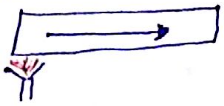
MODE OF HEAT TRANSFER

|1| → CONDUCTION
|2| → CONVECTION
|3| → RADIATION

1. → <u>CONDUCTION</u> → Method of heat transfer in wich Medium particle transfered heat one place to another place without change its own position.

EX →



NOTE → (i) → * conduction method is possible in solid, liquid & gas.

(ii) → * Thermal conductivity (K) is max for solid Medium.

*** $\boxed{K_{solid} > K_{liq} > K_{gas}}$

(iii) → * Thermal conductivity is directelly propersnal to Electrical conductivity. Except → Human body.

** जो Body Electricity का conductor hai वो Heat का भी Good conductor होगा Except Human Body.

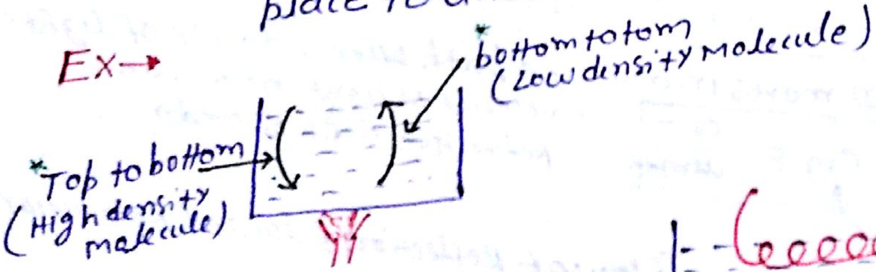
EX → $\boxed{\begin{array}{c} \sigma_{cu} < \sigma_{Al} \\ K_{cu} > K_{Al} \end{array}}$ $\boxed{K_{metal} > K_{Non\text{-}metal}}$

* (iv) → * In a <u>solid</u> medium heat transfer take <u>place only from conduction method.</u>

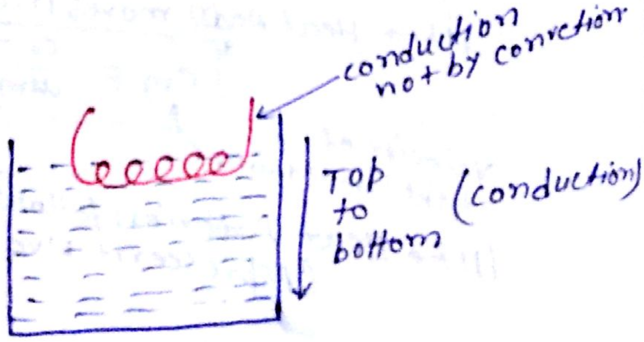
BCECE 2015

2. → <u>CONVECTION</u> → Method of Heat transfered in wich medium particle transfered heat one place to another place due to density differerce.

EX →



* convection method is possible from bottom to Top.



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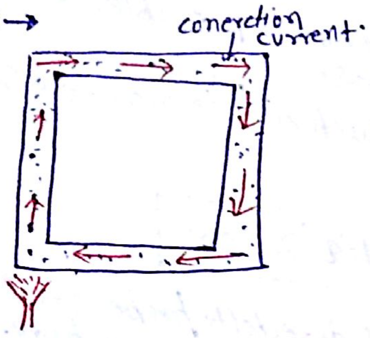
NOTE → * Medium & Gravity is necessory for convection Method.
* For best Heating devices place at bottom & for best calling devices place at Top.
* In a Artificial satellite, freelly falling lift, at the centre of earth Heat transfer not takes place from covection method.

Forced convection → If medium particle circulate forcely.

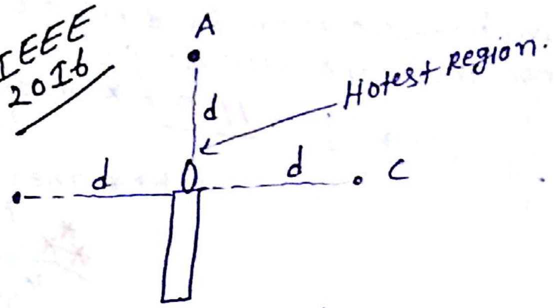
EX → FAN, coller, AC, duct, Heat pump). * BCECE 2015 main

convection current :→

EX →



AIEEE 2016



$$\boxed{T_A > T_B = T_C}$$

T_A → convection + Radiation

$T_B = T_C$ → only Radiation

EX →

|3| → RADIATION → Method of Heat transfer in which medium is not necessory & Heat transfer takes place with velocity of light.

NOTE → * Solid → only conduction.
* Liquid & Gas → conduction, convection & Radiation.
Imp * vaccume → only Radiation.
* $\boxed{\text{Radiation} > \text{convection} > \text{conduction}}$ *

Radiation → velo of light; convection → slow; conduction → slowest.

Properties of thermal Radiation or, Heat Radiation or, Infrared Radn.

|i| → Heat Radn moves in a st. line path with velocity of light.

* $$\boxed{C_m = \frac{C_0}{\mu_m}}$$

C_0 → velocity of light in vaccume.
μ_m → Refrective Index of medm.
C_m → velocity of light in medium.

|ii| → Heat Radiation follow law of Reflection & law of Refraction (represent wve nature.)

|iii| →

Radiation	γ-ray	X-Radⁿ	U·V Radⁿ	visible VIBGYOR	I·R or, Heat Radⁿ or, Thermal Radⁿ	M·W	R·W
Wavelength Range	$<0.01 A°$	$0.01 A°$ – $100 A°$	$100 A°$ – $3800 A°$	$3800 A°$ – $7800 A°$	$7800 A°$ – $10^6 A°$	$>10^6 A$	mm, cm, m Range
Energy Range	>1.24 MeV	124 eV – 124 keV	3.1 eV – 124 eV	1.3 eV – 3.1 eV	0.0124 eV – 1.3 eV	<0.0124 eV	

$* \lambda \uparrow, \ \nu = \frac{c}{\lambda} \downarrow \Rightarrow E_{ph} = h\nu \downarrow \Rightarrow P.P \downarrow$

**

$$\boxed{E_{ph} = h\nu = \frac{hc}{\lambda} = \frac{12400}{\lambda(A°)} eV = \frac{1240}{\lambda(nm)} eV}$$

(I.R Radiation)

Wavelength Range of Heat Radⁿ ⇒ $7800 A° - 10^6 A°$

* Energy ⇓ 0.0124 eV – 1.3 eV

" " " Radⁿ ⇒ $0 - \infty$

A/R AIIMS

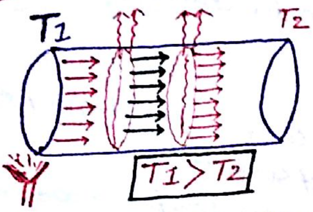
|1| → CONDUCTION →

* Thermal Energy ↑, vibrational K.E of surface Molecule. It is further devide into 3-part.

