3. Thermal Physics

Part – A

1. **What are the basic entities responsible for thermal conduction of a solid?**
   (1) Area of cross section (ii) Temperature difference between hot and cold layers (iii) Time of conduction (iv) Thickness of solid
2. **Define coefficient of thermal conductivity?**

   It is defined as amount of heat conducted per second normally across unit area of cross section of the material per unit temperature difference per unit length.

$$K = \frac{Qx}{A(\theta_1 - \theta_2)t} \qquad Wm^{-1}K^{-1}$$

3. **How heat conduction and electrical conduction are are analogous to each other?**

S.No	Heat conduction	Electrical conduction
1.	Heat is conducted from a point of higher temperature to lower temperature	Electricity is conducted from a point of higher potential to lower potential
2.	In metals heat conduction are mainly due to free electrons and contribution of lattice vibration is negligible	IN metals electrical conduction is due to free charge carriers
3.	Quantity of heat conducted per second through unit area of cross section when unit temperature gradient is maintained	Electrical charge flowing per second per unit area of conduction when unit potential gradient is maintained
4.	Thermal resistance = Thermal gradient / Thermal current flow	Electrical resistance = Potential gradient / Electrical current flow

5. **Mention the properties of thermal insulating materials?**

   1. It should be fire proof
   2. Materials have high volumetric specific heat
   3. It should have low thermal conductivity
   4. It should be a poor absorber of moisture
   5. It should withstand under any environmental conditions.

6. **The ends of two rods A and B with thermal conductivities K_1 and K_2 respectively are maintained at temperature θ_1 and θ_2. The rods are of equal length. What is the condition under which there will be equal rate of heat flow of heat through both the rods?**

If θ_1 and θ_2 are end temperatures of two rods, then the condition for equal rate of flow of heat through both rods is

$$\theta_1 - \theta_2 = \frac{Ql}{A}\left[\frac{1}{K_1} + \frac{1}{K_2}\right]$$

7. **Write down the formula for the coefficient of thermal conductivity of square shaped thin bad conductor in the Lee's disc method. In this experiment instead of metallic disc, metallic square plate is used.**

$$K = \frac{MSd\left(\frac{d\theta}{dt}\right)_{\theta_2}}{\left(\pi r^2\right)^2(\theta_1 - \theta_2)}\frac{(r+4t)}{(2r+4t)} \; Wm^{-1}K^{-1}$$

8. **Distinguish between conduction and convection?**
   Conduction: It is the process of transmission of heat from one point to another through substance without the actual movement of the particles
   Convection: It is the process of transmission of heat from one point to another through substance with the actual movement of the particles

9. **Define radiation and give an example.**
   It is the process of transmission of heat from one point to another without the necessity of the intervening medium. **Example**: sun radiation falling on earth experienced by the humans

10. **What is meant by thermal expansion in solids?**

When metal is heated, due to increase in temperature it will expand and when it is cooled it contracts. However, an internal force will always act so as to keep the metal to regain its original position.

Thermal expansion: *The expansion of a metal, when subjected to heat is called thermal expansion.*

11. Define coefficient of thermal expansion.

Coefficient of thermal expansion is the ratio between the changes in length to the original length per unit rise in temperature

The coefficient of thermal expansion $\alpha = \frac{dl}{l\theta}$, If θ = 1,then $\alpha = \frac{dl}{l}$

12. Define coefficient of volume expansion.

The coefficient of volume expansion "β" is defined as the ratio between the fractional change (ΔV) in volume to the original volume (V) per unit rise of temperature (ΔT) $\beta = \frac{\Delta V}{V}$

13. What do you understand from the term Bimetallic strip give its use?

Bimetallic strips are made up to two thin strips with different coefficient of thermal expansion. Bimetallic strips are commonly used in water heaters as temperature controller

14. What is meant by temperature gradient?

The rate of fall of temperature with respect to the distance is called as temperature gradient. In general it is denoted as –dθ/dx. The negative sign indicates the fall of temperature with the increase in distance

15. Give the methods of determining the good and bad conductors of thermal conductivities?

Searle's and Forbe's method – thermal conductivity of good conductors
Lee's disc – thermal conductivity of bad conductors

16. What is meant by thermal resistance?

It is a measure of its opposition to the flow of heat through it

17. What is meant by thermal insulation?

Thermal insulation is made for reducing the heat transfer between the objects in thermal contact (or) in range of radiative influence. It also provides a region of insulation in which thermal conduction is reduced. In other way we can say that the thermal radiation is reflected rather than absorbed by the body at lower temperature

18. How will you classify the thermal insulating materials?

There are three types of thermal insulating materials

(1) Fibrous thermal insulating materials **Eg:** Sugarcane fiber, fur, wool and hair
(2) Granular thermal insulating materials **Eg:** Sand and saw dust & **(3)** Porous thermal insulating materials **Eg:** asbestos, aluminium foil, foam rubber, cork, etc., all of which have a number of tiny air-pockets within them.

19. How will you classify the thermal insulating materials based on density?

S.No	Less dense thermal insulation materials	High dense thermal insulation materials
1.	It has high resistive power	It has low resistive power
2.	Materials are quickly heated and cooled	Materials takes more time for both heating and cooling
3.	Materials will not absorb more heat	Materials will absorb enormous heat
4.	Eg: cork, cardboard, thermocool, etc.,	Eg: brick, stone, concrete, etc.,

20. What is meant by heat exchanger? How the heat is measured using it?

A heat exchanger is a device that is used to transfer the heat between two fluids without mixing. It is used to reduce the heat provide by the device

Measurement in heat exchanger, the driving temperature across the heat transfer surface varies with position. Therefore the temperature difference is measured only in terms of log mean temperature difference

21. Mention the applications of heat exchangers?

1. Used in refrigerators and air conditioner
2. Used in power plants and engine to cool the exhaust hot gases
3. Used in petroleum refineries, petro chemical plants

4. Used in natural gas processing and sewage water treatment plants
5. Used in internal combustion engine and radiator coil
6. Reducing the space heating the transferring the heat generated by electronic devices.

