t} \quad \left\{ \begin{array}{l} \text{rate of flow} \\ \text{of heat} \end{array} \right.$$

$$\begin{aligned} H &\propto A \\ H &\propto (T_1 - T_2) \\ H &\propto L \\ H &\propto \frac{A(T_1 + T_2)}{L} \end{aligned}$$

$$\frac{dQ}{dt} \propto \frac{A(T_1 - T_2)}{L}$$



$$H = \frac{dQ}{dt} = \frac{K A (T_1 - T_2)}{L}$$

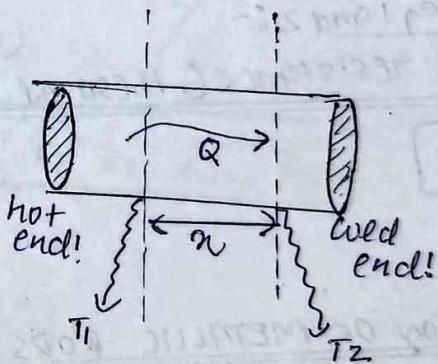
where:

K is Coefficient of Thermal Conductivity.
It is a Material specific property.

> TEMPERATURE GRADIENT:-

Temperature Gradient;

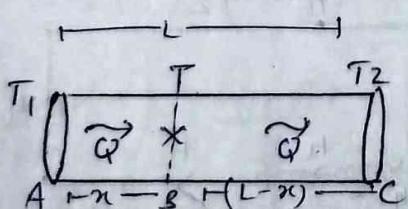
$$\Rightarrow \frac{(T_1 - T_2)}{x}$$



Hence; Heat Current is;

$$H = \frac{\Delta Q}{\Delta t} = K A (T_1 - T_2) = -\frac{KA\Delta T}{L}$$

application!



$$T = ? \quad \left(\frac{dQ}{dt} \right)_{AC} = \left(\frac{dQ}{dt} \right)_{BC}$$

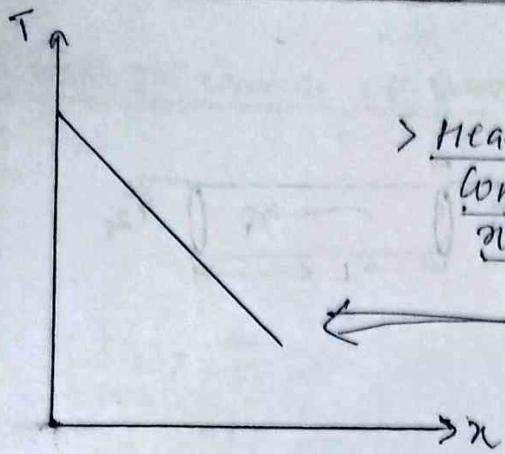
$$\frac{KA(T_1 - T)}{x} = \frac{KA(T_1 - T_2)}{L}$$

$$\frac{T_1 - T}{x} = \frac{T_1 - T_2}{L}$$

$$T_1 L - T_2 L = T_1 x - T_2 x$$

$$\Leftarrow T_L = T_1 L - T_1 x + T_2 x$$

$$T = T_1 - (T_1 - T_2) \frac{x}{L}$$



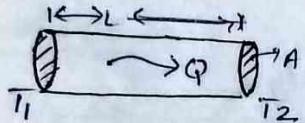
> Heat is flowing through a conductor of length l from $x=0$ to $x=l$, then $T \propto x$?

$$T = T_1 - \left(\frac{T_1 - T_2}{l} \right) x$$

THERMAL RESISTANCE :-

$$H = \frac{KA(T_1 - T_2)}{L}$$

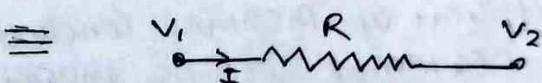
$$H = \frac{(T_1 - T_2)}{\frac{KA}{L}}$$