↓

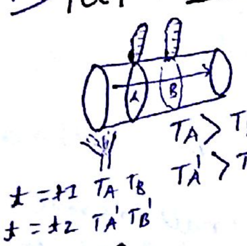
Some part is absorb by the surface molecule, some part is Radiated & Remaning part is transfered to the nearest surface molecule.

2016 AIIMS



A/R * In the direction of Heat flow, temp. of conductor is ↓. It explain from the Internal Resistance of path.

A/R |a| → varible condition → If temp. of same surface charge w.r.t time condition is called variable condition.



$\boxed{T = f(x, t)}$

$\boxed{T_A' \neq T_A \quad T_B \neq T_B'}$

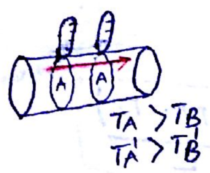
* Heat flow or, Heat current

$$\boxed{\frac{dQ}{dt} = \text{Non-uniform}}$$

↓

Reason → In a variable condition Radiated & absorbing part is not equal to zero.

A/R |b| → Steady State condition → If temp. of same surface Remain unchange w.r.t condition.



$\boxed{T_A = T_A' \quad T_B = T_B'}$

$\boxed{T = f(x)}$

$$\boxed{\frac{dQ}{dt} = c(\text{uniform})}$$

↓

Reason → ✓

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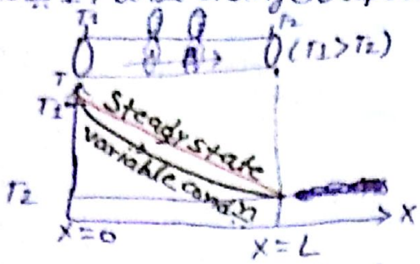
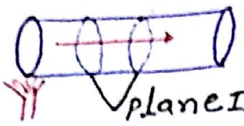
* In a steady state condⁿ temp. change linearly w.r.t distance from heating end & in variable condⁿ it will change exponentially.



|c| → **Isothermal surface** → In the ⊥ direction of heat flow surface which has same temp. molecule is called Isothermal surface.

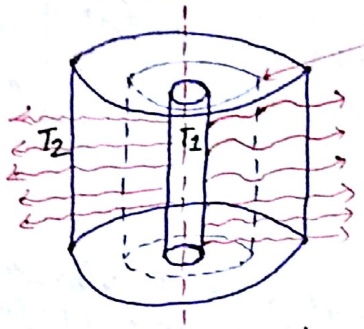
EX →

|i| → Rod (Heat flow along length) →



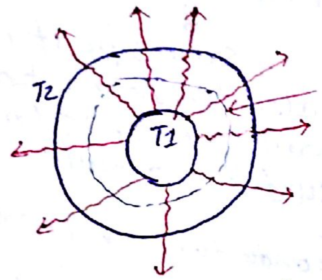
Plane Isothermal surface (2-D surface)

|ii| → Hollow cyllinder →



cylindrical I.T surface (3D)

|iii| → Hollow sphere →



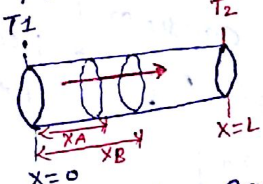
spherical I.T surface (3D surface)

NOTE → size & shape of I.T surface depend on direction of heat flow.

|iv| → Temp. Greadient → change in temp. w.r.t position represent temp. greadient of surface.

* In a steady state condⁿ temp. greadiend remain in the direction of heat flow.

* Greadient word puri phy में कहीं भी means change w.r.t position.



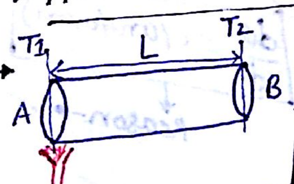
$$\boxed{T.G = \frac{\Delta L}{\Delta x} = \frac{T_2 - T_1}{L - 0} = \frac{T_A - T_A}{x_B - x_A}}$$

* unit → $\frac{°C}{cm}$, $\frac{K}{m}$

* Heat flow Rate $\left(R_H = \frac{dQ}{dt}\right)$

|v| → Heat flow Rate (steady state condⁿ) →

|a| → For 2-D surface →



Heat flow rate directly propersnal to cross section area & temp. diff b/w ends & inversally propersnal to the legth of conductor.

K = Thermal conductivity

$$\boxed{\frac{dQ}{dt} \propto A} \qquad \boxed{\frac{dQ}{dt} \propto \frac{1}{L}}$$

$$\boxed{\frac{dQ}{dt} \propto \frac{A(T_1 - T_2)}{L}} \qquad \boxed{\frac{dQ}{dt} = \frac{KA(T_1 - T_2)}{L}}$$

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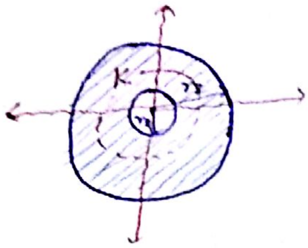
NOTE → * Thermal conductivity depend on nature of material it is independ from Geometry & Heat flow Rate.

