PH8151 ENGINEERING PHYSICS

UNIT-III

THERMAL PHYSICS

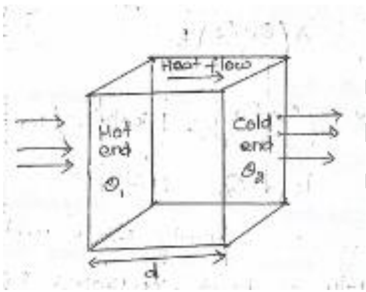
PART-B

1. What are the factors on which the thermal conductivity depends on?

Thermal conductivity:

When a metal rod is heated at one end, heat gradually flows along the length of the rod and the other end of the rod also becomes hot after sometime.

Let us consider a solid material slab having an area of cross-section ‘A’ thickness‘d’. Let the temperature at the hot end be θ_1 and cold end be θ_2



The amount of heat (Q) flowing from hot end to cold end is directly proportional to

i) The area of cross-section ‘A’ i.e., $Q \propto A$

ii) The temperature difference $(\theta_1 - \theta_2)$ $ie.,$ $Q \propto (\theta_1 - \theta_2)$

iii) The time of conduction‘t’ i.e., $Q \propto t$ and

iv) Inversely proportional to the thickness of the material‘d’ i.e., $Q \propto \frac{1}{d}$

Combine all the factors,

$$Q \propto \frac{A(\theta_1 - \theta_2)t}{d}$$

$$Q = \frac{KA(\theta_1 - \theta_2)}{d} \text{ ------ (1)}$$

Where K is the proportionality constant, known as thermal conductivity of the material.

From eqn (1)

$$K = \frac{Q}{A\left(\frac{\theta_1-\theta_2}{d}\right)t} \quad Wm^{-1}K^{-1} \text{ ------- (2)}$$

If A = 1m^2, $\left(\frac{\theta_1-\theta_2}{d}\right) = 1\ Kelvin/metre\ and\ t = 1\,sec$

Then, K = Q

Therefore, Thermal conductivity of a material is define as the amount of heat conducted per second normally across the unit area of cross-section maintained at unit temperature gradient.

Therefore, $\frac{(\theta_1-\theta_2)}{d}$ represents the rate of fall of temperature.

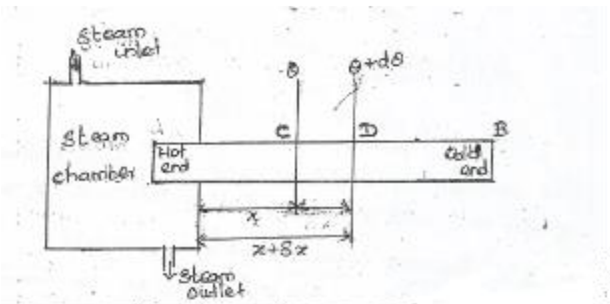
The rate of fall of temperature with respect to the thickness (or) distance is known as temperature gradient.

2. Derive a differential equation to describe the heat conduction along a uniform bar. Hence obtain the steady state condition of it.

OR

Derive the equation for one-dimensional flow of heat and solve it under steady state condition.

Consider a long rod of A & B of uniform cross-section heated at one end.



Consider two planes C and D perpendicular to the length of the rod of distance x and x + 8x from the hot end.

Temperature at C = θ

Temperature gradient at C = $\frac{d\theta}{dx}$

Temperature at D = $\left(\theta + \frac{d\theta}{dx}\delta x\right)$

Temperature gradient at D = $\frac{d}{dx}\left(\theta + \frac{d\theta}{dx}\,\delta x\right)$

Amount of heat conducted per second at A,

$$Q_1 = -KA\,\frac{d\theta}{dx} \text{ ------- (1)}$$

Amount of heat conducted per second at B,

$$Q_2 = -KA\,\frac{d}{dx}\left[\theta + \frac{d\theta}{dx}\delta x\right] \text{ ------- (2)}$$

Amount of heat gained by the rod per second between A & B

$$Q \,\vdots\, Q_1 - Q_2 \text{ ------- (3)}$$

Sub eqn (1) & (2) in eqn (3)

$$Q = -KA\frac{d\theta}{dx} - \left[-KA\frac{d}{dx}\left(\theta + \frac{d\theta}{dx}\delta x\right)\right]$$

$$Q = -KA\frac{d\theta}{dx} - \left[-KA\frac{d\theta}{dx} - KA\frac{d^2\theta}{dx^2}\,\delta x\right]$$

$$Q = -KA\frac{d\theta}{dx} + KA\frac{d\theta}{dx} + KA\frac{d^2\theta}{dx^2}\delta x$$

$$Q = KA\frac{d^2\theta}{dx^2}\delta x \text{ -------- (4)}$$

This amount of heat is used to increase the temperature of the rod and a part of it is lost due to radiation.

