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Chapter – Thermal properties of matter

Heat → a form of Energy
Temperature ⇒ Coldness/hotness

$$\frac{T_C - 0}{100} = \frac{T_F - 32}{180} = \frac{T_K - 273.15}{100}$$

☆ Conversion

Ex:- 30°C → F, K

$$\boxed{T_K = T_C + 273}$$

(i) C → K

$$\frac{T_C}{\cancel{5}} = \frac{T_K - 273}{\cancel{5}}$$

$$T_C = T_K - 273$$

$$\boxed{T_K = T_C + 273}$$

$$\boxed{T_K = 303\,K}$$

(ii) 30°C → F

$$\frac{T_C}{5} = \frac{T_F - 32}{9}$$

$$\frac{30}{5} = \frac{T_F - 32}{9}$$

$$6 = \frac{T_F - 32}{9}$$

$$54 = T_F - 32$$

$$T_F = 54 + 32$$
$$= 86F$$

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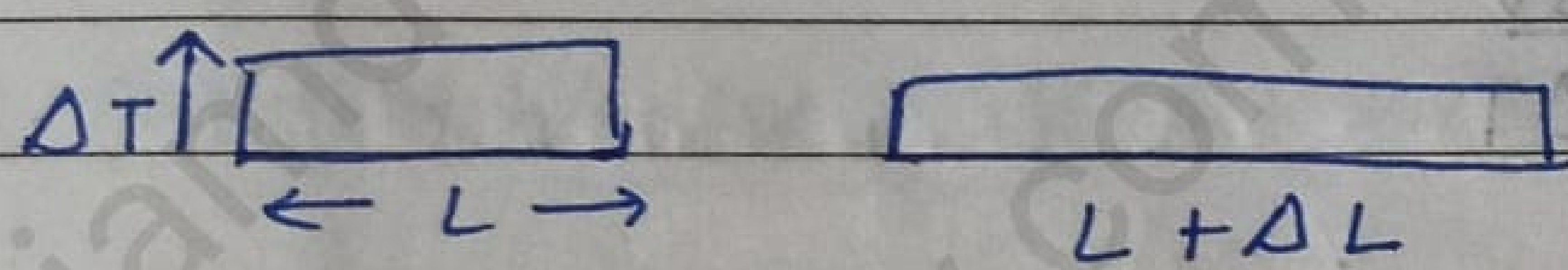
Ex:- $60^\circ C \rightarrow F\,?$, $K\,?$

$$\frac{T_c}{5} = \frac{T_K - 273}{5} \Rightarrow T_K = T_c + 273$$

$$T_K = 60 + 273$$
$$T_K = 333\,K$$

Thermal Expansion



$\Delta L \rightarrow$ change in length / Linear expansion

$\Delta L \propto \Delta T$ — (1)

$\Delta L \propto L$ — (2)

$$\Delta L \propto L \Delta T$$
$$\Delta L = \alpha L \Delta T$$
$$\alpha = \frac{\Delta L}{L \Delta T}$$

if $L = 1$

$\Delta T = 1^\circ C$

$\Rightarrow$ $\boxed{\alpha = \Delta L}$

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$$\rightarrow \boxed{A} \rightarrow A+\Delta A$$

$$\Delta A \propto \Delta T$$
$$\Delta A \propto A$$
$$\Delta A \propto A.\Delta T$$
$$\Delta A = \beta A \Delta T$$
$$\cancel{\beta = \frac{\Delta A}{A\Delta T}} \qquad \beta = \frac{\Delta A}{A\Delta T}$$

$$\beta = \frac{\Delta V}{V\Delta T}$$

α, β and γ

α = Cofficient of Linear Expansion $= \dfrac{\Delta L}{L\Delta T}$ — (1)

β = Cofficient of Area Expansion $= \dfrac{\Delta A}{A\Delta T}$ — (2)