** * Thermal conductivity of conductor ∝ with temp. but in steady state condition state condition it will Remain same. * (except - Human body)

* Thermal conductivity ∝ Electrical conductivity.

|b| → 3-D surface

|a| → Hollow sphere →



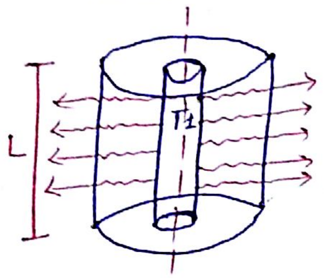
$$\frac{dQ}{dt} = H = \text{same} = K(4\pi x^2)\left(-\frac{\Delta T}{\Delta x}\right)$$

$$\int_{r_1}^{r_2} \frac{\Delta x}{x} = \frac{-4\pi K}{\frac{dQ}{dt}} \int_{T_1}^{T_2} \Delta T$$

*

$$\boxed{\frac{dQ}{dt} = \frac{4\pi K (T_1 - T_2) r_1 r_2}{r_2 - r_1}}$$

|b| → Hollow cyllinder →



*

$$\boxed{\frac{dQ}{dt} = \frac{2\pi K L (T_1 - T_2)}{\log_e (r_2/r_1)}}$$

Relation b/w $\left(\frac{dQ}{dt}\right)$ & T.G

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

$$\frac{dQ}{dt} = KA\left[\frac{T_1 - T_2}{L}\right]$$

**

$$\boxed{\frac{dQ}{dt} = K(-T.G) \quad \text{or,} \quad \frac{dQ}{dt} = KA\left(-\frac{\Delta T}{\Delta x}\right)}$$

Comparision b/w Electrical conduction & Thermal conduction.

Electrical conduction		Thermal conduction
* Flow High pot. to Low pot.	$\Delta V \equiv \Delta T$	* Flow from High temp. to Low temp.
* Electrical current (i) $\boxed{i = \frac{dq}{dt}}$	$i \equiv H$	* Heat current = Heat flow rate $\boxed{H = \frac{dQ}{dt}}$
* Electrical Resistance $\boxed{R = \frac{\Delta V}{i}}$ * $\boxed{R = \rho\frac{L}{A} = \frac{1}{\sigma}\frac{L}{A}}$	$\sigma \equiv H$	* Thermal Resistance $\boxed{R_{th} = \frac{\Delta T}{H}}$ $R_{Th} = \frac{\Delta T}{KA\left(\frac{\Delta T}{L}\right)}$ * $\boxed{R_{TH} = \frac{L}{KA}}$

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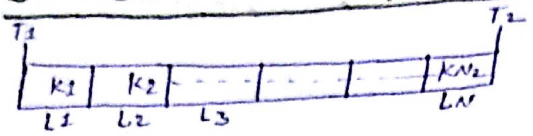
COMBINATION OF CONDUCTOR

|1| → Series combination / End to End combination →

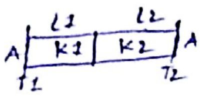


|i| → Heat current same

$H_1 = H_2 = H_3 = - - - - H_N$

$$\boxed{\left(\frac{dQ}{dt}\right)_1 = \left(\frac{dQ}{dt}\right)_2 = - - - = \left(\frac{dQ}{dt}\right)_N}$$

|ii| → contact point temp. / common temp.



$\boxed{H_1 = H_2}$

*

$$\boxed{T_C = \frac{\frac{K_1}{L_1}T_1 + \frac{K_2}{L_2}T_2}{\frac{K_1}{L_1} + \frac{K_2}{L_2}}}$$

** Standard

If $K_1 = K_2$

$$\boxed{T_C = \frac{T_1 L_2 + T_2 L_1}{L_1 + L_2}}$$

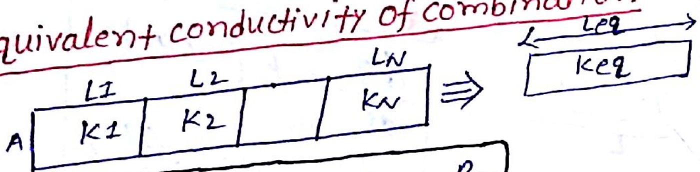
Exemplar # If $K_1 \neq K_2$, $L_1 = L_2$

$$\boxed{T_C = \frac{K_1 T_1 + K_2 T_2}{K_1 + K_2}}$$

$K_1 = K_2$ ~~=~~ $L_1 = L_2$

$$\boxed{T_C = \frac{T_1 + T_2}{2}} \Longrightarrow T_{Avg}.$$

Equivalent conductivity of combination



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

*

$$\boxed{K_{eq} = \frac{L_1 + L_2 + - - - L_N}{\frac{L_1}{K_1} + \frac{L_2}{K_2} + - - - \frac{L_N}{K_N}}}$$

** Standard

$L_1 = L_2 = - - - - - L_N = L$

$$\boxed{K_{eq} = \frac{N}{\frac{1}{K_1} + \frac{1}{K_2} + - - - \frac{1}{K_N}}}$$

* $N = 2$ $\begin{bmatrix} L_1 = L_2 \\ A_1 = A_2 \end{bmatrix}$

*

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

Exemplar * $N = 3$

$$\boxed{K_{eq} = \frac{3K_1 K_2 K_3}{K_1 K_2 + K_2 K_3 + K_3 K_1}}$$

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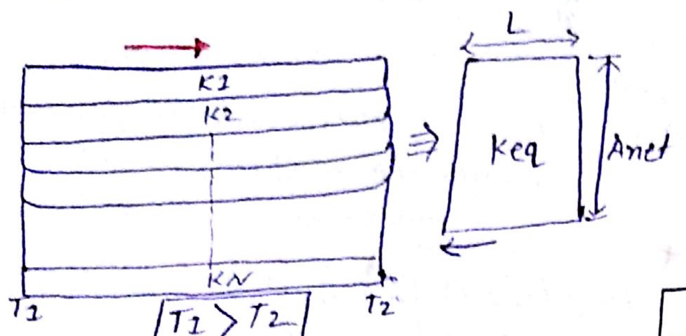
|2| → Parellel combination →



$$\boxed{\frac{1}{R_{net}} = \frac{1}{R_{th1}} + \frac{1}{R_{th2}} + \cdots \frac{1}{R_{thN}}}$$

|i| → ΔT = same

|ii| → $H = \frac{\Delta T}{R_{th}} = \frac{1}{R_{th}}$

$$\boxed{H_{net} = H_1 + H_2 + \cdots H_N}$$

$$\boxed{\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots \frac{1}{R_N}}$$

