ME1251 – HEAT AND MASS TRANSFER

UNIT I CONDUCTION

1. What do you understand by critical radius of insulation and give its expression?
2. Define fin efficiency and effectiveness?
3. What is lumped capacity analysis?
4. What is the main advantage of parabolic fins?
5. What is sensitivity of a thermocouple?
6. Temperature difference of 500˚C is applied across a fire – clay brick.10 cm thick having a thermal conductivity of 1.0 W/m. K. Find the heat transfer rate per unit area.
7. Write the general 3 – D heat conduction equation in cylindrical coordinates.
8. Distinguish b/w Fin Efficiency and Fin Effectiveness.
9. What is the use of Heislers charts?
10. What is Overall heat transfer co-efficient?
11. What is the mechanism of heat conduction in solids?
12. What are boundary and initial conditions?
13. Why heislers charts cannot be used for the case of biot number approaching zero? What is the alternative for solving this typical case?
14. Write down the three dimensional heat conduction equations in rectangular coordinates.
15. Define fin efficiency.
16. State Fourier's law of heat conduction.
17. Write down the three-dimensional heat conduction equation in rectangular coordinate system.
18. Calculate the rate of heat transfer per unit area through a copper plate 45 mm thick and whose one face is maintained at 350◦C and the outer face at 50◦C. Take thermal conductivity of copper as 370 W/m ◦C.
19. State Fourier's law of conduction.
20. Define Coefficient of Thermal conductivity.

PART - B

1. A reactors wall 320 mm thick is made up of an inner layer of fire brick (k=0.84w/m°C). The reactor operates at a temperature of 1325˚C and the ambient temperature is 25˚c. Determine the thickness of the firebrick and insulation which gives minimum heat loss. Calculate the heat loss presuming that the insulating material has a max temperature of 1200˚C.

2. Derive an expression for the heat conduction through a hollow cylinder from the general heat conduction equation .Assume steady state unidirectional heat flow in radial direction and no internal heat generation.

3. A 25mm diameter rod of 360 mm length connects two heat sources maintained at 127°C and 227°C respectively .The curved surface if the rod is losing heat to the surrounding air at 27°C the heat transfer coefficient is 10w/m^2°C. calculate the loss of heat from the rod if it is made of copper (k=335w/m°C.) and steel (k=40w/m˚C)

4. A thermocouple junction is in the form of 8mm diameter sphere. The Properties of the material are c = 420 J/kg˚C , ρ =8000kg/m^3 , K=40w/m˚C. And (h=40w/m˚C) .The junction is initially at 40˚C and inserted in a stream of hot air at 300˚C. Find the time constant of a thermocouple is taken out from the hot air after 10 sec and kept in still air at 30˚C. Assuming heat transfer coefficient in air of 10 W/m˚C. Find the temperature attained by the junction 20 sec after removing from hot air.

5. Drive the general one –dimensional equation of heat conduction in Cartesian coordinates and deduce it to Poisson and laplace Equations.

6. The average heat produced by ripening Oranges is estimated at 300 W/m².Taking the average radius as 0.04 m with k=0.15 W/mK, calculate the temperature at the core when the surface temperature is 10°C.

(ii) Derive the log mean area of a cylinder used to transfer into an equivalent slab.

7. A composite wall is formed of a 2.5 cm copper plate (k = 355 W/mK), a 3.2 mm layer of asbestos (k = 0.110 W/mK) and a 5cm layer of fiber plate (k=0.049 W/mK). The wall is subjected to an overall temperature difference of 560°C (560°C on the Cu plate side and 0°C on the fiber plate side). Estimate the heat flux through this composite wall and the interface temperature between asbestos and fiber plate.

8. When a thermocouple is moved from one medium to anther medium at a different temperature, sufficient time must be given to the thermocouple to come to thermal equilibrium with the new conditions before a reading is taken. Consider a 0.1 cm diameter copper thermocouple wire originally at 150°C. Find the temperature response (i.e.an approximate plot of temperature Vs time for intervals of 0, 40 and 120 seconds) when this wire is suddenly immersed in

(i) water at 40°C (h =80 W/m²K)
(ii) Air at 40°C (h=40 W/m²K)
Assume unit length of wire.

9. Derive the heat conduction equation in cylinder co-ordinates using an elemental volume for a stationary isotropic solid.

10. A 3cm 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.

11. Explain briefly the concept of critical thickness of insulation and state any two applications of the same.

12. A 6 cm long copper rod (k=300 W/mK) 6mm in diameter is exposed to an environment at 20°C.The base temperature of the rod is maintained at 160°C. The heat transfer co-efficient is 20 W/m^{2}K. Calculate the heat given by rod and efficiency and effectiveness of the rod.

13. Drive an expression for steady one dimensional heat conduction through a hollow cylinder.

14. A composite wall is made up of a steel plate 1.5 cm thick lined inside with silica brick 20 Cm thick and on the outside with magnesite brick 20 cm thick . The temperature inside edge of 750 °C and on the outside is 100°C. Find the heat transferred through the wall per square Meter of wall surface and the interface temperatures. The conductivities of silica brick, steel and Magnesite brick are 2.3 x10^{-3} KW/m°C, 0.097 KW/m°C and 5.805 x10^{-3} KW/m°c respectively .It is Required that the heart flow be reduced by 60 % by means of an air gap between steel and Magnesite brick. Estimate the width of the air gap be if the thermal conductivity of the air is 4.64 x10^{-6}kW/m°C.

15. 15. An aluminum rod 25 mm in diameter and 150 mm long protrudes from a wall which is maintained at 260°C .The rod is exposed to an environment at 16 °C. The convection heat transfer coefficient is 15 W/m^{2}k. Calculate the heat loss by the rod .Assume the conductivity of the aluminum as 204 W/m°C.