In electricity:

$$V = IR \Rightarrow \Delta V = IR \Rightarrow (V_1 - V_2) = IR$$

$$I = \frac{V_1 - V_2}{R}$$



Comparing eq 1 and 2 :-

H_{KA} is a resistance (thermal resistance R_H)

$$\begin{cases} \therefore T \equiv V \\ \therefore H \equiv I \\ \therefore R_H \equiv R \end{cases}$$

$$R_H = \frac{L}{KA}$$

COMBINATION OF METALLIC RODS :-

If R_1, R_2, \dots are thermal resistance of rods then
eq. resistance is given by :-

$$R_H = R_1 + R_2 + R_3 + \dots + R_n$$

* The heat current remains same throughout the circuit

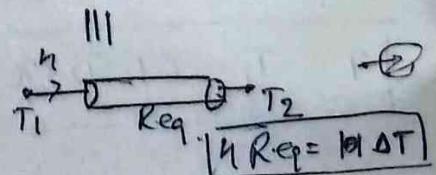
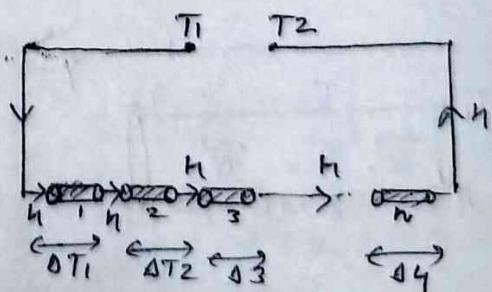
$$\Delta T_1 = HR_1$$

$$\Delta T_2 = HR_2$$

$$\Delta T_3 = HR_3$$

$$\Delta T_n = HR_n$$

$$(\Delta T_1 + \Delta T_2 + \Delta T_3 + \dots + \Delta T_n) = H(R_1 + R_2 + R_3 + \dots + R_n)$$



> From eq 1 and 2 :-

$$H_{\text{Req}} = K(CR_1 + R_2 + R_3 + \dots + R_n)$$

$$\underline{R_{\text{eq}} = R_1 + R_2 + R_3 + \dots + R_n}$$

PARALLEL COMBINATION :-

$$\frac{1}{R_{\text{eq}}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots + \frac{1}{R_n}$$

$$h_1 = \frac{(T_1 - T_2)}{R_1} \quad \text{--- (1)}$$

$$h_2 = \frac{h_2(T_1 - T_2)}{R_2} \quad \text{--- (2)}$$

$$h_3 = \frac{(T_1 - T_2)}{R_3} \quad \text{--- (3)}$$

$$h_n = \frac{(T_1 - T_2)}{R_n} \quad \text{--- (4)}$$

$$(h_1 + h_2 + h_3 + \dots + h_n) = \frac{(T_1 - T_2)}{(R_1 + R_2 + R_3 + \dots + R_n)}$$

Total Heat Current.

$$\underline{\frac{dQ}{dt} = \frac{(T_1 - T_2)}{(R_1 + R_2 + \dots + R_n)}} \Rightarrow \underline{\frac{1}{R_{\text{eq}}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots + \frac{1}{R_n}}$$

FORMATION OF ICE ON PONDS :-

$$\frac{dQ}{dt} = \frac{K_{\text{ice}} A [0 - (-T)]}{y} \quad \text{--- (1)}$$

also;

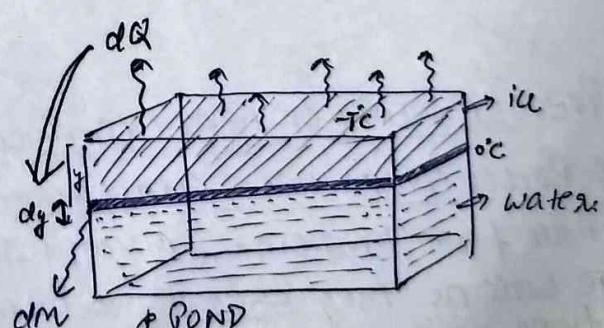
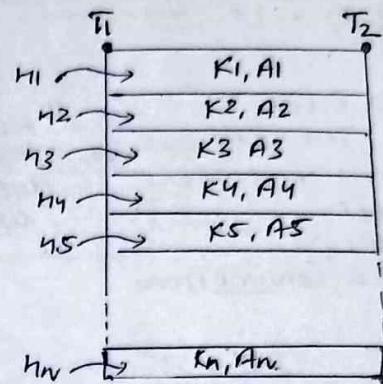
$$dQ = L(dm)$$