Equivalent conductivity →

$$R_1 = \frac{L}{K_1 A_1}, \quad R_2 = \frac{L}{K_2 A_2}$$

* $$\boxed{R_{eq} = \frac{L}{K_{eq}(A_1 + A_2 + \cdots + A_N)}}$$

* $$\boxed{K_{eq} = \frac{K_1 A_1 + K_2 A_2 \cdots \cdots K_N A_N}{A_1 + A_2 \cdots\cdots A_N}}$$

*** standard:

$A_1 = A_2 = \cdots\cdots A_N$

$$\boxed{K_{eq} = \frac{K_1 + K_2 + \cdots + K_N}{N}}$$

* $N = 2$, $L_1 = L_2$, $K_1 = K_2$ $\quad \boxed{K_{eq} = \frac{K_1 + K_2}{2}}$

* $K_1 = K_2 = \cdots\cdots K_N$

$$\boxed{K_{eq} = K}$$

*** standard

$L_1 = L_2$, $A_1 = A_2$

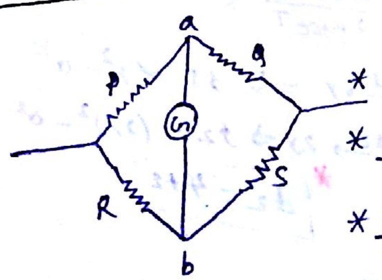
* $K_{series} = \frac{2K_1K_2}{K_1 K_2} \Rightarrow$ H.M

* $K_{parellel} = \frac{K_1 + K_2}{2} \Rightarrow$ A.M

* $\frac{K_s}{K_p} = \frac{4K_1K_2}{(K_1+K_2)^2}$

*** NOTE → If two identical Rod or, identical plates connected in series & parellel ratio of time taken for same Heat flow is 4:1.

***



* $\frac{P}{q} = \frac{R}{S} \Rightarrow I_G = 0 \Rightarrow V_a = V_b$

* $\frac{P}{q} > \frac{R}{S} \Rightarrow V_a < V_b$] $i_G \neq 0$

* $\frac{P}{q} < \frac{R}{S} \Rightarrow V_a > V_b$]

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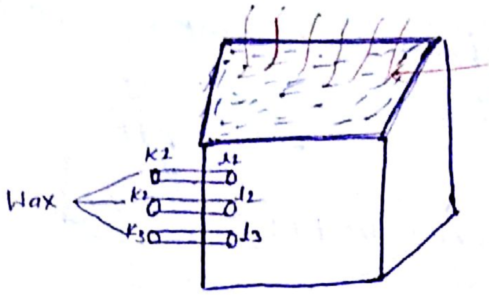
Ingon-hauzz Exp:→

$$\frac{dQ}{dt} = \frac{KA}{L}(T_1 - T_2) \propto K$$



BHU 2007
condn → From Ingon Hauzzexp. practically compair thermal conductivity material

* $\boxed{\begin{matrix} l_3 > l_2 > l_1 \\ K_3 > K_2 > K_1 \end{matrix}}$

* $\boxed{K \propto l^2}$ ← Melted Length.

Wedman-Fronz Law → At const. temp. ratio of thermal conductivity & electrical conductivity remain same.

Termal conductivity → K; Electrical conductivity → σ

$$\boxed{\frac{K}{\sigma T} = \text{const.}}$$

* $T = \text{const.}$

* $\boxed{K \propto \sigma}$

Diffusivity(D):→ It is a Ratio of thermal conductivity & Heat capacity per unit vol.

$$\boxed{D = \frac{K}{\left(\frac{Hc}{V}\right)}}$$

$$\boxed{\text{Heat cap.} = Mc = Vdc}$$

$$\boxed{\frac{Mc}{V} = d}$$

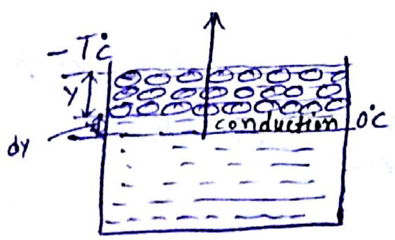
$$\boxed{D = \frac{K}{dc}}$$

K → Thermal conductivity; c → sp. heat; d → density.

$\boxed{T = C}$ $\boxed{K \propto \sigma}$

NOTE→ Diffusivity of material on nature of material.

Formation of Ice → Ice formation in a lake take place top to bottom from conduction method.



A/R
* Ice not melt even lower Water give heat bcoz Steady state condn.

* $$\boxed{dQ = \frac{K_{Ice} A}{y}(T)\,dt}$$

* $$\boxed{dQ = (d_{ice} A L_f)\,dy}$$

* $$\boxed{\int_{t_1}^{t_2} dt = \left(\frac{d_{ice} L_f}{K_{ice}}\right)\int_{y_1}^{y_2} y\,dy}$$

$$\Delta t = t_2 - t_1 = \frac{d_{ice} L_f}{2K_{ice} T}\left(y_2^2 - y_1^2\right)$$

|a|→ $0 \xrightarrow{t_1} y \xrightarrow{t_2} 2y$

$t_1 \propto y^2 - 0^2$
$t_2 \propto (2y)^2 - y^2$

* $\boxed{t_2 = 3t_1}$

|b|→ $0 \xrightarrow{t_1} y \Rightarrow t_1 \propto y^2 - 0^2$

$0 \xrightarrow{t_2} 2y \Rightarrow t_2 \propto (2y)^2 - 0^2$

* $\boxed{t_2 = 4t_1}$

* $0 \xrightarrow{t_1} y \xrightarrow{t_2} 2y \xrightarrow{t_3} 3y$

$t \propto y_2^2 - y_1^2$

* $\boxed{t_1 : t_2 : t_3 = 1 : 3 : 5}$

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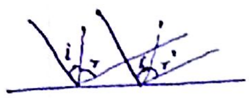
3. RADIATION

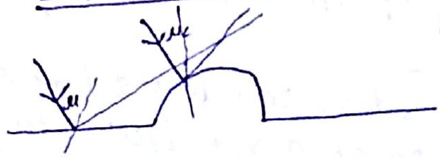
I. → Properties of Radiation or, Thermal Radiation / Infrared Radiation →

|i| →
|ii| →] → Learn from back page.
|iii| →
|iv| → Heat radiation represent dual nature wave & particle nature.
* particle nature → Heat Radiation exert pressure on surface.

