SEMBODAI RUKMANI VARATHARAJAN ENGINEERING COLLEGE

HEAT & MASS TRANSFER

Unit I - CONDUCTION

1. Define Heat transfer?

Heat transfer can be defined as the transmission of energy from one region to another region to temperature difference. `

2. What are the modes of heat transfer?

1. Conduction
2. Convection
3. Radiation

3. What is conduction?

Heat conduction is a mechanism of heat transfer from a region of high temperature to a region of low temperature with in a medium (Solid, liquid or Gases) or different medium in direct physical contact.

In conduction, energy exchange takes place by the kinematics motion or direct impact of molecules .Pure conduction is found only in solids.

4. Define convection.

Convection is a process of heat transfer that will occur between solid surface and a fluid medium when they are at different temperatures. Convection is possible only in the presence of fluid medium.

5. Define Radiation.

The heat transfer from one body to another without any transmitting medium is known as radiation .It is an electromagnetic wave phenomenon.

6. State Fourier's law of conduction.

The rate of heat conduction is proportional to the area measured normal to the direction of heat flow and to the temperature gradient in that direction.

$$Q \propto -A \frac{DT}{dx}$$

$$Q = -kA\ \frac{DT}{dx}$$

Where, A – Area in m^2

$$\frac{dT}{dx} = Temperature\ Gradient\frac{K}{m}$$

k= Thermal conductivity, W/mK

7. Define Thermal conductivity.

Thermal conductivity is defined as the ability of a substance to conduct heat.

8. Write down the three dimensional heat conduction equation in Cartesian co-ordinate system.

The general three dimensional heat conduction equation in Cartesian co -ordinate is

$$\frac{\partial^2 T}{dx^2} + \frac{\partial^2 T}{dy^2} + \frac{\partial^2 T}{dz^2} + \frac{q}{k} = \frac{1}{\propto}\ \frac{\partial T}{\partial t}$$

Where q - heat generators –W/m^2

α – Thermal diffusivity – m^2/s

9. Write down the three dimensional heat conduction equations in cylindrical co- ordinate system.

The general three dimensional heat conduction equation in cylindrical co- ordinate system is

$$\frac{\partial^2 T}{dr^2} + \frac{1}{r} + \frac{\partial T}{\partial r} + \frac{1}{r^2} + \frac{\partial^2 T}{d\Phi^2} + \frac{\partial^2 T}{dz^2} + \frac{q}{k} = \frac{1}{\propto}\ \frac{\partial T}{\partial \theta}$$

10. List down the three types of boundary conditions

1. Prescribed temperature
2. Prescribed heat flux
3. Convection boundary conditions.

11. Write the equation for conduction of heat through a slab or plane wall.

Heat transfer ,Q = $\frac{\Delta T\ overall}{R}$

$\Delta T = T_1 - T_2$

R $= \frac{L}{KA}$ Thermal resistance of slab

L – Thickness of slab

K -- Thermal conductivity of slab, A - Area

12. Write the equation for conduction of heat through a hollow cylinder.

Heat transfer, Q = $\frac{\Delta T\ overall}{R}$

$\Delta T = T_1 - T_2$

R $= \frac{L}{2\Pi Lk} \ln \frac{r2}{r1}$ Thermal resistance of slab

L – Length of cylinder

K -- Thermal conductivity of

r2 – Outer radious

r1- Inner radious

13. Write the equation for conduction of heat through a hollow sphere.

Heat transfer, Q = $\frac{\Delta T\ overall}{R}$

$\Delta T = T_1 - T_2$

R $= \frac{r2-r1}{4\Pi k(r1r2)}$ Thermal resistance of hollow sphere

14. State Newton's law of cooling or convection law.

Heat transfer by convection is given by Newton's law of cooling

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

Where

A- Area exposed to heat transfer in m^2

h - Heat transfer coefficient of the surface in K

T_s-Temperature of the surface in K

T_∞- Temperature of the fluid in K

15. Write the equation for heat transfer through a composite plane wall.

Heat transfer, $Q = \frac{\Delta T\ overall}{R}$

$\Delta T = T_a - T_b$

$$R = \frac{1}{haA} + \frac{L1}{k1A} + \frac{L2}{k2A} + \frac{L3}{k3A} + \frac{1}{hbA}$$

L-Thickness of slab

A-Area

ha -Heat transfer coefficient at inner diameter.

hb - Heat transfer coefficient outer side.

