

Hindbookcenter



Hind Book Center & Photostat

MADE EASY

Mechanical Engineering

Toppers Handwritten Notes

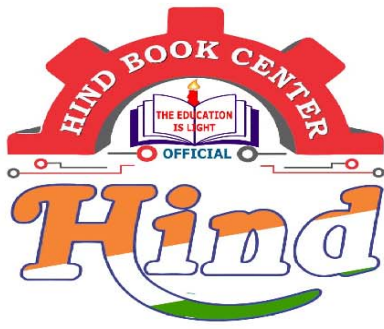
Heat And Mass Transfer

By-Manoz Sir

- Colour Print Out
- Blackinwhite Print Out
- Spiral Binding,& Hard Binding
- Test Paper For IES GATE PSUs IAS, CAT
- All Notes Available & All Book Availabile
- Best Quaity Handwritten Classroom Notes & Study Materials
- IES GATE PSUs IAS CAT Other Competitive/Entrence Exams

Visit us:-www.hindbookcenter.com

Courier Facility All Over India
(DTDC & INDIA POST)
Mob-9711475393



Hindbookcenter



ALL NOTES BOOKS AVAILABLE ALL STUDY MATERIAL AVAILABLE
COURIERS SERVICE AVAILABLE

MADE EASY, IES MASTER, ACE ACADEMY, KREATRYX

ESE, GATE, PSUs BEST QUALITY TOPPER HAND WRITTEN NOTES
MINIMUM PRICE AVAILABLE @ OUR WEBSITE

- | | |
|--------------------------------|---------------------------|
| 1. ELECTRONICS ENGINEERING | 2. ELECTRICAL ENGINEERING |
| 3. MECHANICAL ENGINEERING | 4. CIVIL ENGINEERING |
| 5. INSTRUMENTATION ENGINEERING | 6. COMPUTER SCIENCE |

IES, GATE, PSU TEST SERIES AVAILABLE @ OUR WEBSITE

- ❖ IES –PRELIMS & MAINS
- ❖ GATE

➤ NOTE;- ALL ENGINEERING BRANCHS

➤ ALL PSUs PREVIOUS YEAR QUESTION PAPER @ OUR WEBSITE

PUBLICATIONS BOOKS -

MADE EASY, IES MASTER, ACE ACADEMY, KREATRYX, GATE ACADEMY, ARIHANT, GK
RAKESH YADAV, KD CAMPUS, FOUNDATION, MC –GRAW HILL (TMH), PEARSON...OTHERS

HEAVY DISCOUNTS BOOKS AVAILABLE @ OUR WEBSITE

Shop No.7/8 Saidulajab Market Neb Sarai More, Saket, New Delhi-30	Shop No: 46 100 Futa M.G. Rd Near Made Easy Ghitorni, New Delhi-30	F518 Near Kali Maa Mandir Lado Sarai New Delhi-110030	
--	---	--	--

Website: www.hindbookcenter.com

Contact Us: 9711475393

H.T.

Conductive.
↓ Solids.
Fourier eqn.

$$q = -KA \frac{dT}{dx}$$

↓
solids.

Metals Nonmetals

lattice vibration

lattice lattice
electron flow, ..

Convection
↓ fluids

$$q = hA (T_s - T_\infty)$$

(fluids)
liquids & gases

↳ molecular collision

Thermal Radiation

All medium /
without medium.

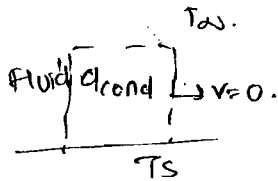
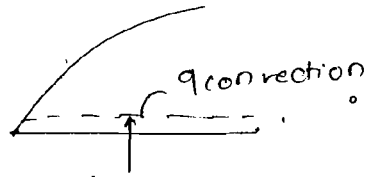
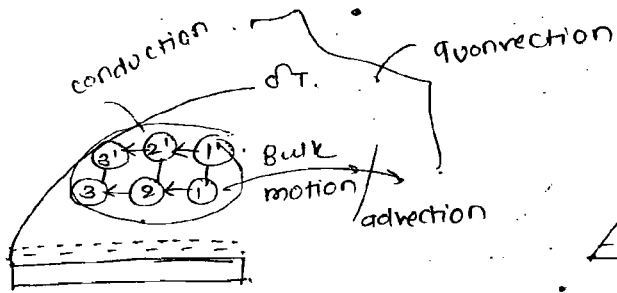
Stefan boltzmann law

$$E_b = \sigma T^4$$

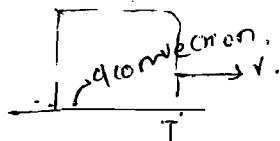
Energy transfer:

