ME8693 HEAT AND MASS TRANSFER

IMPORTANT QUESTIONS AND QUESTION BANK

UNIT I – CONDUCTION

2-Marks

1. 1.Point out Fourier's Law of heat conduction?
2. 2.Write the expression to determine the thermal conductivity as the function of temperature and unit of thermal conductivity?
3. 3.What is meant by lumped heat capacity analysis? When is it used?
4. 4.Define the term thermal conductivity. Also list the behavior of metal, liquid and gases thermal conductivity for increase in temparature?
5. 5.Write any two examples of heat conduction with heat generation?
6. 6.Define critical thickness of insulation with its significance?
7. 7.Write the three dimensional heat transfer Poisson and Laplace equations in Cartesian co-ordinates?
8. 8.What is meant by transient heat conduction? Also give any two examples?
9. 9.Define thermal diffusivity. Briefly explain its importance in heat conduction problems?
10. 10. what are Biot and Fourier numbers?

Part-B

1. A furnace wall consists of three layers. The inner layer of 10cm 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?
2. An electrical wire of 10 m length and 1 mm diameter dissipates200 W in air at 25°C.The convection heat transfer coefficient between the wire surface and air is 15 W/m^{2}K. Calculate the critical radius of insulation and also determine the temperature of the wire if it is insulated to the critical thickness of insulation?
3. A furnace wall is made up of three layer of thicknesses 25 cm, 10 cm and 15 cm with thermal conductivities of 1.65W/m-K, 4.83W/m K and 9.2 W/m-K respectively. The inside is exposed to gases at 1250°C with a convection coefficient of 25 W/m^2°C and the inside surface is at 1100°C, the outside surface is exposed to air at 25°C with convection coefficient of 12 W/m^2°C.Determine (i) The unknown thermal conductivity (ii) The overall heat transfer coefficient (iii) All the surface temperature?

4. A pipe consists of 100 mm internal diameter and 8 mm thickness carries steam at 170°C. The convective heat transfer coefficient on the inner surface of pipe is 75 $W/m^{2o}C$. The pipe is insulated by two layers of insulation. The first layer of insulation is 46 mm in thickness having thermal conductivity of 0.14 W/m°C. The second layer of insulation is also 46 mm in thickness having thermal conductivity of 0.46 W/m°C. Ambient air temperature = 33°C. The convective heat transfer coefficient from the outer surface of pipe = 12 $W/m^{2o}C$. Thermal conductivity of steam pipe = 46 W/m°C. Calculate the heat loss per unit length of pipe and determine the interface temperatures. Suggest the materials used for insulation?
5. A long rod is exposed to air at 298°C. It is heated at one end. At steady state conditions, the temperatures at two points along the rod separated by 120 mm are found to be 130°C and 110°C respectively. The diameter of the rod is 25 mm OD and its thermal conductivity is 116 W/m°C. Calculate the heat transfer coefficient at the surface of the rod and also the heat transfer rate?
6. Derive the dissipation equation through pin fin with insulated end?
7. A temperature rise of 50°C in a circular shaft of 50 mm diameter is caused by the amount of heat generated due to friction in the bearing mounted on the crankshaft. The thermal conductivity of shaft material is 55W/m-K and heat transfer co efficient is 7 W/m^2K. Determine the amount of heat transferred through shaft assume that the shaft is a rod of infinite length?
8. An aluminum rod (k = 204 W/m-K), 2 cm in diameter and 20 long protrudes from a wall which is maintained at 300°C. The end of the rod is insulated and the surface of the rod is exposed to air at 30°C. The heat transfer coefficient between the rod's surface and air is 10 W/m^2K. Calculate the heat lost by the rod and the temperature of the rod at a distance of 10 cm from the wall?
9. A large iron plate of 10 cm thickness and originally at 800°C is suddenly exposed to an environment at O°C where the convection coefficient is 50 W/m^2K. Calculate the temperature at a depth of 4 cm from one of the faces 100 seconds after the plate is exposed to the environment. How much energy has been lost per unit area of the plate during this time?
10. Explain the different modes of heat transfer with appropriate expressions?
11. A composite wall consists. of 10 cm thick layer of building brick, k =0.7 W/m-K and 3 cm thick plaster, k = 0.5 W/m-K. An insulating material of k = 0.08 W/m-K is to be added to reduce the heat transfer through the wall by 40%. Find its thickness?
12. Derive an expression for heat flow through a sphere and prove that if the thickness of the sphere is small it can be taken as a flat slab?
13. Circumferential aluminum fins of rectangular profile (1.5 cm wide and 1 mm thick) are fitted to a 90 mm engine cylinder with a pitch of 10 mm. The height of the cylinder is 120 mm. The cylinder base temperature before and after fitting the fins are 200°C and 150°C respectively. Take ambient at 30°C and h (average) = 100 W/m2-K. Estimate the heat dissipated from the finned and the unfinned surface area of cylindrical body?
14. A 3 cm OD steam pipe is to be covered with two layers of insulation each having a thickness of 2.5 cm. The average thermal conductivity of one insulation is 5 times that of the other. Determine the percentage decrease in

