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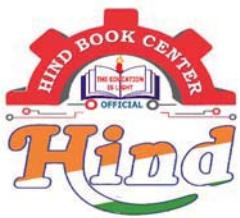
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Unacademy Mechanical Engineering Toppers Handwritten Notes Heat And Mass Transfer By-Praveen Kulkarni Sir

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Thermodynamics deals with the amount of heat transfer & makes no reference as to how long the process occurs.

The rate of heat transfer and temperature variation with time is dealt in heat transfer. Heat transfer is an extension of thermodynamics, thermodynamics does not include time as a variable whereas heat transfer includes time as a variable.

Thermodynamics + Time → Heat transfer

Applications of Heat transfer:-

[1] civil Engineering- building, Railway track, etc.

[2] Electrical Engineering → transformer, Motors, etc

[3] Metallurgical Engineering- furnaces, Heat treatment, etc

[4] Mechanical Engineering- boiler, turbine, engines etc.

Modes of Heat transfer

(1) Conduction:-

(2) convection

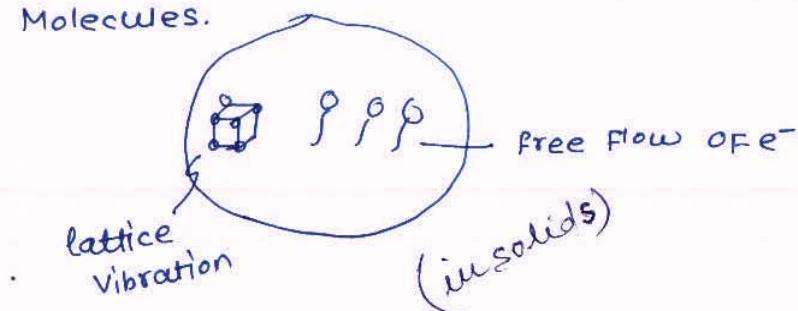
(3) Radiation.