- Energy transfer defined by rate of energy transfer known as heat transfer rate.
- If it is due to temp. difference within the body or between bodies.
- The temp. of the body may be function of space & time
- $T = f(x, y, z, t)$. So HT rate is due either due to change of temp. within space or with time

S, u, T₀.



conduction
 $q_{adv} = 0$



$q_{convection}$
 $= q_{cond} + q_{adv}$

$$Nu = \frac{(q_{conv})}{(q_{cond})_F}$$

$$Nu = \frac{q_{cond} + q_{adv}}{q_{cond}} = 1 + \frac{q_{adv}}{q_{cond}}$$

$adv = 0 \rightarrow conduction$
 $Nu = 1$

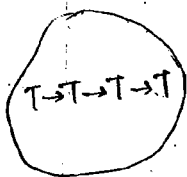
$adv \neq 0 \rightarrow convection$
 $Nu > 1$

$$Nu = \frac{h A (T_s - T_0)}{\frac{k A (T_s - T_0)}{L_c}}$$

$$Nu = \frac{h L_c}{k_f} \rightarrow \text{fluid}$$

Note:

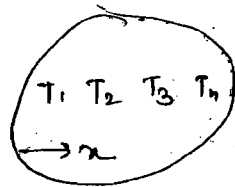
Uni for



$$\frac{dT}{dx} = 0$$

$T \neq f(x)$

Non uniform



$$\frac{dT}{dx} \neq 0$$

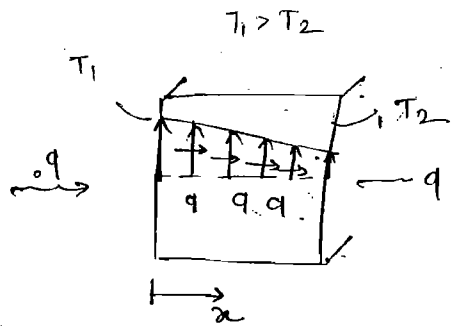
$T = f(x)$

$T = f(t)$
 Unsteady state

$$\frac{\partial T}{\partial t} \neq 0$$

$T \neq f(t)$
 Steady state

$$\frac{dT}{dt} = 0$$



Steady state $q \neq f(x)$

$T \neq f(\text{time})$

$$\frac{dT}{dt} = 0$$

$T = f(x)$ - Nonuniform

* Application of Heat Transfer:-

Condenser, evaporator, transformer, IC engine, electronic devices, Heat exchanger etc.

Thermodynamic

Heat Transfer.

① It is the science which deals the heat transfer (amount) from one equilibrium state to another without concerned with time.

① It defines the rate of the heat transfer

* Mechanism of Heat transfer:- (mode):-

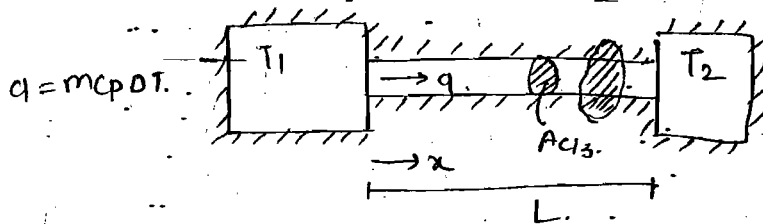
① Conduction

② Convection

③ Radiation

① Conduction mechanism:- (Microscopic form of energy transfer)

