UNIT 1

2 MARKS

1. State Fourier's Law of conduction. (May 05, May 06, Dec 09, May 10, May 11, May 13, Nov 13)

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.

$$Q \alpha - A\frac{dT}{dx} \qquad Q = -KA\frac{dT}{dx} \qquad \text{where A – are in } m^2$$

$$\frac{dT}{dx} \text{ - Temperature gradient in K/m} \qquad \text{K – Thermal conductivity W/mK.}$$

2. What is a Fin? What are the different types of fin profiles? (May 07, Dec 08, Nov 11, May 13, May 15)

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 or sometimes known as fins.

1. Straight fins
2. Tapered fins
3. Pin fin
4. Tapered pin fins
5. Triangular fins
6. Parabolic spine

3. What critical radius of insulation? (May 04, Nov 04, Nov 06, Dec 08, May 14)

Critical radius = rc   Critical thickness = rc – r1

Addition of insulating material on a surface does not reduce the amount of heat transfer rate always. In fact under certain circumstances it actually increases the heat loss up to certain thickness of insulation. The radius of insulation for which the heat transfer is maximum is called critical radius of insulation, and the corresponding thickness is called critical thickness.

4. Define thermal Diffusivity. (May 09, May 15)

In heat transfer analysis, **thermal diffusivity** is the thermal conductivity divided by density and specific heat capacity at constant pressure. It measures the ability of a material to conduct thermal energy relative to its ability to store thermal energy. It has the SI unit of m^2/s.

$$\alpha = \frac{k}{\rho c_p}$$

5. Define efficiency of the fin. (Nov 04, Nov 05, May 07, Dec 08, May 13)

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

$$\eta_{fin} = \frac{Q_{fin}}{Q_{\max}}$$

6. Define effectiveness of the fin. (Nov 04, Nov 05, May 07, Dec 08, May 13)

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

$$\text{Fin effectiveness} = \frac{Q_{with\ fin}}{Q_{without\ fin}}$$

7. What is lumped analysis? (Dec 08, May 10, May 11, May 13)

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

8. Write the three dimensional heat equations in Cartesian co-ordinate system.

(May 06, May 05, May14)

$$\frac{\partial}{\partial x}\left(k\frac{\partial T}{\partial x}\right) + \frac{\partial}{\partial y}\left(k\frac{\partial T}{\partial y}\right) + \frac{\partial}{\partial z}\left(k\frac{\partial T}{\partial z}\right) + q''' = \rho c\frac{\partial T}{\partial t}$$

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

(May 08, Nov 2015)

$$\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial T}{\partial r}\right) + \frac{1}{r^2}\frac{\partial^2 T}{\partial \phi^2} + \frac{\partial^2 T}{\partial z^2} + \frac{\dot{q}_G}{k} = \frac{1}{\alpha}\frac{\partial T}{\partial t}$$

10. What is coefficient of Thermal conductivity? (Dec 09, Dec 12)

Thermal **conductivity** (often denoted k, λ, or κ) is the property of a material to conduct heat. It is evaluated primarily in terms of Fourier's Law for heat conduction. In SI units, thermal conductivity is measured in watts per meter-kelvin (W/ (m·K)).

11. What is meant by Transient heat conduction? (May 09, Nov 16)

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.

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

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

13. What is meant by semi infinite solids?

In a semi infinite solid 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 semis infinite solids the biot number value is infinity.

PART B

1. Explain the mechanism of heat conduction in solids and gases. **(May 2013)**
2. Derive the heat conduction equation in cylindrical co-ordinates using an elemental Volume for a stationary isotropic solid. **(May 07, May 10, Nov 14)**
3. Derive the heat conduction equation in Cartesian co-ordinates. **(Dec 06)**
4. An exterior wall of house may be approximated by a 0.1 m layer of common brick (k = 0.7 W/m° C) followed by a 0.04 m layer of gypsum plaster (k = 0.48 W/m° C).