<u>Case (i): Before steady state is reached:</u>

Before steady state is reached, the amount of heat gained is by two ways.

1. Part of the heart is used to raise the temperature of the rod.
2. Remaining heat is lost by radiation from the surface of the rod.
1. The quantity of heat required to raise the temperature of the rod:

= mass x specific heat capacity x rate of change of temperature

$= (A \ x \ \delta x)\, PS \ x \ \frac{d\theta}{dt}$ ------ (5)

Density = $\frac{Mass}{Volume}$

Mass = density x volume

Mass = (A x δx) P

2. Heat loss per second due to radiation

= EP$\delta x\theta$ ------- (6)

Where,

E is the missive power of the surface.

P is the perimeter

θ is the average excess of temperature of the rod between the planes A &B

Amount of heat = Amount of heat gained + Amount of heat lost

$Q = AS \ x \ PS\frac{d\theta}{dt} + Ep\delta x \ \theta$ ------- (7)

Sub the value of Q from eqn (4)

KA $\frac{d^2\theta}{dx^2}\delta x = A\delta x \ PS\frac{d\theta}{dt} + Ep\delta x\theta$

Divided by KAδx on both side

$\frac{KA\frac{d^2\theta}{dx^2}\delta x}{KA\delta x} = \frac{A\delta x \ es\frac{d\theta}{dt}}{KA\delta x} + \frac{EP\delta x\theta}{KA\delta x}$

$\frac{d^2\theta}{dx^2} = \frac{\rho s}{K}\frac{d\theta}{dt} + \frac{EP}{KA}\theta$ --------- (8)

This is the standard differential equation for the linear heat flow in one direction.

If the rod is thermally insulated completed by covering it by insulating materials, the heat lost due to radiation will be zero.

i.e., $EP\delta \ x\theta = 0$

Therefore, Eqn (8) becomes

$\frac{d^2\theta}{dx^2} \neq \frac{\rho s}{K}\frac{d\theta}{dt}$

$\frac{d^2\theta}{dx^2} = \frac{1}{h}\frac{d\theta}{dt}$ -------- (9)

Where, $h = \frac{K}{\rho S}$ is known as thermal diffusivity of the rod.

<u>Case (ii): After steady state is reached:</u>

After steady state is reached, no heat is required to raise the temperature. i.e., temperature is constant.

$$\frac{d\theta}{dt} = \theta$$

Therefore, Eqn (8) becomes,

$$\frac{d^2\theta}{dx^2} = \frac{EP}{KA}\,\theta$$

$$\frac{d^2\theta}{dx^2} = \mu^2\theta$$ ------- (10) Where, $\mu^2 = \frac{EP}{KA}$

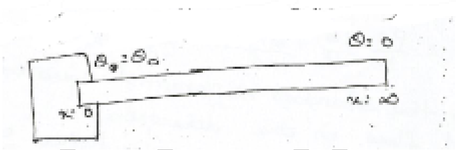
Eqn (10) is a second order differential equation.

The general solution of this differential equation is,

$$\theta = Ae^{\mu x} + Be^{-\mu x}$$ -------- (11)

Where A & B are constants. The values can be determined from the boundary condition.

Suppose the rod is of infinite length:



Let the excess temperature above the surrounding at the hot end be θ_0

Excess temperature above the surrounding of cold end = 0

i) Boundary condition, x=0, $\theta = \theta_0$

Therefore, Eqn (11) becomes,

$$\theta_0 = Ae^0 + Be^{-0}$$ $e^0 = 1,\ e^{-0} = \frac{1}{e^0} = \frac{1}{1} = 1$

$$\theta_0 = A + B$$ ------- (12)

ii) Boundary condition: $x = \infty,\ \theta = 0$

$$\theta = Ae^{\infty} + Be^{-\infty}$$

$$0 = Ae^{\infty} + 0$$

$$e^{\infty} \neq 0$$

A = 0 ------- (13)

Sub eqn (13) in eqn (12)

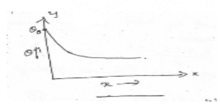
$$\theta_0 = 0 + B$$

$B = \theta_0$ -------- (14)

Sub the value of A & B in eqn (16)

$\theta = \theta_0\, e^{-\mu x}$ ----------- (15)

This equation indicates that the temperature falls exponentially from the hot end.



3. Derive an expression for the quantity of heat flow through a metal slab whose faces are kept at two different temperature.

[OR]

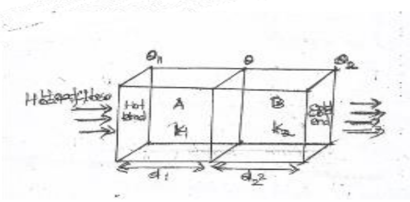
Derive an expression for the flow of heat through the compound media.