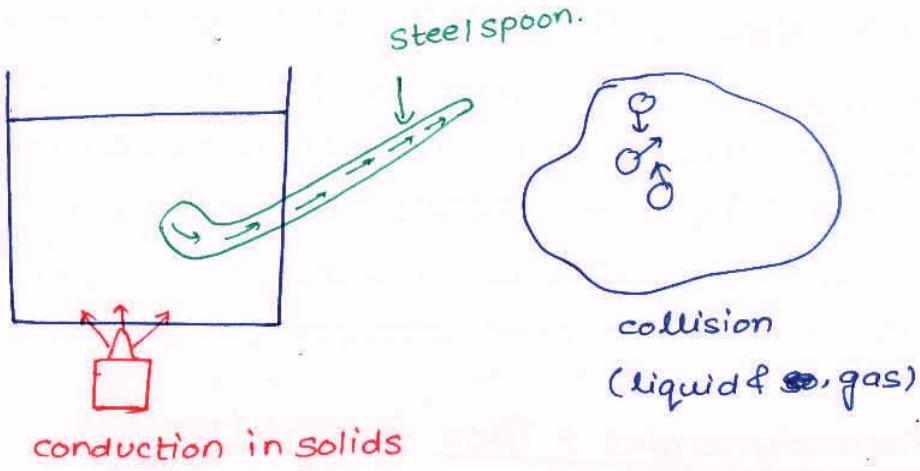


Conduction

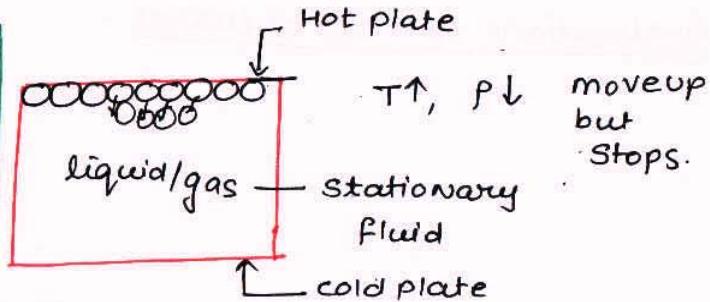
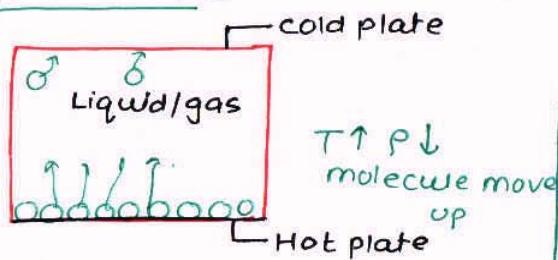
It is a microscopic phenomenon. The mechanism of heat transfer due to temperature difference in a stationary Medium is known as conduction.

Conduction can occur in solid, liquids & gases. In Solids conduction is due to Lattice vibrations & free flow of electrons, whereas in liquids & gases conduction is due to collision of molecules.





Not conduction



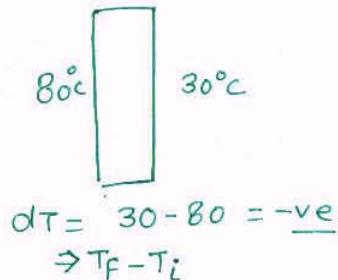
There is Flow of molecules
So it is not conduction.

The governing equation for conduction is given by Fourier's law, according to Fourier's law, conduction heat transfer is directly proportional to area (perpendicular to heat flow) and temperature gradient ($\frac{dT}{dx}$) i.e.

$$Q \propto A \frac{dT}{dx}$$

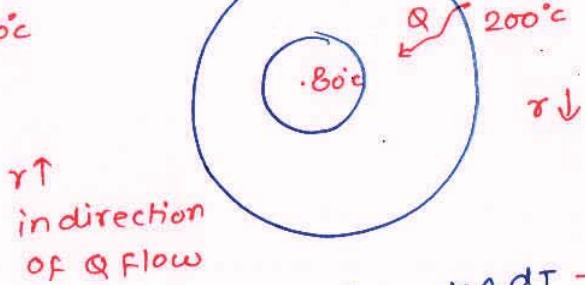
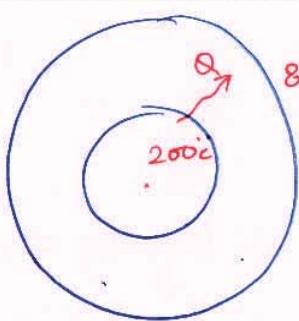
$$Q = -k A \frac{dT}{dx}$$

(-ve)



The -ve sign is taken because to keep the heat transfer positive in the direction of flow of heat

IMP:



$$Q = -KA \frac{dT}{dr} \quad (\text{H.T. +ve})$$

Multiply -ve sign to keep the H.T. +ve in the direction of flow.

$$Q = -KA \frac{dT}{dr}$$

(H.T. is positive No need to multiply -ve sign)

$$Q = KA \frac{dT}{dr} \rightarrow \oplus$$

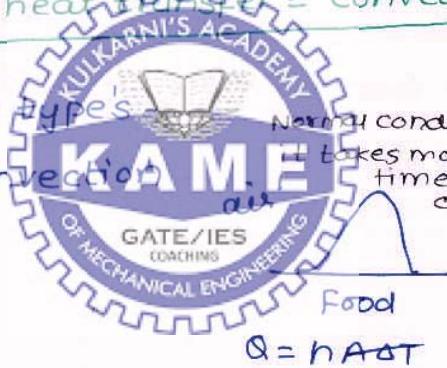
Convection:-

It is a macroscopic phenomenon in this heat transfer fluid particles themselves moves & carry heat from higher temp. to lower temperature.