What is the thickness of loosely packed rock wool insulation (k = 0.065 W/mº C) Should be added to reduce the heat loss or gain through the wall by 80 %. **(May 04, Dec 06)**

5. A furnace wall consists of three layers. The inner layer of 10 cm thickness is made of firebrick *(k* =1.04 W/m K). The intermediate layer of 25 cm thickness is made of masonry brick (k = 0.69 W/m K) followed by a 5 cm thick concrete wall (k = 1.37 W/m K). When the furnace is in continuous operation the inner surface of the furnace is at 800° C while the outer concrete surface is at 50°C. Calculate the rate of heat loss per unit area of the wall, the temperature at the interface of the firebrick and masonry brick and the temperature at the interface of the masonry brick and concrete. **(May 06)**

6. A 150 mm steam pipe has inside diameter of 120 mm and outside diameter of 160 mm. It is insulated at the outside with asbestos. The steam temperature is 150º C and the air temperature is 20º C h (steam) = 100 W/m² C, h (air) = 100 W/m² C, K (asbestos) = 0.8 W/mº C and K (steel) = 42 W/mº C. How thick the asbestos should be provided in order to limit the heat losses to 2.1 Kw/m². **(Dec 12)**

7. An aluminium pipe carries steam at 110° C The pipe and K = 185 W/mº C. Has an inner diameter of 100 mm and outer diameter of 120 mm. The pipe is located in a room where the ambient air temperature is 30° C and the convective heat transfer co-efficient between the pipe and air is 15 W/m² C. Determine the heat transfer rate per unit length of pipe. To reduce the heat loss from the pipe, it is covered with a 50 mm thick layer of insulation (K = 0.20 W/m °C). Determine the heat transfer rate per unit length from the insulated pipe. Assume that the convective resistance of the steam is negligible. **(May 12)**

8. An electrical wire of 10 m length and 1 mm diameter dissipates 200 W in air at 25°C. The convection heat transfer coefficient between the wire surface and air is 15 W/m2K. Calculate the critical radius of insulation and also determine the temperature of the wire if it is insulated to the critical thickness of insulation. **(May / Dec 06)**

9. A steel ball of 5 cm diameter was initially at 450°C and is suddenly placed in environment at 100°C, heat transfer coefficient between the steel ball and the fluid is 10 W/m² K, For steel CP =

0.46 kj/kg K , ρ=7800 kg/m³. K= 35W/m K. Calculate time required for the ball to reach a temperature of 150°C Also find the rate of cooling after 12 hr. **(Nov 15)**

10. With neat sketches, explain the different fin profiles. **(May 13)**

11. Find out the amount of heat transferred through an iron fin of length 50 mm, width 100 mm and thickness 5 mm. Assume k = 58 W/mº C and h = 12 W/m²C for the material of the fin and the temperature at the base of the fin as 80 º C. Also Determine the temperature at tip of the fin if the atmosphere temperature is 20º C. **(Dec 06)**

12. A Cylinder 1 m long and 5 cm in diameter is placed in an atmosphere at 45º C. It is provided with 10 longitudinal straight fins of material having k = 120 W/m K. The height of 0.76 mm thick fins is 1.27 cm from the cylinder surface. The heat transfer co-efficient between cylinder and atmosphere air is 17 W/m²K. Calculate the rate of heat transfer and temperature at the end of fins if surface temperature of cylinder is 150º C. **(May 05)**

UNIT 2

2 MARKS

1. Define – Convection **(Nov/Dec-2012)**

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

2. Define – Nusselt number (Nu) **(Nov/Dec-2012)**

It is defined as the ratio of the heat flow by convection process under an unit temperature gradient to the heat flow rate by conduction under an unit temperature gradient through a stationary thickness (L) of meter.

$$\text{Nusselt number (Nu)} = \frac{Q_{conv}}{Q_{cond}}.$$

3. What is meant by laminar flow and turbulent flow? **(May 12, May 15)**

Laminar flow: Laminar flow is sometimes called stream line flow. In this type of flow, the fluid moves in layers and each fluid particle follows a smooth continuous path. The fluid particles 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 frequency observed in nature. This type of flow is called turbulent flow. The path of any individual particle is zig –zag and irregular. Fig. shows the instantaneous velocity in laminar and turbulent flow.