Plane Radiation



Diffuse Radiation



$P_r = \frac{2}{3}\mu$

$P_a = \frac{4}{3}$

* *

* Radiation press → S.P Reflecting $\Rightarrow P_r = 2\left(\frac{I}{c}\right)$
→ S.P Absorbing $\Rightarrow P_a\left(\frac{I}{c}\right)$

$\frac{I}{c} = \mu$ = Energy density.

AIPMT
|V| → **Intensity of Radiation (I)** → Intensity of Radⁿ only depend on power of Radiation source & distance from Radiation source. It is Independent from Freq. & wavelength of Radiation.

$$\boxed{I = \frac{E}{At} = P/A}$$

P = power of Radiation source
A = Area in which Radiation distributed.

AIPMT
|a| → point/spherical source →

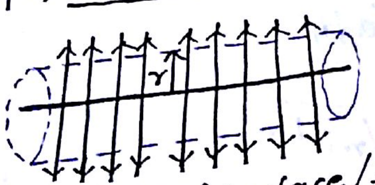
$$\boxed{I = \frac{P}{A} = \frac{P}{4\pi r^2}} \propto \frac{1}{r^2} \propto a^2$$

$$\boxed{a \propto \frac{1}{r}}$$

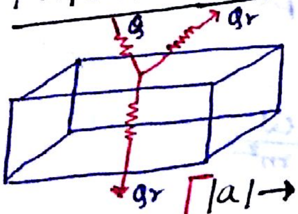
***
|b| → Linear/cylindrical source →

$$\boxed{I = \frac{P}{A} = \frac{P}{2\pi r L}} \propto \frac{1}{r}$$

$$\boxed{a \propto \frac{1}{\sqrt{r}}}$$



2. → Property of surface / Interaction Radiation with surface →



q ⇒ Incident quantity
q_r ⇒ Reflected "
q_t ⇒ Transmited "
q_a ⇒ Absorbing cap
] ⇒ quantity ≡ Energy or, Intensity.

|a| → Reflecting cap./Reflectance/Reflecting part → $\boxed{r = \frac{q_r}{q}}$

|b| → Transmition cap./Transmitance/Transmiting part → $\boxed{t = \frac{q_t}{q}}$

|c| → Absorbing cap./Absorbing cap. → $\boxed{a = \frac{q_a}{q}}$

Imp
* All Are unitless & Dimensionless

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Energy conservation

$$\boxed{q = q_a + q_t + q_r}$$

$$\boxed{1 = \frac{q_a}{q} + \frac{q_t}{q} + \frac{q_r}{q}}$$

***

NOTE →

* $a = t = 0 \Rightarrow r = 1\ (100\%) \Rightarrow$ perfectelly Reflecting body/surface.
* $a = r = 0 \Rightarrow t = 1\ (100\%) \Rightarrow$ P.T body
* $t = r = 0 \Rightarrow a = 1\ (100\%) \Rightarrow$ P.A surface (I.B.B)
* $\left.\begin{matrix} a \neq 0 \\ t \neq 0 \\ r = 0 \end{matrix}\right]$ partially absorbing / partially Absorbing.

$\Rightarrow a, r \ \&\ t \Rightarrow$ unitless & dimensionless quantity.

$\Rightarrow$ Range of a, r, t b/w 0 to 1.

$$\boxed{0 \leq (a, r, t) \leq 1}$$

3. Basic defination

|I| → Energy density (U) → Energy stored per unit vol.

$$\boxed{U = \frac{q}{V}}$$ $q \rightarrow$ 0 to ∞ Range, $V \rightarrow$ vol.

$$\boxed{U = \frac{I}{c}}$$ $I \rightarrow$ Intensity, $c \rightarrow$ velo. of light

* unit ⇒ J/m^3

|II| → (u_λ) Spectral Energy density :→ Energy stored in a per unit vol. of particular fixed wavelength range Radiation.

$$\boxed{U_\lambda = \frac{q_\lambda}{V}}$$ $q_\lambda \rightarrow$ '$\Delta\lambda$' Range

$$\boxed{u = \int_0^\infty u_\lambda d\lambda}$$

* unit → $J/m^3/A^\circ$ or, J/m^4.

|III| → Absorbing cap. (a) →

$$\boxed{a = \frac{q_a}{q}}$$

$$\boxed{a = \int_0^\infty a_\lambda d\lambda}$$

$$\boxed{a_\lambda = \frac{q_{a\lambda}}{q}}$$

* unit → $A^{\circ -1}/m^{-1}$.

|IV| → Emmisive power/cap (E) → Radiated (Q_R) per unit time per unit time.

$$\boxed{E = \frac{q_r}{At} = I = P/A}$$ (q_r: 0 to ∞)

unit → $\frac{W}{m^2}$

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|V| → **Spectral emmisive power** → Radiated energy of particular fixed Wavelength range radiation per unt area per unit time.

$$\boxed{E_\lambda = \frac{(Q_r)_\lambda}{At}}$$ $$\boxed{E = \int_0^\infty E_\lambda d\lambda}$$ * unit → $\frac{W}{m^2/A^\circ}$, $\frac{W}{m^3}$

2014 BCECE BHU

|VI| → **Emissivity / emmision co-efficient (e)** → Ratio of emissive power of general body to emmisive power of Ideal black body.

$$\boxed{e = \frac{E_{G \cdot B}}{E_{I \cdot B \cdot B}}}$$

* unitless, Dimensionless quanity

$\boxed{0 \leq e \leq 1}$ *

$\boxed{(e_{I \cdot B \cdot B})_{max} = 1}$

$\boxed{0 \leq e_{G \cdot B} < 1}$

* $\boxed{e_{G \cdot B} < 1}$

NOTE →

$\boxed{a_{I \cdot B \cdot B} = e_{I \cdot B \cdot B} = 1}$

$\boxed{e_{G \cdot B} = a_{G \cdot B} < 1}$

BHU * Emissivity depend on nature of surface.

