**VALLIAMMAI ENGINEERING COLLEGE**
**DEPARTMENT OF MECHANICAL ENGINEERING**
**ME-6502 HEAT AND MASS TRANSFER**
**QUESTION BANK**

## UNIT –I

### PART – A

1. What is Fourier's Law of heat conduction?
2. What is temperature gradient?
3. What is coefficient of Thermal conductivity?
4. Give some examples of heat transfer in engineering.
6. Define Temperature field.
7. Define heat flux.
8. Define thermal Diffusivity.
9. What is Lap lace equation for heat flow?
10. What is Poisson's equation for heat flow?
11. What critical radius of insulation;
12. Give examples for initial'&; boundary conditions.
13. What is a Fin?
14. Define efficiency of the fin.
15. Define effectiveness of the fin.
16. Give examples of use of fins in various engineering applications.
17. What is meant by Transient heat conduction?
18. Give governing differential equation for the one dimensional transient heat flow.
19. What is Biot number?
20. What is Newtonian heating or cooling process?
21. Give examples for Transient heat transfer.
22. What is meant by thermal resistance?
23. What is meant by periodic heat transfer?
24. What are Heisler chart?
25. What is the function of insulating materials?

### PART – B

1. A pipe consists of 100 mm internal diameter and 8mm thickness carries steam at 170°C. The convective heat transfer coefficient on the inner surface of pipe is 75 W/m2C. 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/m2C. 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.

2. 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 is25mmOD 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.

3. (i) A furnace wall consists of three layers. The inner layer of 10 cm thickness is made of firebrick (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/mK). 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. (8)
(ii) 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. (8)

4. (i) An aluminium 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 $W/m^2K$. Calculate the heat lost by the rod and the temperature of the rod at a distance of 10 cm from the wall. (7)
(ii) 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/m2K. Calculate the temperature at a depth of 4 em 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?

5. (i) Explain the different modes of heat transfer with appropriate expressions. (6)
(ii) A composite wall consists. of 10 cm thick layer of building brick, k = 0.7 W/mK and 3 cm thick plaster, k = 0.5 W/mK. An insulating material of k = 0.08 W/mK is to be added to reduce the heat transfer through the wall by 40%. Find its thickness. (10)

6. Circumferential aluminium fins of rectangular profile (1.5cmwide and 1mm 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 respectively. Take ambient at 30°C and h(average) =100 W/m2K. Estimate the heat dissipated from the finned and the unfinned surface areas of cylinder body. (16)

7. (i) Derive the heat conduction equation in cylindrical co-ordinates using an elemental volume for a stationary isotropic solid. (8)
(ii) 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. (8)

8. (i) Explain briefly the concept of critical thickness of insulation and state any two applications of the same. (8)
(ii) A 6 em 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/m2K. Calculate the heat given by the rod and efficiency and effectiveness of the rod. (8)

9. (i) Define the Biot and Fourier numbers. (4)
(ii) What is meant lumped capacity? What are the physical assumptions necessary for a lumped capacity unsteady state analysis to apply? (4)

(iii)A slab of Aluminium 5 cm thick initially at 200°C is suddenly immersed in a liquid at 70°C for which the convection heat transfer co-efficient is 525 W/m2K. 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. Take P = 2700 bar, $C_p$ = 0.9 kJlkg. OK, k=215W/mK, ά = 8.4X 10-5 m2/s.(8)

10. A composite wall is formed of a 2.5 cm copper plate (k = 355 W/m.K), a 3.2 mm layer of asbestos (k = 0.110 W/m.K) and a 5 cm layer of fibre plate (k = 0.049 W/m.K). The wall is subjected to an overall temperature difference of 560°C (560°C on the Cu plate side and O°C on the fiber plate side). Estimate the heat flux through this composite ~all and the interface temperature between asbestos and fibre plate. (16)

11. A steel tube k=43.26 W/mK of 5.08 cm 10 and 7.62 cm 00 is covered with 2.54 cm of asbestos insulation k=0.208 W/Mk. The inside surface of the tube receives heat by convection from a hotgas at a -temperature of 316°C with heat transfer coefficient ha=284 W/m2K while the outer surface of Insulation is exposed to atmosphere air at 38°C with heat transfer coefficient of 17 $W/m^2K$ Calculate heat loss to atmosphere for 3 m length of the tube and temperature drop across each layer. (16)