4. What is meant by free or natural convection & forced convection? **(Dec 04, May 10, May 12)**

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

5. Define – Reynolds number (Re) , Prandtl number (Pr) **(May 05, Dec 08, Dec 11, May 14)**

Reynolds number is defined as the ratio of inertia force to viscous force.

Prandtl number is the ratio of the momentum diffusivity of the thermal diffusivity. Inertia force Re Viscous force.

$$\text{Re} = \frac{\text{Inertia force}}{\text{Viscous force}}$$

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

6. Define – Grash of number (Gr) , Stanton number (St) (May 10)(Nov/Dec-2011)

1. It is defined as the ratio of product of inertia force and buoyancy force to the square of viscous force.

2. **Stanton number** is the ratio of nusselt number to the product of Reynolds number and prandtl number.

$$\text{Gr} = \frac{\text{Inertia force} \times \text{Buyoyancy force}}{(\text{Viscous force})^2}$$

$$\text{St} = \frac{\text{Nu}}{\text{Re} \times \text{Pr}}$$

7. What is meant by Newtonian and non – Newtonian fluids? (April/May-2011)

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

8. Define boundary layer thickness. (April/May-2011)

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.

9. What is the form of equation used to calculate heat transfer for flow through cylindrical pipes? (April/May-2008)

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

$$n = 0.4 \text{ for heating of fluids}$$

$$n = 0.3 \text{ for cooling of fluids}$$

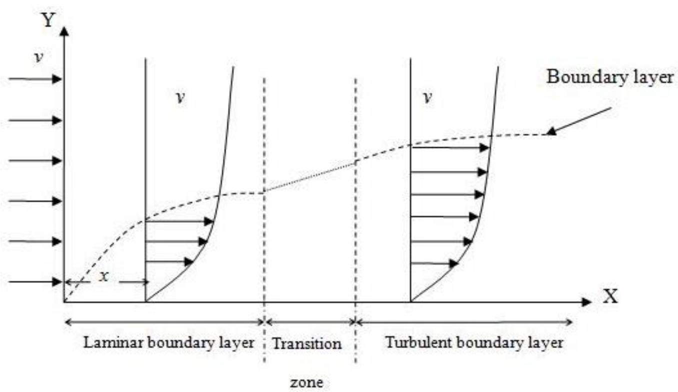
10. What is thermal boundary layer ? **(Dec 04, May 07, May 10, May 11)**

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

11. Define velocity boundary layer thickness **(Dec 05, May 11, May 13, May 15)**

The **thickness** of the **velocity boundary layer** is normally defined as the distance from the solid body to the point at which the viscous flow **velocity** is 99% of the freestream **velocity** (the surface **velocity** of an inviscid flow).

12. Sketch the boundary layer for a vertical plate in case of free convection. **(May 09)**



13. What is meant by dimensional analysis? **(Nov/Dec- 1996)**

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

14. 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.