16. Define overall heat transfer co-efficient.

The overall heat transfer by combined modes is usually expressed in terms of an overall conductance or overall heat transfer co-efficient'

Heat transfer, $Q = UA\Delta T$

17. Define fins or extended surfaces.

It is possible to increase the heat transfer rate by increasing the surface of heat transfer. The surfaces used for increasing heat transfer are called extended surfaces sometimes known as fins.

18. State the applications of fins.

1. Cooling of electronic components.
2. Cooling of motor cycle engines.
3. Cooling of small capacity compressors
4. Cooling of transformers.

19. Define fin efficiency.

The efficiency of a fin is defined as the ratio of actual heat transferred to the maximum possible to heat transferred by the fin.

$$\eta_{fin} = \frac{Qfin}{Qmax}$$

20. Define Fin effectiveness.

Fin effectiveness is the ratio of heat transfer with fin to that without fin

$$\text{Fin effectiveness} = \frac{Qwith\ fin}{Q\ \ without\ fin}$$

21. What is meant by steady state heat conduction?

If the temperature of a body does not vary with time, it is said to be in a steady state and that type of conduction is known as steady state heat conduction.

22. What is meant by transient heat conduction or unsteady state conduction?

If the temperature of a body varies with time, it is said to be in a transient state and that type of conduction is known as transient heat conduction or unsteady state conduction

23. What is Periodic heat flow?

In Periodic heat flow, the temperature varies on a regular basis

Example;

1. Cylinder of an IC engine.

2. Surface of earth during a period of 24 hours

24. What is non Periodic heat flow?

In non Periodic heat flow, the temperature at any point within the system varies non linearly with time.

Example:

1. Heating of an ingot in furnace.
2. Cooling of bars.

24. What is meant by Newtonian heating or cooling process?

The process in which the internal resistance is assumed as negligible in comparison with its surface resistance is known as Newtonian heating or cooling process.

25. What is meant by Lumped heat analysis?

In a Newtonian heating or cooling process the temperature throughout the solid is considered to be uniform at a given time. Such an analysis is called Lumped heat capacity analysis.

26. What is meant by semi-infinite solids?

In semi-infinite solids, at any instant of time ,there is always a point where the effect of heating or cooling at one of its boundaries is not felt at all .At this point the temperature remains unchanged .In semi infinite solids, the biot number values is ∞.

27. What is meant by infinite solid?

A solid which extends itself infinitely in all directions of space is known as infinite solid.

In infinite solids, the biot number value is in between 0.1 and 100.

$0.1 < B_i < 100$

28. Define Biot number.

It is defined as the ratio of internal conductive resistance to the surface conductive resistance

$$B_i = \frac{Internal\ conductive\ resistance}{Surface\ conductive\ resistance}$$

$$B_i = \frac{hLc}{k}$$

29. What is the significance of Biot number?

Biot number is used to find Lumped heat analysis, Semi infinite solids and infinite solids

If $B_i < 0.1 \rightarrow$ Lumped heat analysis.

$B_i = \infty \rightarrow$ Semi infinite solids.

$0.1 < B_i < 100 \rightarrow$ Infinite solids.

