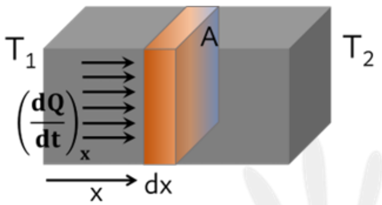
Mode	Medium	Bulk of Medium
1. Conduction	Required	Not transferred
2. Convection	Required	Transferred
3. Radiation	Not required	

Conduction

FOURIER'S LAW

$T_1 > T_2$



$$\left(\frac{dQ}{dt}\right)_x = -KA\left(\frac{dT}{dx}\right)$$

K = Thermal Conductivity of the substance (property of substance)

$\left(\frac{dQ}{dt}\right)_x$ is the amount of heat flow per unit time through a given cross–section area A. It is known as 'Heat Current'.

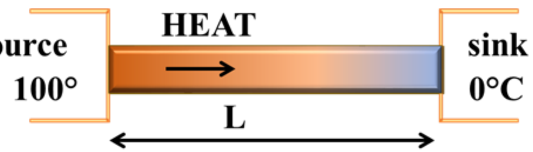
$\left(\frac{dT}{dx}\right)$ is the temperature gradient at the place where $\left(\frac{dQ}{dt}\right)$ is measured.

–ve sign indicates that heat flows in the direction of decreasing temperature.

MIND MAP

Heat Transfer

Heat Flow In A Uniform Rod In Steady State



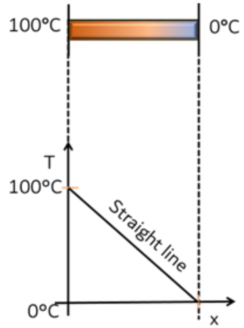
Rate of heat flow from each cross-section of the rod will be same.

$$\left(\frac{dQ}{dt}\right) = KA\left(\frac{dT}{dx}\right) = KA\left(\frac{\Delta T}{\Delta x}\right)$$

For a uniform rod, K and A are same for each element

$$i_H = KA\left(\frac{\Delta T}{\Delta x}\right)$$

Variation of Temperature



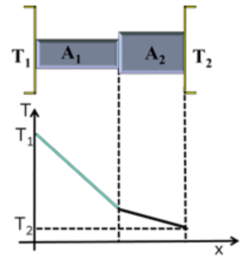
$$i_H = KA\left(\frac{dT}{dx}\right)$$

$\left|\frac{dT}{dx}\right|$ is same

K is same & A different.

$$i_H = KA\left(\frac{dT}{dx}\right)$$

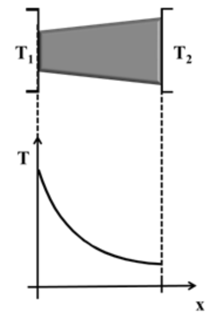
$$\left|\frac{dT}{dx}\right| \propto \frac{1}{A}$$



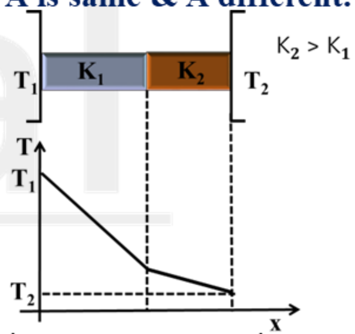
K is same & A different.

$$i_H = KA\left(\frac{dT}{dx}\right)$$

$$\left|\frac{dT}{dx}\right| \propto \frac{1}{A}$$

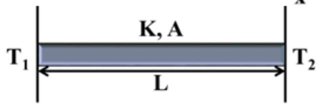


A is same & A different.