15. What is hydrodynamic boundary layer?

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

PART B

1. Discuss briefly the development of velocity boundary layer for flow through a pipe. **(May 13)**
2. Water at 60°C and a velocity of 2 cm/s flows over a 5 m long flat plate which is maintained at a temperature of 20°C. Determine the total drag force and the rate of heat transfer per unit width of the entire plate. **(May 13)**
3. Air at 200 kPa and 200°C is heated as it flows through a tube with a diameter of 25 mm at a velocity of 10 m/sec. The wall temperature is maintained constant and is 20°C above the air temperature all along the length of
   tube. Calculate:
   i) The rate of heat transfer per unit length of the tube.
   ii) Increase in the bulk temperature of air over a 3 m length of the tube. **(Dec 12)**
4. A fine wire having a diameter of 0.02 mm is maintained at a constant temperature of 54º C by an electric current. The wire is exposed to air at 1 atm. And 0º C. Calculate the electric power necessary to maintain the wire temperature if the length is 50 cm. **(Dec 12)**
5. Air stream at 27° C is moving at 0.3 m/s across a 100 W electric bulb at 127° C If the bulb is approximated by a 60mm diameter sphere, estimate the heat transfer rate and percentage of power lost due to convection. **(May 12)**
6. Engine oil at 60°C flows with a velocity of 2 m/s over a 5 m long flat plate whose temperature is 20°C. Determine the drag force exerted by oil on the plate and the rate of heat transfer for 1m. **(Dec 11)**
7. Air at 20° C and at a pressure of 1 bar is flowing over a flat plate at a velocity of 3m/s. If the plate is 280 mm wide and 56°C. Calculate the following x =280 mm.
   i) Boundary layer thickness.
   ii) Local friction co-efficient.
   ii) Average friction co-efficient.
   iv) Thickness of thermal boundary layer.
   v) Local convective heat transfer co-efficient.
   vi) Average convective heat transfer co-efficient.
   vii) Rate of heat transfer by convection. **(Dec 08)**

8. The water is heated in a tank by dipping a plate of 20 cm X 40 cm in size. The temperature of the plate surface is maintained at 100°C. Assuming the temperature of the surrounding water is at 30° C, Find the heat loss from the plate 20 cm side is in vertical plane. **(May 07)**

9. A steam pipe 10 cm outside diameter runs horizontally in a room at 23°C. Take the outside surface temperature of pipe as 165°C. Determine the heat loss per unit length . **(Dec 05)**

10. Explain in detail about boundary layer concept. **(Nov 13)**

11. A horizontal heated plate measuring 1.5 m x 1.1 m and at 215°C, facing upwards is placed in still air at 25°C. Calculate the heat loss by natural convection. Use the relation h = 3.05 (Tf)1/4, Tf = Mean film temperature. **(May 14)**

12. Explain in detail about boundary layer concept **(Nov 13)**

13. Water at 60°C enters a tube of 2.54 mm diameter at a mean flow velocity of 2 cm/s. Calculate the exit water temperature if the tube is 3 m long and the wall temperature is constant at 80° C. **(May 15)**

UNIT 3

PART A

1. What is meant by boiling and condensation? (Nov/Dec-2012) (May 07)

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

2. What is meant by pool boiling? (May 04, Dec 08,Dec 12, May 13, May 14)

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

3. What is meant by LMTD? (May 11, May 13)

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

$Q = U A (\Delta T)m$ Where U – Overall heat transfer coefficient W/m^2K A – Area in m^2

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

4. Write about the applications of boiling and condensation. (April/May-2012)

Boiling and condensation process finds wide applications as mentioned below.

i) Thermal and nuclear power plant.

ii) Refrigerating systems

iii) Process of heating and cooling

iv) Air conditioning systems

v) Heat exchangers

5. What are the various types of heat exchangers? **(Dec 05, May 12, May 15)**

The types of heat exchangers are as follows

i) Direct contact heat exchangers

ii) Indirect contact heat exchangers

iii) Surface heat exchangers

iv) Parallel flow heat exchangers

v) Counter flow heat exchangers

vi) Cross flow heat exchangers

vii) Shell and tube heat exchangers

6. Write about the merits of drop wise condensation. **(Dec 04, Dec 05, May 06, Dec-2010)**

In drop wise condensation, a large portion of the area of the plate is directly exposed to vapour. The heat transfer rate in drop wise condensation is 10 times higher than in film condensation.

7. What is meant by film wise and drop wise condensation? **(Dec 04, Dec 05, May 06, May-2010)**

The liquid condensate wets the solid surface, spreads out and forms a continuous film over the entire surface is known as film wise condensation. In drop wise condensation the vapour condenses into small liquid droplets of various sizes which fall down the surface in a random fashion.