22. What is meant by refrigerator? Give its principle?

It is an equipment used to reduce and maintain the below atmospheric temperature and this obtained by removing the heat from the space continuously.

Principle: *without doing external work it is impossible to transfer heat from a cold body to cold body"*

23. What is meant by refrigerant?

It is a fluid which absorbs the heat rom the body and rejects the heat at high temperature. Example: Ammonia, carbon di oxide, Freon, methyl chloride, chloro fluoro carbon (CFC)

24. What is meant by Capacity of refrigerator (or) Refrigeration effect

It is the amount of heat extracted from the cold body per unit mass per second. (or) the rate at which the refrigeration produced is called the capacity for the refrigerator. It is expressed in tonne of refrigeration.

25. Define tonne of refrigeration?

A tonne fo refrigeration is defined as the amount of refrigeration effect produced by uniform melting of one tonne of ice at 0°C to water in 24 hours.

1 Tonne refrigeration = 210 KJ/min (or) 3.5kJ/sec.

26. Define Performance coefficient

It is the ratio of het extracted to work done $COP = \frac{Heat\ extracted}{Work\ done}$

27. What is meant by oven? Give its types?

Oven is a thermally insulated chamber used for heating, baking or drying of a substance and most commonly used for cooking. Kilns and furnaces are special-purpose ovens used in pottery and metalworking respectively

Types of oven

Double oven, ceramic oven, Gas oven, Microwave oven, Toaster oven and Hot air oven

28. What is meant by solar power? How will you estimate it?

Solar power is the process of converting (or) utilizing the abundantly available solar energy either directly as heat (or) indirectly by converting it into electrical power by using photo-voltaic cells

Solar energy reaches the Earth at the rate of 1.4KW per square meter of surface perpendicular to the direction of the sun rays.

∴ The total power radiated by the sun can be written as

ρ = Energy received by the earth x Surface area of the earth

we know that, Surface area of the sphere = $4\pi r^2$

The mean radius of the earth's orbit = 1.5×10^{11} m

∴ $\rho = 1.4 \times 10^3 \times 4 \times 3.14 \times (1.5 \times 10^{11})^2$

$\rho = 3.956 \times 10^{26}$

∴ Total solar power (ρ) = 4×10^{26} Watts

29. Mention any two applications of solar power

Active systems

It is utilized by trapping the heat from escaping, through file plate collectors

Example : Green houses, File plate collectors, etc.,

Passive systems

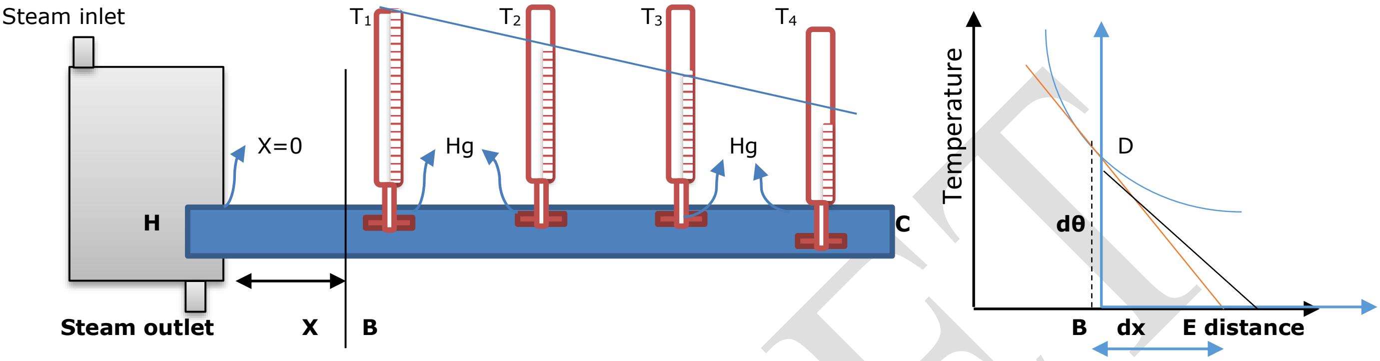
It is used to operate machineries such as fans, heaters, etc., using photo-voltaic cells

Example: Solar water heater, Solar cooker, Solar driers, furnaces, etc.,

Part – B

1. Describe Forb's method to determine the thermal conductivity of a good conductor in the form of a long bar?

This method is used to determine the absolute thermal conductivity of metals. It consists of long rod (HC) of uniform area of cross section. One end of the rod is enclosed by a steam chamber and the other end is let free as shown in fig. A number of provision are made in the rod at equal distance in which the thermometers are inserted. A small quantity of mercury is poured in each provision to have good thermal contact between the rod and the thermometers.