heat transfer if better insulating material is next to pipe than it is the outer layer. Assume that the outside and inside temperatures of composite insulation are fixed?

15. A bar of square cross-section connects two metallic structures. One structure is maintained at a temperature 200°C and the other is maintained at 50°C. The bar, 20 mm x 20 mm is 100 mm long and is made of mild steel (k= 0.06 kW/m-K). The surroundings are at 20°C and the heat transfer coefficient between the bar and the surroundings is 0.01kW/m^2K. Derive an equation for the temperature distribution along the bar and hence calculate the total heat flow rate from the bar to the surroundings?

UNIT-II CONVECTION

2-Marks

1. What are the differences between natural and forced convection?
2. Briefly explain the concept of free convection heat transfer mechanism?
3. Define bulk temperature. How is it used?
4. Differentiate viscous sublayer and buffer layer?
5. State Newton's law of cooling?
6. A square plate 40 x 40 cm maintained at 400 K is suspended vertically in atmospheric air at 300 K. Determine the boundary layer thickness at trailing edge of the plate?
7. What is colburnand Reynolds analogy?
8. Distinguish between laminar & turbulent flow?
9. What is Dittus-Boelter equation?
10. Why heat transfer coefficient for natural convection is much lesser than that for forced convection?

Part -B

1. Nitrogen at a pressure of 0.1 atm. flows over a flat plate with a free stream velocity of 8 m/s. The temperature of the gas is, – 20°C. The plate temperature is 20°C. Determine the length for the flow to turn turbulent. Assume 5×10^5 as critical Reynolds number. Also determine the thickness of thermal and velocity boundary layers and the average convection coefficient for a plate length of 0.3 m. Properties are to be found at film temperature
2. What is Reynold's analogy? Describe the relation between fluid friction and heat transfer?
3. Castor oil at 25°C flows at a velocity of 0.1 m/s part a flat plate, in a certain process. If the plate is 4.5 m long and is maintained at a uniform temperature of 95°C, calculate the following (i) The hydrodynamic and thermal boundary layer thicknesses on one side of the plate. The total drag force per unit width on one side of the plate. (iii) The local heat transfer coefficient at the trailing

edge and (iv) The heat transfer rate ; properties of oil at 60°C are ρ = 956.8 kg/m^3, ∞ = 7.2 x 10^{-8} m^2/s; k = 0.213 W/m-K ; v = 0.65 x 10^{-4} m^2/s?

4. Engine oil at 80°C flows over a flat surface at 40°C for cooling purpose, the flow velocity being 2 m/s. Determine at a distance of 0.4 m from the leading edge the hydrodynamic and thermal boundary layer thickness. Also determine the local and average values of friction and convection coefficients?
5. Air at 1 atm. and 30°C is forced through a horizontal 30 mm diameter 0.5 m long tube at an average velocity of 0.25 m/s. The tube wall is maintained at 135°C. Calculate (i) the heat transfer coefficient and (ii) percentage error if the calculation is made strictly on the basis of laminar forced convection?
6. A metal plate 0.609 m high forms the vertical wall of an oven and is at a temperature of 161°C. Within the oven air is at a temperature of 93.0°C and one atmosphere. Assuming that natural convection conditions hold near the plate, estimate the mean heat transfer coefficient and the rate of heat transfer per unit width of the plate?
7. A 10 mm diameter spherical steel ball at 260°C is immersed in air at 90°C. Estimate the rate of convective heat loss?
8. Air at 20°C is flowing along a heated plate at 134°C at a velocity of 3 m/s. The plate is 2 m long and 1.5 m wide, Calculate the thickness of the hydrodynamic boundary layer and the skin friction coefficient at 40 cm from the leading edge of the plate?
9. 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?
10. The Vertical 0.8 m high, 2 m wide double pane window consists of two sheets of glass separated by a 2 cm air gap at atmospheric pressure. If the glass surface temperatures across the air gap are measured to be 12°C and 2°C, determine the rate of heat transfer through the window?
11. 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 of the pipe?
12. Distinguish between free and forced convection giving examples?
13. A steam pipe 10 cm OD runs horizontally in a room at 23° C. Take outside temperature of pipe as 165 ° C. Determine the heat loss per unit length of the pipe. Pipe surface temperature reduces to 80° C with 1.5 cm insulation. What is the reduction in heat loss?
14. Nitrogen gas at 0°C is flowing over a 1.2 m long, 2 m wide plate maintained at 80°C with a velocity of 2.5 m/s. For nitrogen, ρ = 1.142 kg/m^3, Cp= 1.04 kJ /kg-K , υ= 15.63 x 10^{-6} m^2/s and k=0.0262 W/m-K. To find (i) The average heat transfer coefficient and (ii) the total heat transfer from the plate?
15. A cylindrical body of 300 mm diameter and 1.6 m height is maintained at a constant temperature of 36.5 C. The

