# Thermal Properties of Matter

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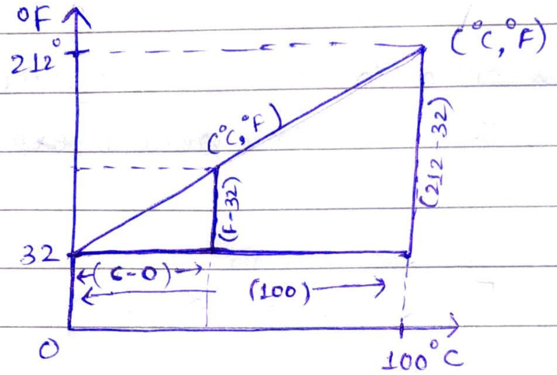
**Temperature** → Degree of hotness or coldness

Boiling point of water → $100^\circ C$ or $212^\circ F$
Freezing point of water → $0^\circ C$ or $32^\circ F$

⇒ In case of Celsius, the heat required to raise the temperature by $1^\circ$ is more than that of Farheneit. $\boxed{1^\circ C > 1^\circ F}$




$$\frac{F-32}{212-32} = \frac{C-0}{100-0}$$

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

**Thermometer** → A device used to measure temperature

**Heat** → Heat is a form of energy that transfers from higher energy to lower energy.

$\boxed{\text{Pressure, Volume, Temperature}}$

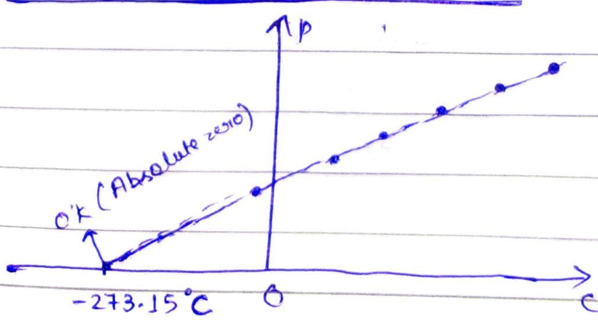
When volume is constant, $P \propto T$ $\quad P = KT$

$$\boxed{\frac{P}{T} = \text{constant}}$$

When pressure is constant, $V \propto T$ $\quad V = KT$

$$\boxed{\frac{V}{T} = \text{constant}}$$

## Absolute Scale (Kelvin scale)




Agar kisi gas ka temperature 0 ho jaaega, to uska pressure bhi khatam ho jaaega

$$0^\circ C = 273.15\,K$$
$$100^\circ C = 373.15\,K$$

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⇒ Kelvin ke gap celsius ke gap ke barabar maane gaye.

$$\boxed{1^\circ C = 1^\circ K}$$

$$\boxed{^\circ C = K - 273.15} \qquad \boxed{K = {}^\circ C + 273.15}$$

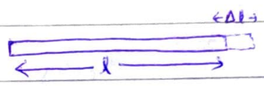
$$\boxed{\frac{C}{100} = \frac{F-32}{180} = \frac{K-273.15}{100}}$$

## Thermal Expansion

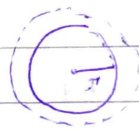
When heat energy is given to any substance, its length, area and volume expands. This is called thermal expansion.

Types of Expansion

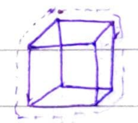
(i) Linear Expansion →




(ii) Area Expansion →



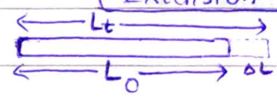

(iii) Volumetric Expansion →




⇒ Thermal Coefficient of Linear Expansion → $\alpha$

When we raise the temperature of a body by 1°C, the change in its length is 1m

(Extension in length by 1m due to increase in temperature by 1°C)




$$L_0 \xrightarrow{\text{when temperature increases}} L_t$$

$$\Delta L \longrightarrow L_t - L_0$$

$$1 \longrightarrow \frac{L_t - L_0}{L_0}$$

$$\Delta T \longrightarrow \frac{L_t - L_0}{L_0}$$

$$1 \longrightarrow \frac{L_t - L_0}{L_0 . \Delta T}$$

$$\alpha = \frac{L_t - L_0}{L_0 . \Delta T}$$

$\beta = 2\alpha \qquad \gamma = 3\alpha$

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$\alpha(L_0.\Delta T) = L_t - L_0 \qquad L_t = \alpha(L_0.\Delta T) + L_0$