16. A thermocouple bead of 2mm diameter (spherical) of material density 8500 kg/m^3, thermal

Conductivity 20 W/mk and specific heat 0.4 KJ/Kg K, initially at 25 °C is suddenly exposed to gases at 200˚C with coefficient of 300 W/m^{2}k. Calculate the temperature of the bead after 5 seconds.

17. The inner surface at r = a and the outer surface at r =b of a hollow cylinder are maintained at uniform temperatures T1 and T2, respectively. The thermal conductivity k of the solid is constant. Develop an expression for the one-dimensional, steady-state temperature distribution T (r) in the cylinder. Develop an expression for the radial heat flow rate Q through the cylinder of length H Develop an expression for the thermal resistance of a hollow cylinder of length H.

18. A steel rod of diameter D = 2 cm, length L = 25 cm, and thermal conductivity k = 50 W/(m°C) is exposed to ambient air at T∞ = 20°C with a heat transfer coefficient h = 64 W/(m²°C). If one end of the rod is maintained at a temperature of a120°C, calculate the heat loss from the rod.

19. Consider one-dimensional, steady state heat flow along two stainless-steel bars, each of diameter D =2 cm, length L = 3 cm and pressed together with a pressure of 10 atm. The surface has roughness of about 90°C. Calculate the heat flow rate along the bars and the temperature drop at the interface.

20. A 5-cm-thick iron plate [k = 60 W/(m°C), Cp = 460 J/(kg°C), ρ = 7850 kg/m³, and α = 1.6 x 10^{-5} m²/s] is initially at T1 = 225°C Suddenly, both surfaces are exposed to an ambient at T∞ = 25°C with a heat transfer coefficient h = 500 W/(m²°C). Calculate the centre temperature at t = 2 min after the start of the cooling, the temperature at a depth 1 cm from the surface at t = 2 min after the start of the cooling and the energy removed from the plate per square meter during t his time.

21. A furnace wall consists of three layers. The inner layer of 10 cm thickness is made of fire brick (k = 1.04) W/mK. The intermediate layer of 25 cm thickness is made of masonry brick (k = 0.69 W/mK) 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.

22. 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.

OR

23. An aluminum rod (k = 204 W/mK) 2 cm in diameter and 20 cm 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/m²K. Calculate the heat lost by the rod and the temperature of the rod at a distance of 10 cm from the wall.

24. A large iron plate of 10 cm thickness and originally at 800°C is suddenly exposed to an environment at 0°C where the convection coefficient is 50 W/m²K. 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?

25. Obtain an expression for the general heat conduction equation in Cartesian coordinates.

An exterior wall of a house is covered by a 0.1 m layer of gypsum plaster (k = 0.48 W/m°C) should be added to reduce the heat loss of gain through the wall by 80%?

26. 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/m ◦C and h = 12 W/m2 C for the material of the fin and the temperature at tip of the fin if the atmosphere temperature 20°C.

27. 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/m^2K. Calculate the critical radius of insulation and also determine the temperature of the wire if it is insulated to the critical thickness of insulation.

28. A cylinder 1 m long and 5 cm in diameter is placed in an atmosphere at 45°C. It is provided with 10 longitudinal straight fins of material having k= 120 W/m2K. The height of 0.76 mm thick fins is 1.27 cm from the cylinder surface. The heat transfer coefficient between cylinder and atmosphere air is $17W/m^2K$. Calculate the rate of heat transfer and the temperature at the end of fins if surface temp of cylinder is 150°C

29. A steel tube with 5 cm ID, 7.6 cm OD and k = 15 W/mC is covered with an insulating covering of thickness 2 cm and k = 0.2W/mC. A hot gas at 330º C with h = $400W/m^2C$ flows inside the tube. The outer surface of the insulation is exposed to cooler air at 30º C with h = 60 W/m^2C. Calculate the heat loss from the tube to the air flow for 10 m of the tube and the temperature drops resulting form the thermal resistances of the hot gas flow, the steel tube, the insulation layer and the outside air.

30. The inner surface at r = a and the outer surface at r = b of a hollow cylinder are maintained at uniform temperature T1 and T2 respectively. The thermal conductivity of the solid is constant. Develop an expression for the one dimensional steady state temperature distribution in the cylinder and for the radial heat flow rate through the cylinder over a length H.

31. What is lumped capacity analysis and obtain the expression for temperature distribution of the same.

32. A slap of Aluminum 10 cm thick is originally at a temperature of 500 C. It is suddenly immersed in a liquid at 100° C resulting in a heat transfer coefficient of 1200 W/m^2K. Determine the temperature at the centerline and the total thermal energy removed per unit area of the slap during this period. The properties of Aluminum for the given condition are: $\alpha = 8.4 \times 10^{-5} m^2/s$, k = 215W/mK, $\rho = 2700\ kg/m^3$, c = 0.9 KJ/kgK.

33. Explain the different modes of heat transfer with appropriate expressions?

34. A composite wall consists of 10 cm thick layer of building brick, k=0.7 W/mK and 3cm thick plaster, k=0.5 W/mK is to be added to reduce the heat transfer through the wall by 40%. Find its thickness?

35. Circumferential aluminum fins of rectangular profile (1.5 cm wide and 1 mm thick) are fitted on 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. Estimate the heat dissipated from the finned and the unfinned surface areas of cylinder body

36. A copper wire of 40 mm diameter carries 250 A and has a resistance of $0.25 \times 10^{-4}\ \Omega$ cm/ length surface temperature of copper wire is 250°C and the ambient air temperature is 10°C. If the thermal conductivity of the copper wire is 175 W/mK, calculate

1. Heat transfer co-efficient between wire surface and ambient air.
2. Maximum temperature in the wire.

37. A hollow cylinder of 5 cm ID and 10 cm OD has an inner surface temperature of 200º C and an outer surface temperature of 100º C. If the thermal conductivity of the cylinder material is 70 W/mK. Determine the heat flow through the cylinder per unit length.