$$dQ = L(S_{\text{ice}})(Ady) \quad \text{--- (2)}$$

$$\frac{L S_{\text{ice}} A dy}{dt} = \frac{K_{\text{ice}} A T}{y}$$

$$dt = \frac{L S_{\text{ice}} y dy}{K_{\text{ice}} T}$$

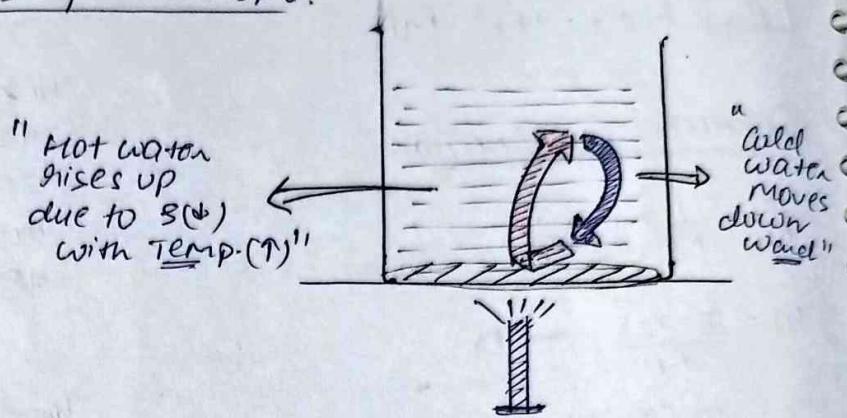
$$\underline{dt = \frac{L S_{\text{ice}} y dy}{K_{\text{ice}} T}}$$



> CONVECTION:-

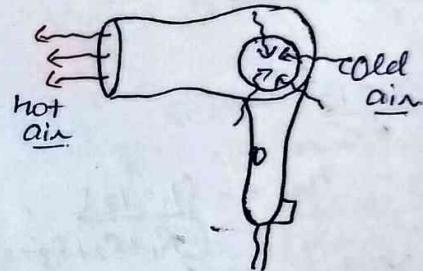
Heat flow from higher temp. to lower temp. by actual movement of particles of medium.

DUE TO DIFF.
IN S., THE PROCESS
OF HEAT TRANSFER
IS CALLED
NATURAL OR
FREE CONVECTION



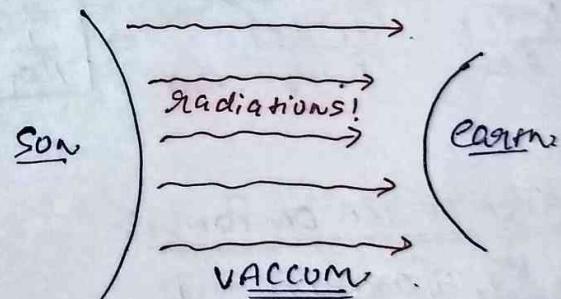
> FORCED CONVECTION:-

Heated material is forced to move by a machine like a Blower or Pump. The process of heat transfer is known as forced convection.



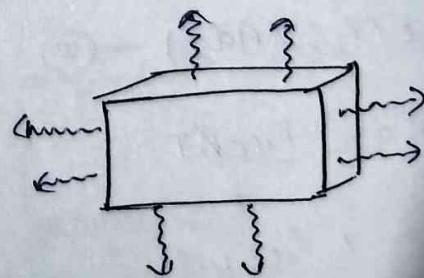
> RADIATION:-

Heat is transmitted without heating and transferring intervening medium!!

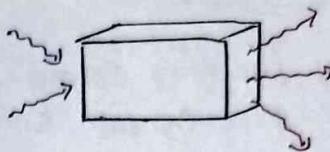


> PREVOST THEORY OF HEAT EXCHANGE:-

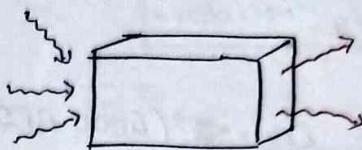
All bodies emit heat radiation at all finite Temperature (except OK) as well as they absorb radiations from surrounding.