$$\boxed{L_t = L_0(1 + \alpha.\Delta T)}$$

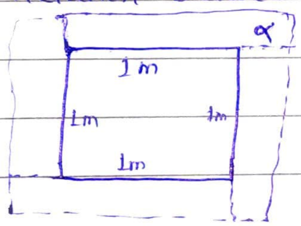
⇒ Thermal Coefficient of Area Expansion $= \beta$

$$\boxed{A_t = A_0(1 + \beta.\Delta T)}$$

⇒ Thermal coefficient of Volumetric Expansion $= \gamma$

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

# Relation between α and β




Old area $= 1$

New area $= (1+\alpha)^2 = 1^2 + \alpha^2 + 2\alpha$

Change in area $= \cancel{1} + \alpha^2 + 2\alpha - \cancel{1}$

α is very small, therefore its square is also small. So it is neglected

$= \underbrace{\alpha^2}_{\text{Neglected}} + 2\alpha$

Change in area by 1 unit when temperature is increased by $1°C = \beta$

$$\therefore \boxed{\beta = 2\alpha}$$

## Thermal Stress

When a body expands, due to increase in temperature, it tends to gain its original configuration (when temperature decreases)

$$\alpha = \frac{L_t - L_0}{L_0.\Delta T} \qquad \boxed{\frac{\Delta l}{l.\Delta T}} \qquad \boxed{\frac{\Delta l}{l} = \alpha.\Delta T} \quad \text{— (i)}$$

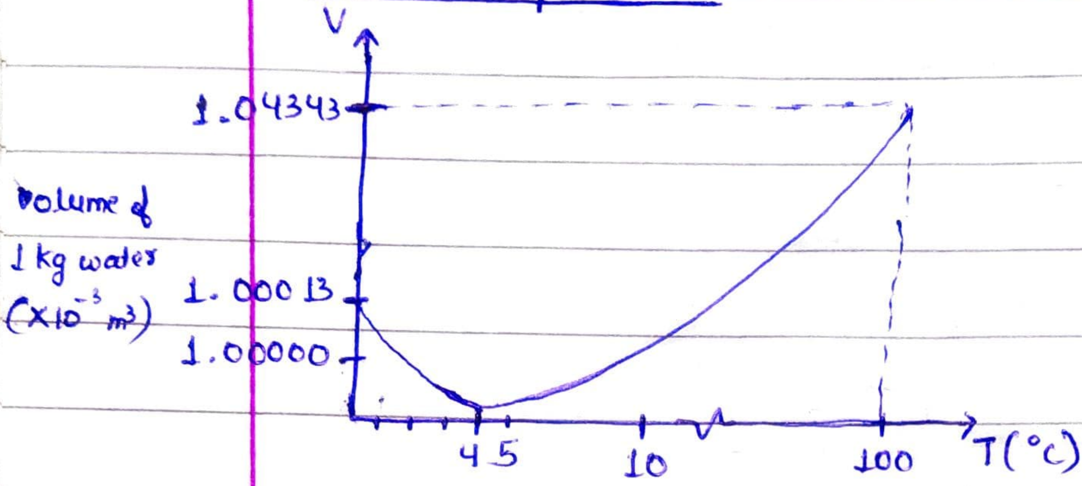
$$Y = \frac{F/A}{\Delta l/l} \Rightarrow \boxed{\frac{\Delta l}{l} = \frac{F}{AY}} \quad \text{— (ii)}$$