- The conduction heat transfer occurs due to temp. difference within the medium (liquids, solids or gases) or betn different mediums. (due to direct physical contact)
- In solids, the conduction is due to lattice vibration and electron flow.
- In metals it is mainly due to electron flow. In nonmetals mainly due to lattice vibration.
- In gases it is due to molecular collision/ also known as molecular diffusion.
- In liquids, conduction mechanism is similar to gases.
- The conduction heat transfer is given by fundamental law known as fouriers law. ~~as per fouriers law~~
- As per fourier's law,



$$q \propto (T_1 - T_2)$$

$$q \propto A_{cs}$$

$$q \propto \frac{1}{L}$$

$$\therefore q \propto A_{cs} \times \frac{(T_1 - T_2)}{L}$$

$$q = k A_{cs} \frac{(T_1 - T_2)}{L} \quad W$$

$$q = -kA \frac{dT}{dx}$$

$$\therefore k = \frac{q}{-A \left(\frac{dT}{dx} \right)}$$

$$\text{If } A=1, \frac{dT}{dx} = 1$$

$$\therefore \boxed{k = q}$$

$$k = \frac{q}{A_{cs} \frac{(T_1 - T_2)}{L}} = \frac{W}{m^2 \cdot ^\circ C} \text{ or } \frac{W}{mk}$$

For temp. diffn $\frac{W}{m^2} = \frac{W}{mk}$

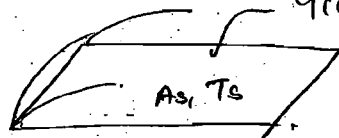
- k = Thermal conductivity of material.
- It is the property of material which defines the heat conduction rate.

② Convection heat transfer:- (Macroscopic form of energy transfer)

- When fluid flows over the ~~relative~~ solid surface (relative) the mode of heat transfer is known as convection heat transfer.
- The convection heat transfer is defined by conduction and advection heat transfer.
- It is given by Newton's law of cooling & heating.
- The heat transfer coefficient (h) depends upon:-
 - ① Velocity of flow (forced conv)
 - ② Property of fluid
 - ③ Geometry of surface
 - ④ Type of fluid flow (laminar or turbulent)
 - ⑤ Orientation of surface in free convection.

q^* = heat flux.

$$q^* = \frac{q}{A} \frac{W}{m^2}$$



$$q_{conv} = h A_s (T_s - T_\infty)$$

$$q_{conv} \propto (T_s - T_\infty)$$

$$q_{conv} = h (T_s - T_\infty) \frac{W}{m^2}$$

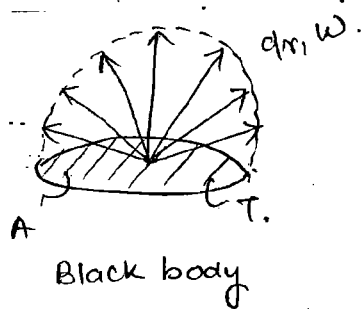
$$h = \frac{q_{conv}}{As(T_s - T_a)} = \frac{W}{m^2 \cdot ^\circ C} = \frac{W}{m^2 \cdot K}$$

$$Nu = f(Re, Pr)$$

↳ Convective heat transfer coefficient.

③ Thermal radiation

- Unlike conduction & convection Thermal radiation does not require any medium.
- The radiation heat transfer is more effective in vacuum.
- The radiation emitted by the ^{black} body above absolute zero temp. is given by a Stefan Boltzmann law.

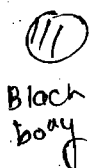
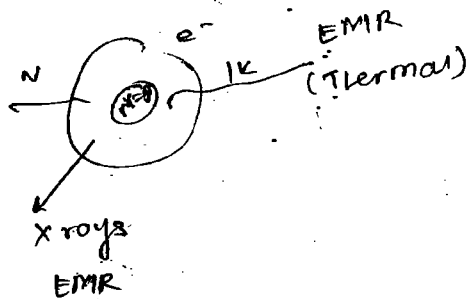
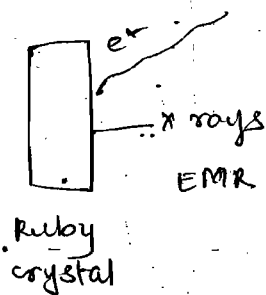
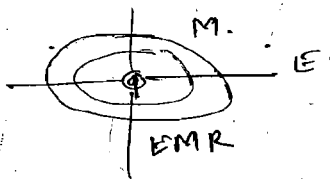


