LEARNING MATERIALS

ON

ENGINEERING PHYSICS

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Lect. Physics

Unit-7: Heat and Thermodynamics

Heat:-

Heat is the energy of a body that is transferred from one body to another due to temperature difference between the two bodies.

When a hot body is placed in contact with a cold body, heat (energy) is transferred from the hot body to cold body. This transfer of energy between two bodies as a result of temperature difference is called heat.

Units of heat :-

(i) Calorie :-

One calorie is the amount of heat required to raise the temperature of 1 gm of water through $1^\circ C$.

(ii) Joule :-

It is the SI unit of energy.

1 calorie = 4.186 Joules

CGS unit :-

$1 \text{ Joule} = 1\ kg \times m^2/s^2$ (SI)

$- gm\ cm^2/s^2$

FPS unit :-

$- lb \times ft^2/s^2$

MKS unit :-

$- kg \times m^2/s^2$

Temperature :-

> The temperature of a body is its degree of hotness or coldness.

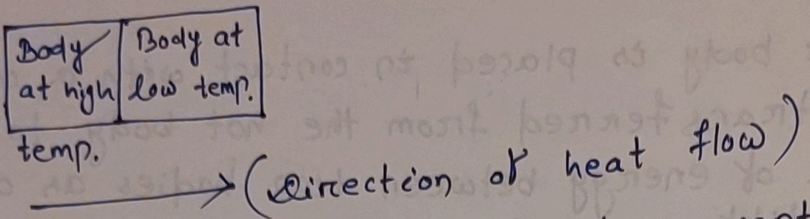
> The temperature of a body is an indicator of the average termal energy of the molecules of the body.

(The thermal energy of a body is the total kinetic energy of all the molecules of the body.)

> When two bodies at different temperatures are brought in contact, heat flows from a body at higher temperature to the body at lower

temperature till the temperature of the two bodies is the same.

Thus the temperature of the two bodies decides the direction of heat flow when the two bodies are brought in contact.



Hence when two bodies are brought in contact, the direction of heat flow determines which body is at higher temperature.

Note :- Two bodies are said to be in thermal equillibrium if no transfer of heat takes when they are brought in contact. clearly, the two bodies are at same temperature.

Scales of temperature :-

(i) Celcius Scale :-

On this scale, the melting point of ice is $0^\circ c$ and boiling Point of water is $100^\circ c$. The interval between these points is divided into 100 equal parts.

(ii) Farenheit scale :-

On this scale, the ice point is marked as $32^\circ F$ and the steam Point is marked as $212^\circ F$. The interval bet^n these points is divided into 180 equal parts.

$$\frac{t_c - 0}{100} = \frac{t_F - 32}{180}$$

$$\Rightarrow \boxed{t_F = \frac{9}{5} t_c + 32}$$

(Relationship between celcius scale and Farenheit scale)

(iii) kelvin or absolute temp. scale :-

Ice point → 273.15 k

Steam point → 373.15 k

$$\boxed{\frac{t_c - 0}{100} = \frac{t_F - 32}{180} = \frac{T - 273.15}{100}}$$ (Relationship along three scales)

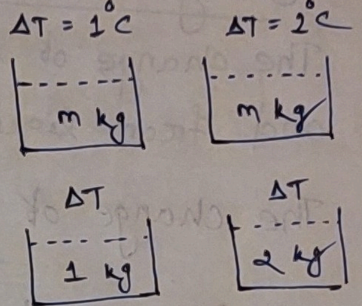
$$\frac{t_c - 0}{100} = \frac{T - 273.15}{100}$$

$$\Rightarrow \boxed{T = t_c + 273.15}$$ (Relationship betn celcius scale and kelvin scale)

Specific heat capacity (s) :-

To raise the temp. of the system, we need to provide heat or work.