<u>Bodies in Series:</u>

Let us consider a compound media of two different materials A & B with thermal conductivities K_1 & K_2 *and thickness* d_1 & d_2.

The temperature of the outer faces of A and B are θ_1 and θ_2 and the temperature of the surface in contact is θ.

After steady state is reached, the amount of heat flowing per second (Q) through every layer is same.



Amount of heat flowing through the material A per second

$Q_1 = \frac{K_1 A(\theta_1 - \theta)}{d_1}$ -------- (1)

Amount of heat flowing through the material B per second.

$$Q_2 = \frac{K_2 A(\theta - \theta_2)}{d_2} \quad \text{----------} \ (2)$$

At steady state, the amount of heat flowing through the materials A & B is equal.

$$Q_1 = Q_2$$

$$\frac{K_1 A(\theta_1 - \theta)}{d_1} = \frac{K_2 A(\theta - \theta_2)}{d_2}$$

Rearranging the eqn,

$$K_1 A(\theta_1 - \theta) d_2 = K_2 A(\theta - \theta_2) d_1$$

$$K_1 \theta_1 d_2 - K_1 \theta d_2 = K_2 \theta d_1 - K_2 \theta_2 d_1$$

$$K_1 \theta_1 d_2 + K_2 \theta_2 d_1 = K_2 \theta d_1 + K_1 \theta d_2$$

$$K_1 \theta_1 d_2 + K_2 \theta_2 d_1 = \theta (K_2 d_1 + K_1 d_2)$$

$$\theta = \frac{K_1 \theta_1 d_2 + K_2 \theta_2 d_1}{K_2 d_1 + K_1 d_2} \quad \text{--------} \ (3)$$

This equation g is the interface temperature of two media in series.

Sub eqn (3) in eqn (1)

$$Q_1 = \frac{K_1 A}{d_1} \left[\theta_1 - \frac{K_1 \theta_1 d_2 + K_2 \theta_2 d_1}{K_2 d_1 + K_1 d_2} \right]$$

$$= \frac{K_1 A}{d_1} \left[\frac{\theta_1 (K_2 d_1 + K_1 d_2) - K_1 \theta_1 d_2 - K_2 \theta_2 d_1}{K_2 d_1 + K_1 d_2} \right]$$

$$= \frac{K_1 A}{d_1} \left[\frac{K_2 \theta_1 d_1 + K_1 \theta_1 d_2 - K_1 \theta_1 d_2 - K_2 \theta_2 d_1}{K_2 d_1 + K_1 d_2} \right]$$

$$= \frac{K_1 A}{d_1} \left[\frac{K_2 \theta_1 d_1 - K_2 \theta_2 d_1}{K_2 d_1 + K_1 d_2} \right]$$

$$= \frac{K_1 A}{d_1} \left[\frac{K_2 d_1 (\theta_1 - \theta_2)}{K_2 d_1 + K_1 d_2} \right]$$

$$= \frac{K_1 K_2 A d_1 (\theta_1 - \theta_2)}{d_1 (K_2 d_1 + K_1 d_2)}$$

$$= \frac{K_1 K_2 A (\theta_1 - \theta_2)}{K_2 d_1 + K_1 d_2}$$

$$= \frac{A(\theta_1 - \theta_2)}{\frac{K_2 d_1}{K_1 K_2} + \frac{K_1 d_2}{K_1 K_2}}$$

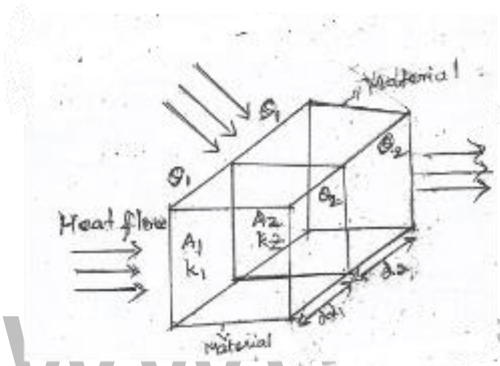
$Q = \frac{A(\theta_1-\theta_2)}{\frac{d_1}{K_1}+\frac{d_2}{K_2}}$ This eqn is the amount of heat flowing.

In general, $Q = \frac{A(\theta_1-\theta_2)}{\sum_{i=1}^{A}\frac{d_i}{K_i}}$

Bodies in parallel:

Consider a compound media of two different materials A & B with thermal conductivities K_1 & K_2 with thickness d_1 & d_2. The faces of the material A and B are at temperature θ_1 and the other end faces of A & B are at temperatureθ_2.

A_1 & A_2 are the area of cross-section of the material.