30. Explain the significance of Fourier number.

It is defined as the ratio of characteristic body dimension to temperature wave penetration depth in time.

$$\text{Fourier number} = \frac{Characteristic\ body\ dimension}{Temperature\ \ wave\ penetration\ depth\ in\ time}$$

It signifies the degree of penetration of heating or cooling effect of solid

31. What are the factors affecting the thermal conductivity?

1. Moisture
2. Density of material
3. Pressure
4. Temperature
5. Structural of material

32. Explain the significance of thermal diffusivity.

The physical significance of thermal diffusivity is that it tells us how fast heat is propagated or it diffuses through a material during changes of temperature with time

33. What are Heisler charts?

In Heisler chart, the solutions for temperature distributions and heat flows in plane walls, long cylinders and spheres with finite internal and surface resistance are presented. Heisler charts are nothing but a analytical solutions in the form of graphs

Unit II CONVECTION

1. What is dimensional analysis?

Dimensional analysis is a mathematical method which makes use of the study of the dimensions for solving several engineering problems. This method can be applied to all types of fluid resistance, heat flow problems in fluid mechanics and thermodynamics.

2. State Buckingham's Π theorem.

Buckingham's Π theorem states as follows: "If there are n variables in a dimensionally homogeneous equation and if these contain M fundamental dimensions, then the variables are arranged into (n-m) dimensionless terms. These dimensional terms are called Π terms.

3. What are all the advantages of dimensional analysis?

1. It expresses the functional relationship between the variables in dimensional terms.

2. It enables getting up a theoretical solution in a simplified dimensional form.

3. The results of one series of test can be applied to alarge number of other similar problem with the help of dimensional analysis

4. What are all the limitations of dimensional analysis?

1. The complete information is not provided by dimensional analysis .It only indicates that there is some relationship between the parameters.

2. No information is given about the internal mechanism of physical phenomenon.

3. Dimensional analysis does not give any clue regarding the selection of variables.

5. Define Reynolds number (Re)

It is defined as the ratio of inertia force to viscos force.

$$Re = \frac{Inertia\ force}{Viscos\ force}$$

6. Define Prandtl number (Pr)

It is the ratio of the momentum diffusivity to the thermal diffusivity.

$$Pr = \frac{Momentum\ diffusivity}{Thermal\ diffusivity}$$

7. Define Nusselt Number (Nu).

It is defined as the ratio of the heat flow by convection process under an unit temperature gradiant to the heat flow rate by conduction under an unit temperature gradient through a stationary thickness (L) of meter. Nusselt Number (Nu). = $\frac{q\ conv}{q\ cond}$

8. Define Grashof number (Gr).

It is defined as the ratio of product of inertia force and buoyancy force to the squre of viscous force

$$Gr = \frac{Inertia\ force\ x\ Buoyancy\ force}{(viscos\ force)^2}$$

9. Define Stanton number (St)

It is the ratio of Mussels number to the product of Reynolds number and Prandtl number

$$St = \frac{Nu}{Re\ x\ Pr}$$

10. What is meant by Newtonian and non- Newtonian fluids?

The fluids which obey the Newton's law of viscosity are called Newtonians fluids and those which do not obey are called non Newtonian fluids.

11. What is meant by laminar flow and turbulent flow?

Laminar flow:

Laminar flow is sometimes called streams line flow .In this type of flow , the fluid moves in layer and each fluid particle follows a smooth continuous path. The fluid particals in each layer remain in an orderly sequence without mixing with each other.

Turbulent flow:

In addition to the laminar type of flow , a distinct irregular flow is frequently observed in nature. This type of flow is called turbulent flow .The path of any individual particle is zig-zag and irregular.

12. What is hydro dynamics boundary layer?

In hydrodynamics boundary layer, velocity of the fluid is less than 99% of free stream velocity.

13. What is thermal boundary layer?

In thermal boundary layer, temperature of the fluid is less than 99% of free stream temperature.

14. Define convection.

Convection is a process of heat transfer that will occur between a solid surface and a fluid medium when they are at different temperatures.