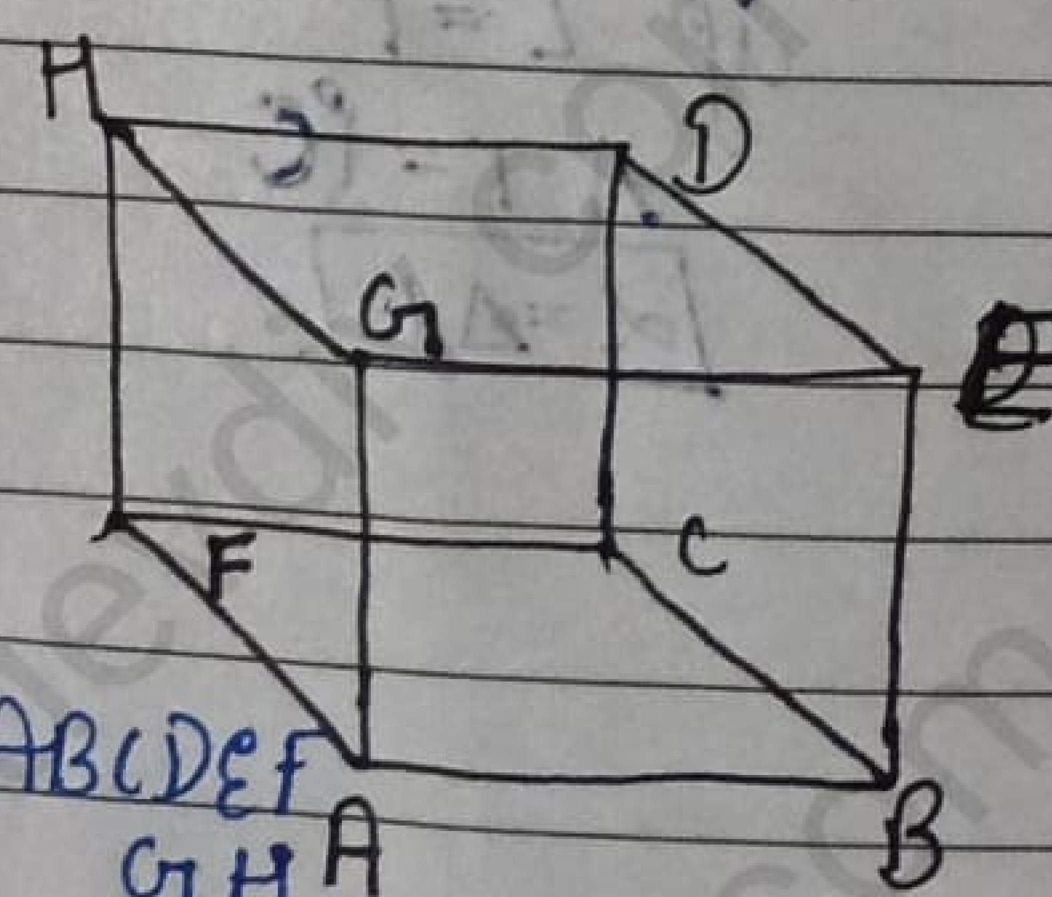
γ = Cofficient of Volume Expansion $= \dfrac{\Delta V}{V\Delta T}$ — (3)

Cube/Cubical body

Initial Length = L

Initial Area = A $= L^2$

Initial Volume = V $= L^3$



$\Delta T \rightarrow$ Raised ↑ Given Temp. Cube ABCDEFGH

Change in length = ΔL

" " Area = ΔA

" " Volume = ΔV

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Case I Relation b/w α & β

After raised ΔT Temp. Change in Area ΔA, so

$$A + \Delta A = (L + \Delta L)^2$$
$$A + \beta A \Delta T = (L + \alpha L \Delta T)^2$$
$$\cancel{A}(1 + \beta \Delta T) = \cancel{L^2}[1 + \alpha \Delta T]^2$$
$$1 + \beta \Delta T = (1 + \alpha \Delta T)^2$$
$$\cancel{1} + \beta \Delta T = \cancel{1} + \alpha^2 \Delta T^2 + 2\alpha \Delta T$$
$$\alpha^2 \Delta T^2 << 1$$
$$\cancel{\Delta T \beta = 2\alpha \Delta T} \quad \Delta T \beta = 2\alpha \Delta T$$
$$\boxed{\beta = 2\alpha} \text{ — (iv)}$$

Case 2 Relation b/w α & γ.