Amount of heat flowing through the material A per second.

$$Q_1 = \frac{K_1A_1(\theta_1-\theta_2)}{d_1}$$

Amount of heat flowing through the material B per second

$$Q_2 = \frac{K_1A_2(\theta_1-\theta_2)}{d_2}$$

The total amount of heat flowing through the two material per second.

$$Q = Q_1 + Q_2$$

$$Q = \frac{K_1A_1(\theta_1-\theta_2)}{d_1} + \frac{K_2A_2(\theta_1-\theta_2)}{d_2}$$

$$Q = (\theta_1-\theta_2)\left[\frac{K_1A_1}{d_1} + \frac{K_2A_2}{d_2}\right]$$

Therefore, This equation gives the amount of heat flowing through the compound media in parallel.

4. Describe Forbes's method to determine the thermal conductivity of a conductor is the form Of a long bar.

[OR]

Explain the Forbes's method of determining absolute thermal conductivity of good Conductors.

[OR]

Explain the method of determining thermal conductivity of good conductors. (Long rod)

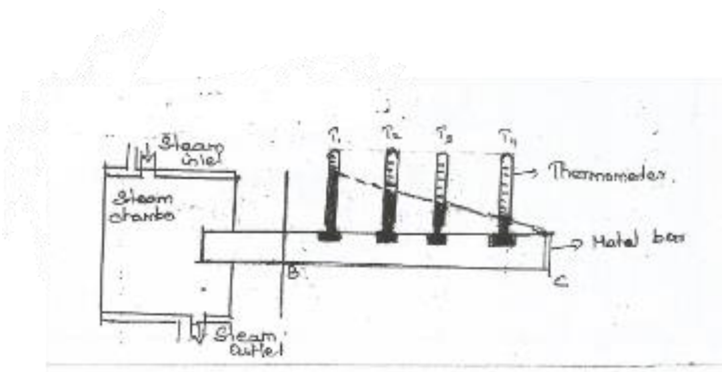
Forbes's method is used to measure the thermal conductivity of good conductors such as Aluminium, copper, Brass etc.

Principle:

At steady state, the quantity of heat passing through any section of a bar will be equal to the quantity of heat lost by radiation in the remaining part of the bar.

Description:

Consider a long metal rod of uniform cross-section. One end of the rod is enclosed in a steam chamber and the other end is left free. The rod has number of holes at equal distances in which thermometers are inserted.



Theory:

The rod is heated.

Amount of heat flowing per second at the point B,

$$Q = KA\left(\frac{d\theta}{dx}\right)_B$$

The amount of heat lost per second by radiation by and B (between B and C).

= mass x specific heat capacity x rate of fall of temperature.

= m x s x $\frac{d\theta}{dx}$ $\qquad$ $density = \frac{Mass}{Volume}$

$= (Ad\ x\ \rho)S\ x\ \frac{d\theta}{dx}$

Total heat lost by the portion of the rod between B and the end C.

$$Q = \int_B^C A\ dx\ \rho S\ \frac{d\theta}{dt}$$

At steady stats,

The amount of heat conducted = Total heat lost by radiation between B and C.

Per second at B

$$KA\left(\frac{d\theta}{dx}\right)_B = \int_B^C A\ dx\ \rho S\ \left(\frac{d\theta}{dt}\right)$$

$$K = \frac{\int_B^C A\ dx\ \rho S\left(\frac{d\theta}{dt}\right)}{A\left(\frac{d\theta}{dx}\right)B}$$

$$K = \frac{A\ \rho\ S\ \int_B^C\left(\frac{d\theta}{dt}\right)dx}{A\left(\frac{d\theta}{dx}\right)B}$$

$$K = \frac{\rho S\ \int_B^C\left(\frac{d\theta}{dt}\right)dx}{\left(\frac{d\theta}{dx}\right)B}$$

Experiment:

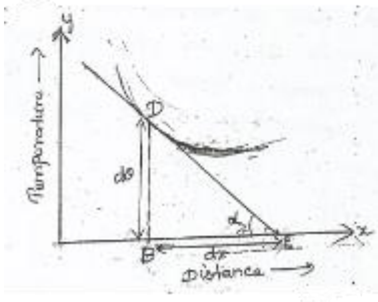
i) Static experiment to find $\left(\frac{d\theta}{dx}\right)_B$

ii) Dynamic experiment to find $\rho S\ \int_B^C\left(\frac{d\theta}{dt}\right)dx$

i) Static experiment:

The rod is heated until the steady state is reached. The temperature indicated by the different thermometers are noted. The distance of the thermometers from the steam chamber are measured.

A graph is plotted by taking the distance along the X-axis and temperature along Y-axis A curve is obtained.



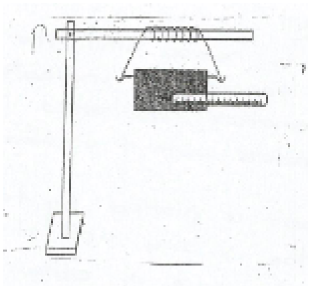
A tangent is drawn to the curve at a point corresponding to the point B near the hot end.