Heat is directly proportional to the change in temperature :



$$\Delta Q \propto \Delta T \quad \text{——— (1)}$$

Heat is directly proportional to the mass of the body and also depends upon the nature of the substance.

$$\Delta Q \propto m \quad \text{——— (2)}$$

Combining these,

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

$$\Rightarrow \Delta Q = s\, m \Delta T$$

$$\Rightarrow \boxed{s = \frac{1}{m} \frac{\Delta Q}{\Delta T}}$$ (s = specific heat capacity)

$\Rightarrow$ Unit of s = $J\ kg^{-1}\ K^{-1}$

Dimension of s = $\frac{[M^1 L^2 T^{-2}]}{[M^1 L^0 T^0][M^0 L^0 T^0 K^1]} = [M^0 L^2 T^{-2} K^{-1}]$

Specific heat capacity is defined as the amount of heat required to raise the temperature of 1 gm of a substance by 1°c.

Specific heat (s) :-

It is the amount of heat required to change the temperature from T to $T + \Delta T$.

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

SI unit → $J K^{-1}$

dim → $[M^1 L^2 T^{-2} K^{-1}]$

Specific heat / heat capacity	Specific heat capacity
→ It depends on amount of substance (mass) as well as nature of the material.	→ It depends on nature of substance, temperature and pressure. → It is independent of mass.

Change of State :-

The change of state from solid to liquid is called melting and from liquid to solid is called fusion.

The change of state from liquid to gas is called vapourisation.

The change of state from gas to liquid is called condensation.

" " " " " solid to gas " " sublimation

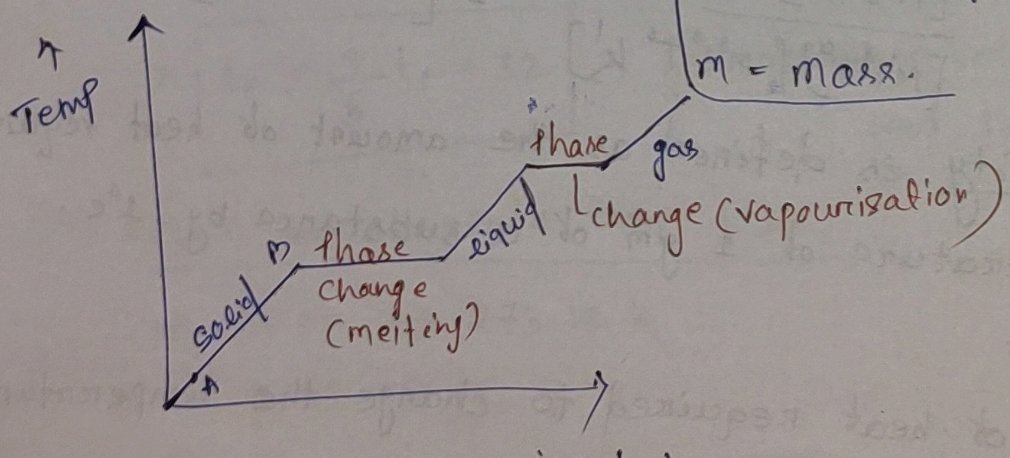
" " " " " gas to solid " " deposition

Latent Heat :-

The heat i.e. supplied during change of phase is not used to increase the temperature but to change the internal - structure of the substance. this heat is called latent heat.

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

L = Latent heat of a substance
Q = Energy released or absorbed during phase change
m = mass.



Latent heat of fusion :-

The heat supplied during change of phase from solid to liquid is called latent heat of fusion.

Latent heat of vapourisation :-

The heat supplied during change of phase from liquid to gas is called latent heat of vapourisation.

THERMAL EXPANSION OF SOLID :-

The change of size of a body due to change in the temperature is called thermal expansion. When a solid is heated its length, breadth & height will increase, so thermal expansion of solid can be treated in 3 ways.

1. Linear or longitudinal expansion
2. Superficial or area expansion
3. Cubical or volume expansion

Linear expansion :-

This is known as expansion along one dimension. When a solid is heated, its length increases.

Let L_0 be the length at $0°c$.

If it is heated to $T°c$, its length becomes L_T.

The increase in length $\Delta L = L_T - L_0$ is directly proportional to (i) original length L_0 at $0°c$.