15. State Newton's law of convection.

Heat transfer from the moving fluid to solid surface is given by the equation

$Q = h\,A(T_w - T_\infty)$

This equation is referred to as Newton's law of cooling

Where h – local heat transfer coefficient in W/m^2K.

A- Surface area in m^2.

T_w- surface (or) Wall temperature in K.

T_∞ -Temperature of fluid in K

16. What is meant by free or natural convection?

If the fluid motion is produced due to change in density resulting from temperature gradients, the mode of heat transfer is said to be free or natural convection.

17. What is forced convection?

If the fluid motion is artificially created by means of an external force like a blower of fan ,that type of heat transfer is known as forced convection.

18. What is the form of equation used to calculate transfer for flow through cylindrical pipes?

$Nu = 0.023(Re)^{0.8}(Pr)^n$

n = 0.4 for heating of fluids.

n =0.3 for cooling of fluids.

19. What are the dimensional parameters used in forced convection?

1. Reynolds number (Re)
2. Nusselt Number (Nu)
3. Prandtl number (Pr)

20. Define boundary layer thickness.

The thickness of the boundary layer has been defined as the distance from the surface at which the local velocity or temperature reaches 99% of the external velocity or temperature.

21. Indicate the concept of significance of boundary layer.

In the boundary layer concept the flow field over a body is divided into two regions:

- A thin region near the body called the boundary layer where the velocity and the temperature gradients are large.
- The region outside the boundary layer where the velocity and the temperature gradients are very nearly equal to their free stream values.

22. Write down the momentum equation for a steady, two dimensional flow of an incompressible, constant property Newtonian fluid in the rectangular coordinate system and mention the physical significance of each term.

Momentum equation,

$$P\left[u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y}\right] = F_x - \frac{\partial P}{\partial x} + \mu\left[\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2}\right]$$

Where $P\left[u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y}\right] =$ Inertia forces.

$F_x =$ Body force

$\frac{\partial P}{\partial x}$ = Pressure force

$\left[\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2}\right]$ = Viscous forces.

23. Define displacement thickness.

The displacement thickness is the distance, measured perpendicular to the boundary, by which the free stream is displaced on account of formation of boundary layer.

24. Define momentum thickness.

The momentum thickness is defined as the distance through which the total loss of momentum per second be equal to if it were passing a stationary plate.

25. Define energy thickness.

The energy thickness can be defined as the distance, measured perpendicular to the boundary of the solid body ,by which the boundary should be displaced to compensate for the reduction in kinetic energy of the flowing fluid on account of boundary layer formation

Unit III PHASE CHANGE HEAT TRANSFER AND HEAT EXCHANGES

1. Define boiling.

The change of phase from liquid to vapour state is known as boiling.

2. What is meant by condensation?

The change of phase from vapour to liquid state is known as condensation.

3. Give the application of boiling and condensation.

Boiling and condensation process finds wide application as mentioned below.

1. Thermal and nuclear power point

2. Refrigeration systems.

3. Process of heating and cooling.

4. Air conditioning system.

4. What is meant pool boiling?

If heat is added to a liquid from a submerged solid surface, the boiling process is referred to as pool boiling. In this case the liquid above the hot surface is essentially stagnant and it motion near the surface is due to free convection and mixing induced by bubble growth and detachment.

5. What are the modes of condensation?

There are two modes of condensation

1. Film wise condensation.

2. Dropwise condensation

6. What is Film wise condensation?

The liquid condensate wets the solid surface, spread out and forms a continuous film over the entire surface is known as film wise condensation.

7. What is Dropwise condensation?

The vapour condenses into small liquid droplets of various sizes which fall down the surface in a random fashion.

8. Write the force balance equation on a volume element for film wise condensation on a vertical plane surface.

$$\frac{\partial^2 U}{\partial y^2} = \frac{1}{\mu_l} \frac{\partial p}{\partial x} - \frac{Bx}{\mu_l}$$

Where

Bx – Body force in x direction

$\frac{\partial p}{\partial x}$ - Pressure gradient

9. What is heat exchange?

The heat exchange is defined as equipment which transfers the heat from a hot fluid to a cold fluid.