8. What is meant by effectiveness? **(April/May-2010)**

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

$$\text{Effectiveness } \varepsilon = \frac{\text{Actual heat transfer}}{\text{Maximum possible heat transfer}} = \frac{Q}{Q_{max}}$$

9. Define – Heat exchanger **(April/May-2009)**

A heat exchanger is defined as equipment which transfers the heat from a hot fluid to a cold fluid.

10. What is meant by fouling factor? **(April/May-2009)**

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

11. What is meant by film wise condensation? **(Dec 04, Dec 05, May 06)**

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

12. What is meant by NTU method? **(May 09, May 10)**

NTU is a measure of the size of heat exchanger, it provides some indication of the size of the heat exchanger.

$$NTU = \frac{UA}{c_{min}}$$

Where U=overall heat transfer co-efficient.

A = surface area (m^2/s)

PART B

1.The bottom of copper pan, 300 mm in diameter is maintained at 120° C by an electric heater. Calculate the power required to boil water in this pan. What is the evaporation rate? Estimate the critical heat flux**.** **(Dec12)**

2. Water at the rate of 4 kg/s is heated from 40° C to 55° C in a shell and tube heat exchanger. On shell side one pass is used with water as heating fluid (m = 2 kg/s), entering the exchanger at 95° C The overall heat transfer co-efficient is 1500 W/m² ° C and average water velocity in the 2 cm diameter tubes is 0.5m/s. Because of space limitations the tube length must not exceed 3 m. Calculate the number of tube passes keeping in mind the design constraint. **(Dec 12)**

3.Water is boiling on a horizontal tube whose wall temperature is maintained At 15°C above the saturation temperature of water. Calculate the nucleate boiling heat transfer coefficient. Assume the water to be at a pressure of 20 atm. And also find the change in value of heat transfer coefficient when.

1. The temperature difference is increased to 30°C at a pressure of 10 atm.
2. The pressure is raised to 20 atm at Δ T = 15°C

4. Derive LMTD for a parallel flow heat exchanger stating the assumptions. **(May 10)**

5. Explain the various regimes of pool boiling. **(May 07,May 09, May 15)**

6. A counter flow concentric tube heat exchanger is used to cool engine oil [C = 2130J/kg K] from 1600C to 600C with water available at 250C as the cooling medium. The flow rate of cooling water through the inner tube of 0.5m is 2kg/s while the flow rate of oil through the outer annulus, Outer diameter = 0.7m is also 2kg/s. If U is 250Wm2K, how long must the heat exchanger be to meet its cooling requirement? **(May 05)**

7. What are the different types of fouling in heat exchangers? **(May 15)**

8. Hot exhaust gases which enter a cross-flow heat exchanger at 300°C and leave at 100°C are used to heat water at a flow rate of 1 kg/s from 35 to 125°C. The specific heat of the gas is 1000 J/kg.K and the overall heat transfer coefficient based on the gas side surface is 100 W/m2 .K Find the required gas side surface area using the NTU method and LMTD method. **(May 13)**

UNIT 4

PART A

1. **Define emissive power [E] and monochromatic emissive power. [Eb] (Dec.05) (May 14)**

   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/m2. The energy emitted by the surface at a given length per unit time per unit area in all directions is known as monochromatic emissive power.

2. **What is meant by absorptivity, reflectivity and Transmissivity? (Dec.04) (Dec 11)**

   Absorptivity is defined as the ratio between radiation absorbed and incident radiation. Reflectivity is defined as the ratio of radiation reflected to the incident radiation. Transmissivity is defined as the ratio of radiation transmitted to the incident radiation.

3. **What is black body and grey body? (Dec.04, Dec.05 May 06,May 07,May 09, May 12)**

   Black body is an ideal surface having the following properties. A black body absorbs all incident radiation, regardless of wave length and direction. For a prescribed temperature and wave length, no surface can emit more energy than black 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.