(ii) Rise in temperature ΔT.

Hence $\Delta L \propto L_0$

$\Delta L \propto \Delta T$

Combining, $\Delta L \propto L_0 \Delta T$

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

$\Rightarrow \alpha = \frac{\Delta L}{L_0 \Delta T}$, where α is called co-efficient of linear expansion.

The co-efficient of linear expansion can be defined as the rate of unit length per unit degree change in temperature.

unit of α = $°C^{-1}$ / K^{-1} / per °C / Per °K

dimension of α = $[M^0 L^0 T^0 K^{-1}]$

SUPERFICIAL OR AREA EXPANSION :-

This is the expansion along two dimensions. When a solid is heated, its surface area increases.

Let A^0 be the area at 0°C.
If it is heated to T°C, its area becomes A_T.
The increase in area, $\Delta A = A_T - A_0$ is directly proportional to (i) original area A_0 at 0°C
(ii) Rise in temperature ΔT

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

Combining these, $\Delta A \propto A_0 \Delta T$

$\Rightarrow \Delta A = \beta A_0 \Delta T$

$\Rightarrow \beta = \frac{\Delta A}{A_0 \Delta T}$, where β is called as co-efficient of superficial expansion.

Defⁿ: The co-efficient of superficial expansion can be defined as the increase in area per unit degree rise in temperature.

Unit $\Rightarrow$ $°C^{-1}$ or K^{-1}

Dim $\Rightarrow$ $[M^0 L^0 T^0 K^{-1}]$

CUBICAL OR VOLUME EXPANSION :-

This is the expansion along three dimensions.

When a solid is heated, its volume increases.

Let V_0 be the volume at $0°C$.

If it is heated to $T°C$, its volume increases to V_T.

The increase in volume $\Delta V = V_T - V_0$ is directly proportional to (i) original volume at $0°C$

(ii) Rise in temp. (ΔT)

Hence, $\Delta V \propto V_0$

$\Delta V \propto \Delta T$

Combining, $\Delta V \propto V_0 \Delta T$

$\Delta V = \gamma V_0 \Delta T$; where γ is the co-efficient of cubical expansion

$$\Rightarrow \gamma = \frac{\Delta V}{V_0 \Delta T}$$

The co-efficient of cubical expansion (γ) can be defined as the increase in volume per unit volume per unit rise of temperature.

unit :- $°C^{-1}$ or K^{-1}

dimension :- $[M^0 L^0 T^0 K^{-1}]$

Relation between α, β & γ :-

we know that, $\alpha = \frac{1}{L}\left(\frac{dL}{dT}\right)$

$$\beta = \frac{1}{A}\left(\frac{dA}{dT}\right)$$

$$\gamma = \frac{1}{V}\left(\frac{dV}{dT}\right)$$

Relation between α & β :-

$$\beta = \frac{1}{A}\left(\frac{dA}{dT}\right)$$

But $A = L^2$

$$\beta = \frac{1}{L^2}\frac{d}{dT}(L^2)$$

$$= \frac{2L}{L^2}\frac{dL}{dT}$$

$$= 2\frac{1}{L}\frac{dL}{dT}$$

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

Relation between α & γ :-

$$\gamma = \frac{1}{V}\left(\frac{dV}{dT}\right)$$

But $V = L^3$

$$\Rightarrow \gamma = \frac{1}{L^3}\frac{d}{dT}L^3$$

$$= \frac{3L^2}{L^3}\frac{dL}{dT}$$

$$= \frac{3}{L}\frac{dL}{dT}$$

$$\Rightarrow \gamma = 3\left(\frac{1}{L}\frac{dL}{dT}\right)$$

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

$$\beta = 2\alpha \Rightarrow \alpha = \frac{\beta}{2}$$

$$\gamma = 3\alpha \Rightarrow \alpha = \frac{\gamma}{3} \quad \therefore \boxed{\alpha = \frac{\beta}{2} = \frac{\gamma}{3}}$$

Work & Heat :-

According to Joule, there is an equivalence between work & heat."