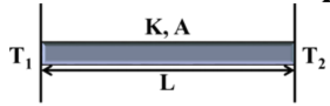
$$i_H = KA\left(\frac{dT}{dx}\right)$$

$$\left|\frac{dT}{dx}\right| \propto \frac{1}{A}$$



$$i_H = \frac{KA\,(T_1 - T2)}{L}$$

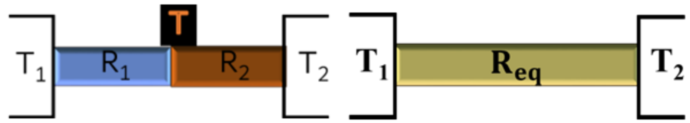
Thermal Resistance $R = \frac{L}{KA}$



$$i_H = \frac{(T_1 - T2)}{R}$$

Equivalent Resistance

Series Combination



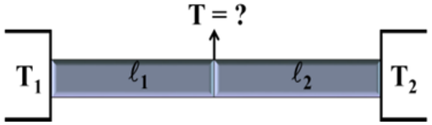
$R_1 = \frac{\ell_1}{K_1 A_1}$ $R_2 = \frac{\ell_2}{K_2 A_2}$

$R_{eq} = R_1 + R_2$

Parallel Combination

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

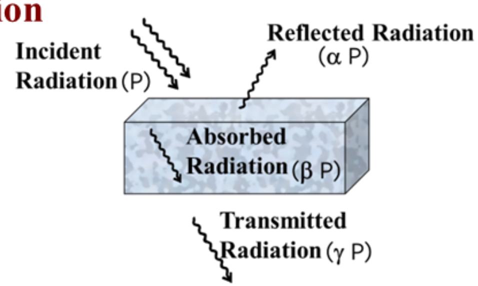
Junction Rule



$\frac{T_1 - T}{R_1} = \frac{T - T_2}{R_2}$ $i_1 + i_2 = 0$

$\sum \text{Outgoing} = 0$ $\frac{T - T_1}{R_1} + \frac{T - T_2}{R_2} = 0$

Radiation



MIND MAP

Heat Transfer

$\alpha P + \beta P + \gamma P = P$

Transmittivity

Reflectivity

$\alpha + \beta + \gamma = 1$

Absorptivity

Opaque body : $\gamma = 0$

$\alpha + \beta = 1$

Black body :

$\alpha = 0,\ \beta = 1,\ \gamma = 0$

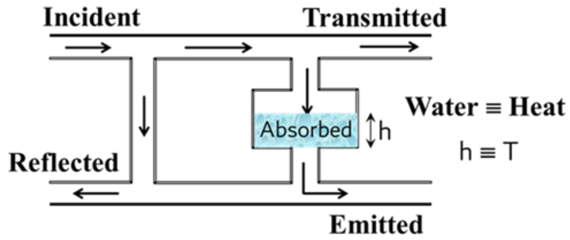
$T_b > T_s$: Rate of emission > Rate of absorbing $\Rightarrow T_b \downarrow$

$T_b < T_s$: Rate of emission < Rate of absorbing $\Rightarrow T_b \uparrow$

$T_b = T_s$: Rate of emission = Rate of absorbing $\Rightarrow T_b$ no change

Emitted Radiation

Due to its own temperature a body also emits radiation (caused by thermal vibrations of atoms, molecules & dipoles) which is known as Emitted Radiation.

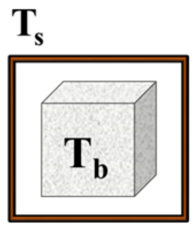


Prevost Theory

All bodies absorb as well as emit radiation at all temperatures.

Rate of emission of radiation depends on nature & temperature of the surface of the body.

Rate of absorbing radiation depends on nature of surface of the body & temperature of the surrounding.



Absorptive Power

Absorptive power of a body is defined as the fraction of incident radiation absorbed by the surface.

$a = \frac{\text{Absorbed radiation}}{\text{Incident radiation}} = \beta(\text{Unitless})$

$0 \le a \le 1$

For a Black body : $a = 1$

MIND MAP

Heat Transfer

Emissive Power

$E = \frac{\Delta Q}{A\,\Delta t}$ Unit : W/m^2

Amount of radiation energy emitted by a surface per unit time per unit area is called its Emissive Power.

