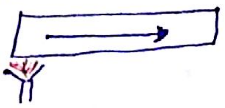
MODE OF HEAT TRANSFER

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

1. → CONDUCTION

→ 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 solid medium heat transfer take place only from conduction method.

BCECE 2015

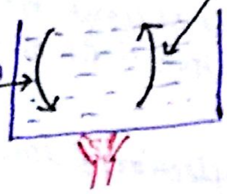
2. → CONVECTION

→ Method of Heat transfered in wich medium particle transfered heat one place to another place due to density differerce.

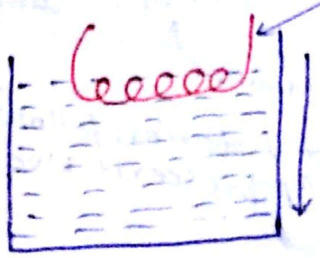
EX →

*bottom to tom (Low density molecule)

*Top to bottom (High density molecule)



conduction not by convection



Top to bottom (conduction)

* convection method is possible from bottom to Top.

NOTE → * Medium & Gravity is necessory for convection Method.

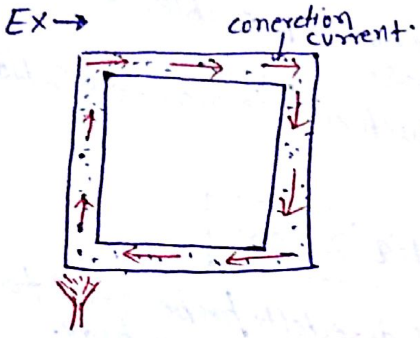
* For best Heating devices place at bottom & for best calling devices place at Top.
* In a Artificial satellite, freelly falling lift, at the centre of earth Heat transfer not takes place from covection method.

Forced convection → If medium particle circulate forcely.

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

convection current :→

EX →



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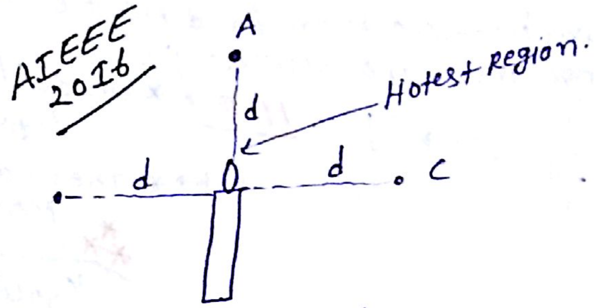


$$\boxed{T_A > T_B = CT_C}$$

T_A ↑ convection + Radiation

$T_B = CT_C$ ↓ only Radiation

EX →

|3| → RADIATION → Method of Heat transfer in Wich 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.

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

C_o → 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 wave 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	

* $\lambda\uparrow,\ v=\frac{c}{\lambda}\downarrow \Rightarrow E_{ph}=hv\downarrow \Rightarrow$ P·P↓

**

$$\boxed{E_{ph}=hv=\frac{hc}{\lambda}=\frac{12400}{\lambda(A^\circ)}ev=\frac{1240}{\lambda(nm)}ev}$$

(I.R Radiation)

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

" " " Radn ⇒ 0 – ∞

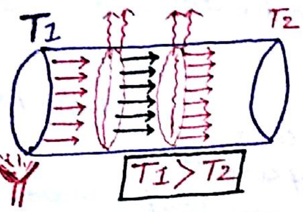
* Energy ⇓ 0·0124 ev – 1·3 ev

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.

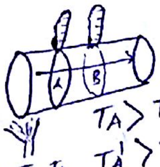
2016 AIIMS



T1 > T2

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.



$T_A > T_B$

$T_A' > T_B'$

$t=t_1$ T_A T_B

$t=t_2$ T_A' T_B'

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

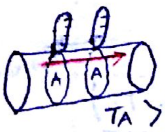
$T_A' \neq T_A$

$T_B \neq T_B'$

* Heat flow or Heat current

** $\frac{dQ}{dt}$ = 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.



$T_A > T_B$

$T_A' > T_B'$

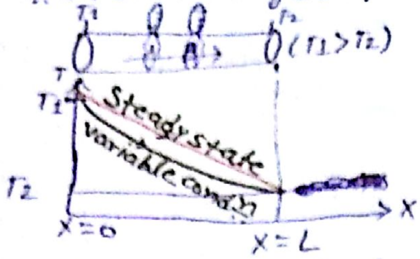
$T_A = T_A'$

$T_B = T_B'$

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

$\frac{dQ}{dt}$ = c(uniform)
↓
Reason → ✓

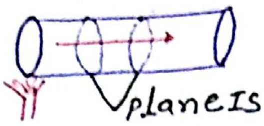
* In a steady state condn temp. change linearly w.r.t distance from heating end & in variable condn it will change exponentially.