Joule's mechanical equivalent of Heat -

whenevere a work is converted into heat or vice-versa, the quantity of work disappearing in the system is equivalent to the quantity of heat appearing in that system.

Thus work (w) & heat (Q) are found to be directely proportional to each other.

$$w \propto Q$$

$\Rightarrow w = JQ$; where J is the Joule's mechanical equivalent of heat.

$$\Rightarrow \boxed{J = \frac{w}{Q}}$$

Defn :- If $Q = 1$, then $w = J$

Hence mechanical equivalent of heat is defined as the amount of mechanical work done to produce unit quantity of heat.

$J = 4.186$ Joule/calorie (M.K.S. system)

$J = 1$ (SI unit)

$J = 4.186 \times 10^7$ erg/cal (CGS system)

J is constant for a system of unit & has no dimensions.

FIRST LAW OF THERMODYNAMICS :-

The amount of heat supplied to a system is equal to the sum of the increase of its internal energy & external work done by it.

$$dQ = dU + dW$$

where ; dQ = Heat supplied to the system

dU = change in internal energy

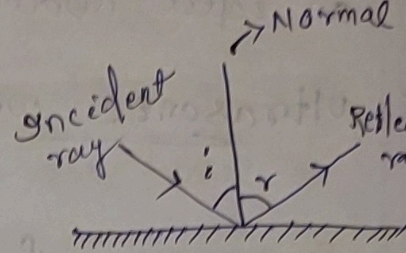
dW = External work done by it.

Unit-8

OPTICS

Reflection :-

Reflection is when light bounces off an object. when the light is incident on the smooth and shiny surface, then the light will reflect at the same angle as it hit the surface.



Laws of Reflection :-

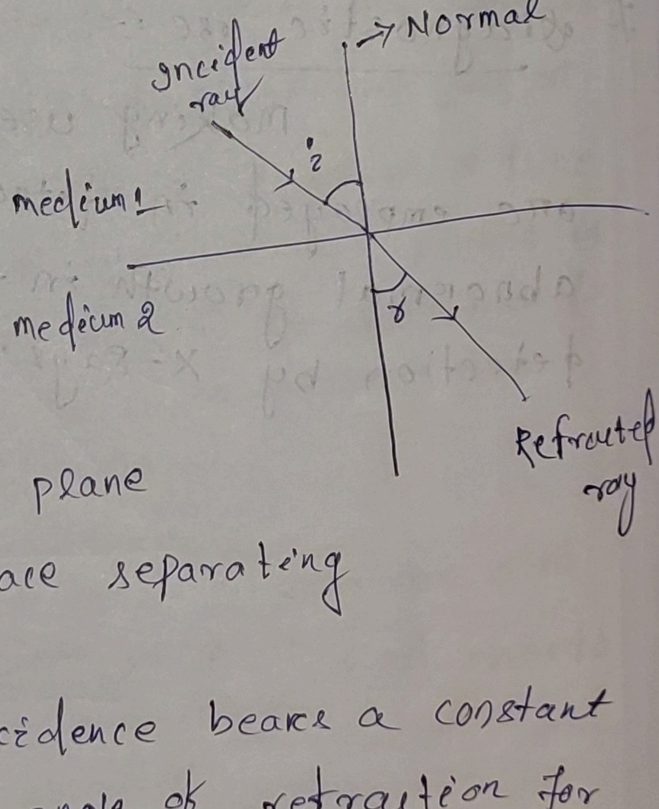
1- The incident ray, the reflected ray and the normal to the reflecting surface at the point of the incedence lie in one plane.

2- The angle of incidence is equal to the angle of reflection.

i.e. $\angle i = \angle r$

Refraction :-

Refraction is the phenomenon by virtue of which a ray of light going from one medium to othere undergoes a change in its velacity.



Laws of Refraction :-

(i) The incident ray, the refracted ray & the normal to the incidence at the point of incidence all lie in one plane and that plane is perpendicular to the interface separating the two lines.