38. The wall of an oven consists of 3 layers of brick. Inside one is built of 20 cm of fire bricks surrounded by 10 cm of insulating brick and outside layer is binding bricks of 12 cm thick. The oven operates at 900º C, such that the outside surface of the oven is maintained at 60º C. Calculate

(i). The heat loss per m^2 in surface

(ii). The interfacial temperature.

Given the thermal conductivity of fire brick, insulating brick and binding are 1.2, 0.26 and 0.68 respectively in W/mº C.

39. What is meant by lumped capacity? What are the physical assumptions necessary for a lumped capacity unsteady state analysis to apply?

40. A slab of Aluminum 5cm thick initially at 200ºC is suddenly immersed in a liquid at 70ºC for which the convection heat transfer co-efficient is 525 W/m^2K. Determine the temperature at a depth of 12.5 mm from one of the faces 1 minute after the immersion. Also calculate the energy removed per unit area from the plate during 1 minute of immersion. Where P =2700 bar, Cp=0.9 kJ/kgK, k=215 W/mK, α (alpha)=$8.4X10^{-5}$ m^2/s

UNIT II CONVECTION

1. State Buckingham’s π theorem.
2. Define Prandtl and grashof no.
3. Mention the importance of Biot number.
4. Biot number is the ratio between ___________________and_____________________.
5. Define bulk temperature.
6. A vertical flat is maintained at a temperature lower than the surrounding fluid. Draw the velocity and temperature profiles assuming natural convection.
7. What is the significance of Dimensional number?
8. What is velocity and thermal boundary layer?
9. Define Nusselt and Prandtl number.
10. An electrically heated plate dissipates heat by convection at a rate of 8000 W/m² into the ambient air at 25°C. If the surface of the hot plate is at 125°C, calculate the heat transfer coefficient for convection between the plate and air.
11. Define Reynolds number and Prandtl number.
12. What do you understand by free and forced convection?
13. Define Reynolds number and Grashof number.
14. What is the importance of boundary layer?
15. Mention the difference between free and forced convection?
16. What is the ratio of the hydrodynamic boundary layer to thermal boundary layer in the case of laminar flow over a plate?
17. Explain why the temperature boundary layer grows much more rapidly than the velocity boundary in liquid metals.

PART - B

1. Air at 20º C and at a pressure of 1 bar is flowing over a flat plate at a velocity of 3 m/sec. if the plate is 280 mm wide and 56 º C calculate the following at x =280 mm

I. boundary layer thickness
II. Local friction coefficient
III. Average friction coefficient
IV. Thickness of the thermal boundary layer
V. Local connective heat transfer coefficient
VI. Average connective heat transfer coefficient
VII. Rate of heat transfer by convection
VIII. Total drag force on the plate

2. A cylindrical body of 300 mm diameter and 1.6 m height is maintained at constant temperature of 36.5º C. the surrounding temperature is 13.5º C. find the amount heat generated by the body /hour if C_p=0.96KJ/kg˚c, ρ =1.025kg/m^3 , k=0.0892W/m˚c, υ=15.06 x 10^{-}6m^2/sec and β=1/298k^{-1}. Assume Nu=0.12(Gr.Pr)$^{1/3}$.

3. A nuclear reactor with its core constructed of parallel vertical plates 2.2 m height and 1.4 m wide has been designed on free convection heating of liquid bismuth. The max temperature of the plate surface is limited to 960º C while the lowest allowable temperature of bismuth is 340º C. Calculate the max possible heat dissipation from both sides of each plate. The properties of the bismuth at room temperature c_p = 150.7kg/kg˚c,
ρ =1000kg/m^3,k=13.02W/m°c,μ=3.12 x 10^{-6}kg/m h. assume Nu=0.12(Gr.Pr)$^{1/3}$

4. Assuming that a man can be represented as a cylinder of 0.30 m radius and height 1.7 m with a surface temperature of 30º C. Calculate the heat he would lose while standing in a 36 km/hour wind at 10º C.

5. Air stream of 30°C moves with a velocity of 0.3 m/s across a 100 W electric bulb at 130° C. If the bulb is approximated by a 0.06 m diameter sphere, estimate the rate and the percentage lost due to convection alone.

6. Air at 8 KN/m² and 242° C flows over a flat plate of 0.3 m wide and 1 m long at a velocity of 8 m/s. If the plate is maintained at a temperature of 78°C, estimate the heat to be removed continuously from the plate.

7. A 0,30 m long glass plate at 77° C is hung vertically in air at 27° C. Calculate the boundary layer thickness at the trailing edge and the average Nusselt number of the plate.

8. Air at 400 K and 1 atm. pressure flows at a speed of 1.5 m/s over a flat plate of 2 m long. The plate is maintained at a uniform temperature of 300 K. If the plate has a width of 0.5 m. Estimate the heat transfer coefficient and the rate of heat transfer from the air stream to the plate. Also estimate the drag force acting on the plate.

9. Cylindrical cans of 150 mm length and 65 mm diameter are to be cooled from an initial temperature of 20°C by placing them in a cooler containing air at a temperature of 1°C and a pressure of 1 bar. Determine the cooling rates when the cans are kept

(I) Horizontal position
(II)Vertical position

10. Explain for fluid flow along a flat plate:

(1) Velocity distribution in hydrodynamic boundary layer.
(2) Temperature distribution in thermal boundary line.
(3) Variation of local heat transfer co-efficient along the flow.

11. The water is heated in a tank by dipping a plate of 20cm X 40cm 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.