From the graph,

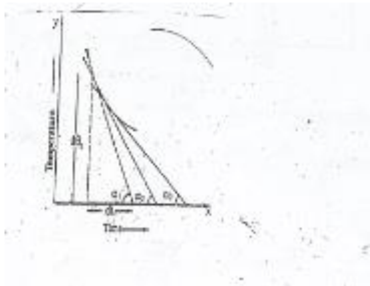
$$\left(\frac{d\theta}{dx}\right)_B = \tan\alpha = \frac{BD}{BE}$$

ii) Dynamic Experiment:

A sample place of the original rod is heated to a temperature slightly greater than the hot end of the metal rod. It is then suspended on a stand with a thermometer inserted at its centre to measure the fall is temperature.

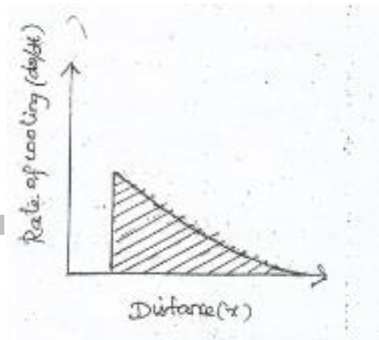


The fall in temperature is noted at regular intervals of time until it cools to room temperature. A graph is drawn by taking time along the X-axis and temperature along the Y-axis. A cooling curve is obtained.



Different tangents are drawn at points corresponding to the temperature indicated by different thermometers in static experiment and the rate of cooling $\frac{d\theta}{dt}$ are obtained.

With the data obtained, another graph is drawn with distance of the thermometers from the hot and along X-axis and the corresponding rate of cooling $\frac{d\theta}{dt}$ along Y-axis.



The curve is extended to meet the X-axis and a point is located on the curve corresponding to the point B and the area is shaded.

The area of the shaded portion $= \int_B^C \left(\frac{d\theta}{dt}\right) dx$

Therefore, The thermal conductivity K = $\frac{\rho S \ x \ area \ of \ the \ shaded \ portion}{\tan \alpha}$

Hence K can be determined.

5. i) Describe Lee's disc method to find coefficient of thermal conductivity of a bad Conductor.

[OR]

ii) How will you determine the thermal conductivity of a poor conductor using Lee's disc Method? Give the necessary theory.

Lee's Disc method:

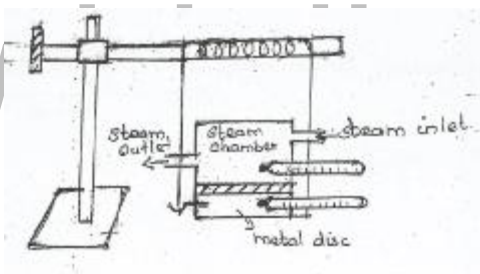
Principle:

Heat is conducted from the steam chamber to the disc through a bad conductor. When steady state is reached, heat conducted through the bad conductor per second is same as the heat radiated per second by the disc.

Construction:

The thermal conductivity of bad conductors such as ebonite or cardboard is determined by this method.

The apparatus consists of a circular metal disc or slab suspended on a stand. The bad conductor is taken in the form of a disc (D). This bad conductor has the same diameter of the slab and placed on it.



A steam chamber having the same diameter as that of a slab is placed on the bad conductor. θ_1 & θ_2 are the temperatures of the steam chamber and slab respectively.

Working:

Steam is passed through the chamber till steady state is reached. Now the temperature of steam chamber θ_1 *and slab* θ_2 are notes.

Let d be the thickness of the bad conductor,

M be the mass of the slab.

S be the specific heat capacity of the slat

r be the radius of the slab

A be the area of cross-section

θ_1 & θ_2 be the steady state temperature of steam chamber and slab.

The Amount of heat conducted by bad conductor per second is given by,

$$Q = \frac{KA(\theta_1 - \theta_2)}{d}$$

Where, A = πr^2

$$Q = \frac{K\pi r^2(\theta_1 - \theta_2)}{d} \quad \text{-------- (1)}$$

Amount of heat lost by radiation by the slab Q = Mass x specific heat capacity x Rate of Cooling.

Q = M S R_C -------- (2)

At steady state, Amount of heat conducted = Amount of heat lost by the slab.