10. What are the types of heat exchanger?

The types of heat exchanger are as follows.

1. Direct contact heat exchangers.

2. Indirect contact heat exchangers

3. Surface heat exchangers

4. Parallel flow heat exchangers

5. Counter flow heat exchangers
6. Cross flow heat exchangers
7. Shell and tube heat exchangers
8. Compact heat exchangers

11. What is meant by Direct contact heat exchangers or open heat exchangers?

In direct contact heat exchangers, the heat exchange takes place by direct mixing of hot and cold fluids.

12 What is meant by in direct contact heat exchangers?

In this type of heat exchangers, the transfer of heat between two fluids could be carried out by transmission through a wall which separates the two fluids

13. What is meant by Regenerators?

In this type of heat exchangers, hot and cold fluids flow alternately through the same space.

Examples: IC engines, Gas turbine.

14. What is meant by Recuperators or surface heat exchangers?

This is the most common type of heat exchangers in which the hot and cold fluid do not come into direct contact with each other but are separated by a tube wall or a surface

Examples: Automobile radiators, Air preheaters , economizers

15. What is meant by parallel flow heat exchangers?

In this type of heat exchangers, hot and cold fluids move in the same direction.

16. What is meant by Counter flow heat exchangers?

In this type of heat exchangers, hot and cold fluids move in parallel but opposite direction

17. What is meant by cross flow heat exchangers?

In this type of heat exchangers, hot and cold fluids move at right angles to each other.

18. What is meant by Shell and tube heat exchangers?

In this type of heat exchangers, one of the fluids moves through a bundle of tubes enclosed by a shell. The other fluid is forced through the shell and it moves over the outside surface of the tubes.

19. What is meant by Compact heat exchangers?

There are many special purpose heat exchangers called compact heat exchangers. They are generally employed when convection heat transfer co-efficient associated with one of the fluids is much smaller than that associated with the other fluid.

20. What is meant by LMTD?

We know that the temperature difference between the hot and cold fluids in the heat exchangers varies from point to point. In addition various modes of heat exchanger are involved. Therefore based on concept of appropriate mean temperature difference, also called logarithmic mean temperature difference, the total heat transfer rate in the heat exchanger is expressed as

$Q = UA(\Delta T)_m$

Where

U - Over all heat transfer co-efficient, W/m^2K

A – Area m^2

$(\Delta T)_m$ - Logarithmic mean temperature difference.

21. What is meant Fouling factor?

We know, the surfaces of a heat exchangers do not remain clean after it has been in use for some time .The surface become fouled with scaling or deposits .The effect of these deposits affecting the value of overall heat transfer co –efficient. This effect is taken care of by introducing an additional thermal resistance called fouling resistance.

22. What is meant by Effectiveness?

The heat exchanger effectiveness is defined as the ratio of actual heat transfer to the maximum possible heat transfer.

$$\text{Effectiveness } \epsilon = \frac{Actual\ \ heat\ transfer}{Maximum\ possible\ heat\ transfer}$$

$$= \frac{Q}{Q_{max}}$$

Unit IV RADIATION

1. Define Radiation?

The heat transfer from one body to another without any transmitting medium is known as radiation .It is an electromagnetic wave phenomenon.

2. Define emissive power?

The emissive power is defined as the total amount of radiation emitted by a body per unit time and unit area .It is expressed in W/m^2.

3. Define monochromatic emissive power.

The energy emitted by the surface at a given length per unit time area in all direction is known as monochromatic emissive power.