4. **State Planck's distribution law. (May 13)**

   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.

$$E_{b\lambda} = \frac{C_1 \lambda^{-5}}{e^{\left(\frac{C_2}{\lambda T}\right)} - 1}$$

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

λ = Wave length – m

$c_1 = 0.374 \times 10^{-15}$ W m^2

$c_2 = 14.4 \times 10^{-3}$ mK

6. What is meant by thermal radiation? **(May 08,May 11)**

Thermal radiation is electro-magnetic **radiation** generated by the **thermal** motion of charged particles in matter. All matter with a temperature greater than absolute zero emits **thermal radiation**.

7. State Wien's displacement law.

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

$$\lambda_{mas} T = c_3$$

Where $c_3 = 2.9 \times 10^{-3}$ [Radiation constant]

$$\Rightarrow \quad \lambda_{mas} T = 2.9 \times 10^{-3} \text{ mK}$$

8. State Stefan – Boltzmann law. **(May 12)**

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

$$E_b \propto T^4$$

$$E_b = \sigma T^4$$

Where E_b = Emissive power, w/m^2

σ = Stefan. Boltzmann constant

= 5.67×10^{-8} W/m^2 K^4

T = Temperature, K

9. 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 any body to the emissive power of a black body of equal temperature.

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

10. State Kirchoff's law of radiation. **(May 10,Dec 12, May 15)**

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 surroundings. This can be written as

$$\frac{E_1}{\alpha_1} = \frac{E_2}{\alpha_2} = \frac{E_3}{\alpha_3}$$

11. Define irradiation (G) and radiosity (J) **(May 05,Dec 08, May 13, May 15)**

It is defined as the total radiation incident upon a surface per unit time per unit area. It is expressed in W/m2. It is used to indicate the total radiation leaving a surface per unit time per unit area. It is expressed in W/m2.

12. What is meant by shape factor and mention its physical significance? (May 05, Nov 14)

The shape factor is defined as ''the fraction of the radiative energy that is diffused from one surface element and strikes the other surface directly with no intervening reflections ''. It is represented by Fij. Other names for radiation shape factor are view factor, angle factor and configuration factor. The shape factor is used in the analysis of radiating heat exchange between two surfaces.

13. What is Radiosity?

It is used to indicate the total radiation leaving a surface per unit time per unit area. It is expressed in W/m2

PART B

1. A gray, diffuse opaque surface ($\alpha = 0.8$) is at 100° C and receives an irradiation 100W/m². If the surface area is 0.1 m². Calculate

   i) Radiosity of the surface

   ii) Net radiative heat transfer rate from the surface

   iii) Calculate above quantities, if surface is black. **(Dec 12)**

2. Emissivities of two large parallel plate maintained at 800° C and 300° C and 0.3 and 0.5 respectively. Find the net heat exchange per square meter of these plates. **(Dec 12)**

3. Two rectangles 50X 50 cm are placed perpendicular with common edge. One surface has T1 = 1000 K; ε = 0.6; While the other surface is insulated and in radiant balance with a large surrounding room at 300 K . Determine the temperature of the insulated surface and heat lost by the surface at 1000 K. **(Dec 12)**

4. Two black square plates of size 1.0 by 1.0 m are placed parallel to each other at a distance of 0.4 m. One plate is maintained at a temperature of 900° C and the other at 400° C. Find the net exchange of energy due to radiation between the two plates. **(May 12)**

5. The surfaces of a doubled walled spherical vessel used for storing liquid oxygen are covered with a layer of silver having, an emissivity of 0.03.The temperature of the outer surface of the inner wall is 153° C and the temperature of the inner surface of the outer wall is 27° C. The spheres are 210 mm and 300 mm in diameter, with the space between them evacuated. Calculate the radiation heat transfer through the walls into the vessel and the rate of the evaporation of liquid oxygen if its rate of vaporization is 220kJ/kg. **(May 12)**