surrounding temperature is 13.5 C. Find out the amount of heat to be generated by the body per hour if ρ = 1.025 kg/m^3; cp= 0.96 kJ/kg C; v = 15.06 x 10 $^{-6}$ m^2/s; k= 0.0892 kJ/m-h- C and β = 1/298 K^{-1}. Assume Nu = 0.12 (Gr. Pr) $^{1/3}$ (the symbols have their usual meanings)?

UNIT III - PHASE CHANGE HEAT TRANSFER AND HEAT EXCHANGERS

2-Marks

1. Distinguish between the two basic types of condensation?
2. Briefly explain fouling. And how does it affect the rate of heat transfer?
3. Compare subcooled or local boiling and saturated boiling?
4. Describe the different regimes involved in pool boiling?
5. Define pool boiling Give an example for it?
6. Distinguish fin efficiency and fin effectiveness?
7. Distinguish pool boiling from forced convection boiling?
8. Differentiate boiling and condensation?
9. Briefly explain the excess temperature in boiling?
10. Show the heat flux curve for various regions of flow boiling?

Part-B

1. Explain in detail about the different regimes of pool boiling and boiling curve with neat sketch?
2. Water is boiled at a rate of 30 kg/h in a copper pan, 30 cm in diameter, at atmospheric pressure. Estimate the temperature of the bottom surface of the pan assuming nucleate boiling conditions?
3. Water is boiled at atmospheric pressure by horizontal polished copper heating element of diameter D=5mm and emissivity 0.05 immersed in water. If the surface temperature of the heating element is 350°C. Determine the rate of heat transfer from the wire to the water per unit length of the wire?
4. A tube of 1.5 m length and 20 mm outer diameter is to condense saturated steam at 90°C while the tube surface is maintained at 90°C. Estimate the average heat transfer co-efficient and the rate of condensation of steam if the tube is kept horizontal. The steam condenses on the outside of the tube?
5. Saturated steam at 120°C is condensing on the outer tube surface of a single pass heat exchanger. The heat transfer coefficient is U0 = 1800 W/m^2.K. Determine the surface area of a heat exchanger capable of heating 1000 kg/h of water from 20°C to 90°C. Also compute the rate of condensation of steam hfg = 2200 kJ/kg?