4. What is meant by absorptivity?

Absorptivity is defined as the ratio between radiation absorbed and incident radiation

$$\text{Absorptivity, } \alpha = \frac{Radiation\ absorbed}{Incident\ radiation}$$

5. What is meant by reflectivity?

Reflectivity is defined as the ratio of radiation reflected to the incident radiation

Reflectivity, $\rho = \frac{Radiation\ \text{reflected}}{Incident\ radiation}$

6. What is meant by transmissivity?

Transmissivity is defined as the ratio of radiation transmitted to the incident radiation

Transmissivity , $\tau = \frac{Radiation\ \text{transmitted}}{Incident\ radiation}$

7. What is black body?

Black body is an ideal surface having the following properties.

1. A black body absorbs all incident radiation, regardless of wave length and direction.

2. For a prescribed temperature and wave length, no surface can emit more energy than black body.

8. State Planck's distribution law.

The relationship between the monochromatic emissive power of a black body and wave length of a radiation at a particular temperature is given by the following expression, by Planck

$$E_{b\lambda} = \frac{c1\ \lambda^{-5}}{\left[e^{\left(\frac{c2}{\lambda T}\right)} - 1\right]}$$

Where $E_{b\lambda}$ = Monochromatic emissive power W/m^2

λ = Wave length – m

c_1 = 0.374 * 10 $^{-15}$ W/m^2

c_2 = 14.4 * 10^{-3} mk

9. State Wien's displacement law.

The Wien's displacement law gives the relationship between temperature and wave length corresponding to the maximum spectral emissive power of the black body at that temperature.

$\lambda_{max} T = C_3$

$C_3 = 2.9 * 10^{-3}$

$\lambda_{max} T = 2.9 * 10^{-3}$ mk

10. State the Stefan – Boltzmann law.

The emissive power of a black body is proportional to the fourth power of absolute temperature.

$E_b \infty T4$

$E_b = \sigma T4$

E_b = Emissive power W/m^2

σ = Stefan – Boltzmann constant = 5.67 * 10^{-8} W/m^2 K^4

T = Temperature, K

11. Define Emissivity.

It is defined as the ability of the surface of a body to radiate heat .It is also defined as the ratio of emissive power of anybody to the emissive power of a black body of equal temperature

Emissivity, $\varepsilon = \frac{E}{E_b}$

12 .What is meant by gray body?

If a body absorbs a definite percentage of incident radiation irrespective of their wave length, the body is known as gray body. The emissive power of a gray body is always less than that of the black body.

13. State Kirchoff's law of radiation.

This law states that the ratio of total emissive power to the absorptivity is constant for all surfaces which are in thermal equilibrium with the surrounding. This can be written as

$$\frac{E_1}{\infty_1} = \frac{E_2}{\infty_2} = \frac{E_3}{\infty_3}$$

It also states that the emissivity of the body is always equal to its absorptivity when the body remains in thermal equilibrium with its surroundings.

∞_1 E_1 ; $\infty_2 = E_2$ and so on.

14. Define intensity of radiation (I_b).

It is defined as the rate of energy leaving a space in a given direction per unit solid angle per unit area of the emitting surface normal to the mean direction in space.

$$I_n = \frac{E_b}{\pi}$$

15. State Lambert's cosine law.

It states that the total emissive power E_b from a radiating plane surface in any direction proportional to the cosine of the angle of emission

$E_b \;\; \alpha \cos \theta$

16. What is the purpose of radiation shield?

Radiation shield constructed from low emissivity (high reflective) materials. It is used to reduce the net radiation transfer between two surfaces.

17. Define Irradiation (G)?

It is defined as the total radiation incident upon a surface per unit time per unit area. It is expressed in W/m^2

18. What is radiosity (J)

It is used to indicate the total radiation leaving a surface per unit time per unit area. It is expressed in W/m^2 .

19. What are the assumptions made to calculate radiation exchange between the surfaces?

1. All surfaces are considered to be either black of gray.

2. Radiation and reflection process are assumed to be diffuse.

3. The absorptivity of a surface is taken equal to the emissivity and independent of temperature of the source of the incident radiation.

