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

The <u>rate</u> 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 where as 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, IC engines etc.

Modes of Heat transfer:-

(1) Conduction:-

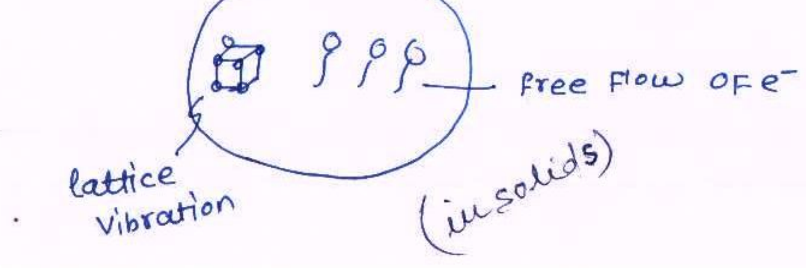
(2) Convection

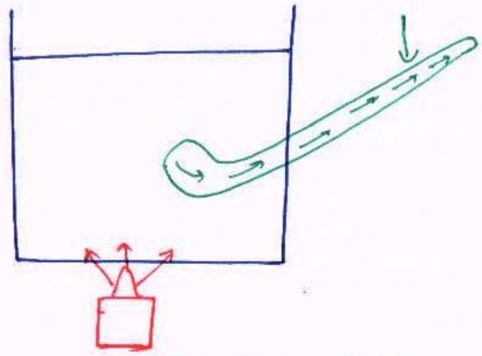
(3) Radiation.

Conduction

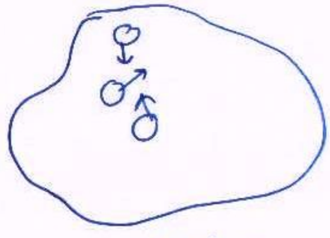
It is a microscopic phenomenon. The mechanism of heat transfer due to temperature difference in a stationary Medium. is known as conduction.

Conduction can occur in solid, liquids & gases. In Solids conduction is due to lattice vibrations & free flow of electron. where as in liquids & gases Conduction is due to collision of Molecules.



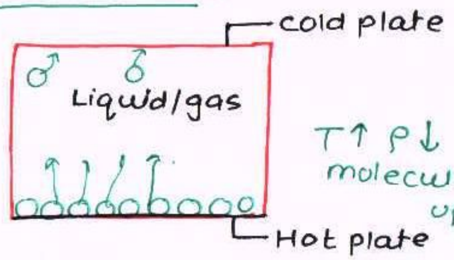


conduction in solids



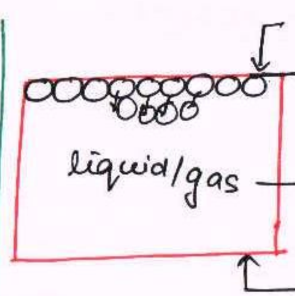
collision
(liquid & gas)

Not conduction



$T\uparrow$ $\rho\downarrow$
molecule move up

There is Flow of molecules
So it is not conduction.



$T\uparrow$, $\rho\downarrow$ moveup but stops.

The governing equation for conduction is given by fouriers law, according to fouriers law of conduction heat transfer is directly preportion to area (perpendicular to heat flow) and temperature gradient $\left(\frac{dT}{dx}\right)$ i.e.

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

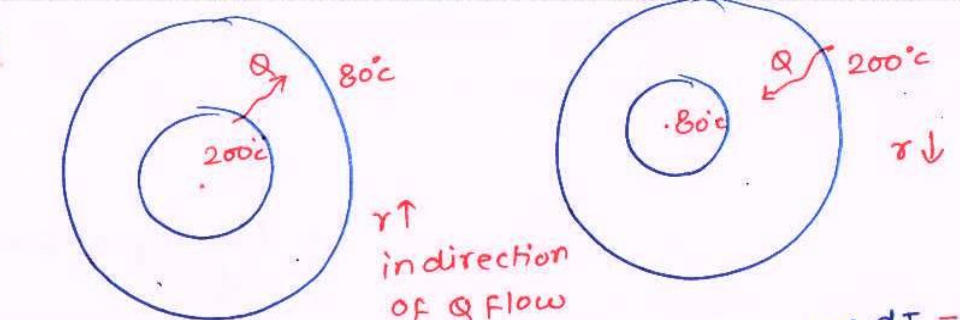
$$\boxed{Q = -kA\frac{dT}{dx}}$$

$\frac{dT}{dx}$ — (-ve)

$dT = 30 - 80 = -ve$
$\Rightarrow T_f - T_i$

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

Imp:



$Q = -KA\frac{dT^{-}}{dr_{+ve}}$ (Negative H.T. Multiply -ve sign to keep the H.T. +ve in the direction of flow)

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

$Q = KA\frac{dT^{-}}{dr_{-}} \rightarrow (+)$

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

(H.T. is positive No Need to Multiply -ve sign)