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

EX →

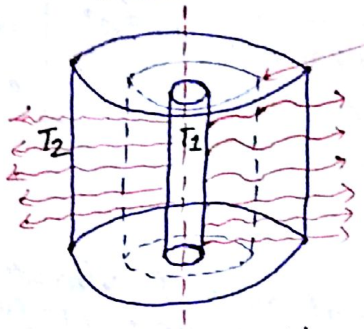
|i| → Rod (Heat flow along length) →



Plane Isothermal surface (2-D surface)

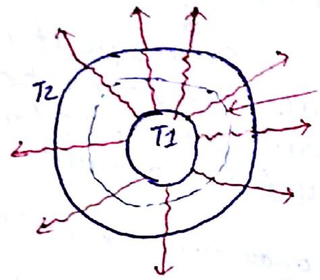
|ii| → Hollow cyllinder →

cylindrical I.T surface (3D)



|iii| → Hollow sphere →

Spherical I.T surface (3D surface)

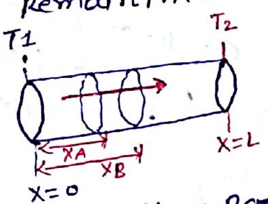


NOTE → Size & shape of I.T surface depend on direction of heat flow.

|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.



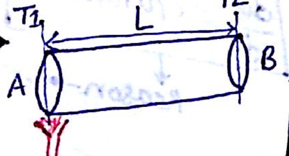
$$T.G = \frac{\Delta L}{\Delta x} = \frac{T_2 - T_1}{L - 0} = \frac{T_A - T_A}{x_B - x_A}$$

* 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.

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

K = Thermal conductivity

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

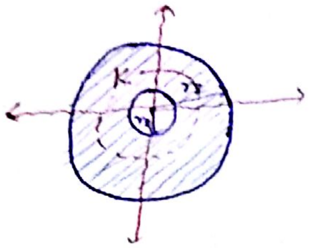
NOTE → * Thermal conductivity depend on nature of material it is independ from Geometry & Heat flow Rate.

** * Thermal conductivity of conductor ∝ with temp. but in steady state condition it will Remain same.

* Thermal conductivity ∝ Electrical conductivity. (except - Human body)

|b| → 3-D surface

|a| → Hollow sphere →



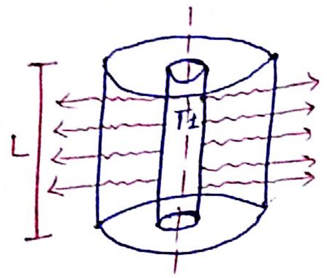
$$\frac{dQ}{dt} = H = \text{same} = K(4\pi x^2)\left(-\frac{\Delta T}{\Delta x}\right)$$

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

*

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

|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

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

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

**

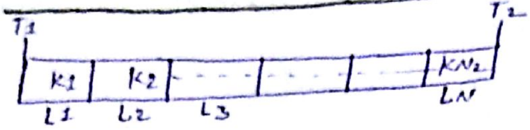
$$\boxed{\frac{dQ}{dt} = K(-T.G) \quad \text{or,} \quad \frac{dQ}{dt} = KA\left(-\frac{\Delta T}{\Delta x}\right)}$$

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 $\boxed{R_{th} = \frac{\Delta T}{H}}$ $R_{Th} = \frac{\Delta T}{KA\left(\frac{\Delta T}{L}\right)}$ * $\boxed{R_{TH} = \frac{L}{KA}}$