14. 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.

15. A large vertical plate 5 m high is maintained at 100°C and exposed to air at 30°C. Calculate the convection heat transfer coefficient.

16. Sketch the boundary layer development of a flow over a flat plate and explain the significance of the boundary layer.

17. Atmospheric air 275 K and a free stream velocity of 20 m/s flows over a flat plate 1.5 m long that is maintained at a uniform temperature of 325 K. Calculate the average heat transfer coefficient over the region where the boundary layer is laminar, the average heat transfer coefficient over the entire length of the plate and the total heat transfer rate from the plate to the air over the length 1.5 m and width 1 m. Assume transition occurs at Re $= 2 \times 10^5$.

18. A flat plate, 1 m wide and 1.5 m long is to be maintained at 90°C in air with a free stream temperature of 10°C. Determine the velocity with which air must flow over flat plate along 1.5 m side so that the rate of energy dissipation from the plate is 3.75 KW. Take the following properties of air at 50°C.

$\rho=1.09 kg/m^3$, $\mu = 2.03 \times 10^{-5}$ kg/m-S, Pr = 0.7
K=0.028 W/m°C, Cp =1.007 KJ/kg°C.

19. A hot plate 1.2 m wide, 0.35 m high and at 115°C is exposed to the ambient still air at 25°C. Calculate the following;

1. Maximum velocity at 180 mm from the leading edge of the plate.
2. The boundary layer thickness at 180 mm from the leading edge of the plate.
3. Local heat transfer coefficient at 180 mm from the leading edge of the plate.
4. Average heat transfer coefficient over the surface of the plate.
5. Total mass flow through the boundary.
6. Heat loss from the plate.
7. Rise in temperature of the air passing through the boundary.
8. Use the approximate solution.

20. 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. If pipe surface temperature reduces to 80°C with 1.5 cm insulation, what is the reduction in heat loss?

21. A steam pipe 20 cm outside diameter runs horizontally in a room at 23º C. Take the outside surface temperature of pipe as 165º C. Determine the heat loss per meter length of the pipe.

22. A sphere of diameter 25 mm at 200º C is immersed in air at 40º C. Calculate the convective heat loss.

UNIT III PHASE CHANGE HEAT TRANSFER AND HEAT EXCHANGERS

1. Differentiate between pool and flow boiling.
2. What do you understand by fouling and heat exchanger effectiveness?
3. Write an equation for Fouling Resistance.
4. Write a note on LMTD correction factor?
5. What is burnout point? Why is it called so?
6. What is a compact heat exchanger? Give examples.
7. What is Condensation process?
8. What is Fouling Factor?
9. Draw the temperature variation in parallel flow and counter flow heat exchangers.
10. State the difference between film wise and drop wise condensation.
11. Draw the film growth, velocity and temperature profiles when laminar film condensation takes place on a vertical plate.
12. Why fouling factors are considered in the design of heat exchangers?
13. Write the force balance equation on a volume element for film wise condensation on a vertical plane surface.
14. What are parallel flow and counter flow heat exchanger?
15. Sketch the temperature variations in parallel flow and counter flow heat exchangers?
16. What is pool boiling?
17. What are the modes of heat transfer present in steam generator?
18. Define log-mean temperature difference.
19. What are the parameters affecting the fouling?

PART - B

1. Water at atmospheric pressure is to be boiled in polished copper pan the dia of the pan 350 mm and is kept at 115ºC. Calculate the power of the burner, rate of the evaporation in kg/h and the critical heat flux.

2. A vertical cooling fin approximating a flat plate 40 cm in height is exposed to saturated steam at atmospheric pressure. The fin is maintained at a temperature of 90ºC. Estimate the thickness of the film at the bottom of the fin, overall heat transfer coefficient and heat transfer rate after incorporating Mc Adam's correction.

3. Explain how heat exchangers are classified.

4. A counter flow double pipe heat exchanger using superheated steam is used to heat water at the rate of 10500 kg/h. The steam enters the heat exchanger at 180ºC and leaves at 130ºC. The inlet and exit temperatures of water are 30ºC and 80ºC respectively. If U=814 $W/m^2 {}^\circ C$. Calculate the heat transfer area. What would be the increase in area if the fluid flows were parallel?

5. Derive the heat transfer equation of a parallel flow heat exchanger stating the assumptions.

6. Saturated Stream at 120ºC condenses on the outer tube surface of a single pass heat exchanger. Determine the surface area to heat 1000 kg/hour of water from 20ºC to 90ºC. Find the mass of the Condensate Take heat transfer Coefficient $U_0 = 1800$ W/m^2 and $h_{fg} = 2200$ KJ/kg.

7. Water is heated from 20ºC to 50ºC by condensing steam at 120ºC. If the inlet temperature of water falls to 15ºC with flow remaining constant, what will be the new outlet temperature?

8. Water is to be boiled at atmospheric in a mechanically polished stainless steel pan placed on top of a heating unit. The inner surface of the bottom of the pan is maintained at 108ºC. The diameter of the bottom of the pan is 30 cm. Assuming $C_{sf} = 0.0130$. Calculate

(I) The rate of heat transfer to the water, and
(II) The rate of evaporation of water.

9. Define effectiveness of a heat exchanger. Derive an expression for the effectiveness of a double pipe parallel flow heat exchanger. State the assumptions made.

10. With a neat and labeled sketch explain the various regimes in boiling heat transfer.

11. A vertical plate 0.5 m^2 in area at temperature of 92°C is exposed to steam at atmospheric pressure. If the steam is dry and saturated estimate the heat transfer rate and condensate mass per hour. The vertical length of the plate is 0.5 m. Properties of water at film temperatures of 96°C can be obtained from tables.