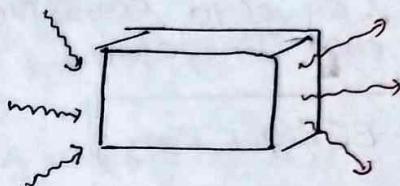
\therefore If amount of
 $(\text{Radiation})_{\text{abs}} < (\text{Radiation})_{\text{emit}}$.
then temperature of Body (\downarrow)



\therefore If amount of
 $(\text{Radiation})_{\text{abs}} > (\text{Radiation})_{\text{emit}}$.
Temperature of Body (\uparrow)



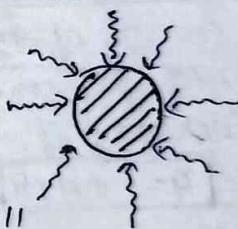
\therefore If amount of
 $(\text{Radiation})_{\text{abs}} = (\text{Radiation})_{\text{emit}}$.
Body is in Thermal eq.
with Surrounding.



> BLACK BODY :-

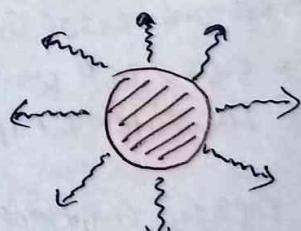
> A Body that absorbs all radiations falling on it!!

Lamp black is close to perfect Black Body



> A Body that emits all radiation falling on it!!

Sun is close to perfect Black Body

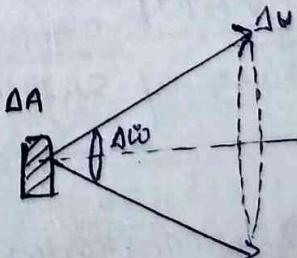


> EMISSIVE POWERS :-

Energy radiation by ΔA area of
surface in Solid Angle $\Delta \omega$ in
time Δt by ΔU .

then,

$$> \text{EMISSIVE POWER} = \frac{(\Delta U)}{(\Delta A)(\Delta t)\Delta \omega}$$



ABSORPTIVE POWER:-

fraction of incident radiation that is absorbed by the body.

$$\alpha = \frac{\text{energy absorbed}}{\text{energy incident}}$$

> KIRCHHOFF's LAW: \Rightarrow (GOOD ABSORBERS ARE GOOD EMITTERS)

Ratio of emissive power to absorptive power of any body is constant & equal to emissive power of perfect black body at that temperature.

$$\therefore \frac{E(\text{Body})}{\alpha E(\text{Body})} = E(\text{Black Body})$$

> STEFAN BOLTZMANN LAW:-

> The energy of thermal radiation emitted per unit time by a blackbody of surface A is given by

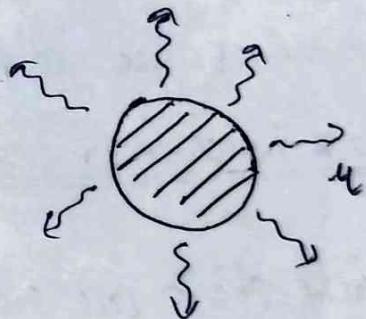
$$U = \sigma AT^4$$

where;

σ is a universal constant (Stefan Boltzmann Constant)

$$\therefore \sigma = 5.67 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4}$$

T = Absolute Temperature,



> The energy emitted by a non-blackbody per unit time is

$$U = e\sigma AT^4$$

e is emissivity of surface

NOW:-

$$\frac{E(\text{Body})}{\alpha E(\text{Body})} \Rightarrow \frac{E(\text{Body})}{E(\text{Black Body})} ; \Rightarrow \frac{E(\text{Body})}{E(\text{Black Body})} = \alpha$$

$$\Rightarrow \left(\frac{e\sigma AT^4}{\sigma AT^4} \right) = \alpha \Rightarrow e = \alpha$$