COMBINATION OF CONDUCTOR

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

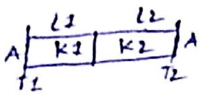


|i| → Heat current same

$H_1 = H_2 = H_3 = \text{- - - -} H_N$

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

|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 $K_1 = K_2$

$$\boxed{T_c = \frac{T_1L_2 + T_2L_1}{L_1 + L_2}}$$

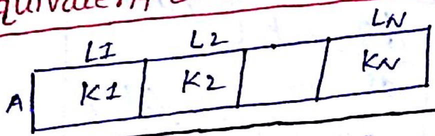
Exemplar # If $K_1 \neq K_2$, $L_1 = L_2$

$$\boxed{T_c = \frac{K_1T_1 + K_2T_2}{K_1 + K_2}}$$

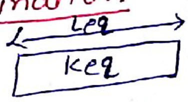
$K_1 = K_2$ & $L_1 = L_2$

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

Equivalent conductivity of combination



⇒



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

*

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

*** Standard

$L_1 = L_2 = \text{- - - - -} L_N = L$

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

* $N = 2$ $\left[\begin{matrix} L_1 = L_2 \\ A_1 = A_2 \end{matrix}\right]$

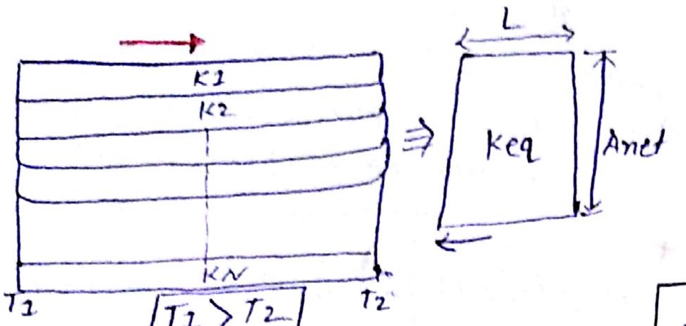
*

$$\boxed{K_{eq} = \frac{2K_1K_2}{K_1 + K_2}}$$

Exemplar * $N = 3$

$$\boxed{K_{eq} = \frac{3K_1K_2K_3}{K_1K_2 + K_2K_3 + K_3K_1}}$$

(2) → Parallel combination →



$\boxed{T_1 > T_2}$

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

(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:

$A_1 = A_2 = \cdots\cdots A_N$

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

* $N = 2$
$L_1 = L_2$
$K_1 = K_2$

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

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

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

*** standard:

$L_1 = L_2$, $A_1 = A_2$

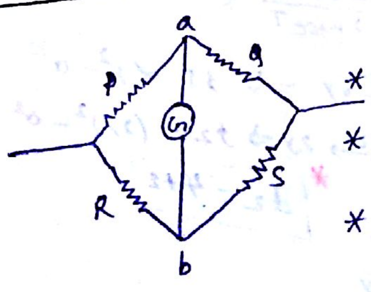
* $K_{series} = \frac{2K_1K_2}{K_1 K_2} \Rightarrow$ H.M

* $K_{parallel} = \frac{K_1 + K_2}{2} \Rightarrow$ 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 & parallel ratio of time taken for same Heat flow is 4:1.

***



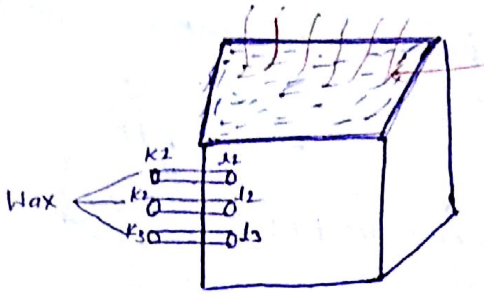
* $\frac{P}{Q} = \frac{R}{S} \Rightarrow I_G = 0 \Rightarrow V_a = V_b$

* $\frac{P}{Q} > \frac{R}{S} \Longrightarrow V_a < V_b$

* $\frac{P}{Q} < \frac{R}{S} \Longrightarrow V_a > V_b$

$I_G \neq 0$

Ingon-hauzz Exp:→



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

BHU 2007
Condn → From Ingon Hauzz exp. 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.

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

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

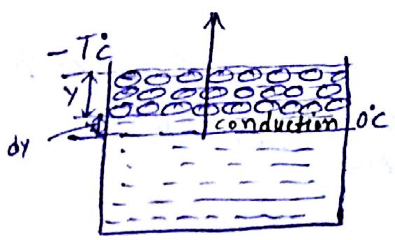
$\boxed{\frac{Mc}{V} = d}$

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

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

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

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

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

|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| →
|iii| →] → Learn from back page.

|iv| → Heat radiation represent dual nature Wave & particle nature.
Heat Radiation exert pressure on surface.
* 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 ⇒ $P_r = 2\left(\frac{I}{c}\right)$
→ S.P Absorbing ⇒ $P_a\left(\frac{I}{c}\right)$