Ex → * $\boxed{e_b > e_w}$

* $\boxed{e_R > e_S}$

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|VII| → **Ideal Black Body (I·B·B)** → Body wich is absorb all wavelength range Radiation at low temp. & emmit all those radiation at high temp. Ex → Sun, Black Hole.

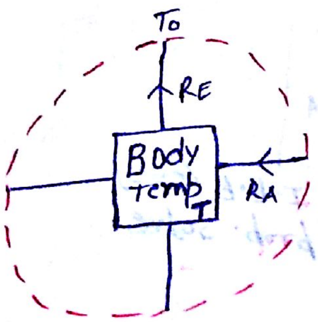
A → Black body is an ideal body that emits and absorb radiations of all frequency.

R → The frequency of Radiation emitted by a body goes from a lower freq. to heigher freq with an ↑ in temp.

Ans → C

4. → LAW OF RADIATION →

[A] → **Privost theory of Heat exchange** → Body emit & absorb simultaniously at all temp. up to ∞ time at all temp.



**

$T > T_0 \Rightarrow$	$R_E > R_A \Rightarrow T\downarrow$	$\Rightarrow$ calling Effect.	
$T < T_0 \Rightarrow$	$R_E < R_A \Rightarrow T\uparrow$	$\Rightarrow$ Heating Effect.	
$T = T_0 \Rightarrow$	$R_E \rightleftharpoons R_A \Rightarrow T \Rightarrow$ const.		

Limitation → Privost theor of Heat exchange is applicable on all temp. Except 0°K (at 0°K thermal energy of Molecule become zero.)

A/R **

AIPMT 2014

[B] → STEAFAN LAW → Emissive power of I·B·B is directelly propersnal to Fourth power of temp.

* AIPMT 2007

$$\boxed{E_{I \cdot B \cdot B} \propto T^4}$$

$$\boxed{E_{I \cdot B \cdot B} = \sigma T^4}$$

σ = Steafan const.

* $\sigma = 5.67 \times 10^{-8} \frac{W}{m^2 K^4}$ ✓ [S.I]

$\sigma \neq 5.67 \times 10^{-8} \frac{W}{m^2 \, ^\circ C^4}$ ✗

$$\boxed{e = \frac{E_{G \cdot B}}{E_{I \cdot B \cdot B}}} \quad \boxed{E_{G \cdot B} = e E_{I \cdot BB}}$$

$$\boxed{E = e(\sigma T^4)}$$

***

G·B →

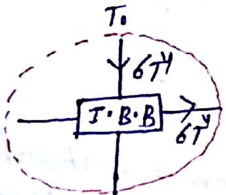
- Emissive power → $E_{G \cdot B} = e(\sigma T^4) \; \frac{W}{m^2}$
- Radiate * energy → * $\boxed{q_r = EAt = e(\sigma T^4)At}$ W
- Radiated power → $P_r = \frac{q_r}{t} = e(\sigma T^4)A$ J/cal.

A = Surface Area.

[C] → Steafan - Boltzman Law : →

$$\boxed{\text{Net emitted quantity} = \text{Emitted quantity} - \text{absorb quantity}}$$

$$\boxed{E_{I \cdot B \cdot B} = \sigma(T^4 - T_0^4)}$$



$E_{G \cdot B} = e E_{I \cdot B \cdot B}$

$$\boxed{E_{G \cdot B} = e\sigma(T^4 - T_0^4)}$$

***

G·B →

- Emissive power → $E_{G \cdot B} = e\sigma(T^4 - T_0^4)$
- Radiated energy → $q_r = EAt = e\sigma(T^4 - T_0^4)At$
- Radiated power → $P_r = \frac{q_r}{t} = e\sigma(T^4 - T_0^4)A$

NOTE → * If nature of surface is not define consider I·B·B (e=1).
* If ~~nature~~ surrounding temp is not define prob. solve from Steafan law.

→

Rate of Heat loss (RH)

Rate of fall in temp (RF)
or,
Rate of ↓ in temp.
or,
Rate of colling (Rc)
or,
Wich is colling Faster
or,
Wich is colling 1st.

(i) → $\boxed{R_H = \frac{dQ}{dt} = eA\sigma(T^4 - T_0^4) = P_r}$ *

$\boxed{R_F = \frac{R_H}{Mc}}$ *

(ii) → $\boxed{R_F = \left|\frac{dT}{dt}\right|}$

$\boxed{R_c = -\frac{dT}{dt}}$

* $\boxed{R_F = \frac{dT}{dt} = \frac{eA\sigma(T^4 - T_0^4)}{Mc}}$

AIIMS
NOTE →
* Rate of Heat loss depend on nature of surface, surface Area, temp of body & surrounding. It is independent from nature of material.

AIR
* Rate of fall in temp. is depend on nature of surface as well as nature of material, surface Area, temp. of body & surrounding temp.

Rate of colling

* unit → $\frac{cal}{sec}$, Watt = RH
* unit → $\frac{°C}{sec}$, $\frac{K}{sec}$ = RF

***
***
NOTE → Same material, same shape object heated up to same temp. & placed in a same surrounding for colling through Radiation then small dimension object colling First.

* $\boxed{R_F = \frac{dT}{dt} \propto \frac{1}{R}}$ ⇒ * t = same ⇒ $dT \propto \frac{1}{R}$ ⇒ $R_1 > R_2$ ⇒ $dT_1 < dT_2$
* dT ⇒ same ⇒ $t \propto R$ ⇒ $R_1 > R_2$ ⇒ $t_1 > t_2$

* Rate of Heat loss is independent from nature of material but rate of fall in temp. depend on nature of material.