6. A vertical tube of 50 mm outside diameter and 2 mm long it exposed to steam at atmospheric pressure. The outer surface of the tube is maintained at a temperature of 84°C by circulating cold water through the tube. Determine the rate of heat transfer and also condensate mass flow rate?
7. Derive the LMTD for a parallel flow heat exchanger stating the A counter flow concentric heat exchanger is used to cool the lubricating oil for a large industrial gas turbine engine. The flow rate of cooling water through the inner tube (di = 20 mm) is 0.18 kg/s while the flow rate of oil through the outer annulus (do = 40 mm) is 0.12 kg/s. The inlet and outlet temperature of the oil are 95°C and65°C respectively. The water enters at 30°C to the exchanger. Neglecting tube wall thermal resistance, fouling factors and heat to the surroundings, calculate the length of the tube. Take the following properties at the bulk mean temperature: Engine oil at 80°C; Cp=2131 J/kg°C; μ=0.0325 N-s/m^2; k=0.138w/m°C. Water at 35°C; Cp=4174 J/kg °C; μ=725×10^{-6} N-s/m^2; k=0.625w/m°C; pr = 4.85. (13) assumptions?
8. Dry saturated steam at a pressure of 2.45 bar condenses on the surface of a vertical tube of height 1 m. The tube surface temperature is kept at 117°C. Estimate the thickness of the condensate film and the local heat transfer coefficient at a distance of 0.2 m from the upper end of the tube?
9. Hot exhaust gases, which enter a finned-tube, cross-flow heat exchanger at 300°C and leave at 100°C, are used to heat pressurized water at a flow rate of 1 kg/s from 35 to 125°C. The exhaust gas specific heat is approximately 1000 J/kg-K, and the overall heat transfer coefficient based on the gas-side surface area is Uh= 100 W/m^2K. Determine the required gas-side surface area Ah using the NTU method.?
10. Water at the rate of 3.8 kg/s is heated from 38 to 55˚C in a shell tube heat exchanger. On the shell side one pass is used with water as the heating fluid, 1.9 kg/s entering the exchanger at 93˚C. The overall heat transfer coefficient is 1419 W/m^2˚C, and the average water velocity in the 1.9 cm diameter tubes is 0.366 m/s. Because of space limitations the tube length must not be longer than 2.5 m. Calculate the number of tube passes, the number of tube per pass, and the length of the tube, consistent with this restriction.?
11. The outer surface of a vertical tube 80 mm in outer diameter and 1 m long is exposed to saturated steam at atmospheric pressure. The tube surface is maintained at 50°C by flow of water through the tube. What is the rate of heat transfer to coolant and what is the rate of condensation of steam?
12. The outer surface of the vertical tube, which is 1 m long and has an outer diameter of 80 mm, is exposed to saturated steam at atmospheric pressure and is maintained at 50°C by the flow of cool water through the tube. What is the rate of

heat transfer to coolant and what is the rate at which the steam is condensed at the surface?

13. Hot oil with a capacity rate of 2500 W/K flows through the 300°C.cold fluid enters at 30°C and leaves at 200°C. If the overall heat transfer coefficient is 800 W/m^{2}K. Determine the heat exchanger area required for (i) parallel flow and (ii) counter flow double pipe heat exchanger. It enters at 360°C and leaves at?
14. Explain about fouling factor?

UNIT-IV RADIATION

2-Marks

1. State Stefan Boltzmann law and planks law. How are they related?
2. List out the use of radiation shield?
3. What is thermal radiation? What is its wavelength band?
4. How do you define the black body and emissivity of a surface?
5. Differentiate opaque body & perfectly transparent surface?
6. Explain emissive power and monochromatic emissivity?
7. Define Planck's distribution law?
8. Define Wien's distribution law?
9. What do you mean by opaque body and white body?
10. Define the terms absorptivity, transmissivity and reflectivity.

Part-B

1. Two parallel plates of size 1.0 m × 1.0 m spaced 0.5 m apart are located in very large room; the walls are maintained at a temperature of 27°C. One plate is maintained at a temperature of 900°C and other at 400°C. The emissivities are the 0.2 and 0.5 respectively. If the plates exchange heat between themselves and surroundings, find the heat transfer to each plate and to them. Consider only the plate surfaces facing each other?
2. What is view factor and shape factor? State laws of black body radiation?
3. Two large parallel plates are at temperatures T1 = 500 K and T2 = 300 K. The emissivity's are ε1= 0.85 and ε2= 0.90. What is the radiation flux between the plates?
4. Two parallel plates 2 m x 1 m are spaced 1 m apart. The plates are at temperatures of 727°C and 227°C and their emissivities are 0.3 and 0.5 respectively. The plates are located in a large room, the walls of which are at 27°C. Determine the rate of radiant heat loss from each plate and the heat gain by the walls?
5. Emissivity's of two large parallel plates maintained at 800 °C and 300°C are 0.3 and 0.5 respectively. Find the net radiant heat exchange per meter for these plates?
6. Liquid Helium at 4.2 K is stored in a dewar flask of inner diameter = 0.48

m and outer diameter = 0.5 m. The dewar flask can be treated as a spherical vessel. The outer surface of the inner vessel and the inner surface of the outer vessel are well polished and the emissivity of these surfaces is 0.05. The space between the two vessels is thoroughly evacuated. The inner surface of the dewar flask is at 4.2 K while the outer surface is at 300 K. Estimate the rate of heat transfer between the surfaces?