From (i) and (ii), $\alpha.\Delta T = \dfrac{F}{AY}$

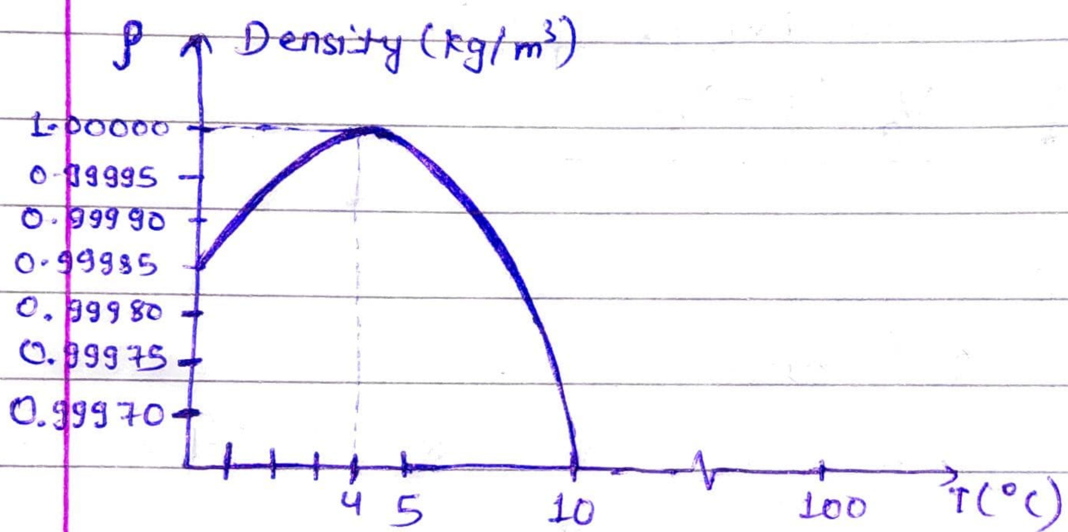
$$\boxed{\frac{F}{A} = \alpha.\Delta T.Y}$$

$\frac{F}{A}$ is stress

# Water Expansion




At 4°C, the volume of water in minimum




At 4°c, the density of water is maximum.

Water Equivalent → The water equivalent of body is defined as the mass of water which requires the same amount of heat as required by the given body for the same rise of temperature.

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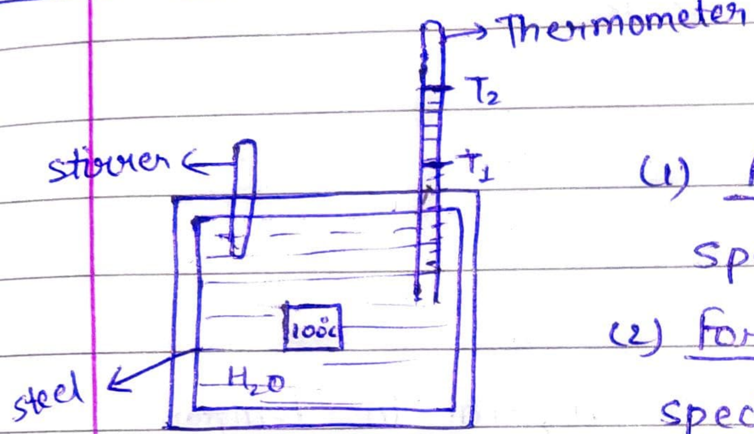
## Calorimetry

$$\boxed{m_1 s_1 \Delta T_1 = m_2 s_2 \Delta T_2}$$ (Energy conservation)




$\boxed{T = 100°C \text{ (object)}}$

(1) For object, mass $= m_1$

specific heat capacity $= S_1$, $\Delta T_1 = (100 - T_2)$

(2) For water, mass $= m_2$

specific heat capacity $= S_2$, $\Delta T_2 = (T_2 - T_1)$

$$\boxed{S_1 = \frac{m_2 S_2 (T_2 - T_1)}{m_1 (100 - T_2)}}$$

→ Not accurate because steel will also absorb some heat

$$m_1 S_1 \Delta T_1 = m_2 S_2 \Delta T_2 + m_3 S_3 \Delta T_3$$

$$\boxed{m_1 S_1 \Delta T_1 = m_2 S_2 \Delta T_2 + m_3 S_3 \Delta T_3}$$

($m_2 S_2 = m_3 S_3$)
(water equivalent)

Specific Heat → Temperature change
Latent Heat → State change.

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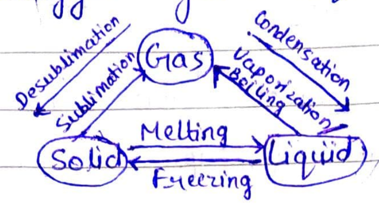
## Transformation of state

Intermolecular force : solid > liquid > gas
Potential energy : gas > liquid > solid




- Heat ek time par ek hi kaam karti hai, ya to temperature change hoga ya state change hogi.