Working

The rod is heated till the steady state is reached. i.e., all the thermometers indicates a different constant values. Then

The amount of heat flowing per second across 'B' at a distance x from the hot end = $KA\left(\frac{d\theta}{dx}\right)_B$ (1)

The heat conducted at ***B*** is somehow should be lost between ***B*** to end ***C*** , therefore

The amount of heat lost per second by radiation by the rod beyond the section ***B*** = $\int_B^C mS\left(\frac{d\theta}{dt}\right)$ (2)

Since ***Mass = volume X density**, we get **Mass = Adx.ρ***

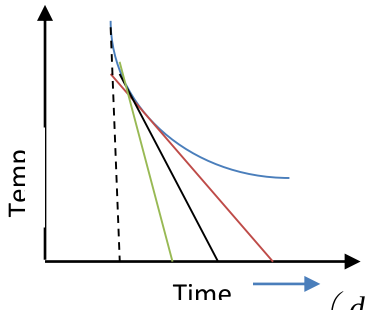
Therefore Heat lost per second = $\int_B^C A.dx.\rho.S.\left(\frac{d\theta}{dt}\right)$

At steady state,

The amount of heat conducted per second at ***B*** = The amount of heat lost per second by radiation between ***B*** and ***C***

Equating equations (1) and (2), we get $KA\left(\frac{d\theta}{dx}\right)_B = \int_B^C A.dx.\rho.S\left(\frac{d\theta}{dt}\right)$

i.e., $K = \frac{\rho.S\int_B^C\left(\frac{d\theta}{dt}\right)dx}{\left(\frac{d\theta}{dx}\right)_B} Wm^{-1}K^{-1}$ (3)



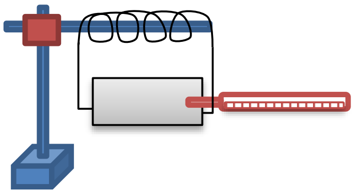
In order to find ***K***, we have to find $\left(\frac{d\theta}{dx}\right)_B$ and $\int_B^C\left(\frac{d\theta}{dt}\right)dx$. Here, static experiment was used to determine $\left(\frac{d\theta}{dx}\right)_B$

and dynamic method was used to determine $\int_B^C\left(\frac{d\theta}{dt}\right)dx$

(1) Static Experiment:

The experiment setup is shown in figure. The rod is heated up to six (or) seven hours until the steady state is reached. The temperatures indicated by the thermometers T_1, T_2, T_3, T_4 are noted as θ_1, θ_2, θ_3, θ_4 respectively. The distance of the thermometer from the hot end is also noted. A graph is plotted taking distance along x – axis and temperature along y – axis as shown in figure. A tangent is drawn to the corresponding distance (B) i.e., on point 'D' in the curve.

From the graph, we can write $\left(\frac{d\theta}{dx}\right)_B = \tan\alpha = \frac{BD}{BE}$ (4)



Hence $\left(\frac{d\theta}{dx}\right)_B$ has been found.

(ii) Dynamic experiment

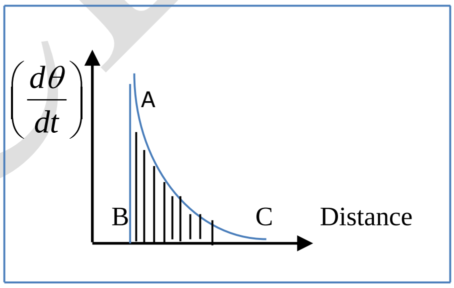
A sample piece of the original rod of same area of cross section is heated till it reaches the temperature of the hot en (H). Then, the sample rod is fixed with a thermometer at the center of the rod is suspended in the open atmosphere and is allowed to cool as shown in figure.

The fall of temperature is noted as the same range measured in the static experiment at regular intervals of time until it reaches the temperature below the section '**B**' temperature as chosen in static experiment. A graph is drawn taking time along x – axis and temperature along Y axis. Different tangents are drawn for the corresponding temperature indicated by thermometer T_1, T_2, T_3 and T_4 in the static experiment.

Now, we get the $\left(\frac{d\theta}{dt}\right)_{x_1} = \tan\alpha_1$, $\left(\frac{d\theta}{dt}\right)_{x_2} = \tan\alpha_2$, etc.,

i.e., Rate of cooling at that corresponding distances beyond the section '**B**' in static experiment is obtained.
With the above data, a third graph is plotted taking 'x' distance from hot end beyond the section **B** along x- axis and $\left(\frac{d\theta}{dx}\right)_{x_1}$, $\left(\frac{d\theta}{dx}\right)_{x_2}$, etc., along y – axis as shown in figure.

Then the area of the shaded portion of the curve will correspond to $\int_B^C \left(\frac{d\theta}{dt}\right) dx$, where **B** is the point chosen in the static experiment.



∴ Area of the shaded portion = $\int_B^C \left(\frac{d\theta}{dt}\right) dx$ (5)

Substitute the value of (4) and (5) in equation (3), we get

The thermal conductivity $K = \frac{\rho.S \times \text{Area of shaded portion}}{\left(\frac{BD}{BE}\right)} Wm^{-1}K^{-1}$

The experiment is repeated by choosing the point **B** at different distances from the hot end and the average value of **K** is determined.

Limitations

(i) It is tedious to draw to three graphs
(ii) It takes long time to complete the experiment
(iii) Distribution of heat is not uniform throughout the bar in static and dynamic experiments.

2. Describe Lee's disc method for determining the coefficient of thermal conductivity of a bad conductor?

The thermal conductivity of bad conductors like ebonite or cardboard can be determined by this method.

Description

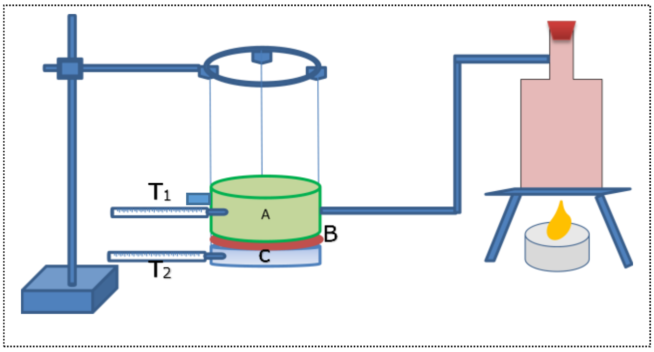
The apparatus consists of a circular metal disc or slab C (Lee's disc) suspended by strings from a stand as shown in fig. The given bad conductors (such as glass, ebonite) is taken in the form disc (B). This disc has the same diameter as that of the slab and is placed over it. A cylindrical hollow steam chamber (A) having the same diameter as that of the slab is placed over the bad conductor. There are holes in the steam chamber and slab through which thermometer (T_1) and (T_2) are inserted to record the respective temperatures.