After raised ΔT Temperature change in Volume of cube ΔV, so

$$V + \Delta V = (L + \Delta L)^3$$
$$V + \gamma V \Delta T = [L + \alpha L \Delta T]^3$$
$$\cancel{V}[1 + \gamma \Delta T] = \cancel{L^3}[1 + \alpha \Delta T]^3$$
$$1 + \gamma \Delta T = (1 + \alpha \Delta T)^3$$
$$= 1 + \alpha^3 \Delta T^3 + 3\alpha \Delta T(1 + \alpha \Delta T)$$
$$= 1 + \gamma \Delta T = 1 + \alpha^3 \Delta T^3 + 3\alpha \Delta T + 3\alpha^2 \Delta T^2$$
$$= \cancel{1} + \gamma \Delta T = \cancel{1} + 3\alpha \Delta T$$
$$\gamma \cancel{\Delta T} = 3\alpha \cancel{\Delta T}$$
$$\boxed{\gamma = 3\alpha} \text{ — (v)}$$

From the above equation (iv) & (v) we can say that

$$\alpha : \beta : \gamma = \alpha : 2\alpha : 3\alpha = 1 : 2 : 3$$

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Thermal Stress:- It is the stress which is set up in a metallic rod on heating if the two ends of rod are rigidly held between the two fixed support.

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

$$\frac{\Delta L}{L} = \alpha \Delta T$$

$$\text{Youngs Modulus} = Y = \frac{\text{Thermal stress}}{\text{Longitudinal strain}}$$

$$\text{Thermal stress} = Y \times \text{longitudinal strain}$$
$$= Y \frac{\Delta L}{L}$$

$$\text{Thermal stress} = Y \alpha \Delta T$$

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

$$F = Y \alpha A \Delta T$$

Expansion of Liquid

It can be defined as the cofficient of real expansion of liquid as the real increase in volume of the liquid per unit orignal volume per degree celsius ~~right~~ rise in temperature It always represent by

$$\gamma_r = \frac{\text{Real increase in volume}}{\text{Original Volume} \times \text{rise in temp.}}$$

Note:- Coffecient of apparent expansion of liquid it can be defined as the apparent increase in volume per unit original volume per degree celsius in temp. it is represent by $\gamma_a = \frac{\text{apparent increase in volume}}{\text{Original volume} \times \text{rise in temp.}}$

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☆ Specific heat capacity or Specific heat

Specific heat of a substance may be defined as the amount of heat required to raise the temperature of unit mass of the substances through unit degree. Let us consider ΔQ is a small amount of heat energy required to raise the temperature of a certain mass 'm' of a substance due to small amount of temp. ΔT then it is observed that:-

$$\Delta Q \propto m \quad \text{--- (1)}$$
$$\Delta Q \propto \Delta T \quad \text{--- (2)}$$

from (1) & (2)

$$\Delta Q \propto m \Delta T$$

$$\therefore \Delta Q = S m \Delta T$$

m → mass of substance

ΔT → Raised temperature

ΔQ → Heat Energy

S → Specific heat or specific heat Capacity

OR $$\boxed{S = \frac{\Delta Q}{m \Delta T}}$$

Unit → calorie / gm-K
OR
Joule / kg. K

1 J = 4.18 Calorie
1 J = 4.2 Calorie

Note:- The specific heat of water is $4180\ J\,kg^{-1}\,K^{-1}$

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☆ Molar specific heat

It is defined as the amount of heat energy required to raise the temp. of 1 gm mole of the substance through a unit degree. It always represent by 'C' or. 1 mole of any substance is a quantity of substance, whose mass in gm is numerically equal to the molecular mass 'M'

$$\boxed{C = MS}$$

⇒ Note:- $m = nM$

The general formula for molar specific heat

$$C = \frac{1}{n} \frac{\Delta Q}{\Delta T}$$

Unit of C = Calorie / gm. mol. K

OR

Calorie gm^{-1} mol^{-1} K^{-1}

☆ Thermal Capacity

Thermal Capacity of a body is defined as the amount of heat required to raise the temperature of the whole body through 1°C or 1°K.