12. (i) A plane wall 20 cm thickness generates heat at the rate of 5 x $10^4$ $W/m^3$ when an electric current is passed through it. The convective heat transfer coefficient between each face of the wall and the ambient air is 60 W/m2K. Determine.
    (i) The surface temperature (4)
    (ii) The maximum temperature in the wall. Assume ambient air temperature to be 25°C and the thermal conductivity of the wall material to be 16 W/mK. (4)

    (ii) A steel ball 100 mm diameter was initially at 50~C and is placed in air which is at 35°C. Calculate time required to attain 400°C and 300°C. (8)
    k steel = 35 W/mK c = 0.46 kJ/kgK p = 7800 $kg/m^3$ h = 10 $W/m^2K$

## UNIT –II

### PART – A

1. What is Convective heat transfer?
2. Sketch formation of boundary layer and show laminar, transition & turbulent flow.
3. Write down differential equation for Continuity of fluid flow.
4. State Newton's law of cooling.
5. Differentiate between Natural & Forced convection.
6. State Buckingham's 1t'theorem.
7. What is meant by Dimensional analysis?" ,
8. Sketch boundary layer development in a circular pipe.
9. What is Reynolds analogy?
10. What is Colburn analogy?
11. Define the Bulk temperature.
12. Define velocity boundary layer thickness.
13. Define thermal boundary layer thickness.
14. Distinguish between laminar & turbulent flow.
15. What is meant by critical Reynolds number?
16. Define skin friction coefficient.
17. Give examples for free convection.
18. Define Grashof number.
19. Sketch, temperature and velocity profiles in free convection on a vertical wall.
20. Define momentum thickness.
21. Define Displacement thickness.
22. List the dimensionless numbers.
23. What are the uses of dimensional analysis?
24. Explain the term Dimensional homogeneity.
25. What are the limitations of Dimensional analysis?

### PART – B

1. 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. (16)

2. 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. (6)
   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. (10)
3. Sketch the boundary layer development of a flow over a flat plate and explain the significance of the boundary layer. (6)
   (ii) Atmospheric air at 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 = $2x10^5$ (10)

4. What is Reynold's analogy? Describe the relation between fluid friction and heat transfer? (4)

(ii) Air at 25°C flows over 1 m x 3 m (3 m long) horizontal plate maintained at 200°C at 10 m/s. Calculate the average heat transfer coefficients for both laminar and turbulent regions. Take Re (critical) = $3.5 \times 10^5$ (12)

5. Define Reynold's, Nusselt and Prandtl numbers. (6)
   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. (10)

6. Explain for fluid flow along a flat plate:
   (i) Velocity distribution in hydrodynamic boundary layer
   (ii) Temperature distribution in thermal boundary layer
   (iii) Variation of local heat transfer co-efficient along the flow. (8)

7. 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.

8. Distinguish between free and forced convection giving examples. (4)
   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? (12)

9. 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. (16)

10. 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 in horizontal and vertical positions. (16)

11. A circular disc heater 0.2m in diameter is exposed to ambient air at 25°C. One surface of the disc is insulated at 130°C. Calculate the amount of heat transferred from the disc when it is.
   (i) Horizontal with hot surface facing up (5)
   (ii) Horizontal with hot surface facing down (5) (iii) Vertical (6)

## UNIT - III

### PART A

1. What is a Heat Exchanger?
2. How heat exchangers are classified?
3. Give examples of non mixing type heat exchangers.
4. Sketch temperature distribution graph for condensers & evaporators.
5. What is overall heat transfer coefficient in a heat exchanger?
6. What is LMTD?
7. What is effectiveness of a heat exchanger?
8. Discuss the advantage of NTU method over the LMTD method.
9. What are the assumptions made during LMTD analysis?
10. What are the factors are involved in designing a heat exchangers? . . ~;
11. , In what way Boiling & Condensation differs from other types of heat exchange?
12. What is Excess temperature in boiling?
13. What is meant by sub cooled or local boiling?
14. What is nucleate boiling?
15. Give expression for heat transfer coefficient in Nucleate boiling.
16. What is flow boiling?
17. What is meant by condensation?
18. Draw heat flux curve for various regions of flow boiling.
19. Define Film wise condensation.
20. Define Drop wise condensation.
21. How is the Reynolds number in condensation defined?