7. Calculate the following for an industrial furnace in the form of black body and emitting radiation at 2500°C i. Monochromatic emissive power at 1.2 µm length ii. Wave length at which the emission is maximum iii. Maximum emissive power iv. Total emissive power and total emissive power of the furnace if it is assumed as a real surface with emissivity equal to 0.9?
8. Two parallel plate of size 1.0 m by 1.0 m spaced 0.5 m apart are located in a very large room, the walls of which are maintained at temperature of 27°C. One plate is maintained at a temperature of 900°C and the other at 400°C. Their emissivities are 0.2 and 0.5 respectively. If the plates exchange heat between themselves and surroundings. Find the net heat transfer to each plate and to the room. Consider only the plate surfaces facing each other?
9. A black body emits radiation at 2000 K. Calculate (i) the monochromatic emissive power at 1 µm wavelength, (ii) wavelength at which the emission is maximum, and (iii) the maximum emissive power?
10. An enclosure measures 1.5 m x 1.7 m with a height of 2 m. The walls and ceiling are maintained at 250°C and the floor is at 130°C. The walls and ceiling have an emissivity of 0.82 and the floor 0.7. Determine the net radiation to the floor?
11. An oven is approximated as a long equilateral triangular duct, which heat 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 maintained at a temperature at 1200 K. What is the temperature of the insulated surface?
12. The filament of a 75 W light bulb may be considered as black body radiating into a black enclosure at 70°C. The filament diameter is 0.10 mm and length is 50 mm. Considering the radiation, determine the filament temperature?
13. Emissivity of two large parallel plates maintained at 800°C and 300°C and of 10 cm. Calculate the shape factor between the top surface and the side and also the shape factor between the side and itself?
14. A cryogenic fluid is carried in a pipe of 10 mm OD at a temperature of 100 K. The pipe is surrounded coaxially by another pipe of OD 13 mm with the space between the pipes evacuated. The other pipe is at 5°C. The emissivity for both surfaces is 0.22. Determine the radiant heat flow for 3 m length. If a shield of emissivity of 0.05 and of diameter 11.5 mm is placed between the pipes determine the percentage reduction in heat flow?
15. A cylindrical rod(ε = 0.7) of 50 mm diameter is maintained at 1000°C by an electric resistance heating and is kept in a room, the walls (ε = 0.6) of which are at 15°C. Determine the energy which must be supplied per meter length of the rod. If an insulated half circular reflector of 0.45 m diameter is placed around the rod, determine the energy supplied to the rod per meter length?

UNIT-5 MASS TRANSFER

2-Marks

1. How does mass diffusivity of a gas depend on pressure and temperature?
2. State the modes of mass transfer with suitable examples?
3. Define Fourier number & Biot number for mass transfer?
4. Define Mass concentration?
5. Define Mole fraction?
6. Evaluate free convective mass transfer?
7. Show the analogy of Momentum transfer?
8. Point out molecular diffusion?
9. What are the factors considered in evaporation of water into air?
10. Classify the modes of mass transfer?

Part-B

1. Along a horizontal water surface an air stream with velocity U_∞ = 3 m/s is flowing. The temperature of the surface is 15^{o}C, the air temperature is 20^{o}C, the total pressure is 1 atm. (10^{5} N/m^2), and the saturation pressure of the water vapour in the air at 20^{o}C is 2337 N/m^2. The relative humidity of the air is 33%. The water surface along the wind direction has a length of 10 cm. calculate the amount of water evaporated per hour per meter from the water surface. The binary diffusivity of water vapour in the air may be taken as 3.3 x 10^{-5} m^2/s. The saturation vapour pressure of water at 15^{o}C is 1705 N/m^{2}and kinematic viscosity of the air is 1.5 x 10^{5} m^2/s?
2. Dry air at 29°C and 1 atm. flows over a wet flat plate 52 cm long and velocity of 50 m/s. Calculate the mass transfer co-efficient of water vapour in air at the end of the plate. Take D = 0.27 x 10^{-4} m^2/ s.
3. A vessel contains binary mixture of O2 and N2 with partial pressure in the ratio of 0.21 and 0.79 at 15^{o}C. The total partial pressure of the mixture is 1.1 bar. Calculate the following: (i) Molar concentrations (ii) Mass densities (iii) Mass fractions & Molar fraction of each species?
4. Air at 1 atm. and 25^{o}C containing small quantities of iodine, flows with a velocity of 6.2 m/s inside a 35 mm diameter tube. Calculate the mass transfer coefficient for iodine. The thermo physical properties of air are: υ =15.5 x 10^{-6} m^2/s ; D=0.82 x 10^{-5} m^2/s.?
5. To maintain a pressure close to 1 atm. an industrial pipeline containing ammonia gas is vented to ambient air. Venting is achieved by tapping the pipe and inserting a 3 mm diameter tube, which extends for 20 m into the atmosphere. With the entire system operating at 25°C, determine the mass rate of ammonia lost to the atmosphere and the mass rate of contamination of the pipe

with air. What are the mole and mass fractions of air in the pipe when the ammonia flow rate is 5 kg/h?