Latent heat → चिपी हुई Heat

## Latent Heat (L)

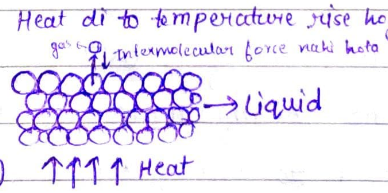
The amount of heat required to change the state of unit mass of substance at constant temperature and pressure is called latent heat of the substance.

$$Q = mL$$

$$\boxed{L = \frac{Q}{m}}$$

Heat di to temperature rise hoga (100°C)

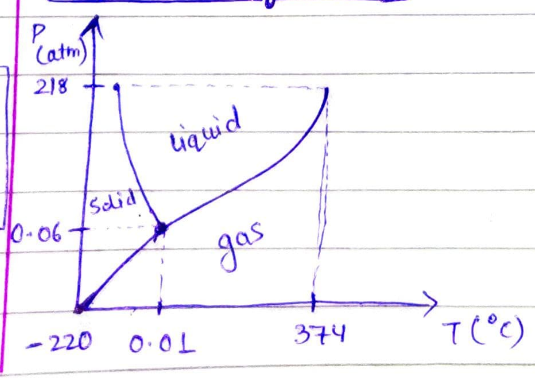
100°C ke baad temperature rise nahi hoga. State change hogi (Liquid → gas)




- Agar upar se pressure badh jaaye to boiling point rise ho jata hai. (110°C) → Ex
- Pressure kam karne se boiling point kam ho jata hai (80°C) → Ex

## Triple Point of Water

0.01°C or 273.16 K and 0.06 atm

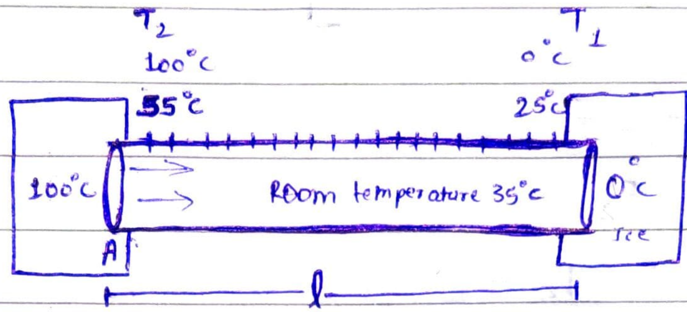



Agar temperature same rakhe aur pressure badha de to solid liquid mein convert ho jaaega.

# Heat Transfer

(Higher temperature to lower temperature)

## (I) Conduction




Heat flows due to temperature gradient

→ Rate of transfer (flow) of heat $= \frac{dQ}{dt}$

$\frac{dQ}{dt} \propto A$ $\quad$ $\frac{dQ}{dt} \propto \frac{1}{l}$ $\quad$ $\frac{dQ}{dt} \propto (T_2 - T_1)$

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

$$\boxed{\frac{dQ}{dt} = \frac{kA(T_2 - T_1)}{l}}$$

k = coefficient of heat / coefficient of thermal conductivity

Unit of k → J/s/m/K

Heat Current $I = \frac{dQ}{dt} = \frac{kA(T_2 - T_1)}{l}$

Heat Current I = $\frac{\text{Temperature difference}}{\text{Thermal Resistance}}$ $= \frac{(T_2 - T_1)}{\frac{l}{kA}}$

→ Driving force

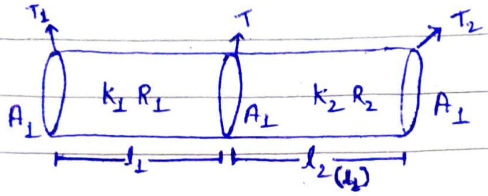
→ Resistance

$$\boxed{\text{Thermal Resistance } R = \frac{l}{kA}}$$

# Thermal Combinations of rod

(1) Series Combination

$I = \frac{Q}{t}$




$l_1 = l_2$

Heat current in the combination remains same (Entering current = Exiting current)

$\mathcal{Q}c = \quad R_1 = \frac{T - T_1}{I} \quad \Rightarrow T - T_1 = IR_1$

$R_2 = \frac{T_2 - T}{I} \quad \Rightarrow T_2 - T = IR_2$

$R_{eq} = \frac{T_2 - T_1}{I} \quad \Rightarrow T_2 - T_1 = I R_{eq}$

$I_2 - I_1 = (T_2 - T) + (T - T_1)$

$\Rightarrow \cancel{I} R_{eq} = \cancel{I} R_2 + \cancel{I} R_1$

$$\boxed{R_{eq} = R_1 + R_2}$$

$I = \frac{T - T_1}{R_1} = \frac{T_2 - T}{R_2}$

$\Rightarrow \frac{T}{R_1} - \frac{T_1}{R_1} = \frac{T_2}{R_2} - \frac{T}{R_2}$

$\Rightarrow \frac{T}{R_1} + \frac{T}{R_2} = \frac{T_2}{R_2} + \frac{T_1}{R_1} \qquad \Rightarrow T\left(\frac{1}{R_1} + \frac{1}{R_2}\right) = \frac{T_2}{R_2} + \frac{T_1}{R_1}$