### PART B

1. A tube of 2 m length and 25 mm outer diameter is to 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. (16)

2. Steam condenses at atmospheric pressure on the external surface of the tubes of a steam condenser. The tubes are 12 in number and each is 30 mm in diameter and 10 m long. The inlet and outlet temperatures of cooling water flowing inside the tubes are 25°C and 60°C respectively. If the flow rate is 1.1 kg/s, calculate
   (i) The rate of condensation of steam
   (ii) The number of transfer units
   (iii) The effectiveness of the condenser. (16)

3. It is desired to boil water at atmospheric pressure on a copper surface which electrically heated. Estimate the heat flux from the surface to the water, if the surface is maintained at 10°c and also the peak heat flux. (8)
   A tube of 2 m length and 25 mm OD is to 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.
4. Give the classification of heat exchangers. (4)
   It is desired to use a double pipe counter flow heat exchanger to cool 3 kg/s of oil (Cp = 2.1 kJ/kgK) from 120°C. Cooling water at 20°C enters the heat exchanger at a rate of 10 kg/so The overall heat transfer coefficient of the heat exchanger is 600 W/m2Kand the heat transfer area is 6 $m^2$.Calculate the exit temperatures of oil and water. (12)

5. Discuss the general arrangement of parallel flow, counter flow and cross flow heat exchangers.

6. In a Double pipe counter flow heat exchanger 10000 kg/h of an oil having a specific heat of 2095 J/kgK 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/m2K. Take Cp for water as 4180 J/kgK (10)

7. Discuss the various regimes of pool boiling heat transfer. (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 0.2m from the upper end of the tube. (8)

8. With a neat and labeled sketch explain the various regimes in boiling heat transfer. (8)
   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. (8)

9. Compare LMTD and NTU method of heat exchanger analysis. (6)
   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 gas specific heat is approximately 1000 J/kg.K, and the overall heat transfer co-efficient based on the gas side surface area is Uh = 100W/m2K. Determine the required gas side surface area Ah using the NTU method. Take Cp,c at Tc = 80°C is 4197 J/kg.K and Cp,h = 1000 J/kg.K . (10)

10. Water is to be boiled at atmospheric pressure 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 lO8°C. The diameter of the bottom of the pan is 30 cm. Assuming Csf = 0.0130. Calculate (i) the rate of heat transfer to the water and ii) the rate of evaporation of water. (16)

11. Define effectiveness of a heat exchanger. Derive an expression for the effectiveness of a double pipe parallel flow heat exchanger. State the assumptions made. (16)

12. Water enters a cross flow Heat exchanger (both fluids unmixed) at 5°C and flows at the rate of 4600 kg/h to cool 4000 kg/h of air that is initially at 40°C. Assume the overall heat transfer coefficient value to be 150 W/m2K For an exchanger surface area of $25m^2$ Calculate the exit temperature of air and water. (16)

13. Describe the principle of parallel flow and counter flow heat exchangers showing the axial temperature distribution. (8)
    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 hi = ho = 600W/m2K. Calculate the area of heat exchanger using E -NTU approach. (8)

## UNIT- IV

**PART - A**

1. Define Radiation heat transfer.
2. What is Stefan's Bolts Mann law?
3. What is Intensity of radiation?
4. Define Shape factor.
5. What is Radiation Shield?
6. Define Quantum theory.
7. Define Emissive power of a black surface.
8. Define concept of Black body.
9. Define Planck's distribution law.
10. Define Wien's distribution law.
11. Define Emissivity of a surface.
12. What is meant by Kirchhoff's law?
13. Define Irradiation.
14. Define Radiosity.
15. Distinguish between Absorptivity & Transmittivity of radiation.
16. What are the gases, which radiate heat?
17. What is mean beam length in Gas Radiation?
18. What is the equation for radiation between two gray bodies?
19. Distinguish between Reflectivity & Transmittivity.
20. Differentiate Opaque body & perfectly transparent surface.
21. Write down the Wien's formula.
22. Write down the heat transfer equation for Radiant exchange between infinite parallel gray planes.