By bad conductor per second lost by the slab.

$$\frac{K\pi r^2(\theta_1 - \theta_2)}{d} = M\ S\ R_C$$

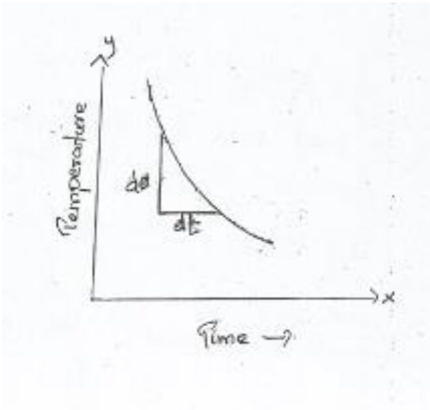
$$K = \frac{M\ S\ R_C d}{\pi r^2(\theta_1 - \theta_2)} \quad \text{-------- (3)}$$

Rate of cooling (R_C):

The bad conductor is removed and the steam chamber is placed directly on the slab. The slab is heated to a temperature of about 5^0C higher than θ_2. Now the steam chamber is removed and slab is allowed to cool. As slab, cools, the temperature of the slab are noted with respect to time, until the temperature of the slab falls between $\theta_2 + 5^\circ C\ \ to\ \theta_2 - 5^\circ C$.

A graph is plotted taking time along the x-axis and temperature along the y-axis.

The rate of cooling (R_c) is found from slope $= \frac{d\theta}{dt}$



R_C is proportional to area exposed.

i) During first part of the experiment, the top surface of slab is covered by bad conductor. Radiation is taking place only from the bottom surface and sides of the slab.

$$R_C = \pi r^2 + 2\pi rh$$

$$= \pi r(r + 2h) \quad \text{------- (4)}$$

ii) In the second part of the experiment, heat is radiated from top surface area, bottom surface area and the sides of the slab alone.

$$\frac{d\theta}{dt} = \pi r^2 + \pi r^2 + 2\pi rh$$

$$= 2\pi r^2 + 2\pi rh$$

$$= 2\pi r(r + h) \quad \text{-------- (5)}$$

From eqns (4) & (5)

$$\frac{R_C}{\frac{d\theta}{dt}} = \frac{\pi r(r+2h)}{2\pi r(r+h)}$$

$$R_C = \frac{d\theta}{dt} \ x \ \frac{\pi r(r+2h)}{2\pi r(r+2h)}$$

$$R_C = \frac{d\theta}{dt}\frac{(r+2h)}{2(r+h)} \quad \text{----------- (6)}$$

Sub eqn (6) in eqn (3), we get

$$K = \frac{M\,S\,d\left(\frac{d\theta}{dt}\right)r+2h}{2\pi r^2(\theta_1-\theta_2)(r+h)} wm^{-1}K^{-1}$$

6. What is meant by heat exchanger? Explain its types

A 'heat exchanger' may be defined as an equipment which transfers the energy from a hot fluid to a cold fluid with maximum rate.

It is a device that is used to transfer the heat between a solid and a liquid (or) between two or more liquid, without mixing and is used to reduce the heat produced by a device (or) machine.

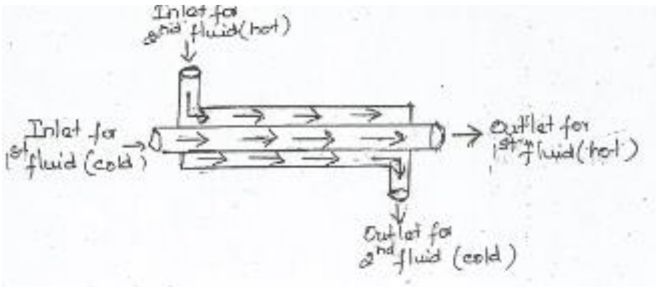
The heat exchangers are classified into the following three categories. They are

1) Parallel-flow heat exchangers.
2) Counter-flow heat exchangers
3) Cross flow heat exchangers

1) Parallel-flow heat exchangers:

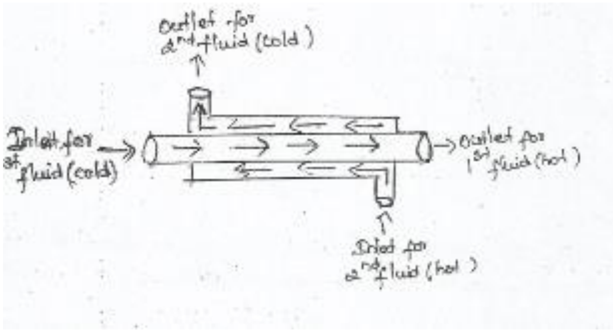
In parallel flow heat exchangers, the two fluids (one cold and other hot) enter the exchangers at the same end and travel in parallel to one another and reaches the other end and there by exchanges the heat.

In this type, the temperature difference between the two fluids are large at the entrance end and becomes very small at the exit end.