Imp
$V_{solid} = \frac{4}{3}\pi R^3$

$V_{Hollow} = \frac{4}{3}\pi(R^3 - r^3)$

$V_{solid} > V_{Hollow}$

$\boxed{R_F \propto \frac{1}{V}}$ → $\boxed{(R_F)_{solid} < (R_F)_{Hollow}}$

* $(R_H)_{sphere} = (R_H)_{cylinder} > (R_H)_{cube}$
* $(R_F)_{cube} > (R_F)_{cylinder} > (R_F)_{sphere}$.
* M = same, V×d = same, V = same

$\boxed{V_{Disc} = V_{spher}}$

$\boxed{A_{Disc} > A_{spher}}$

* RH & RF → $\boxed{\text{Disk} > \text{Sphere}}$

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[D] → Newton's law of calling → Rate of calling is directly proportional to temp. difference b/w body & surrounding.

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$$R_c = c_1(T - T_0)$$

c_1 = Newton calling const.

* $c_1 = \dfrac{4eA\sigma T_0^3}{mc}$

* Low temp change = N.L.C + S.B.L (Newton's law of calling)
* High temp change = S.B.L (Stefan Boltzmann const.)

2004 BHU 2007 AAM

Limition of Newton's Law calling →

(i) → It is applicable only when temp. difference of body & surronding less than equal to surrounding temp.

$\boxed{\Delta T = T - T_0 \le T_0}$ T_0 = surrounding temp.

(ii) → N.L.C is extended part of S.B.L for low temp change.

*(iii) → It is applicable only when body losses its heat from Radiation method & surrounding temp does not change with heat Radiation.

Special case

$\boxed{T_1 \xrightarrow{t} T_2}$

T_0

$$R_c = -\frac{dT}{dt} = c_1(T_{avg} - T_0)$$

$$= -\left(\frac{T_2 - T_1}{t}\right) = c_1\left(\frac{T_1+T_2}{2} - T_0\right)$$

$$\boxed{\left(\frac{T_1 - T_2}{t}\right) = c_1\left(\frac{T_1+T_2}{2} - T_0\right)}$$

Standard

$$T_1 \xrightarrow{t_1} T_2 \xrightarrow{t_2} T_3 \xrightarrow{t_3} T_4$$

(a) → $T_1 - T_2 = T_2 - T_3 = T_3 - T_4$

$\boxed{t_1 < t_2 < t_3}$

(b) → $t_1 = t_2 = t_3$

$\boxed{T_1 - T_2 > T_2 - T_3 > T_3 - T_4}$

Application of Newton's law of calling. (only for liq. not for solid & gas)

To calculate sp. Heat of liq −

Known liq

w, V, A, e, $T_i \xrightarrow{t_1} T_f$, T_0, c_1, d_1

$\boxed{M_1 = Vd_1}$

Unknown liq

w, V, A, e, $T_f \xleftarrow{t_2} T_i$, T_0, c_2, d_2

$\boxed{M_2 = Vd_2}$

$$R_H = \frac{dQ}{dt} = eA\sigma(T^4 - T_0^4) = \text{same}$$

$$\left(\frac{dQ}{dt}\right)_{known} = \left(\frac{dQ}{dt}\right)_{unknown}$$

$$\boxed{\left(\frac{M_1c_1 + W}{t_1}\right) = \left(\frac{M_2c_2W}{t_2}\right)}$$

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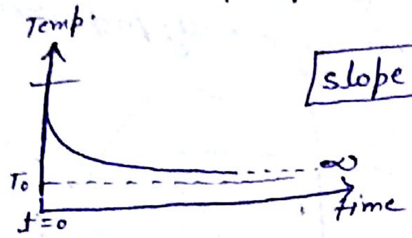
$\boxed{C_2 = \frac{1}{M_2}\left[\frac{t_2}{t_1}(M_1C_1 + w) - W\right]}$

w is not define $(w=0)$

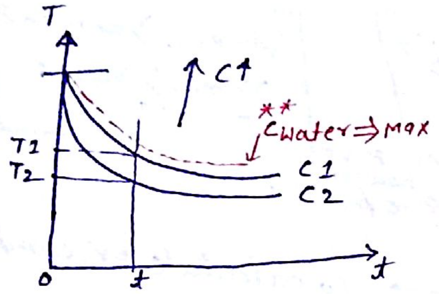
$W = 0 \Rightarrow \boxed{\frac{M_1C_1}{t_1} = \frac{m_2C_2}{t_2}}$ *

colling curve :→ If body cooled through radiation method its temp. ↓ exponentially w.r.t time.



$\boxed{\text{slope} = y/x}$

$* \boxed{\text{slope} = \left|\frac{dT}{dt}\right| = R_F = \frac{eA\sigma(T^4 - T_0^4)}{mc} \propto \frac{1}{c}}$



Imp * slope of Water is max so sp. heat of Water is max.

$\left(\frac{dT}{dt}\right)_1 < \left(\frac{dT}{dt}\right)_2$

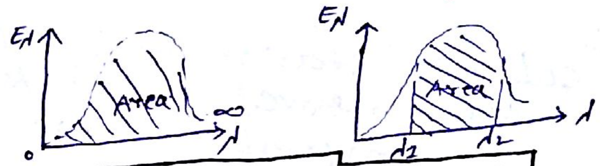
$\boxed{C_1 > C_2}$

Ideal black body spectrum → curve b/w spectral emissive power & corresponding wavelength.

|i| → Ideal black body spectrum is a contineous spectrum b/c I.B.B emit 0 to ∞ Range Radiation.

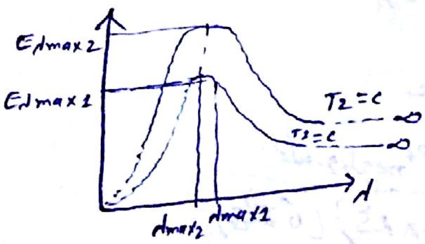
|ii| → Area $= I = \int y\,dx = \int_0^\infty E_\lambda d\lambda = \boxed{E_{I.B.B} = \sigma T^4}$

$\boxed{Area \propto T^4}$



$\boxed{Area = \int_{\lambda_1}^{\lambda_2} E_\lambda d\lambda = E \text{ b/w } \lambda_1 \text{ to } \lambda_2}$

|iii| → on ↑ temp. max emissive power is ↑ but corrosponding wavelength ↓.