Convection:-

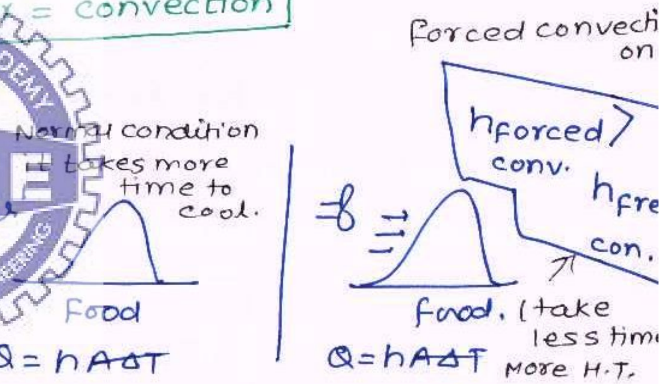
It is a <u>macroscopic</u> phenomenon in this heat transfer fluid particles themselves moves & carry heat from higher temp. to lower temperature.

Fluid Flow + heat transfer = convection

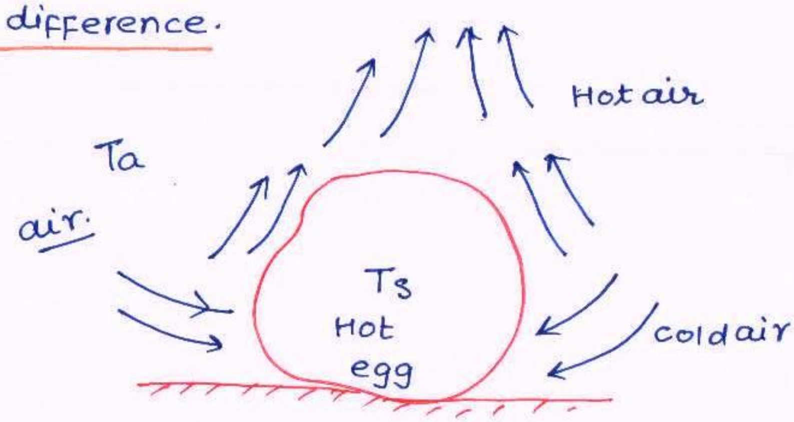
Convection is of two types:

(1) Natural or free convection

(ii) Forced convection.



In <u>natural convection</u> the heat transfer occure due to density difference.

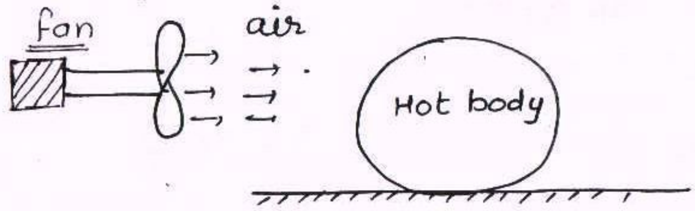


$P = \rho RT$

$P = \text{const.}$ (atmospheric) $= \rho T = \text{constant} \Rightarrow \rho \uparrow\ T \downarrow$

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

Ex: blowing of food
↓
Forced convection



Forced Convection

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

$$Q_{convection} = hA(\Delta T)$$

Where A = Surface Area
h = heat transfer coefficient (it is not a property)

As forced convective heat transfer is ~~greater~~ faster than free convective heat transfer therefore -

$$h_{forced} > h_{free}$$

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 μm to 100 μm 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

$$E = \sigma T^4$$

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

5678

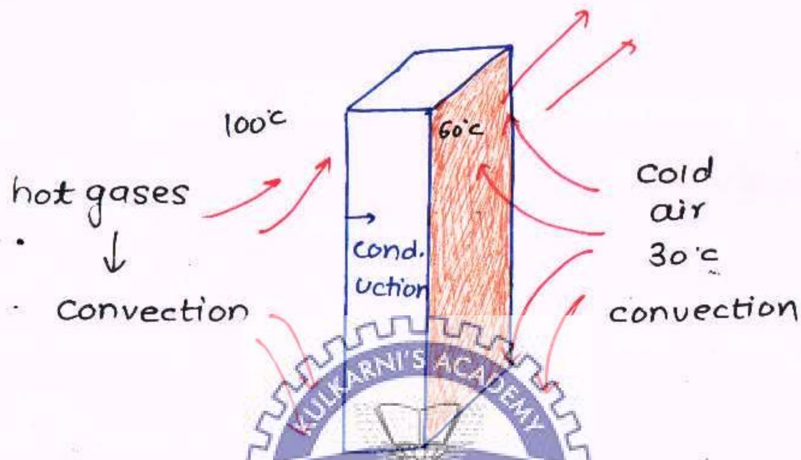
As σ is very small, radiative heat transfer become significant at higher temperature.

$T \rightarrow$ in kelvin.