12. Compare LMTD and NTU method of heat exchanger analysis.

13. Hot exhaust gases which enters 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 has specific heat is approximately 1000 J/kgK, and the overall heat transfer co-efficient based on gas side surface area is U_h=100W/m^2K. Determine the required gas side surface area At the NTU method. Take C_p, c at Tc = 80°C is 4197 kJ/kgK and Cph =1000 J/kg.K.

14. Explain briefly the various regimes of pool boiling.

15. Dry saturated steam at 100°C condenses on a surface at 96°C, The surface is a vertical tube of height 1 m. Determine the film thickness and local heat transfer coefficient at a distance of 0.3 m form the top.

16. What is mean by fouling factor? Discuss the salient features of the correction factor?

17. A single shell pass, four tube pass heat exchanger is used to cool lubricating oil from 70°C to 45°C at a rate of 15 kg/sec. water at 25°C is used at flow rate of 15 kg /sec .Determine the area required if the overall heat transfer coefficient has a value of 150 W/m^2 K. The oil has a specific heat of 2.3 KJ/kg°C .

18. It is desired to boil water at atmospheric pressure on a copper surface to the water, if the surface is maintained at 110°C and also the peak heat flux.

19. A tube of 2 m length and 25 mm OD is be used to condense saturated steam at 100°C while the tube surface is maintained at 92°C. Estimate the average heat transfer coefficient and the rate of condensation of steam if the tube is kept horizontal. The steam condenses on the outside of the tube.

20. Give the classification of heat exchangers.

21. It is desired to use a double pipe counter flow heat exchanger to cool 3 kg/s of oil (C_p = 2.1 KJ/kgK) from 120°C. Cooling water at 20°C enters the heat exchanger at a rate of 10 kg/s. The overall heat transfer coefficient of the heat exchanger is 600 W/m^2K and the heat transfer area is 6 m^2. Calculate the exit temperatures of oil and water.

22. Describe the principle of parallel flow and counter flow heat exchangers showing the axial temperature distribution.

23. In a counter flow double pipe heat exchanger water is heated from 25ºC to 60ºC by an oil with a specific heat of 1.45 KJ/kg K and If the overall heat transfer coefficient is 420 $W/m^2{\circ}C$, calculate (1) the rate of heat transfer, (2) the mass flow rate of water and (3) the surface area of the heat exchanger.

24. Dry saturated steam at a pressure of 2.45 bar condenses on surface of a vertical tube of height 1 m. The tube surface temperature is kept at 117ºC. Estimate the thickness of the condensate film.

25. A counter flow concentric tube heat exchanger is used to cool engine oil (c = 2130 J/kg K) from 160ºC to 60ºC with water available at 25ºC as the cooling medium. The flow rate of cooling water through the inner tube of 0.5 m is 2 kg/s while the flow rate of oil through the outer annulus OD = 0.7 m is also 2 kg/s. If h is 250 W/m^2K, how long must the heat exchanger be to meet its cooling requirement?

26. Discuss the various regimes of pool boiling heat transfer.

27. 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.

28. A parallel flow heat exchanger has hot and cold water stream running through it, the flow rates are 10 and 25 kg/min respectively. Inlet temperatures are 75°C and 25°C on hot and cold sides. The exit temperature on the hot side should not exceed 50°C. Assume $h_i = h_o$ = 600 W/ m^2 K. Calculate the area of heat exchanger using ε – NTU approach.

29. An aluminum pan of 15 cm diameter is used to boil water and the water depth at the time of boiling is 2.5 cm. The pan is placed on an electric stove and the heating element raises the

temperature of the pan to 110°C, Calculate the power input for boiling and the rate of evaporation. Take. $C_{sf} = 0.0132$.

30. It is desired to boil water at atmospheric pressure on a copper surface which is electrically heated. Estimate the heat flux from the surface to the water, if the surface is maintained at 110°C and also the peak heat flux.

33. In a double pipe counter flow heat exchanger 10000 kg/h of an oil having a specific heat of 2095 J/kg K is cooled from 80°C to 50°C by 8000 kg/h of water entering at 25°C. Determine the heat exchanger area for an overall heat transfer coefficient of 300 W/m^2K.Take C_p for water as 4180 J/kg K

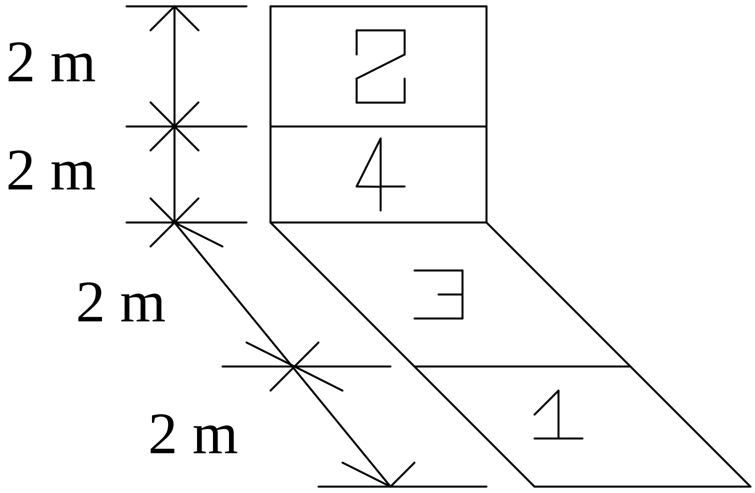
32.Dry saturated steam at a pressure of 2.45 bars condenses on the surface of a vertical tube of height 1 m. The tube surface temperature is kept at 117 ºC. Find the thickness of the condensate film and the local heat transfer coefficient at a distance of 0.2 m from the upper end of the tube.