Working

Steam is passed through the steam chamber until the temperatures of this chamber and the slab are steady. When the thermometer shows steady temperatures the readings θ_1 & θ_2 are noted. The radius (r) of the disc (B) and its thickness (d) are also noted.

Observation & calculation

Thickness of the bad conductor = d
Radius of the metallic disc (or) bad conductor = r
Mass of the metallic disc (c) = M
Steady temperature in the metallic disc = θ_1
Steady temperature in the steam chamber = θ_2
Thermal conductivity of the bad conductor = K
Rate of cooling at θ_2= R
Specific heat capacity of the slab = S
Area of cross section (A) = πr^2



Amount of heat conducted through the specimen

per second (Q) = $$\frac{KA(\theta_1-\theta_2)}{d} = \frac{K\pi r^2(\theta_1-\theta_2)}{d} \qquad (1)$$

At this stage all the heat conductor through the bad conductor is completely radiated by the bottom flat surface and curved surface of the slab (C).

Amount of heat lost per second by the slab (C) Q= mass x specific heat capacity x rate of cooling

Q = M S R (2)

At steady rate, heat conducted through bad conductor per second = heat lost per second by the slab (C)

Hence the equation (1) = equation (2)

i.e., $$\frac{K\pi r^2(\theta_1-\theta_2)}{d} = MSR$$

$$\therefore\ K = \frac{MSRd}{\pi r^2(\theta_1-\theta_2)} \quad \text{Wm}^{-1}\text{K}^{-1} \qquad (3)$$

Determination of rate of cooling (R)

Now, the bad conductor is removed and the steam chamber is placed directly on the slab. This slab is heated to a temperature till [θ_2 + 5°C], then the steam chamber is removed and the steam alone is allowed to cool. As the slab cools, the temperatures of the slab are noted at regular intervals of time until the temperature of the slabs falls below [θ_2 - 5°C].

A graph is drawn by taking time on x – axis and temperature on y – axis. From the slope of the curve, the rate of cooling at steady state of metallic disc is determined $\left(\frac{d\theta}{dt}\right)_{\theta_2}$.

During the first part of experiment, the heat lost by radiation occurs at the bottom and curved surface area of the slab. Since the top layer is covered by the bad conductor.

i.e., Total area = $$\pi r^2 + 2\pi rt = \pi r(r+2t) \qquad (4)$$

In the second part of experiment, the bad conductor and steam chamber are removed and hence the heat lost by radiation will occur at top, bottom and curved surface areas.

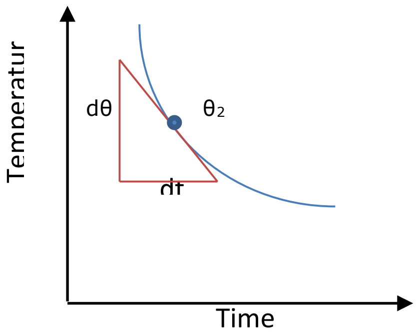
i.e., Total area = $$\pi r^2 + \pi r^2 + 2\pi rt = 2\pi r^2 + 2\pi rt = \pi r(2r+2t) \qquad (5)$$

As the rate of cooling is directly proportional to the surface that are exposed & Hence

$$\frac{R}{\left(\frac{d\theta}{dt}\right)_{\theta_2}} = \frac{\pi r(r+2t)}{\pi r(2r+2t)} = \frac{(r+2t)}{(2r+2t)}$$

(or)

$$R = \frac{(r+2t)}{(2r+2t)}\left(\frac{d\theta}{dt}\right)_{\theta_2} \qquad (6)$$



Substitute the value of **R** in equation (3), we get

$$K = \frac{MSd\left(\frac{d\theta}{dt}\right)_{\theta_2}}{\pi r^2(\theta_1-\theta_2)} \frac{(r+2t)}{(2r+2t)} \quad \text{Wm}^{-1}\text{K}^{-1}$$

Thus the thermal conductivity of the bad conductor is determined.

3. Derive an expression for the heat conduction through compound media of two layers when bodies in series and parallel?

Compound medium in series

Consider a compound medium with two different materials 1 and 2 having thickness x_1 and x_2 as shown in figure. θ_1 and K_1 are the temperature and thermal conductivity of medium 1. θ_2 and K_2 are the temperature and thermal conductivity of medium 2. θ is the temperature of the interface of 1 and 2. Consider medium 1 has higher temperature than 2 medium. Therefore heat is conducted from medium 1 to medium 2

The Amount of heat flowing per second in medium 1 $Q = \frac{K_1 A(\theta_1 - \theta)}{x_1}$ (1)

The Amount of heat flowing per second in medium 2 $Q = \frac{K_2 A(\theta - \theta_2)}{x_2}$ (2)

When the steady state is reached, the heat flowing per second through medium 1 = medium 2

$$\therefore \quad \frac{K_1 A(\theta_1 - \theta)}{x_1} = \frac{K_2 A(\theta - \theta_2)}{x_2} \quad (3)$$