$T_2 > T_1$
$E_\lambda max_2 > E_\lambda max_1$
$\lambda max_2 < \lambda max_1$

$\boxed{E \propto \frac{1}{\lambda}}$

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Wien's Law

|a| → **Weins energy law** → Max^{m} emissive power is directelly propersnal to fifth power of temp.

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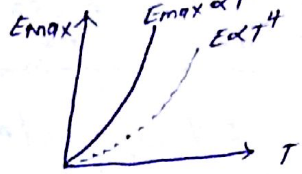
$$\boxed{E_{\lambda max} \propto T^5}$$

$$\boxed{E \propto T^4}$$

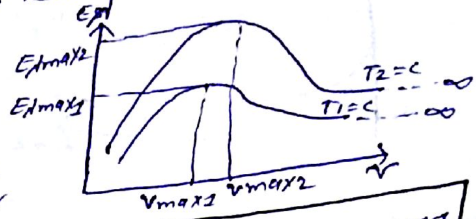


|b| → **Weins disp. law or, Weins Wavelength law:** → Wavelength crossponding to max emissive power is Inversally propernal to temp. of body.

$$\boxed{\lambda_{max} \propto \frac{1}{T}}$$

*
$$\boxed{\lambda_{max} = \frac{b}{T}}$$

b = weins const.
$b = 2.93 \times 10^{-3}$ mK (miter)



$$\boxed{\nu_{max} = \frac{c}{\lambda_{max}}}$$

$$\boxed{\nu_{max} = \left(\frac{c}{b}\right)T = b'T}$$

$E_{\lambda max2} > E_{\lambda max1}$
$\nu_{max2} > \nu_{max1}$
$T_2 > T_1$

* λ_{max} ⇒ Wavelength crosponding to max emissive power.
* ν_{max} ⇒ freq. crospondingto max emmisive power.

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Application of Weins disp. law → To calculate or, compair temp. of planet or, star.

$$\boxed{\lambda_{max} = \frac{b}{T}}$$

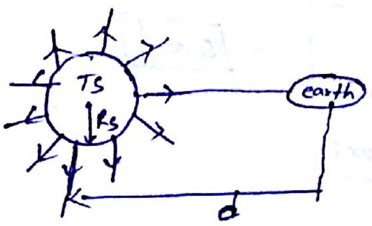
*complementry colour
Red + Grren ⇒ Black
yellow + Blue ⇒ Black

V I B G (W) Y O R →
$\lambda \uparrow$, $T \downarrow$

Imp.
* colour of Star radiation appear White crossponding to max. emissive power the temp. of star → greater than from temp. of sun. $\left(T \propto \frac{1}{\lambda_{max}}\right)$

Solar const [S] →

*
$$\boxed{S = \frac{Q}{It} = I = P/A = \frac{P_{sun}}{4\pi d^2}}$$



$P_{sun} = eA\sigma(T^4 - T_0^4)$
$e_{sun} = 1$
$A_{sun} = 4\pi R_s^2$
$T_{sun} >>>> T_0$, negligible.

**
$$\boxed{P_{sun} = (1)(4\pi R_s^2)(\sigma T_s^4)}$$

*
$$\boxed{S = \sigma T^4 \left(\frac{R_s}{d}\right)^2} \propto \frac{1}{d^2}$$

*
Earth
$S = 1.99 \frac{cal}{min/cm^2}$
$= \frac{2 \times 4.2}{60 \times 10^{-4}} \frac{W}{m^2}$

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* Temp. of Sun become double & Radius ↓ to half then solar const of plant will become → Four time $\left[S = T^4 S^2 = 2^4 \left(\frac{1}{2}\right)^2 = \boxed{S_2 = 4S_1}\right]$

* Solar const. of planet 'S' and its radius 'r' then receved energy per unit time is → $S(\pi r^2)$ $\left[S = \frac{Q}{At},\ \frac{Q}{t} = SA = S(\pi r^2)\right]$

AIIMS
*
***
Kirchoff law → At const temp. ratio of spectral emissive power & spectral absorption co-efficent remain same & equal to emissive power of I.B.B.

*
$$\boxed{\frac{E_\lambda}{a_\lambda} = \text{const} = E_{I.B.B} = \sigma T^4}$$

T = const ⇒ $\boxed{E_\lambda \propto a_\lambda}$

Application of Kirchoff Law →

AIIMS
|i| → If a body is a good emitter it is also a good absorber or, If it is a bad emitter i.e. bad absorber.
EX → A White metal polished ball having some black spots dark room then black spots appears bright as compair to White ball.

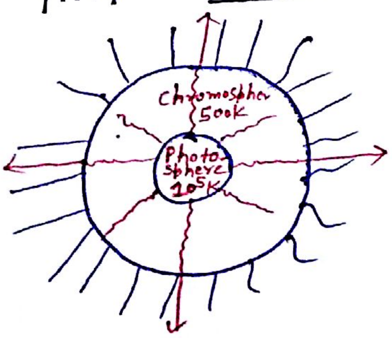
|ii| → Explanation of colour →
|a| → Body transmit & Reflect same colour Radiation & absorb remaning colour & Wich colour it will max absorb complementry colour.
EX → Red & green
Blue & yellow

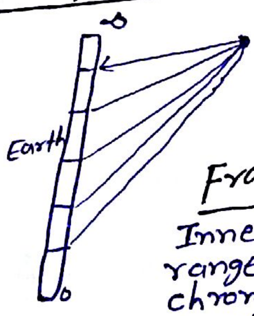
Eg → Red glass heated & seen in dark room it will apper green.

|b| → If complementry colour (R→G, Y→B) radiation incident on body it will appear black.

|c| → If same colour radiation incident on body it will disappear/invisible.

**
|iii| → Explanation of fraunhaffer lines →





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Fraunhaffer line explain absorption spectrum
Inner part of sun is photosphere Wich is emit 0 to ∞ range radiation & outer part Wich is called chromosphere absorb same radiation Wich is ant in spectrum on earth & It will appeared in the form of dark line Wich is called fraunhaffer lines.

* In a solar clipse condn fraunhaffer line appeard bright Wich is explain from kirchoff law.

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