6. A furnace is approximated as an equilateral triangular duct of sufficient length so that end effects can be neglected. The hot wall of the furnace is maintained at 900 K and has an emissivity of 0.8. The cold wall is at 400 K and has the same emissivity. Find the net radiation heat flux leaving the wall. Third wall of the furnace may be assumed as a reradiating surface. **(Dec 11)**

7. Consider two concentric cylinders having diameters 10 cm and 20 cm and a length of 20 cm. designating the open ends of the cylinders as surfaces 3 and 4,

1. Estimate the shape factor, F3-4. **(Dec 11)**

8. Two very large parallel planes exchange heat by radiation. The emissivites of the planes are respectively 0.8 and 0.3. To minimize the radiation exchange between the planes; a polished

aluminium radiation shield is placed between them. If the emissivity of the shield is 0.04 on both sides, find the percentage reduction in heat transfer rate. **(May 11)**

9. Two parallel plates of 1 x 1 m spaced 0.5 m a part in a very large room whose walls are at 27° C. The plates are at 900° C and 400° C with emissivities 0.2 and 0.5 respectively. Find the net heat transfer to each plate and to the room. **(May 10)**

10. State and Prove Kirchhoff s law of thermal radiation. **(May 13)**

11. What is a black body? A 20 cm diameter spherical ball at 527°C is suspended in the air. The ball closely approximates a black body. Determine the total black body emissive power, and spectral black body emissive power at a wavelength of 3 /an. **(May 13)**

12. An oven is approximated as a long equilateral triangular duct, which has a heated surface maintained at a temperature of 1200 K. The other surface is insulated while the third surface is at 500 K. The duct has a. width of a 1 m on a side and the heated and insulated surfaces have an emissivity of 0.8. The emissivity of the third surface is 0.4. For steady state operation find the rate at which energy must be supplied to the heated side per unit length of the duct to maintain its temperature at 1200 K. What is the temperature of the insulated surface?

(May 13)

UNIT V

PART A

1. **What is mass transfer?** **(May 08, May 13)**

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

2. **Give the examples of mass transfer.** **(May 14)**

   Some examples of mass transfer.

   1. Humidification 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?** **(May 15, Nov 13)**

   There are basically two modes of mass transfer,

   1. Diffusion mass transfer

   2. Convective mass transfer

4. **What is molecular diffusion?** **(May 06)**

   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?** **(May 08)**

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

7. **State Fick's law of diffusion.** **(May 09,Dec 12, May 13, Nov 14, May 15)**

   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,

$\frac{ma}{A}$ – Molar flux, $\frac{\text{kg -mole}}{\text{s-m}^2}$

D_{ab} Diffusion coefficient of species a and b, m^2/s

$\frac{dC_a}{dx}$ – concentration gradient, kg/m^3

8. **What is free convective mass transfer?** **(Dec 12)**

   If the fluid motion is produced due to change in density resulting from concentration gradients, 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.** **(Dec 12)**

   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 evaluation if water from an ocean when air blows over it.

10. **Define Schmidt Number.** **(May 13)**

    It is defined as the ratio of the molecular diffusivity of momentum to the molecular diffusivity of mass.

$$Sc = \frac{\text{Molecular diffusivity of momentum}}{\text{Molecular diffusivity of mass}}$$

11. **Define the following: a) Mass concentration b) Molar concentration(May 10/ 15)**

a) The **mass concentration** ρ_i (or γ_i) is defined as the mass of a constituent m_i divided by the volume of the mixture V.

b) **Molar concentration**, also called **molarity**, **amount concentration** or **substance concentration**, is a measure of the concentration of a solute in a solution, or of any chemical species, in terms of amount of substance in a given volume.

PART B

1. Dry air at 27 ^{o}C and 1 atm flows over a wet flat plate 50 cm long at a velocity of 50 m/s. Calculate the mass transfer co-efficient of water vapour in air at the end of the plate. Take the diffusion coefficient of water vapour in air is Das = 0.26 X IO-a m2/s.