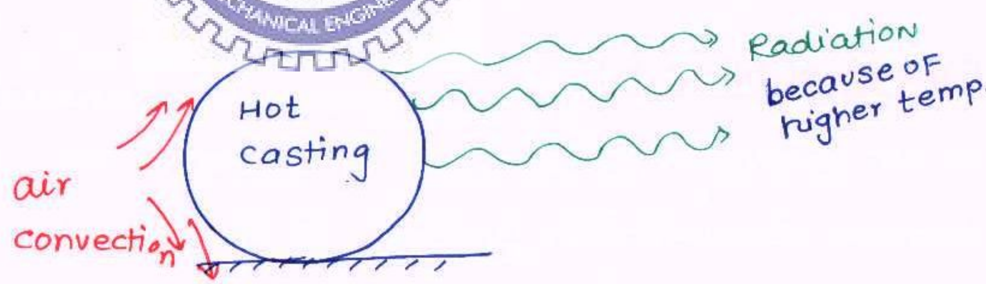
Note: for conduction & convection material medium is required & for radiation No material, Medium is required i.e. radiative heat transfer can take place even in vacuum.

Combined modes of heat transfer:-

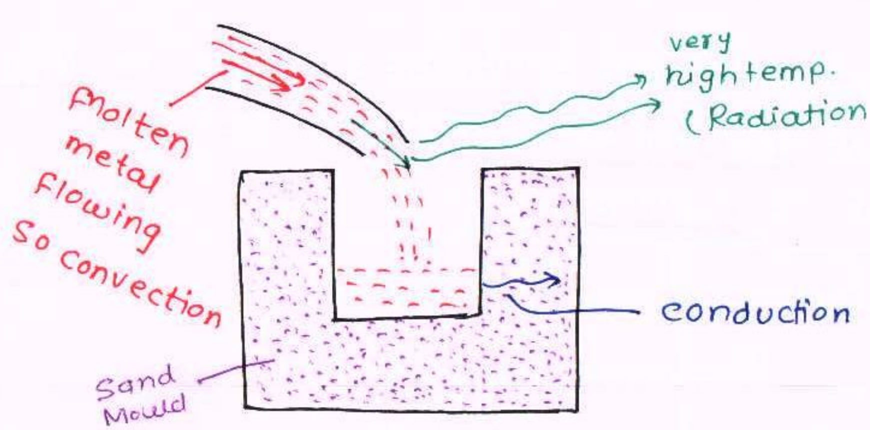
Case:1. A plane slab exposed to hot gases:



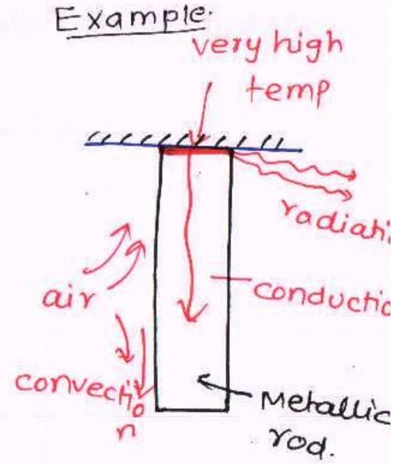
Case:2. A hot casting removed from mould cavity & exposed to atmosphere-



Case:3 Hot molten Metal when poured in mould cavity:



Example



Fouriers law of conduction:

Assumptions:

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

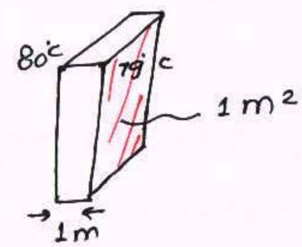
Fouriers law is obtained from experiments conducted by biot. According to fouriers law

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

k - is known as thermal conductivity

Thermal conductivity: (K) It is numerically equal to heat transfer to an area of $1\,m^2$ of a slab of 1m thickness when two faces are maintained at a temperature difference of $1^\circ c$ or 1 k.

Unit of k is → $\frac{W}{m\text{-}K}$ or $\frac{W}{m\text{-}^\circ C}$



Significance of K: Thermal conductivity represent 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 Similarily 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

$$k = k_{\text{Lattice vibration}} + k_{\text{electron}}$$

Lattice vibration → photon conduction

electron → electronic conduction

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

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

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

IMP*

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

Where k_t is thermal Conductivity at any t temperature

k_0 = is thermal conductivity at 0 °C and β is Coefficient which depends on material.

Generally For metallic Solids $\beta \rightarrow -ve$ → i.e. $t\uparrow$ $k_t\downarrow$

Non-Metallic Solids $\beta \rightarrow +ve$ → i.e $t\uparrow$ $k\uparrow$

Material	k (W/mK)	Material	K (W/mK)
Diamond	2300 (Highest)	Brick	0.72
Copper	401	Glasswool	0.043
Silver	429	air	0.026
Gold	317		
Aluminum	237	Glass wool (insulator)	0.04

Note: 1. A good electrical conductor is always a good thermal conductor but a good thermal conductor need not be always good electrical conductor.

2. The thermal conductivity of diamond is the highest of known material this is because diamond has highly organised crystalline structure.

Thermal Conductivity of Liquids:- It is observed from experiments for liquids

$$k \propto \rho$$

therefore with rise in temperature the density decreases and hence "the thermal conductivity of a liquid is decreases with increase in temperature."

$$K_{solid} > k_{liquid} > k_{gas}.$$

Thermal Conductivity of gases :-

With increase in temperature the k.E increase and because of this collisions will also increase therefore incase of gases with increase in temperature the thermal conductivity is increases.

$$k.E = \frac{1}{2} mv^2 = \frac{3}{2} kT$$