$$\boxed{T = \frac{\frac{T_2}{R_2} + \frac{T_1}{R_1}}{\frac{1}{R_1} + \frac{1}{R_2}}} \qquad \boxed{T = \frac{\frac{T_2}{\frac{l}{k_2 A}} + \frac{T_1}{\frac{l}{k_1 A}}}{\frac{1}{\frac{l}{k_1 A}} + \frac{1}{\frac{l}{k_2 A}}}}$$

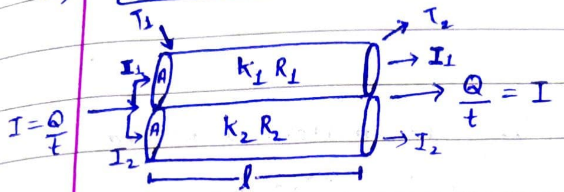
$R_{eq} = R_1 + R_2$

$\frac{2\cancel{l}}{k_{eq} \cancel{A}} = \frac{\cancel{l}}{k_1 \cancel{A}} + \frac{\cancel{l}}{k_2 A}$

$\frac{2}{k_{eq}} = \frac{1}{k_1} + \frac{1}{k_2} \qquad \Rightarrow \frac{2}{k_{eq}} = \frac{k_1 + k_2}{k_1 k_2}$

$$\Rightarrow \boxed{k_{eq} = 2\left(\frac{k_1 k_2}{k_1 + k_2}\right)}$$

(2) Parallel Combination




$I = \frac{Q}{t}$ $\quad I = \frac{T_2 - T_1}{R}$

$R = \frac{l}{kA}$

$I = I_1 + I_2$

$\frac{\cancel{T_2 - T_1}}{R_{eq}} = \frac{\cancel{T_2 - T_1}}{R_1} + \frac{\cancel{T_2 - T_1}}{R_2} \Rightarrow \boxed{\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2}}$

$\boxed{R_{eq} = \frac{R_1 R_2}{R_1 + R_2}}$

$\frac{1}{\frac{\cancel{l}}{K_{eq} 2\cancel{A}}} = \frac{1}{\frac{l}{K_1 \cancel{A}}} + \frac{1}{\frac{l}{K_2 \cancel{A}}} \Rightarrow \boxed{2K_{eq} = K_1 + K_2}$

$\Rightarrow \boxed{K_{eq} = \frac{K_1 + K_2}{2}}$

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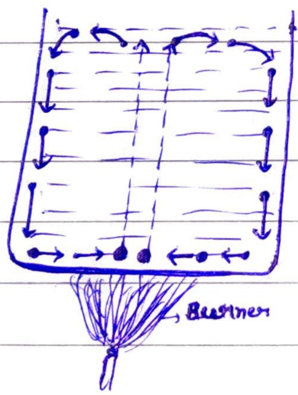
(II) Convection



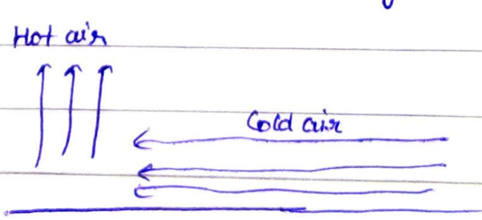

It is the process by which heat flows from the region of higher temperature to the region of lower temperature by the actual movement of the material particles.

(Hot water/air has lower density the cold water/ai

⇒ Land Breeze and Sea Breeze are caused due to convection

⇒ Storms are caused because of convection.

⇒ Monsoon is caused by convection.



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## III Radiation

It is the process by which heat is transmitted from one place to another without heating the .

Q. A slab consist of two portions of different materials of same thickness and having the conductivies $k_1$ and $k_2$ . The $k_{eq}$ is

=) length is equal $k_{eq} = 2\left(\frac{k_1 k_2}{k_1 + k_2}\right)$