$$E_b = \frac{q_r}{A} = \frac{W}{m^2}$$

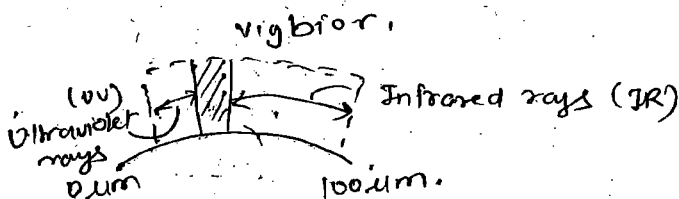
$$E_b \propto T^4$$

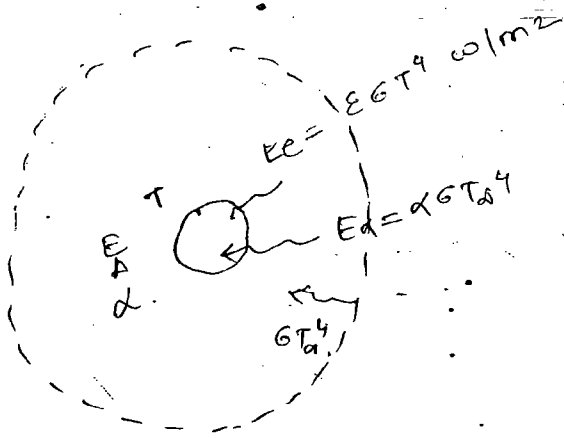
$$E_b = \sigma T^4$$

$$\sigma = 5.67 \times 10^{-8} \frac{W}{m^2 K^4}$$



$$E_b \propto T^4$$





$$q_{net} = E_e - E_a$$

$$q_{net} = \epsilon G T^4 - \alpha G T_0^4 \rightarrow \text{①}$$

Wien's law,

Small body in large enclosure

Thermal equilibrium $T = T_0$.

$$q_{net} = 0$$

$$0 = \epsilon G T^4 - \alpha G T^4$$

$$(\epsilon - \alpha) G T^4 = 0$$

$$\boxed{\epsilon = \alpha}$$

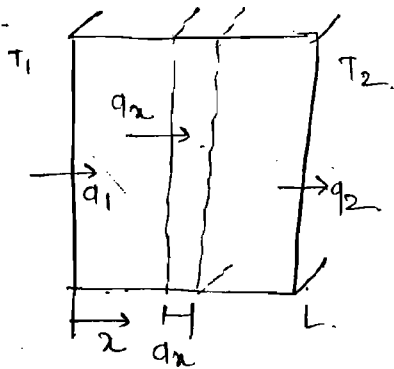
\therefore By eqn ①.

$$\frac{q_{net}}{A} = \epsilon G T^4 - \epsilon G T_0^4$$

$$\boxed{q_{net} = \epsilon A G (T^4 - T_0^4)}$$

CONDUCTION HEAT TRANSFER

* Fourier's eqn in differential form:-



$$\boxed{T_1 > T_2}$$

$$T = f(x)$$

As $x + dx > x$

$$dx > 0$$

$$T + dT < T$$

$$dT < 0$$

$$\frac{dT}{dx} < 0$$

[where -ve sign shows heat

flow from high temp to low

temp]

$$\boxed{q_n = -kA \left(\frac{dT}{dx} \right)}$$

Generalized eqn of Fourier's law.

$$q_n'' \propto \left(\frac{dT}{dx} \right)$$

the -(-ve) -

$$q_n'' = -k_n \left(\frac{dT}{dx} \right)$$

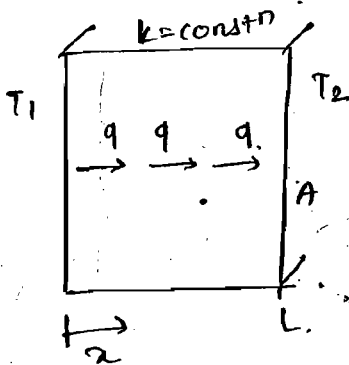
$$\frac{q_n}{A} = -k_2 \left(\frac{dT}{dx} \right)$$

$$\therefore q_1 = -kA \left. \frac{dT}{dx} \right|_{x=0}$$

$$q_2 = -kA \left. \frac{dT}{dx} \right|_{x=L}$$

$$q_1 > q_2 = \text{unsteady state}$$

Now,



Assumption:-

① Steady state $\therefore q \neq f(x)$

② $q_g = 0$

③ 1D heat conduction.