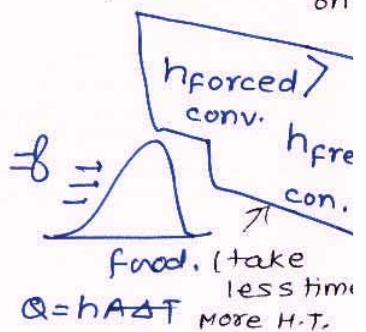
Fluid Flow + heat transfer = convection

Convection is of two types

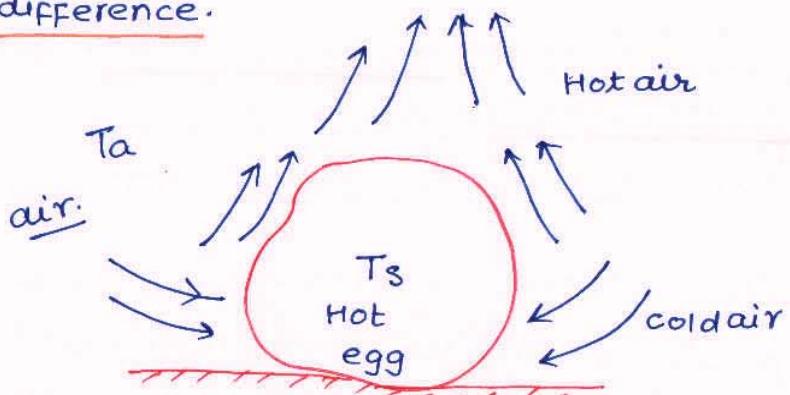
- (i) Natural or free convection.
- (ii) Forced convection.



Forced convection



In natural convection the heat transfer occurs due to density difference.

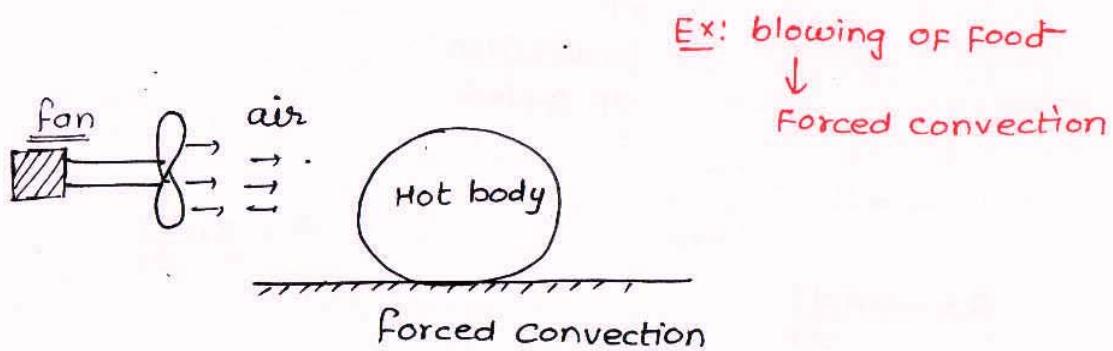


$$\rho = \rho RT$$

$$\rho = \text{const.} = \rho T = \text{constant} \Rightarrow \rho \uparrow T \downarrow$$

(atmospheric)

In forced convection the heat transfer occurs with the help of external agency like fan or pump



The governing equation for convection is given by Newton's law of cooling, according to this law-

$$Q_{\text{convection}} = h A (\Delta T)$$

Where A = Area

h = heat transfer coefficient (it is not a property)

As forced convective heat transfer is greater than free convective heat transfer, therefore faster

$$h_{\text{forced}} > h_{\text{free}}$$

Radiation:-

Every surface above zero kelvin (0K) emits radiation in the form of electromagnetic waves & they travel with Speed of light (3×10^8 m/s) radiation emitted in the range of

$0.1 \mu\text{m}$ to $100 \mu\text{m}$ is known as thermal radiation because it is in this range when absorb gets converted into heat.