33. It is desired to use a shell and tube heat exchanger to heat 68 kg/min of water from 35 ºC to 75 ºC by using oil having a specific heat of 1.9 KJ/kgK. The oil enters at a temperature of 110 ºC and flows at the rate of 170 kg/min. The water makes shell pass and the oil makes two tube passes. Calculate the area required for the heat exchanger assuming the overall heat transfer coefficient to be 300 W/m^2K and specific heat of water to be 4.18 KJ/kgK.

UNIT IV RADIATION

1. Assuming sun to be a blackbody emitting radiation with max intensity at lambda=0.49 µ m, calculate the surface temperature of the sun.
2. What is irradiation and radiosity?
3. What is thermal radiation and what is its wavelength band?
4. What are radiation shields?
5. Explain electric analogy?
6. What is grey body?
7. What must be the color of an umbrella to reduce the absorption of Solar Radiation? Why?
8. State Kirchhoff's Law of Radiation.
9. State and prove the Kirchhoff's law of radiation?
10. State how the radiation from gases is different from the radiation from surfaces.
11. Define total emissive power and Radiosity.
12. Mention the physical significance of view factor.
13. What do you understand by a gray body and blackbody?
14. State Wien's displacement law and Kirchhoff's law?
15. What do you understand by Specular and diffuse reflection?
16. Mention the physical significance of view factor.
17. What do you understand by a gray body and blackbody?
18. Define emissivity.
19. State Stefan Boltzmann law and planks law. How they are related? What is radiation shield?
20. Write a note on black body and grey body.
21. What is a radiation shield?
22. Define emissivity.

1. Find the shape factor F_{1-2} and F_{2-1} for the figure shown below.



2. Discuss how the radiation from gases differs from that of solids.

3. Two very large parallel plates with emissivity 0.5 exchange heat. Determine the percentage reduction in the heat transfer rate if a polished aluminium radiation shield of $\epsilon = 0.04$ is placed in between the plates.

4. Calculate the following for an industrial furnace in the form of a blackbody and emitting radiation at 2500˚C:

   I. Monochromatic emissive power at 1.2μm length.
   II. Wavelength at which is the emission is max
   III. Max emissive power
   IV. Total emissive power
   V. Total emissive power of the furnace if it is assumed as a real surface with emissivity equal to 0.9.

5. Define the following:

   I. black body
   II. Grey body
   III. Opaque body
   IV. White body
   V. Specular reflection
   VI. Diffuse reflection.

6. In the figure (1) the areas A_1 and A_2 are perpendicular but do not share the common edge. Find the shape factor f_{1-2} for the arrangement.

7. Determine the radiant heat exchange in W/m^2 between two large parallel steel plates of emissivity 0.8 and 0.5 held at temperatures of 1000 K and 500 K respectively, if a thin copper plate of emissivity is introduced as a radiation shield between the two plates

8. Discuss briefly the variation of black emissive power with wavelength for different temperatures.

   (II) The spectral emissivity function of an opaque surface at 800 K is approximated as
   Calculate the average emissivity of the surface and its emissive power

9. Explain briefly the following:

   (I) Specular and diffuse reflection

(II) Reflectivity and transmissivity
(III) Reciprocity rule and summation rule.

10. State and prove
1) Kirchhoff's law of radiation
2) Stefan-Boltzmann law

11. Show from energy balance consideration that the radiation heat transfer from a plane composite surface area A_4 and made up of plane surface areas A_2 and A_3 to a plane surface area A_1 is given by:
$A_4F_{41} = A_3F_{31} + A_2F_{21}$ and
$F_{14} = F_{12} + F_{13}$

12. Using the definition of radiosity and irradiation that the radiation heat exchange between two grey bodies is given by the relation:

$$Q_{net} = \frac{\sigma\left(T_1^4 - T_2^4\right)}{\left(\frac{1-\varepsilon_1}{A_1\varepsilon_1}\right) - \left(\frac{1}{A_1F_{12}}\right) + \left(\frac{1-\varepsilon_2}{A_2\varepsilon_2}\right)}$$

13. A surface at 100K with emissivity of 0.10 is protected from a radiation flux of 1250 W/m^2 by a shield with emissivity of 0.05. Determine the percentage cut off and the shield temperature shape factor as 1.

14. Derive the Equivalent Emissivity of a two large parallel gray planes.

15. The intensity of radiations emitted by the sun is maximum at a wave length of 0.5 µ. As a black body, determine its surface temperature and the emissive power.

16. Deduce the generalized equation for heat transfer of a system of two parallel plates separated by "n" screens.

17. Emissivity of two large parallel at 800˚C and 300˚C are 0.3 and 0.5 respectively. Find the net energy transfer rate per square meter.

18. Explain radiation shape factor and the important laws associated with the shape factor

19. Tow very large parallel planes with emissivities of 0.3 and 0.8 exchange heat by radiation. Find the percentage reduction in heat transfer when a polished aluminium radiation shield of Emissivity 0.04 is interposed between them.

20. Derive the expression for the radiation heat exchanger between two real surfaces, using the definition of irradiation and radiosity.

21. Two long coaxial cylinders of 0.3 m and 0.4 m diameter are at 600˚C and 400˚C. The surface emissivities for both are 0.6. The inner cylinder is hotter one. Determine the heat exchanger by radiation per unit length.

22. Define emissivity, absorptivity and reflectivity.
23. Describe the phenomenon of radiation from real surfaces
24. What are radiation view factors and why are they used?
25. Determine the view factor (F_{14}) for the figure shown below.