Formula for thermal capacity is $\Delta Q = mS\Delta T$

$$\Delta T = 1$$

$$\Delta Q = mS \rightarrow \text{Thermal Capacity}$$

$$S = mS \times 1$$

Unit of thermal capacity is Joule per Kelvin or Kelvin per °C.

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☆ Latent Heat

Latent Heat of a substance is the amount ~~of substance~~ of heat energy is required to change the state of unit mass of the substance from solid to liquid or liquid to gas or vapour without any change in temperature.

⇒ Latent Heat is always represent by 'L'

$$L = \frac{\text{Quantity of heat 'Q'}}{\text{mass of substance (m)}}$$

$$L = \frac{Q}{m} \quad \text{OR} \quad Q = mL$$

It's unit is Joule/kg
OR
~~K/I~~ Calorie/gm

Note:- Latent Heat of fusion of ice = 80 Cal./gm
Latent Heat of Vapourisation of water = 540 Cal./gm

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→ **Newton's Law of ~~pulling~~ Cooling**

Newton's Law of ~~pulling~~ Cooling state that the rate of loss of heat of a body ~~each~~ is directly propotional to the difference in the temperature of the body in surrounding provided the difference in temp. is small, not more than 40°C

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

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

Note- A perfectly black body is that which absorb completely the radiation of all wavelengths incidents on it.

imp. ★ **Stephen's Law**

Acc... to this law the amount of heat energy emitted per second by unit area of a perfectly black body is directly propotional to the 4th power of absolute temp. of ~~T of~~ the body.

$$E \propto T^4$$

$$E = \sigma T^4$$

$$\sigma = \frac{E}{T^4}$$

$$\sigma = 5.67 \times 10^{-8} \quad \frac{W}{m^2 K^4} \; (J/sec.)$$

↳ abs.. temp.

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dimensional formula for σ

$$\sigma = \frac{W}{m^2 K^4}$$

$$= \frac{\text{Joule}}{\text{Sec.}} \cdot \frac{1}{m^2} \cdot \frac{1}{K^4}$$

$$= \left[\frac{M\cancel{L^2}T^{-2}}{T} \cdot \frac{1}{\cancel{L^2}} \cdot \frac{1}{K^4}\right]$$

$$= \boxed{M T^{-3} K^{-4}}$$

Wein's displacement law

Acc. to this law the wavelength of maximum intensity of emission of black body radiation is inversely propotional to the absolute temp. 'T' of the black body.

$$\lambda m \propto \frac{1}{T}$$

$$\lambda m = \frac{b}{T} \Rightarrow \lambda m\, T = b$$

OR

$$\boxed{\lambda_1 T_1 = \lambda_2 T_2}$$

The value of wein displacement constant 'b' is

$$b = 2.892 \times 10^{-3}\ mK$$

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Ques - Two stars radiate maximum energy at wavelengths 3.6×10^{-7} m and 4.8×10^{-7} m respectively. What is the ratio of their temperature?

Sol: -

$$\lambda_1 T_1 = \lambda_2 T_2$$

$$\cancel{3.6 \times 10^{-7} = 4.8}$$

$$\frac{\lambda_1}{\lambda_2} = \frac{T_1}{T_2}$$

$$\frac{\cancel{3.6} \times \cancel{10^{-7}}}{\cancel{4.8} \times \cancel{10^{-7}}} = \frac{T_1}{T_2}$$

$$\boxed{T_1 : T_2 = 3 : 4}$$