2) Counter-flow heat exchanger:

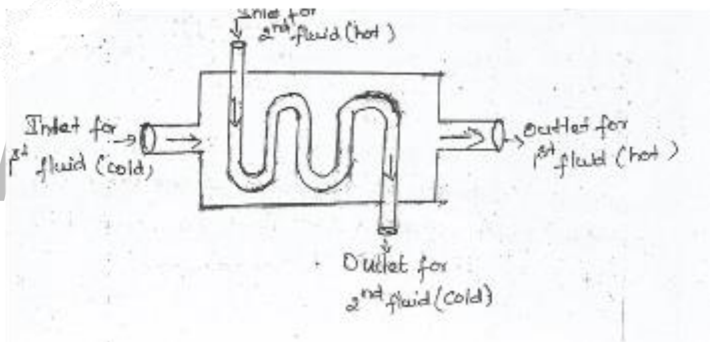
In a counter-flow heat exchanger, the two fluids flow in opposite directions. The hot and cold fluids enter at the opposite ends. Counter flow gives maximum rate of heat transfer for a given surface area. Hence such heat exchangers are most favoured for heating and cooling of the fluids.



3. Cross-flow heat exchangers:

In cross-flow heat exchangers, the two fluids (hot & cold) cross one another in space at right angles.

Ex: Automobile radiators, cooling unit of refrigeration system.



7. With a neat sketch, describe the design and working of a refrigerator. Mention its advantages and disadvantages.

It is a cooling device, which transfers heat from a low temperature region to high temperature region.

Principle:

It works on the principle of second law of thermodynamics, i.e., heat can be made to flow from cold body to a hot body with the help of an external source.

Parts of a refrigerator:

Expansion value:

The expansion value controls the flow of the liquid refrigerant into the evaporator.

Compressor:

The compressor comperes the refrigerant in a cylinder to make a hot high-pressure gas.

Evaporator:

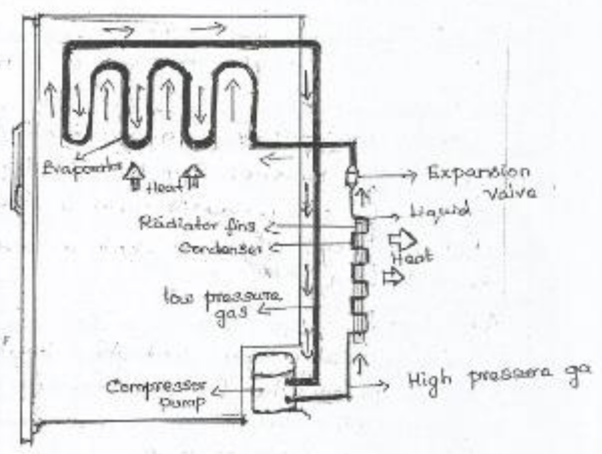
The evaporator absorbs heat from the stuff kept inside the refrigerator. As a result, the liquid refrigerant turns in to vapour.

Condenser:

The condenser helps in the liquefaction of the gaseous refrigerant by absorbing its heat and expelling it to the surroundings.

Refrigerant:

Refrigerant is referred to as the coolant. It is the liquid which absorbs the heat from the body and rejects the heat at high temperatures.



Working:

- Liquid ammonia is used as the working substance for cooling the refrigerator.

- The liquid ammonia at low pressure is passed through the evaporator coils. It absorbs the heat from the refrigerator. Thus the temperature of the liquid ammonia becomes high.
- The liquid ammonia will be converted to a ammonia vapour as the temperature becomes high.
- The ammonia vapour is sent to the compressor. The compressor compresser the ammonia vapour to a very high pressure. Thus the pressure of the ammonia vapour becomes high.
- The ammonia which is at high pressure and temperature is allowed to pass through the condenser coils during which they give heat to the atmospheric air and thus the temperature of the ammonia vapour becomes low.
- The ammonia vapour will be converted to liquid ammonia as the temperature becomes low.
- Finally, the liquid ammonia is sent to the expansion value.
- The expansion value expands the liquid ammonia and reduces the pressure. Then the cold liquid ammonia under low pressure is again sent to the evaporator.
- Thus the cycle of process continues and keeps the refrigerator cool.

Advantages:

1. It is used to store food for a long time.
2. It protects the food from microbes, insects and rodents.
3. It protects the food from direct sunlight and heat.
4. Cost of refrigerant is low.

Disadvantages:

1. It consumes large amount of electricity.
2. It causes global warming.
3. Harmful pollutant gas like CFC (Chlorafluro carbon) is used in refrigerators.
4. Preserving food in refrigerator for a long duration is not good for health.

Applications:

1. It is used for preserving the food, fruits and drinks for a long duration.
2. It is used to preserve flowers, medicines and medical drugs.
3. Refrigerator is used to manufacture ice in ice plants.

4. It is used for producing frozen foods, ice-cream, chemicals and other products.
5. In industries they are used for processing lubricants, rubber, steel etc.

8.Describe the principle, construction and working of microwave oven. Mention its advantages and disadvantages.