The governing equation for radiation is given by Stefan-boltzmann law

$$E = \sigma T^4$$

$$\sigma = \text{Stefan boltzmann const.} = 5.67 \times 10^{-8} \frac{\text{W}}{\text{m}^2 \text{K}^4}$$

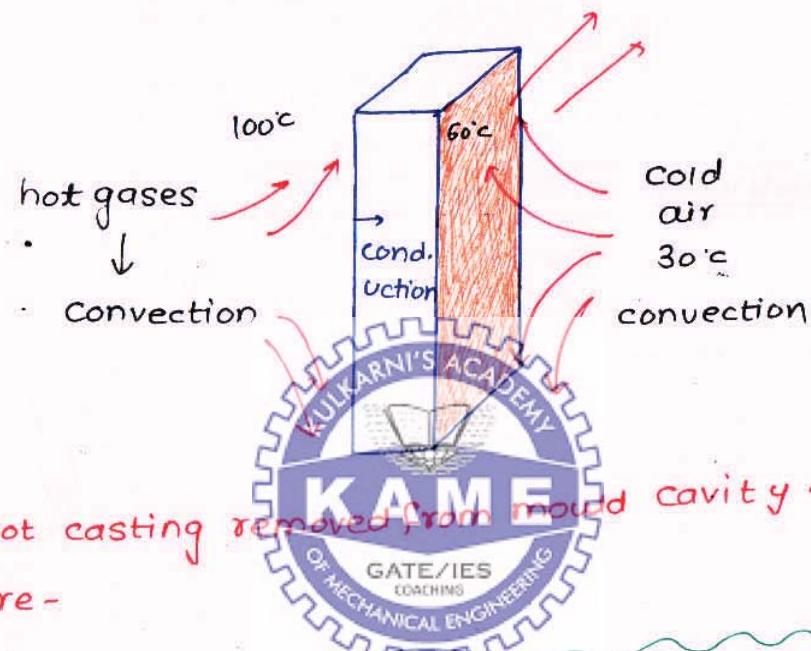
As σ is very small, radiative heat transfer becomes significant at higher temperature.

$T \rightarrow$ in kelvin.

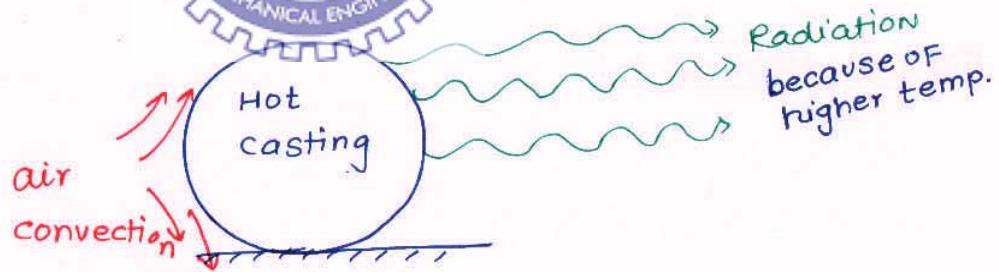
Note: For conduction & convection material medium is required & for radiation No material Medium is required i.e. radiative heat transfer can take place even in vacuum.

Combined modes of heat transfer:-

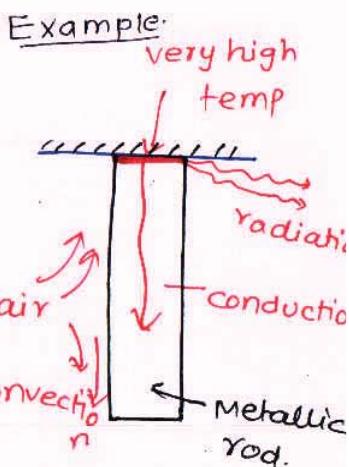
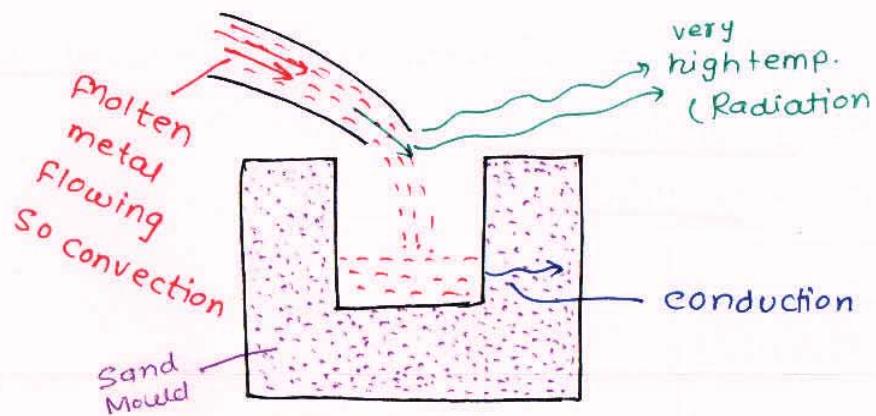
Case:1. A plane slab exposed to hot gases:



Case:2. A hot casting removed from mould cavity & exposed to atmosphere-



case:3 ^{molten} Hot Metal when poured in mould cavity:



Fouier's law of conduction:

Assumptions:

1. Steady heat transfer
2. 1-Dimensional conduction.
3. Material is homogeneous (constant density)
4. The bounding surfaces are isothermal.

Fouier's law is obtained from experiments conducted by Biot. According to Fouier's law

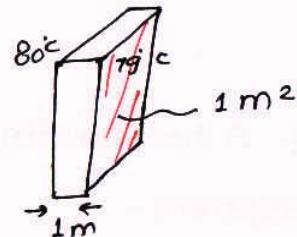
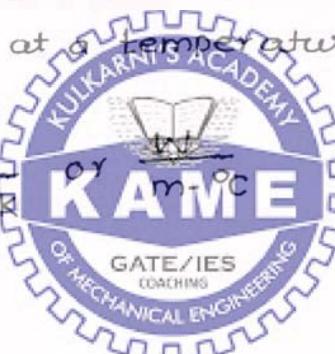
$$Q = -KA \frac{dT}{dx}$$

K - is known as thermal conductivity

Thermal conductivity: (K)

It is numerically equal to heat transfer to an area of 1m^2 of a slab of 1m thickness when two faces are maintained at a temperature difference of 1°C or 1K .

Unit of K is $\rightarrow \frac{\text{W}}{\text{m}\cdot\text{K}}$



Significance of K:

Thermal conductivity represents the ability of the medium to transfer or conduct heat. Greater the thermal conductivity, greater is the ability of the medium to transfer heat.

Difference between thermal conductivity and Specific heat-

Specific heat represents the ability of a medium to absorb or store heat whereas thermal conductivity represents the ability of the medium to transfer heat.

	Iron	Water
K	80.6 W/mK	0.608
C	0.45	4.18 kJ/kg K

From the table it can absorb though iron is good conductor of heat but it is a bad medium to store heat. Similarly though water is good medium to absorb or store heat but it is a bad medium to transfer heat.

Thermal Conductivity of Solids :-

In solids the conduction is due to lattice vibrations & free flow of electrons

$$K = K_{\text{lattice vibration}} + K_{\text{electron}}$$

↓ ↓

photon conduction electronic conduction

In case of metallic solids as the availability of $\text{free } e^-$ is more therefore a thermal conductivity of metallic solids is high.

With increase in temperature lattice vibrations increase & this obstructs the free flow of electrons and hence the "the thermal conductivity of metallic solids decrease with increase in temperature." [except Uranium]

In case of non metallic solids as there are no free flow of e^- with increase in temperature lattice vibrations increase, thereby "the thermal conductivity of non metallic solids increase with increase in temperature."

IM*

$$k_t = K_0 (1 + \beta t)$$

any

Where k_t is thermal conductivity at t temperature

K_0 = is thermal conductivity at 0°C and β is Coefficient which depends on material.

Generally For metallic solids $\beta \rightarrow -ve \left\{ \begin{array}{l} \rightarrow i.e. t \uparrow k_t \downarrow \end{array} \right.$

Non-Metallic Solids $\beta \rightarrow +ve \left\{ \begin{array}{l} \rightarrow i.e. t \uparrow k_t \uparrow \end{array} \right.$