Laws of Radiation

STEFAN-BOLTZMANN LAW

The emissive power from a black body surface is directly proportional to the fourth power of it's absolute Temperature (i.e. in Kelvin). $E \propto T^4$ $E = \sigma T^4$

σ = Stefan-Boltzmann constant

$= 5.67\times10^{-8}\,Wm^{-2}K^{-4}$

$P = A\sigma T^4$ P – Power emitted

A – Surface Area of the body

T – Temperature in Kelvin

Emissivity (e)

The Emissivity of the surface of a material is its effectiveness in emitting energy as thermal radiation. It is the property of surface of the material.

$0 \le e \le 1$ e = 1 for a Black body

Black Body	General
$E = \sigma T^4$	$E = e\sigma T^4$
$P = A\sigma T^4$	$P = eA\sigma T^4$

Kirchhoff's Law of Thermal Radiation

Emissivity of a body is equal to the Absorptivity of the body at a given temperature.

$\boxed{e = a}$

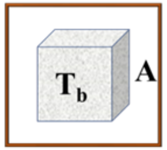
Net Rate of Heat Loss Through Radiation

Rate of heat emission $R_e = eA\sigma T_b^4$

Rate of heat absorption $R_a = eA\sigma T_s^4$

Net rate of heat loss

$\frac{dQ}{dt} = eA\sigma(T_b^4 - T_s^4)$

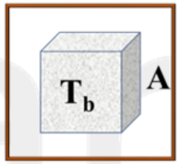


Rate of Cooling

$\frac{dQ}{dt} = eA\sigma(T_b^4 - T_s^4)$

$\frac{dQ}{dt} = -ms\frac{dT_b}{dt}$

$\frac{dT_b}{dt} = -\frac{eA\sigma}{ms}(T_b^4 - T_s^4)$



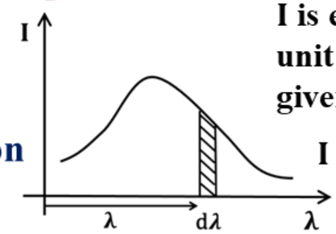
Rate of cooling i.e. Rate of Loss of Temperature

Newton's Law of Cooling

$\frac{dQ}{dt} = k(T_b - T_s) = -ms\frac{dT_b}{dt}$

$\frac{dT_b}{dt} = -\frac{k}{ms}(T_b - T_s)$

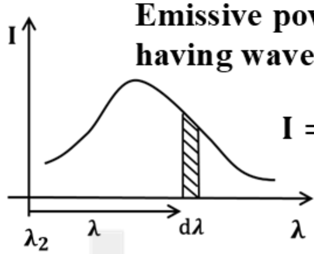
Spectral Emissive Power



I is emissive power per unit wavelength near a given wavelength (λ).

$I = \frac{dE}{d\lambda} \Rightarrow I\,d\lambda = dE$

Emissive power of radiation having wavelength from λ to $\lambda + d\lambda$

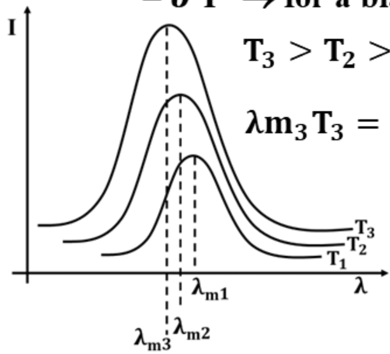


$I = \frac{dE}{d\lambda} \Rightarrow I\,d\lambda = dE$

$\int_{\lambda_1}^{\lambda_2} I d\lambda$ = emissive power of radiation having wavelength from λ_1 to λ_2

$\int_0^{\infty} I d\lambda$ = total emissive power

Total area of graph = Total emissive power $= \sigma T^4 \rightarrow$ for a black body



$T_3 > T_2 > T_1$ Wein's constant

$\lambda m_3 T_3 = \lambda m_2 T_2 = \lambda m_1 T_1 = b$

$b = 0.0029$ m-K for a black body

$\lambda_m T$ = constant