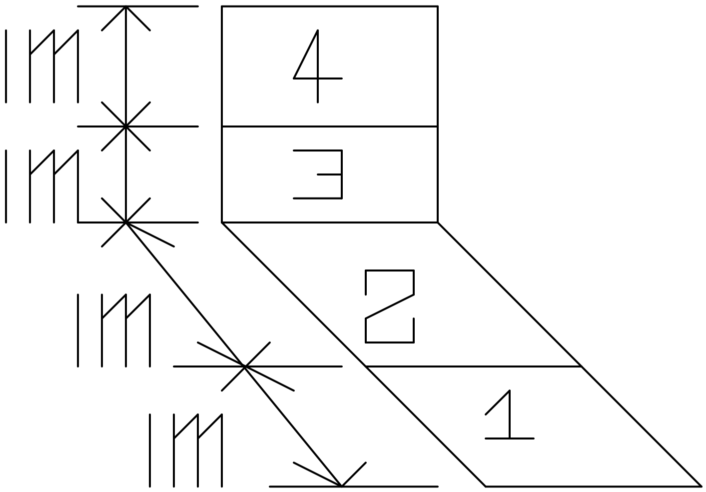


Fig - 2

26. Two square plates, each 1 m by 1 m, are parallel to and directly opposite to each other at a distance 1 m, The hot plate is at T_1 = 800 K and has a emissivity ε_1 = 0.8. The colder plate is at T_2 = 600 K and also has an emissivity ε_2= 0.8. The radiation heat exchange takes place between the plates as well as with a large ambient at T_3 = 300 K through the opening between the plates. Calculate the net heat transfer rate by radiation at each plate to the ambient.

27. Two parallel plates are temperatures T_1 and T_2 and have emissivity's ε_1 = 0.8 and ε_2 = 0.5. A radiation shield having the same emissivity ε_3 of the shield in order to reduce the radiation loss from the system to one-tenth of that without the shield. Distinguish between solid and gas radiation.

28. Discuss how radiation from gases differs from that of solids.

29. Distinguish between a black and gray body and Specular and diffuse surfaces.

30. Describe the phenomenon of radiation from real surfaces.

31. Calculate the shape factor F_{14} for the figure shown below: **Fig -2**

32. Explain how the radiation from solids differs from that of the gases.

33. Write short notes on Gaseous emission and absorption.

34. Calculate the net radiant heat exchange per m² area for two large parallel plates at temperatures of 427°C and 27°C respectively. ε (hot plate) = 0.9 and ε (cold plate)=0.6. If a polished aluminium shield is placed, between them, find the percentage reduction in the heat transfer and temperature of the shield, ε (shield) =0.4.

34. Two very large parallel plates with emissivity 0.5 exchange heat. Determine the percentage reduction in the heat transfer rate if a polished aluminum radiation shield of ε = 0.04 is placed in between the plates.

35. A 40 mm diameter spherical container used for storing liquid nitrogen under atmospheric conditions (boiling point = 90 K) is insulated by enclosing it concentrically within another sphere of 0.75 m diameter. The intervening annular space between the spheres is completely evacuated and the material for both spheres has surface emissivity of 0.4. Make calculation for the radiant heat flow of the temperature if the outer container is 400 K.

36. What will be the reduction in heat loss if a steel screen having an emissivity value of 0.6 on both sides is placed between the brick and steel setting? Also calculate the desired emissivity of the screen if radiation heat loss is 200 W/m^2.

UNIT V MASS TRANSFER

1. How mass transfer takes place through convection and diffusion?
2. What do you mean by equimolar counter diffusion?
3. Explain the physical meaning of Schmidt number.
4. Define Fourier number for Mass Transfer.
5. Explain Mass Transfer Co-efficient.
6. Define Ficks law of Diffusion.
7. Define mass Average Velocity.
8. Sate Fick's law of diffusion, and indicate its limitations?
9. What are the mechanisms of mass transfer by diffusion and convection?
10. A vessel contains a binary mixture of O_2 and N_2 with partial pressures in the ratio 0.21 and 0.79 at 15°C. The total pressure of the mixture is 1.1 bars. Calculate the mass densities of O_2 and N_2.

11. Define molar concentration and mass fraction?
12. State Fick's law of diffusion and give its expression?
13. Define mole fraction and mass concentration.
14. Describe the two mechanisms of mass transfer.
15. Define mass fraction and molar concentration.
16. Give two examples of convective mass transfer?
17. What is Sherwood number?
18. State Fick's law of diffusion.
19. Give examples of mass transfer.

PART - B

1. State Fick's law of diffusion and give its expression. Obtain an expression for the same in terms of partial pressure.

2. Derive the general mass transfer equation in Cartesian co-ordinates.

3. A vessel contains binary mixture of O_2 and N_2 with partial pressures in the ratio 0.21and 0.79 at 15°C. The total pressure of the mixture is 1.1 bars. Calculate the following

I. 1molar concentration

II. Mass density

III. Mass fraction

IV. Molar fraction of each species.

4. Air at 20˚C with D = 4.166 x $10^{-5} m^2/s$ flows over a tray (length = 320mm, width = 420mm) Full of water with velocity of 2.8 m/s. The total pressure of moving air is 1 atm and the partial pressure of water in present in the air is 0.0068 bar. If the temperature on the water surfaces is 15˚C, calculate the evaporation rate of water.

5. Discuss briefly the following:
(I) Fick's law of diffusion
(II) Equimolar counter diffusion
(III) Evaporation process in the atmosphere

6. What are the assumptions made in the 1 –D transient mass diffusion problems?

7. An open pan, 20 cm diameter end 8 cm deep contains water at 25°C and is exposed to dry atmospheric air. Estimate the diffusion coefficient of water in air, if the rate of diffusion of water is 8.54X10^{-4} kg / h.

8. Explain Fick's first and second laws of diffusion.

9. Explain the phenomenon of equimolar counter diffusion. Derive an expression for equimolar counter diffusion b/w two gases or liquids.