Rearranging equation (3), we have

$$K_1 A(\theta_1 - \theta)x_2 = K_2 A(\theta - \theta_2)x_1$$

$$K_1\theta_1 x_2 - K_1\theta x_2 = K_2\theta x_1 - K_2\theta_2 x_1$$

Rearranging

$$K_1\theta_1 x_2 + K_2\theta_2 x_1 = K_2\theta x_1 + K_1\theta x_2$$

(or) $K_1\theta_1 x_2 + K_2\theta_2 x_1 = \theta(K_2 x_1 + K_1 x_2)$

$$\theta = \frac{K_1\theta_1 x_2 + K_2\theta_2 x_1}{K_2 x_1 + K_1 x_2} \quad (4)$$

This expression is the interface temperature of two composite slab in series

Substituting for θ in equation (1), we get

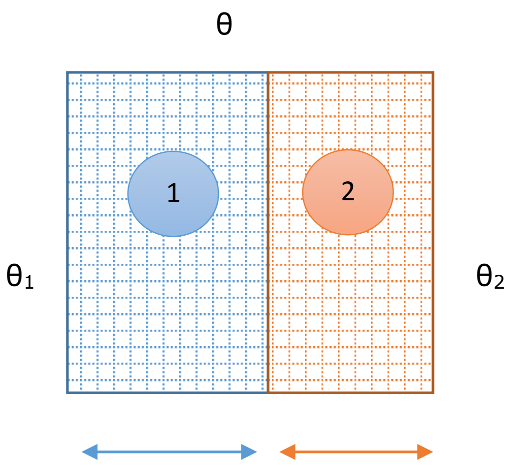
$$Q = \frac{K_1 A}{x_1}\left[\theta_1 - \frac{K_1\theta_1 x_2 + K_2\theta_2 x_1}{K_2 x_1 + K_1 x_2}\right]$$

$$Q = \frac{K_1 A}{x_1}\left[\frac{\theta_1(K_2 x_1 + K_1 x_2) - (K_1\theta_1 x_2 + K_2\theta_2 x_1)}{K_2 x_1 + K_1 x_2}\right]$$

$$Q = \frac{K_1 A}{x_1}\left[\frac{K_2\theta_1 x_1 + K_1\theta_1 x_2 - K_1\theta_1 x_2 - K_2\theta_2 x_1}{K_2 x_1 + K_1 x_2}\right]$$

$$Q = \frac{K_1 A}{x_1}\left[\frac{K_2\theta_1 x_1 - K_2\theta_2 x_1}{K_2 x_1 + K_1 x_2}\right]$$

$$Q = \frac{K_1 K_2 A x_1(\theta_1 - \theta_2)}{x_1\left[K_2 x_1 + K_1 x_2\right]}$$



$$Q = \frac{K_1 K_2 A(\theta_1 - \theta_2)}{[K_2 x_1 + K_1 x_2]}$$

$$Q = \frac{A(\theta_1 - \theta_2)}{\frac{K_2 x_1}{K_1 K_2} + \frac{K_1 x_2}{K_1 K_2}}$$

The amount of heat flowing per second through medium 1 (or) medium 2 or a compound of medium is

$$Q = \frac{A(\theta_1 - \theta_2)}{\frac{x_1}{K_1} + \frac{x_2}{K_2}}$$

This method can also be extended to composite slabs with more than two slabs

In general for any number of slabs, the amount of heat conducted per second is given by

$$Q = \frac{A(\theta_1 - \theta_2)}{\sum \left(\frac{x}{K} \right)}$$

Compound medium in parallel

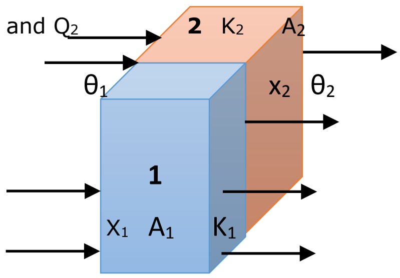
Consider a compound medium of two different materials 1 and 2 connected in parallel with thickness x_1 and x_2 , area of cross sections A_1 and A_2 and thermal conductivities K_1 and K_2 respectively. The faces of the materials 1 and 2 are at temperature θ_1 and the other end faces of 1 and 2 are at temperature θ_2.

The amount of heat flowing through first material in one second $Q_1 = \frac{K_1 A_1(\theta_1 - \theta_2)}{x_1}$ (1)

Similarly, the amount of heat flowing through the second material in one second $Q_2 = \frac{K_2 A_2(\theta_1 - \theta_2)}{x_2}$ (2)

The total heat flowing through these materials per second is equal to the sum of Q_1 and Q_2

$$Q = \frac{K_1 A_1(\theta_1 - \theta_2)}{x_1} + \frac{K_2 A_2(\theta_1 - \theta_2)}{x_2}$$



Amount of heat flowing per second $Q = (\theta_1 - \theta_2)\left[\frac{K_1 A_1}{x_1} + \frac{K_2 A_2}{x_2}\right]$

In general, the net amount of heat flowing per second parallel to the composite slabs is given by $Q = (\theta_1 - \theta_2)\sum \frac{KA}{x}$

There are different methods by which the thermal conductivity of the given material was determined. Out of which Forbe's method is sued to determine the thermal conductivity of good conductors while Lee's Disc method is used to determine the thermal conductivity of bad conductor.