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

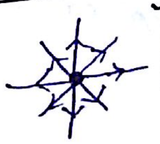
$$\boxed{I = \frac{E}{At} = P/A}$$

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

AIPMT

|a| → point/spherical source →

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



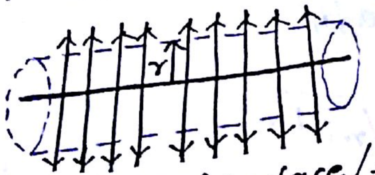
$$\boxed{a \propto \frac{1}{r}}$$

***

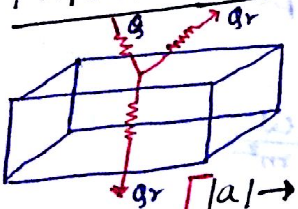
|b| → Linear/cylindrical source →

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

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



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



q ⇒ Incident Quantity
qr ⇒ Reflected "
qt ⇒ Transmited "
qa ⇒ 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

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)
* $\left.\begin{array}{l} a \neq 0 \\ t \neq 0 \\ r = 0 \end{array}\right]$ Partially absorbing / partially Absorbing.

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

⇒ 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 → 0 to ∞ Range, V → vol.

* unit ⇒ J/m^3

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

|II| → **Spectral Energy density (U_λ)** :→ Energy stored in a per unit vol. of particular fixed Wavelength Range Radiation.

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

$$\boxed{U = \int_0^\infty U_\lambda \, d\lambda}$$

* unit → $J/m^3/A°$ or, J/m^4.

|III| → **Absorbing cap. (a)** →

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

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

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

* unit → A'^{-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 → $\frac{W}{m^2}$

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

$$\boxed{E_\lambda = \frac{(q_r)_\lambda}{At}}$$

$$\boxed{E = \int_0^\infty E_\lambda \, d\lambda}$$

* unit → $\frac{W}{m^2/\text{Å}}$, $\frac{W}{m^3}$

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

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

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

$\boxed{0 \leq e_{GB} < 1}$

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

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 → * $\boxed{e_b > e_w}$

* $\boxed{e_R > e_S}$

AIIMS 2015

|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.

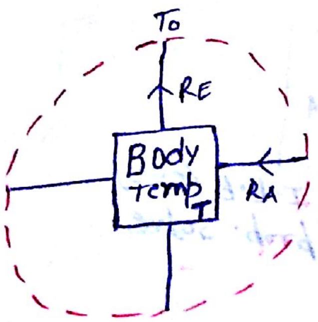
A → Black body is an ideal body that emits and absorb radiations of all frequency.

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.



**

$T > T_0 \Rightarrow$	$R_E > R_A \Rightarrow T\downarrow$	$\Rightarrow$ colling 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 theory of Heat exchange is applicable on all temp. Except 0°K (at 0°K thermal energy of Molecule become zero.)

AIR **

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.

* $\sigma = 5.67\times10^{-8} \frac{W}{m^2 K^4}$ ✓ [S.I]

$\sigma \neq 5.67\times10^{-8} \frac{W}{m^2\, °C^4}$ ✗

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

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

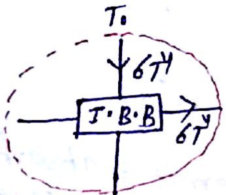
**

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/sec.

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.

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→

Rate of Heat Loss (RH)

↓

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

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

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

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 Ist.

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

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

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

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 obrect heated up to same temp. & placed in a same surrounding for colling through Radiation then small dimension obrect 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
$V_{solid} = \frac{4}{3}\pi R^3$

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

$V_{solid} > V_{Hollow}$

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

* $(R_H)_{sphere} = (R_H)_{cyllinder} > (R_H)_{cube}$
* $(R_F)_{cube} > (R_F)_{cylinder} > (R_F)_{sphere}$.
* 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 cooling is directly proportional to temp. difference b/w body & surrounding.

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

c_1 = Newton colling const.