10. Define the Schmidt, Sherwood and Lewis numbers. What is the physical significance of each?

11. Dry air at 27°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 co-efficient of water vapour in air is
DAB = 0.26 X 10^{-4} m^2/s.

12. Compare diffusion and convective mass transfer.

13. Dry air at 27°C and 1 bar flows over a wet plate 0.5 m long at a velocity of 50 m/s. Calculate the mass transfer coefficient of water vapour in air at the end of the plate.

14. The mole fraction of H_2 and O_2 is 0.4. If H_2 moves with a velocity of 1 m/s and O_2 is stationary, find the mass and molar average velocities, mass and molar fluxes across the stationary surface.

15. Estimate the Diffusion rate of water at 27°C from the bottom of a test tube of 0.02 m diameter and 0.04 m long into dry air at 27°C. Take diffusion coefficient of water in air as $0.26X10^{-4}$ m²/s

16. Define the diffusion coefficient and also specify the similarities between convection heat and mass transfer.

17. Determine the mass of water vapour diffusing through a column of height 10m , if the total pressure is 1 atm and the partial pressure of water vapour at the bottom is 0.1 atm
And at the top is 0.03 atm. The diffusion coefficient is $0.26*10^{-4}$ m^2/sec. Consider unit area.

18. Derive an expression for isothermal equimolal counter diffusion mass transfer

19. Air at 25°C and at atmospheric pressure flows with a velocity of 3 m/sec inside a 10mm diameter tube of 1 meter length. The inside surface of tube contains deposits of naphthalene. Determine the average mass transfer coefficient. (Assume the diffusion coefficient for naphthalene-air as 0.62×10^{-5} m^2/sec)

19. Consider two large vessels, each containing uniform mixtures of nitrogen and carbon dioxide at 1 atm, T = 288.9K, concentrations. Vessel 1 contains 90 mole percent N_2 and percent CO_2, whereas vessel 2 contains 20 mole percent N_2 and 80 mole percent CO_2. The two vessels are connected by a duct of d = O.1524 m inside diameter and L = 1.22 m long. Assuming that steady-state transfer takes place in view of the large capacity of the two reservoirs. The mass diffusivity for the $N_2 – CO_2$ mixture at 1 atm and 288.9 K can be taken as D = $0.16 x10^{-4}$ m ²/s.

20. Atmospheric air at T_w = 40°C flows over a wet bulb thermometer. The reading of the thermometer, which is called the web-bulb reading T_∞ = 20°C. Calculate the concentration of water vapor C_w in the free stream. Also determine the humidity of the air stream (i.e., the ratio of the concentration C_w of water vapor free stream to the saturation concentration at the free-stream temperature T_∞ = 40 °C obtained from the stream table).

21. Atmospheric air at 40°C flows over a wet bulb thermometer and it shows 25°C. Calculate the concentration of water vapour in the free stream and also its relative humidity. Take D (air water) = 0.256×10^{-4} m². If temperatures of dry and wet bulb are 30°C and 25°C respectively, what would be the corresponding values?

22. The molecular weights of the two components A and B of a gas mixture are 24 and 28 respectively. The molecular weight of gas mixture is found to be 30. If the mass concentration of the mixture is 1.2 kg/m3, determine (1) molar fractions, (2) mass fractions and (3) total pressure if the temperature of the mixture is 290 K.

23. An open pan 20 cm in diameter and 8 cm deep contains water at 25°C and is exposed to dry atmospheric air .If the rate of diffusion of water vapour is 8.54×10^{-4} kg/h estimate the diffusion coefficient of water in air.

24. A mixture of O_2 and N_2 with their partial pressures in the ratio 0.21 to 0.79 is in a container at 25°C. Calculate the molar concentration, the mass density, the mole fraction and the mass fraction of each species for a total pressure of 1 bar. What would be the average molecular weight of the mixture?

25. Discuss the analogy between heat and mass transfer?

26. Define mass concentration, molar concentration, mass fraction and mole fraction.

27. The diffusivity of CCl_4 in air is determined by observing the steady state evaporation of CCl_4 in a tube of 1 cm diameter exposed to air. The CCl_4 liquid level is 10 cm below the top level of the tube. The system is held at 25°C and 1 bar pressure. The saturation pressure of CCl_4 at 25 °C is 14.76 kPa. If it observed that the rate of evaporation of CCl4 is 0.1 g/hour determine the diffusivity of CCl_4 into air.

28. The molecular weights of the two components A and B of a gas mixture are 24 and 28 respectively. The molecular weight of gas mixture is found to be 30. If the mass concentration of the mixture is 1.2 kgm^3, determine the following;
(i) Density of component A and B.
(ii) Molar fractions.
(iii) Mass fractions, and
(iv) Total pressure if the temperature of the mixture is 290 K.

29. Explain briefly three modes of mass transfer.

30. Air at 1 atm and 25°C, containing small quantities of iodine, flows with a velocity of 6.2 m/s inside a 35 mm diameter tube. Calculate mass transfer coefficient for iodine. The thermo physical properties of air are; $v=15.5x10^{-6}$ m^2/S, $D=0.82x10^{-5} m^2/S$.

31. Determine the diffusion co-efficient of carbon tetrachloride into air if it evaporates at a rate of 0.012 gm/hr from a tube of 2 cm diameter and length 45 cm. It evaporates at a temperature of 0 º C into dry air at a pressure of 760 mm of Hg. The vapour pressure of carbon tetrachloride at 0 º C is 33 mm of Hg.

32. In a gas mixture consisting of H_2 and O_2, H_2 moves with velocity of 1 m/s and its mole fraction is 0.2. Calculate
(i). The mass and molar average velocities.
(ii). The mass and molar fluxes across a plane which is
    (1). Stationary
    (2). Moving with mass-average velocity
    (3). Moving with molar average velocity.