4. **What is meant by heat exchanger? Explain the different modes in which the heat is exchanged through it?**

A heat exchanger is a device that is used to transfer the heat between two fluids without mixing. It is used to reduce the heat provide by the device

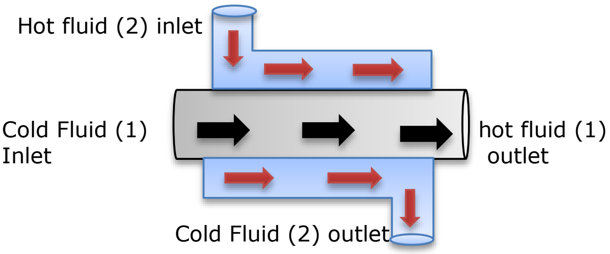
Measurement in heat exchanger, the driving temperature across the heat transfer surface varies with position. Therefore the temperature difference is measured only in terms of log mean temperature difference

Basically Heat exchanger are classified as

(1) Direct transfer heat exchanger (2) storage heat transfer (3) Direct contact heat transfer

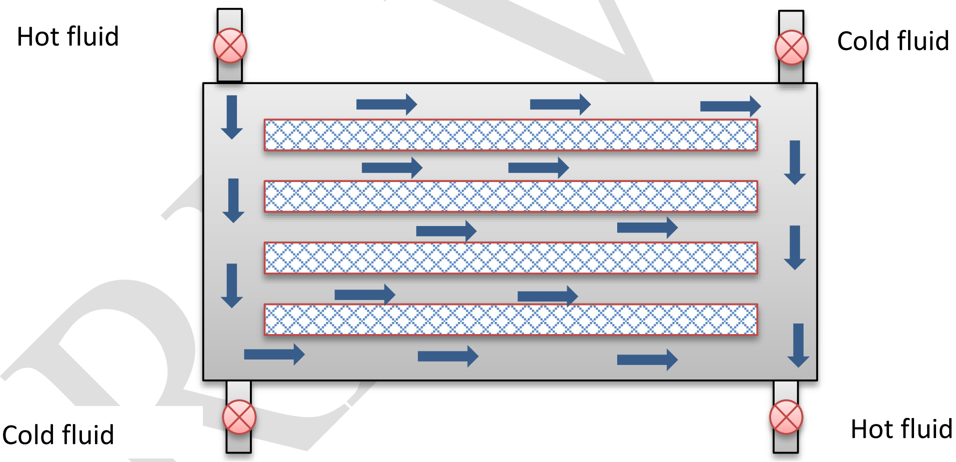
Direct transfer Heat exchanger

Cold and hot fluids flow simultaneously through the device and heat is transferred through wall separating the fluids



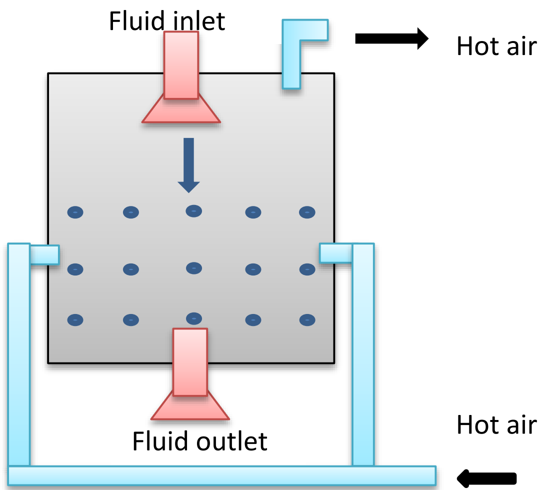
Cold storage Heat exchanger

Heat transfer from hot to cold fluid occurs through coupling medium in the form of porous solid matrix. The hot and cold fluids flow alternatively through the matrix, The hot fluid storing heat in it and cold fluid extracting heat from it



Direct contact Heat exchanger

Two fluids are not separated. If heat is to be transferred between a gas and liquid, the gas is either bubbled through the liquid or the liquid is sprayed in form of droplets in to gas



Based on mode of transfer, the heat will be transfer fro one fluid to other by the following three modes

Parallel flow heat exchanger

In parallel flow heat exchanger, the two fluids (one cold and other hot) enter the exchanger at the same end and travel in parallel to one another and reaches the other end and thereby exchanges the heat. In this type the temperature difference between the two fluids is large at the entrance end and becomes very small at the exit end.

Counter flow heat exchanger

In counter flow heat exchanger, the two fluids (one cold and other hot) enter the exchanger from opposite ends and exchanges the heat between each other. It is the most commonly used heat exchanger for liquid – liquid heat transfer and is more efficient, when compare to parallel flow heat exchanger.

Cross- flow heat exchanger

In cross flow heat exchanger, the fluids (one cold and other hot) travel roughly perpendicular to each other, through the heat exchanger and exchanges the heat between them. In this case, the heat transfer takes place between a liquid flowing inside a tubes. It mainly used to solar water heater, refrigerator and air conditioners.

Types:

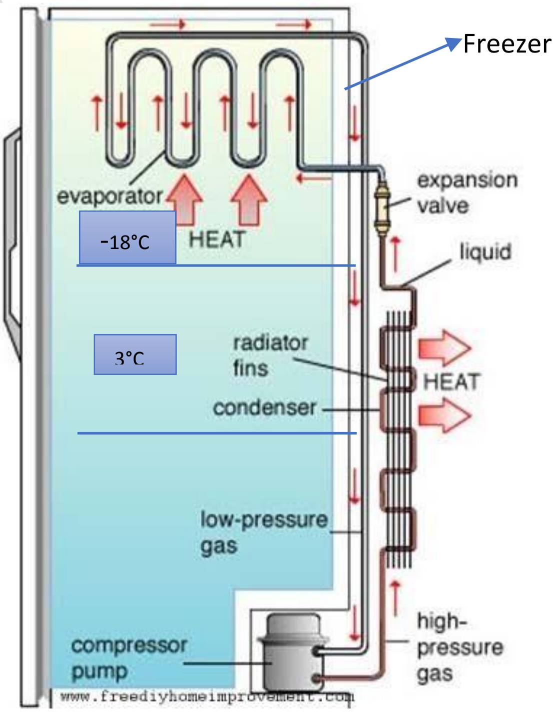
Fluid heat exchanger, Shell and Tube heat exchanger, Plate heat exchanger, Plate and shell heat exchanger, Plate fin heat exchanger, Pillow plate heat exchanger, Micro channel heat exchanger, etc.,

Applications:

7. Used in refrigerators and air conditioner
8. Used in power plants and engine to cool the exhaust hot gases
9. Used in petroleum refineries, petro chemical plants
10. Used in natural gas processing and sewage water treatment plants
11. Used in internal combustion engine and radiator coil
12. Reducing the space heating the transferring the heat generated by electronic devices.