**PART B**

1. 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. (16)

2. A thin aluminium sheet with an emissivity of 0.1 on both sides is placed between two very large parallel plates that are maintained at uniform temperatures Tl = 800 K and T2 = 500 K and have emissivities £"1 = 0.2 and £"2 = 0.7 respectively. Determine the net rate of radiation heat transfer between the two plates per unit surface area of the plates and compare the result to that without shield. (16)

3. Discuss how the radiation from gases differs from that of solids. (6)
   Two very large parallel plates with emissivities 0.5 exchange heat. Determine the percentage reduction in the heat transfer rate if a polished aluminium radiation shield of c = 0.04 is placed in between the plates. (10)

4. Define emissivity, absorptivity and reflectivity (06)
   Describe the phenomenon of radiation from real surfaces. (10)

5. What are the radiation view factors and why they are used? (04)
   Determine the view factor (F1-4) for the figure shown below. (12)

6. State and prove the following laws: (1) Kirchhoff's law of radiation (2) Stefan - Boltzmann law (8)
   Show-from energy-balance consideration that the radiation heat transfer from a plane composite surface area A4 and made up of plane surface areas A2 and A3 to a plane surface area Al is given by: A4F41=A3F31+A2F21 & F14=F12+F13 (8)

7. Explain briefly the following: (i) Specular and diffuse reflection (5)
   Reflectivity and transmissivity (5)
   Reciprocity rule and summation rule (6)

8. Two parallel, infinite grey surface are maintained at temperature of 127°C and 227°C respectively. If the temperature of the hot surface is increased to 327°C, by what factor is the net radiation exchange per unit area increased? Assume the emissivity's of cold and hot surface to be 0.9 and 0.7 respectively. (8)
   Two equal and parallel discs of diameter 25 cm are separated by a distance of 50 cm. If the discs are maintained at 600°C and 250°C. Calculate the radiation heat exchange between them. (8)

9. Two large parallel planes with emissivity's 0.35 and 0.85 exchange heat by radiation. The planes are respectively 1073K and 773K. A radiation shield having the emissivity of 0.04 is placed between them. Find the percentage reduction in radiation heat exchange and temperature of the shield. (16)

## UNIT V

### PART A

1. What is meant by mass transfer?
2. What is Diffusion mass transfer?
3. What is Convective mass transfer?
4. Give some examples of Diffusion mass transfer.
5. What is the governing equation for Diffusion mass transfer?
6. What is mass diffusion velocity?
7. What is the Molar Diffusion velocity?
8. Define Mass concentration.
9. Define Molar concentration
10. What is Counter diffusion?
11. Define mass transfer fluxes.
12. What is the governing equation for Transient Diffusion?
13. Give equation for Counter diffusion.
14. Define Fourier number & Biot number for mass transfer.
15. What are the factors considered in evaporation of water into air?

### PART B

1. A steel sphere of radius 60 mm which is initially at a uniform temperature of 325°C is suddenly exposed to an environment at 25°C; with convection heat transfer coefficient 500 W/m2K. Calculate the temperature at a radius 36 mm and the heat transferred 100 seconds after the sphere is exposed to the environment. (16)

2. The tire tube of a vehicle has a surface area 0.62 $m^2$ and wall thickness 12 mm. The tube has air filled in it at a pressure 2.4 x $10^5$ $N/m^2$. The air pressure drops to 2.3 x $10^5$ $N/m^2$ in 10 days. The volume of air in the tube is 0.034 $m^3$. Calculate the diffusion coefficient of air in rubber at the temperature of 315K. Gas constant value = 287. Solubility of air in rubber tube = 0.075$m^3$ of air/$m^3$ of rubber tube at one atmosphere (16)

3. Define mass concentration, molar concentration, mass fraction and mole fraction.(4)
   The diffusivity of CCl4 in air is determined by observing the steady state evaporation of CCl4 in a tube of 1 cm diameter exposed to air. The CCl4 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 CCl4 at 25°C is 14.76 kPa. If it is observed that the rate of evaporation of CCl4 is 0.1 kg/hour determine the diffusivity of CC14 into air. (12)

4. Dry air at 20°C (p = 1.2 kg/$m^3$, v = 15 x lQ-6 $m^2$/s, D = 4.2 x lQ-5 $m^2$/s) flows over a flat plate of length 50 cm which is covered with a thin layer of water at a velocity of 1 m/s. Estimate the local mass transfer coefficient at a distance of 10 cm from the leading edge and the average mass transfer coefficient. (8)

5. A mixture of $0_2$ 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? (8)
6. Explain Fick's first and second laws of diffusion.
7. Discuss the analogy between heat and mass transfer.
8. Explain the phenomenon of equimolar counter diffusion. Derive an expression for equimolar counter diffusion between two gases or liquids.