> According to Stefan Boltzmann Law :-

" Thermal radiation emitted / unit time :-

$$[U = \sigma A T^4]$$

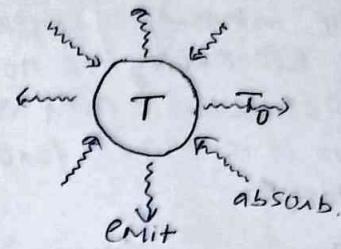
" Thermal radiation absorbed / unit time :-

$$[U_0 = \sigma A T_0^4]$$

" Net loss in Energy per unit time (ΔU) ; $T > T_0$

$$\Delta U = U - U_0$$

$$[\Delta U = \sigma A C (T^4 - T_0^4)]$$



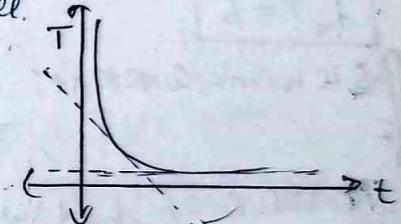
> Newton's Law of Cooling :-

Rate of Cooling of Body is directly \propto to Temp. diff. Between Body and Surrounding provided it to be small. $(T - T_0) \rightarrow$ small.

$$\frac{dT}{dt} \propto (T - T_0)$$

$$\left[\frac{dT}{dt} = -K(T - T_0) \right]$$

$$\because T(\downarrow) \quad \frac{dT}{dt} < 0$$



If $T \rightarrow$ Temp. of Body

$T_0 \rightarrow$ Temp. of Surrounding

$A \rightarrow$ Surface Area of Body

so, rate of loss of due to radiation

$$\Delta U = \sigma A [(T_0 + \Delta T)^4 - T_0^4]$$

$$\Rightarrow \sigma A [T_0^4 \left(1 + \frac{\Delta T}{T_0} \right)^4 - T_0^4]$$

$$\Rightarrow \sigma A T_0^4 \left[\left(1 + \frac{T_0 \Delta T}{T_0} \right)^4 - 1 \right]$$

$$\Rightarrow \sigma A T_0^4 \left[1 + \frac{4 \Delta T}{T_0} - 1 \right]$$

$$\Rightarrow 4 \sigma A T_0^3 (\Delta T)$$

$$(\Delta U \neq 4 \sigma A T_0^3 (\Delta T)) \quad \text{--- (1)}$$

$$\frac{dQ}{dt}$$

$$\frac{\Delta T}{T} = \frac{T - T_0}{T_0 + \Delta T}$$

Also,

$$dQ = -MS(dT) \quad \because (dT \neq 0)$$

$$\left(\frac{dQ}{dt} \right) = -MS \left(\frac{dT}{dt} \right) \quad \text{--- (2)}$$

from eq 1 and 2 :-

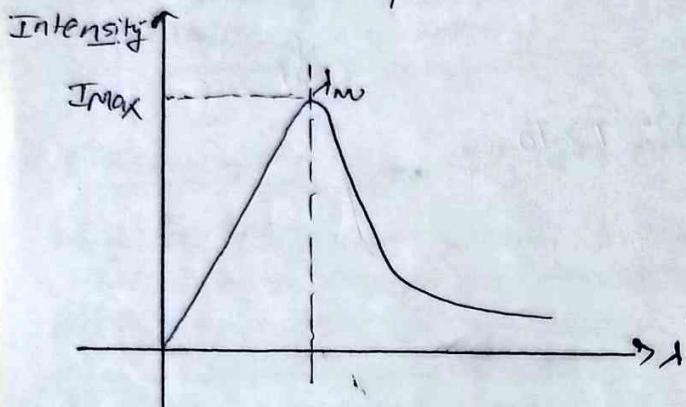
$$-MS \left(\frac{dT}{dt} \right) = 4 \sigma A T_0^3 \Delta T$$

$$\Rightarrow \left[\frac{dT}{dt} = \left(-\frac{4 \sigma A T_0^3}{MS} \right) \Delta T \right]$$

WIEN'S DISPLACEMENT LAW :-

The intensity of energy radiated by a Blackbody is not uniformly distributed over all wavelengths but it is Max. for a Particular wavelength λ_m

? } WIEN'S
LAW!



According to Wien's law; Product of λ corresponding to Max. Intensity (λ_m) & absolute Temp is Constant.

$$\lambda_m T = b$$

b is Wein's Constant; $b = 2.88 \times 10^{-3} \text{ M-K}$

∴ The Value of λ_m (↓) with Increase in Temp ? } WIEN'S
DISPLACEMENT
LAW!