(2) The sine of the angle of incidence bears a constant ratio with the sine of the angle of refraction for

the two same pair of media & same colour of light.

$$\frac{\sin i}{\sin r} = \text{constant}$$

This is known as Snell's law.

Refractive Index :-

Refractive index of a medium w.r.t. the another is defined as the ratio between sin i & sin r.

$$\frac{\sin i}{\sin r} = {}^1\mu_2$$

; ${}^1\mu_2$ = Refractive index of 2nd medium w.r.t. 1st medium.

* Refractive index of a medium 2 w.r.t. medium 1 is defined as the ratio between velocity of light in medium 1 to the velocity of light in medium 2.

i.e. $${}^1\mu_2 = \frac{v_1}{v_2}$$

If the first medium is air or vacuum, then the refractive index is known as absolute refractive index (μ).

$$\mu = \frac{c}{v} \Rightarrow {}^1\mu_2 = \frac{v_1}{v_2} = \frac{c}{v}$$

$$\Rightarrow {}^1\mu_2 = \frac{v_1/c}{v_2/c} \Rightarrow \boxed{{}^1\mu_2 = \frac{\mu_2}{\mu_1}}$$

$${}^1\mu_2 = \frac{\sin i}{\sin r} = \frac{\mu_2}{\mu_1}$$

$$\Rightarrow \boxed{\mu_1 \sin i = \mu_2 \sin r}$$

We know, $v = \lambda f$

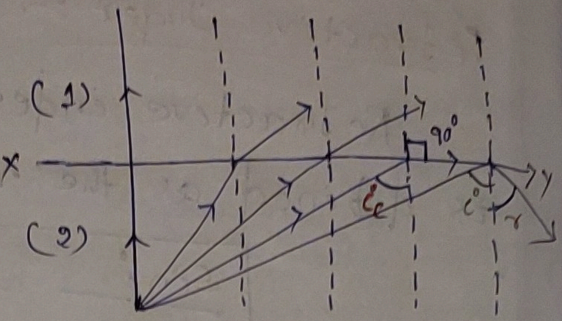
$$\frac{\mu_2}{\mu_1} = \frac{v_1}{v_2} = \frac{\lambda_1 f}{\lambda_2 f} = \frac{\lambda_1}{\lambda_2}$$