$$q = -kA \frac{dT}{dx}$$

$$q dx = -kA dT$$

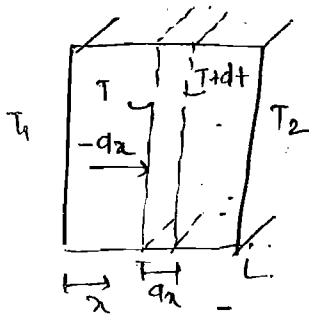
Integrating,

$$q \int_0^L dx = -kA \int_{T_1}^{T_2} dT.$$

$$qL = -kA(T_2 - T_1)$$

$$q = \frac{kA(T_1 - T_2)}{L} \quad \text{for steady state}$$

Case - II



$$T_2 > T_1$$

$$-q'' \propto \frac{dT}{dx}$$

$$q'' \propto q \left(\frac{-dT}{dx} \right)$$

$$q'' = -k \cdot A \cdot \frac{dT}{dx}$$

$$\lambda + d\lambda > \lambda$$

$$dx > 0.$$

$$T + dT > T.$$

$$dT > 0.$$

* Thermal conductivity :-

= It is the property of material which defines the ability of heat conduction.

- It is defined as heat conduction rate per unit area per unit temp. gradient.

$$q = -kA \frac{dT}{dx}$$

$$k = q \quad \text{if } A = 1 \text{ m}^2$$

$$\left(\frac{-dT}{dx} \right) = 1 \text{ K/m.}$$

- Conductivity (k) of vacuum is zero.

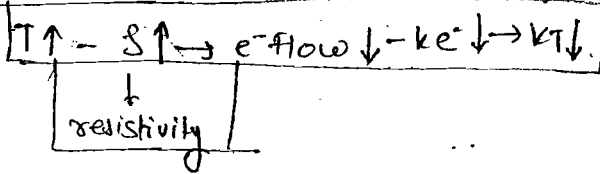
Effect of temp. on conductivities:-

① Solids:-

① Pure metals:-

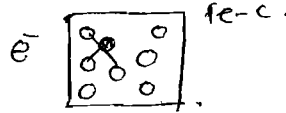
$$k_e \gg k_l$$

$$k_T = k_e$$



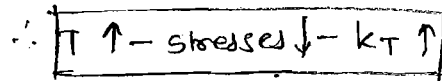
② Alloys:-

$$k_T = k_e + k_l$$



$$k_{Cu} = 400.$$

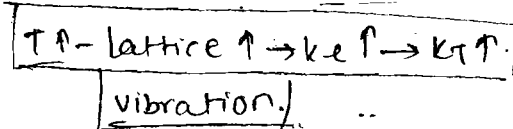
$$k_{brass} = 100.$$



③ Nonmetals:-

$$k_e \ll k_l$$

$$k_T = k_l$$



k_e - electron flow

k_l = lattice vibration.

$$K_{\text{metal}} > K_{\text{alloy}} > K_{\text{nonmetal}}$$

② Gases:-

$$k_{gas} \propto \frac{n V_{rms}}{\lambda}$$

n = no. of molecules/vol m

V_{rms} = root mean square velocity

λ = mean free path.

$$KE = \frac{1}{2} m V_{rms}^2$$

$$\frac{1}{2} m V_{rms}^2 = \frac{3}{2} kT$$

$$KE = \frac{3}{2} kT$$

$$V_{rms} = \sqrt{\frac{3kT}{m}}$$

$$\text{As } \frac{k}{m} = \frac{R}{M}$$

$$V_{rms} = \sqrt{\frac{3RT}{M}}$$

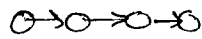
$$V_{rms} \propto \sqrt{T}$$

$$V_{rms} \propto \frac{1}{\sqrt{M}}$$

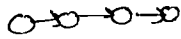
	M	
H ₂ - 2	↑ increasing ↓	↑ k increasing ↓
He - 4		
Air - 24		
CO ₂ - 44		

③ Liquids:-

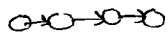
As temp. ↑ - intermolecular distance of liquid molecules ↑
 so the collision ↓ - Conductivity (k) ↓



T ↑ - S ↓



T ↓ - S ↑



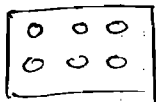
∴ T ↑ - S ↓ - k liquid ↓

Exceptions:-

① Nonmetals:- Nonmetals:-

- Some crystallize solids have high thermal conductivity than metals due to perfect crystalline structure like diamond, graphite, beryllium oxides, quartz etc.

Diamond = k = 2300 W/mk Nonmetal.



Perfect structure.



0.5 ≤ k ≤ 10 W/mk

generally Non perfect structure

k silver = 437 W/mk.