5. With a neat sketch describe the design and working of refrigerator?

Generally heat cannot flow from a cold body to hot body. But this is possible to do so, if some external work (or) pressure is done on the working substance. This concept is used in refrigerators.



Refrigerator

It is an equipment used to reduce and maintain the below atmospheric temperature and this obtained by removing the heat from the space continuously.

Refrigerant

It is a fluid which absorbs the heat from the body and rejects the heat at high temperature. Example: Ammonia, carbon di oxide, Freon, methyl chloride, chloro fluoro carbon (CFC)

Capacity of refrigerator (or) Refrigeration effect

It is the amount of heat extracted from the cold body per unit mass per second. (or) the rate at which the refrigeration produced is called the capacity for the refrigerator. It is expressed in tonne of refrigeration.

A tonne fo refrigeration is defined as the amount of refrigeration effect produced by uniform melting of one tonne of ice at 0°C to water in 24 hours.

1 Tonne refrigeration = 210 KJ/min (or) 3.5kJ/sec.

Principle

According to clausius, second law of thermodynamics states that, "*without doing external work it is impossible to transfer heat from a cold body to cold body*"

Here the ammonia takes heat from the refrigerator and due to external work done on ammonia, it gives heat to atmospheric air and keep the refrigerator continuously cool.

Design

It consists of two coils

(1) Evaporator coil to convert liquid ammonia to vapour and
(2) Condenser coil to convert vapour to liquid ammonia as shown in figure.

The compressor in the refrigerator is used to compress the ammonia vapour using a piston to a very high pressure and it helps in doing the external work on the ammonia. The whole setup is kept in well air circulation area for better performance.

Working

(1) In domestic refrigerator, liquid ammonia is used as the working substance for cooling the refrigerator
(2) Here, liquid ammonia at low pressure is passed through the evaporator coils, wherein it expands and absorbs the heat from the refrigerator.
(3) This liquid ammonia takes up the heat from the refrigerator and is converted into low pressure vapour.
(4) Now the compressor is sued to compress the ammonia vapour externally using a piston, to a very high pressure
(5) This ammonia at high pressure is allowed to pass through the condenser coils.
(6) While passing, the ammonia vapour gives heat to the atmospheric air at room temperature and becomes liquid ammonia again due to cooling.
(7) This cool liquid ammonia in turn act as primary refrigerant and keeps the refrigerator cool
(8) This cycle of process continues and makes the refrigerator to be in cool condition always.
(9) In modern days, chlorofluoro carbon (CFC) is used as refrigerant for effective cooling

Applications

(1) It is sued to preserve foods for a long time.
(2) It is used in refineries for removing wax

Advantages

(1) Protects foods from microbes, insects and rodents
(2) Store food for long time

Disadvantages

(1) It consumes large amount of electricity
(2) Harmful pollutant gas like CFC causes global warming

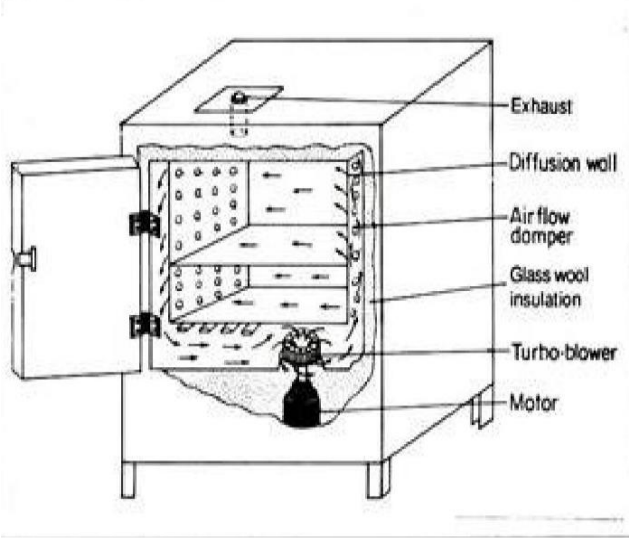
Preserving food for long duration is not good for health

6. **Describe the principle, construction and working of Hot air oven?**

Oven

Oven is a thermally insulated chamber used for heating, baking or drying of a substance and most commonly used for cooking.

Kilns and furnaces are special-purpose ovens used in pottery and metalworking respectively
Types of oven
Double oven, ceramic oven, Gas oven, Microwave oven, Toaster oven and Hot air oven



HOT AIR OVEN

The instrument works on the dry heat to sterilize the specimens and articles. This instrument is operated at 50°C to 250°C using thermostat that controls the temperature.

Operating Principle

It works on the principle of fine gravity air convection in a highly heated electrical chamber

Construction

It consists of large, rectangular, copper – base and covered with asbestos sheets. It is also provided with door and erected on a four legged stand. The roof is provided with a hole through which thermometer is fitted for reading of temperature. The oven has two or three shelves and is heated by electric heater which is fitted at the base of the instrument. There is a regulator at the outside which is used to control the temperature.

Working

Before sterilization, the glassware are drier properly and wrapped in brown paper and then exposed to hot air inside the oven. Now the power is ON. Then the temperature increases up to a desire point (160°C) and remains steady. Then the oven is kept at that temperature for an hour. Then the temperature is brought down gradually and thereafter the sterilization is complete.