(Dec 07, May 10, May 12)

2. Helium gas at 2500 and a pressure of 4 bar is stored in a spherical silica container of 150 mm inside diameter and 3 mm wall thickness. What is the initial rate leakage for the system?

(May 12)

3. The tire tube of a vehicle has a surface area 0.62 m2 and wall thickness 12 mm. The tube has air filled in it at a pressure 2.4 x 105 N/m2•The air pressure drops to 2.3 x 105 N/m2 in 10 days. The volume of air in the tube is 0.034 m3• Calculate the diffusion coefficient of air in rubber at the temperature of 315K. Gas constant value = 287. Solubility of air in rubber tube = 0.075m3 of air/m3 of rubber tube at one atmosphere **(Dec 12)**

4. Dry air at 200C [ρ = 1.2 kg/m3, v = 15 x 10 -6 m2/s. D = 4.2 x 10-5 m2/s] flows over a flat plate of length 50cm which is covered with a thin layer of water at a velocity of 1m/s. Estimate the local mass transfer co-efficient at a distance of 10cm from the leading edge and the average mass transfer co-efficient. **(May 13)**

5. Air at 1 atm and 250C containing small quantities of iodine flow with a velocity of 6.2 m/s inside a 35 mm diameter tube. Calculate mass transfer co-efficient for iodine. The thermo physical properties of air are v = 15.5 x 10-6 m2/s, D = 0.82 x 10-5m2/s. **(May 13)**

6. An open pan 20cm in diameter and 8cm deep contains water at 250C and is exposed to dry atmospheric air. If the rate of diffusion of water vapour is 8.54 x 10-4 kg/h, estimate the diffusion co-efficient of water in air. **(Nov 14)**

7. Air at 20° C with D = 4.166 x10-5 m^2/s flows over a tray (length 320 mm, width 420mm) full of water with a velocity of 2.8 m/s. The total pressure of moving air 1 atm and the partial pressure of water present in the air is 0.0068 bar. If the temperature on the water surface is 15 ° C, Calculate the evaporation rate of water. **(May 08)**

8. A vessel contains binary mixture of O2 and N2 with partial pressure in the ratio 0.21 and 0.79 at 15° C. The total pressure of the mixture is 1.1 bar. Calculate the following

i) Molar concentrations

ii) Mass densities

iii) Mass fractions

iv) Molar fraction for each species **(Dec 08, May 04)**

9. (i) Explain Equimolar counter diffusion in gases.

(ii) Discuss briefly the Analogy between heat and mass transfer **(May 13)**

10. Define mass transfer coefficient. Air at 1 bar pressure and 25°C containing small quantities of iodine flows with a velocity of 5.2 m/s. inside a tube having an inner diameter of 3.05 cm. Find the mass transfer coefficient for iodine transfer from the gas stream to the wall surface. If C_m is the mean-concentration of iodine in (kg. mol/m3) in the air stream, find the rate of deposition of iodine on the tube surface by assuming the wall surface is a perfect sink for iodine deposition. Assume D = 0.0834 cm2 /s. **(May 13)**

11. A narrow cylindrical vessel contains water at the bottom . it is 5 m deep and has 2.5m diameter. The water is diffused to dry ambient air over the top of the vessel. The entire arrangement is maintained at 30°c and 1 atm. the diffusion coefficient is 0.24×10^{-14} m^2/s, calculate the rate of diffusion of water into the air. **(Nov/Dec 2016)**

12. O_2 at 20°c and a pressure of 2 bar is flowing through a rubber pipe of ID 25mm and wall thickness 2.5mm. The diffusivity of O_2 through rubber is $D_{AB} = 0.21 \times 10^{-9}$ m^2/s and solubility of O_2 in rubber is 3.12×10^{-3} mol/m^3 bar. Find the loss of oxygen by diffusion per metre length of pipe. **(Nov/Dec 2016)**