6. Air at 20˚C and 1 atm. pressure flows with a velocity of 2.5 m/s inside a 12 mm diameter tube. The inside surface of the tube contains a deposit of naphthalene. Determine the average mass transfer coefficient for the transfer of naphthalene from the pipe surface into air. Take kinematic viscosity 15.7 x 10^{-6} m^2/s for air and DAB = 0.62 x 10^{-5} m^2/s
7. Dry air at 15˚C and 92 kPa flows over a 2 m long wet surface with a free stream velocity of 4 m/s. Determine the average mass transfer coefficient?
8. Derive the steady state one dimensional expression for the rate of Air at 25^{o}C and 1 atmospheric pressure, containing small quantities of iodine flows with a velocity of 5 m/s inside a 3 cm inner diameter tube. Determine the mass transfer coefficient from the air stream to the wall surface. Assume DAB (iodine air) = 0.82 x 10^{-5} m^2/smass diffusion of species A through a plane wall with neat sketch?
9. The dry bulb and wet bulb temperatures recorded by a thermometer in moist air are 27^{o}C and 17^{o}C respectively. Determine the specific humidity of air assuming the following values. Pr = 0.74, Sc = 0.6, Mv=18, Ma = 29, Cp=1.004 kJ/kg.K, p = 1.0132 x 10^5 N/m^2
10. Gaseous hydrogen is stored at elevated pressure in a rectangular container having steel walls 10 mm thick. The molar concentration of hydrogen in the steel at the inner surface is 1 kmol/m^3, while the concentration of hydrogen in the steel at the outer surface is negligible. The binary diffusion coefficient for hydrogen in steel is 0.26 x 10^{-12} m^2/s. What is the molar diffusive flux for hydrogen through the steel?
11. The water in a 5 m x 15 m outdoor swimming pool is maintained temperature of 27^{o}C. The average ambient temperature and relative humidity are 27^{o}C and 40 percent respectively. Assuming a wind speed of 2 m/s in the direction of the long side of the pool estimate the mass transfer coefficient for the evaporation of water from the pool surface?
12. The case hardening of low carbon steel is done by the process of carburization at high temperature that depends upon the transfer of carbon by diffusion. If this process is affected at 1000^{o}C and a carbon mole fraction 0.02 is maintained at the surface of the steel, estimate the time required to elevate the carbon content of steel from an initial value of 0.04 percent to a value of 1.2 percent at a depth of 1 mm. The diffusivity of carbon in steel at 1000^{o}C is 6 x 10^{-10} m^2/s.?
13. A spherical tank of 0.18 m radius made of fused silica has a wall thickness of 2.5 mm. It is originally filled with helium at 6 bar gauge and 0°C. Determine the rate of pressure drop with time at this condition due to gas diffusion. D = 0.04 × 10^{-12} m^2/s, the density of gas at the solid surface is given by 18 × 10^{-9}kg/m^3 Pa. (also termed solubility).?

14. A tray 40 cm long and 20 cm wide is full of water. Air at 30°C flows over the tray along the length at 2 m/s. The moving air at 1.013 bar and partial pressure of water in the air is 0.007 bar. Calculate the rate of evaporation, if the temperature of the water is 25°C. Take for air $\rho = 1.2\ kg/m^3$, $\upsilon = 15 \times 10^{-6}\ m^2/s$, DAB = 0.145 m^2/h?
15. Water flows down on the surface of a vertical plate at a rate of 0.05 kg/s over a width of 1m. The water film is exposed to pure carbon dioxide. The pressure is 1.013 bar and the temperature is 25°C. Water is essentially CO2 free initially. Determine the rate of absorption of CO2. The molar concentration at this condition for CO2 in water at the surface is 0.0336 kg-mol/ $m^3$of solution D = $1.96 \times 10^{-9}\ m^2/s$, solution density = 998 kg/m^3, $\mu = 0.894 \times 10^{-3}$kg/ms, G=0.05 kg/ms, L = 1 m The notation for convective mass transfer coefficient is hm?