Advantages
(1) It kills bacterial endotoxin
(2) It does not leave any chemical residue
(3) Eliminate Wet pack problems in humid climates

Disadvantages
(1) Plastic and rubber items cannot be sterilized
(2) Dry heat penetrates materials slowly and unevenly

Safety guidelines
(1) Dry glasswares completely
(2) Plug test tubes with cotton wools
(3) Wrap glasswares in kraft papers. Do not overload
(4) Allow free circulation between the materials

Applications
(1) Sterilize glasswares in pharmaceutical industries such as petri dishes, pipettes, bottles, test tubes, flasks, pestle, etc.,

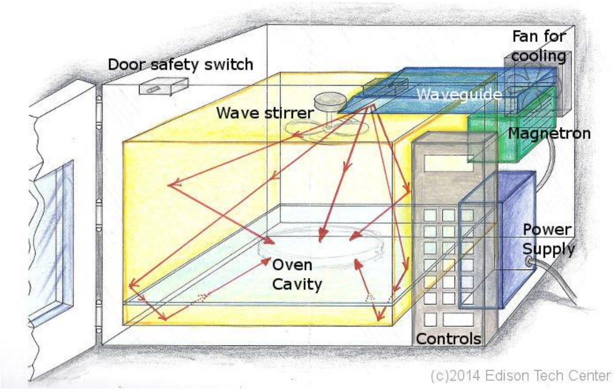
7. **Describe the principle, construction and working of Microwave oven?**

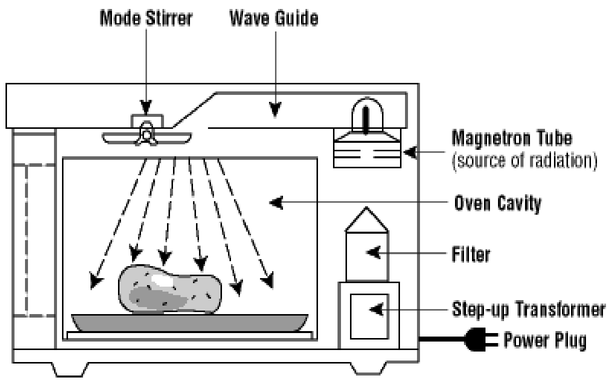
Principle

High powdered 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

It consists of a microwave generator called a magnetron, which is used to take electricity from the power outlet and converts into high powered micro waves as shown in figure. The food compartment is made up of reflective metal walls, just like a mirror, to have effective focusing of microwaves onto the food particles. A rotating spinning arrangement, so called turn table is used to rotate the food stuff so as to cook the food evenly. A channel of common waveguide is used to transfer the microwaves from the magnetron to the food compartment. The total setup is completely surrounded by strong metal boxes for safety. A timer display is also provided in modern microwave ovens to choose various option in cooking variety of food items





Working

1. Food to be cooked is placed on the turn table and the electricity is switched ON.
2. The magnetron converts the electrical energy in to high – powered radio waves, so called microwaves.
3. The magnetron blasts these microwaves in to food compartment though a channel called a common waveguide, thoroughly.
4. The microwaves bounce back and forth between the reflective metal walls and reaches the food
5. These microwaves penetrate inside the food and makes the molecules in the food to vibrate
6. These vibrations creates heat, i.e, faster the molecule vibrates, then the hotter the food becomes
7. In this way, the microwaves pass their energy onto the molecules in the food and cook the food by heating it.
8. The food is evenly cooked by spinning the turntable slowly, so that the microwaves penetrates in entire part of the food.

Advantages

1. Portable and small in size
2. Easy and faster to cook with high efficiency
3. It can penetrate more than 2 cms into the food

Disadvantages

1. Microwaves are dangerous and so there should not be any leakage
2. Every time lock the door should be properly checked
3. Uneven heating (or) cooking of food is not good for health

8. **Describe the principle, construction and working of Solar water heater?**

Principle

It converts solar energy in to electrical energy and then in to heat energy using solar electric panels called solar cells (or) photo voltaic cells. Now a days solar thermal panels are widely used which converts the solar energy directly into heat energy.

Construction

1. A simple roof top solar water heater is shown in figure
2. It consists of a solar thermal panel in which collector is sued to collect, capture and retain the heat radiations from the sun
3. The heat exchanger is made up of coil of copper pipes and is kept inside the water tank.
4. The heat exchanger is used to transfer that heat energy from the hot water passing through the copper pipe in the heat exchanger to the cold water in the water tank
5. An electric pump is sued to pump the cold water coming out from the heat exchanger to the collector from the thermal panel.
6. The total system is controlled by the controller unit, which is used to
   (i) Fill the water with Auto cutoff in the tank
   (ii) Switch on/ off the electric pump, whenever required.

Working

1. Initially with the help of the electric pump, cold water is pumped to the collector in the solar thermal panel
2. Now, due to thermal radiations that fall on the thermal panel, the water in the collector is heated up
3. This hot water is allowed to pass through the water tank with the help of the heat exchangers.

4. The heat exchanger, which is made up of coil of copper pipes, transfers the heat energy from the water inside the copper coils, to the water present in the water tank and therefore the water in the water tank becomes Hot
5. The water coming out from the heat exchanger, after transferring the energy, become cold water and enters into the electric pump again as shown in figure
6. Thus, we can runoff hot water from the tank at any time without affecting the panel's operation.

Advantages

1. Solar energy is free and abundant
2. Solar thermal panels occupies less space than solar photovoltaic panels
3. About 80% efficiency of thermal energy is turned into heat energy
4. Eco friendly way to heat water with less electrical consumption

Disadvantages

1. Capital investment and installation charges are high
2. Annual maintenance is required
3. Not suitable during rainy (or) foggy days
4. It occupies space and depends on the availability of direct sunlight