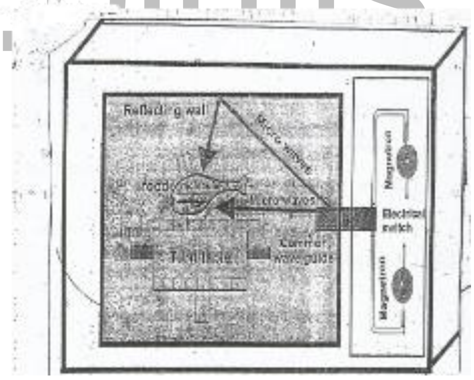
Principle:

High powered microwaves are generated and are allowed to fall on the food stuff. These waves heat the molecules in the food particles evenly and cook the food.

Construction:

A microwave oven consists of

- A high-voltage power source, which passes energy to the magnetron.
- A magnetron, which converts high-voltage electric energy to microwave radiation.
- A short waveguide that feeds the energy to the stirrer.
- A metal cooking chamber.
- A turn table.



Working:

- When the power is switched ON, the magnetron converts electrical energy into high-powered radio waves so called microwaves.
- The magnetron blasts these waves into the food compartment through a channel called a waveguide.
- These microwaves penetrate through the food compartment through a channel called a waveguide.

- Vibrating molecules produces the heat. The faster the molecular vibrate the better will be the food.
- Thus the food is woked.
- Glars, plastic, paper or ceramic containers are wed in microwave cooling as microwaves easily pass through them.

Advantages:

1. Cooking time is short.
2. Destruction of nutrients is less.
3. No physical change in foods.
4. Melting process is easy.

Disadvantages:

1. Metal containers cannot be used.
2. Water evaporation takes place.
3. Closed container is dangerous because it could burst.
4. Surface toasting is impossible.

9. Describe the principle, construction and working of solar water heater. Mention its advantages and disadvantages.

Principle:

A solar water heater is based on the principle of converting solar energy into electrical energy and then in heat energy using solar cells.

Construction:

A solar water heating system consists of

Flat plate collector:

It is used to convert solar energy into thermal energy. Thee collector consists of copper tubes welded to copper sheets with a toughened glass sheet on top and insulating material of the back.

Insulated water storage tank:

It is water tank that is used for storing hot water. It is made of mild steel.

Heat Exchanger:

It is made up of coil of copper pipes and is kept inside the water tank. Heat exchanger is used to transfer the heat energy from the hot water passing through the copper pipe in the heat exchanger to the cold water in the water tank.

System Control:

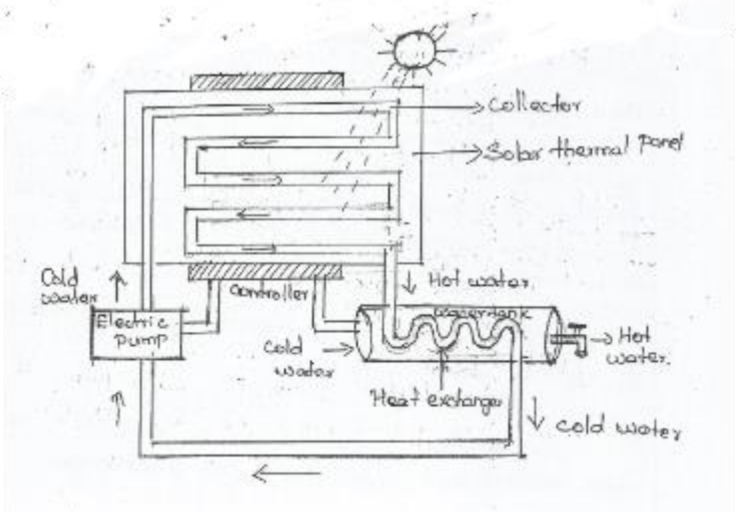
It has a sensor and a control value to avoid reverse flow during night.

Electric pump:

An electric pump is used to pump the cold water coming out from the heat exchanger.

Working:

- The system is installed on the roof or open grounc with the collector facing the sun.
- The electric pump, pumps the cold water to the flat plate collector.
- The water in the flat plate collector is heated up due to the thermal radiations that fall on it.
- This hot water is allowed to pass through the water tank with the help of the heat exchanger.
- The heat exchanger transfer the heat energy to the water present in the water tank and therefore the water in the water tank becomes hot.
- Thus hot water can be obtained from the tank.
- The water coming out from the heat exchanger becomes cold and again enters the electric pump and the cycle of process continue.
- The hot water from the storage tank fitted on roof top is then supplied through pipes into buildings.



Advantages:

1. Simple to construct and install.
2. Cost is low.
3. Requires low temperature.
4. Almost maintenance free.
5. Solar energy is free and abundant.
6. It is more efficient.

Disadvantages:

1. Freezing problem occurs.
2. Not useful during rainy and foggy days.
3. Annual maintenance is required.
4. It occupies space.