$$\Rightarrow \boxed{\frac{\mu_2}{\mu_1} = \frac{\lambda_1}{\lambda_2}}$$

Total Internal Reflection :-

Critical Angle :-

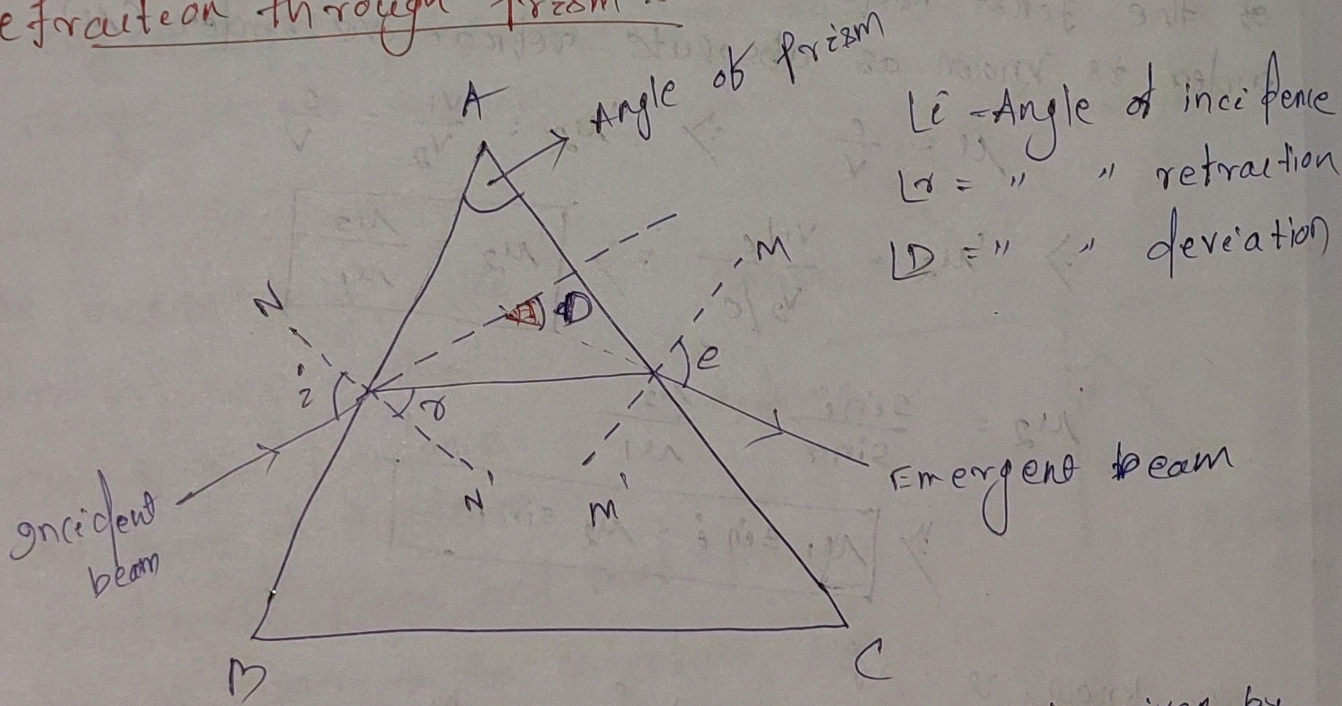
Critical angle is the angle of incidence of a ray of light in denser medium such that its angle of refraction in the rarer medium is 90°.



Total internal reflection :-

Total internal reflection is the phenomenon by virtue of which, a ray of light travelling from a denser to a rarer medium is sent back is the same medium provided, it is incident on the interface at an angle greater than critical angle.

Refraction through prism :-



Refractive index of the material of prism is given by

$$\mu = \frac{\sin\left(\frac{A+D_m}{2}\right)}{\sin\frac{A}{2}}$$

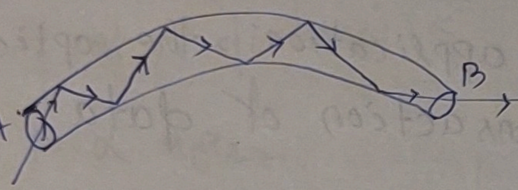
, where D_m = Angle of minimum deviation.

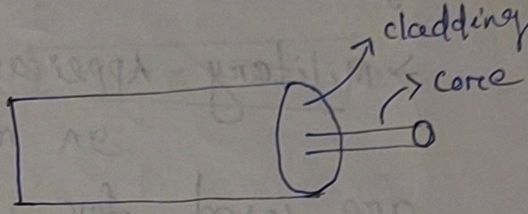
Unit-8 - OPTICS

Fibre optics / Optical fibre

> An optical fibre is a flexible, transparent fibre made by drawing glass (silica) or plastic to a diameter slightley thicker than that of human hair.

> An optical fibre consists of a glass or a plastic core surrounded by a cladding made up of a similar material but with a lower refractive index.





> light can travel in a curved path in optical fibre by using total internal reflection.

Properties of optical fibre :-

> Data transmitted at higher speed.
> Lighter in weight
> No cross talk or reflection problems.
> No risk of short circuits or electrical spark.
> Tampering of data is not easy.
> Less costly for installation and maintence over long distance.

Applications of optical fibre :-

> video transmission :-
It is used to transmit videos at higher speed with less risk for loss of data.

> Broadband services :-

optical fibres are used ~~to~~ for high speed internet connection.

> Computer data communication :-
In LAN, WAN, the optical fibres are used.

> Long distance communication backbones :-
For long distance communication, optical fibres are used for safe communication.

> Military Application :-
In military application, the optical fibres are used for safe transaction of data.