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

(Newton law of calling)

* Low temp change = N.L.C + S.B.L

* High temp change = S.B.L (Stefan Bolteman const)

2004 BHU 2007 AAM

Limitation of Newton's Law calling →

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

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

N.L.C is extended part of S.B.L for low temp change.

|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| → $T_1 - T_2 = T_2 - T_3 = T_3 - T_4$

$\boxed{t_1 < t_2 < t_3}$

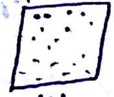
|b| → $t_1 = t_2 = t_3$

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

Application of Newton's law of colling. (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_i, $T_f \xleftarrow{t_2} T_i$, T_0, c_2, d_2

$\boxed{M_2 = Vd_2}$

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

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

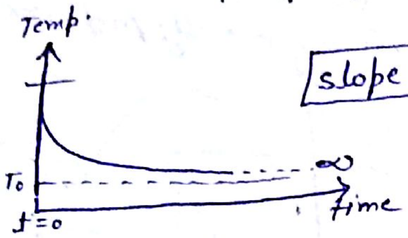
$$\boxed{\left(\frac{M_1 c_1 + W}{t_1}\right) = \left(\frac{M_2 c_2 W}{t_2}\right)}$$

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

w is not define $(w=0)$

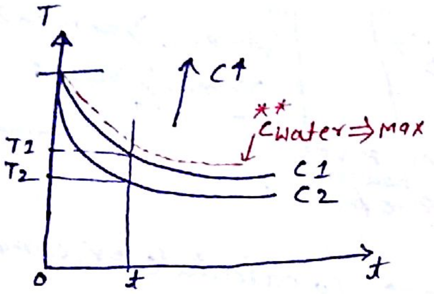
$W = 0 \Rightarrow \boxed{\frac{M_1C_1}{t_1} = \frac{m_2c_2}{t_2}}$ *

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.

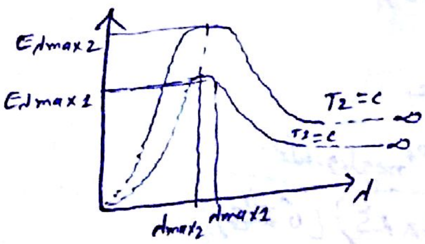
|i|→ Ideal black body spectrum is a contineous spectrum b/c I.B.B emit 0 to ∞ Range Radiation.

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

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

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

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



$T_2 > T_1$

$E_\lambda max_2 > E_\lambda max_1$

$\lambda max_2 < \lambda max_1$

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

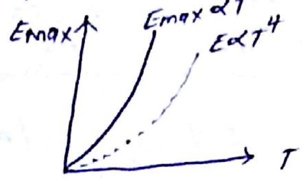
Wien's Law

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

AIPMT

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

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



|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. crosponding to max. emmisive power.

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

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

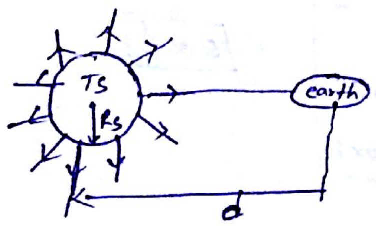
V I B G(W) Y O R →
λ↑ , T↓

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

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.

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

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

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

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

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

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.

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

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

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.

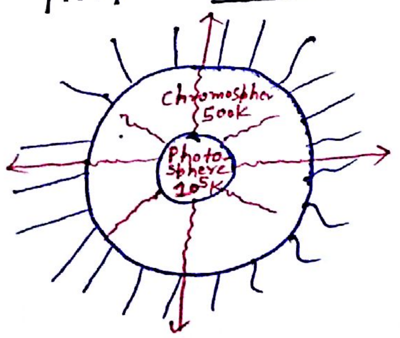
|ii| → Explanation of colour →
|a| → Body transmit & Reflect same colour Radiation & absorb remaning colour & Wich colour it will max absorb complementry colour.
EX → Red & green
Blue & yellow

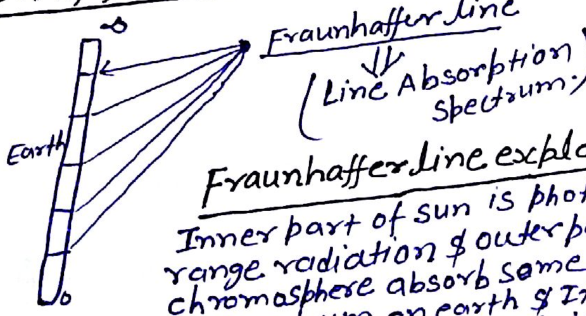
Eg → Red glass heated & seen in dark room it will apper green.

|b| → If complementry colour ($R \to G, Y \to B$) 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 →





AIIMS 2001

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 some radiation Wich is ent in spectrum on earth & It will appeared in the form of dark line Wich is called fraunhaffer lines.

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