20. What is meant by shape factor and mention its physical significance.

The shape factor is defined as "The fraction of the radioactive energy that is diffused from one surface element and strikes the other surface directly with no intervening reflection ".it is represented by F_{ij}.Other names for radiation shape factor are view factor,angle factor and configuration factor .The shape factor is used in the analysis of radioactive heat exchange between two surfaces.

21. Discuss the radiation characteristics of carbon dioxide and water vapour.

The CO_2 and H_2 O both absorb and emit radiation over certain wave length regions called absorption bands.

The radiation in these gases is a volume phenomenon.

The emissivity of CO_2 and the emissivity of H_2O at a particular temperature increase with partial pressure and mean beam length.

Unit V MASS TRANSFER

1. What is mass transfer?

The process of transfer of mass a result of the species concentration difference in a mixture is known as mass transfer.

2. Give the examples of mass transfer.

1. Humidifucation of air in cooling tower.

2. Evaporation of petrol in the carburetor of an IC engine.

3. The transfer of water vapour into dry air

3. What are the modes of mass transfer?

1. Diffusion mass transfer.

2. Convective mass transfer.

4. What is molecular diffusion?

The transport of water on a microscopic level as a result of diffusion from a region of higher concentration to a region of lower concentration in a mixture of liquids or gases is known as molecular diffusion.

5. What is Eddy diffusion?

When one of the diffusion fluids is in turbulent motion ,eddy diffusion takes place.

6. What is Convective mass transfer?

Convective mass transfer is a process of mass transfer that will occur between a surface and a fluid medium when they are at different concentrations.

7. State Fick's law of diffusion.

The diffusion rate is given by the Fick's law, which states that molar flux of an element per unit area is directly proportional to concentration gradient.

$$\frac{m_a}{A} = -D_{ab} \frac{dC_a}{dx}$$

Where

$\frac{m_a}{A}$ = molar flex $\frac{kg-mole}{s-m^2}$

D_{ab} = Diffusion co-efficient of species a and b m^2/s.

$\frac{dC_a}{dx}$ = Concentration gradient, $kg/m^{3.}$

8. What is free Convective mass transfer?

If the fluid motion is produced due to change in density resulting from concentration gradient, the mode of mass transfer is said to be free or natural convective mass transfer.

Example: Evaporation of alcohol.

9. Define forced Convective mass transfer?

If the fluid motion is artificially created by means of an external force like a blower or fan, that type of mass transfer is known as convective mass transfer.

Example: The evaporation of water from an ocean when air blows over it.

10. Define Schmidt Number?

It is defined as the ratio of the molecular diffusivity of momentum to the molecular diffusivity of mass. $Sc = \frac{Molecular\ difusivity\ of\ momentum}{Molecular\ diffusivity\ of\ mass}$

11. Define Scherwood number.

It is defined as the ratio of concentration gradient at the boundary.

$$sh = \frac{h_m x}{D_{ab}}$$

h_m = mass transfer co efficient .m/s.

D_{ab} = Diffusion co efficient ,m^2/s.

x = length, m

12. Define Mass Concentration.

Mass of a component per unit volume of the mixture .It is expressed in kg/m^3.

$$Mass\ concentration = \frac{mass\ of\ components}{Unit\ volume\ of\ mixture}$$

13. Define molar Concentration or molar desity.

Number of molecules of components per unit volume of the mixture. It is expressed in kg –mole/m^3

$$Molar\ concentration = \frac{Number\ of\ moles\ of\ components}{Unit\ volume\ of\ mixture}$$

14. Define mass fraction.

The mass fraction is defined as the ratio of mass concentration of species to the total density of the mixture.

$$Mass\ fraction = \frac{mass\ concentration\ of\ a\ species}{Total\ mass\ density}$$

15 Define mole fractions.

The mole fraction is defined as the ratio of mole concentration of species to the total molar concentration. $Mass\ fraction = \frac{mole\ concentration\ of\ a\ species}{Total\ molar\ concentration}$