Register No : ________________

THE KAVERY ENGINEERING COLLEGE

(An Autonomous Institution)

B.E/B.TECH DEGREE END SEMESTER THEORY EXAMINATIONS, NOV/DEC 2025

Sixth Semester

Mechanical Engineering

ME3691 – Heat and Mass Transfer

(Heat and Mass Transfer Data Book Can be Permitted)

Regulations - 2021

Duration : 3 Hrs *Maximum : 100 Marks*

*PART – A (ANSWER ALL QUESTIONS) (Marks 10*2=20)*

Q.No	Questions	BLT	CO	Marks
1.	What is meant by lumped heat capacity analysis? When is it used?	L1	1	2
2.	Define fin efficiency and fin effectiveness.	L1	1	2
3.	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.	L3	2	2
4.	Define Nusselt and Stanton numbers.	L1	2	2
5.	What advantage does the effectiveness - NTU methods have over the LMTD method?	L2	3	2
6.	What are the factors involved in designing heat exchangers?	L2	3	2
7.	How do you define the black body and emissivity of a surface?	L2	4	2
8.	Define the terms absorptivity, transmissivity and reflectivity.	L1	4	2
9.	Write the expression for determining the rate of mass convection.	L2	5	2
10.	Define Fick's law of diffusion. Give its expression.	L1	5	2

*PART – B (ANSWER ALL QUESTIONS) (Marks 5*16 = 80)*

Q.No			Questions	BLT	CO	Marks
11.	a		Derive the heat conduction equation in cylindrical coordinates and write its 3D equation.	L4	1	16
			Or			
	b	i	The rate of heat generation in a slab of thickness 160 mm (k = 180 W/m °C) is 1.2 x 10^6 W/m^3. If the temperature of each of the surface of solid is 120° C, Determine: a. The temperature at the mid and quarter planes b. The heat flow rate and temperature gradients at the mid and quarter planes.	L4	1	10
		ii	A plate 2 cm thick and 10 cm wide is used to heat a fluid at 30° C. The heat generation rate inside the plate is 7 x 10^6 W/m^3. Determine the heat transfer coefficient to maintain the temperature of the plate below 180°C. Given k(plate) = 26 W/m°C. Neglect heat losses from the edge of the plate.	L4	1	6

12.	a		A horizontal tubular 1-1 condenser is used to condense saturated steam at 80° C. The condenser is a shell and tube one with brass tubes (k = 110 W/m°C) of 1.59 cm OD and 1.34 cm ID. Steam is outside tubes and cooling water enters the tubes at 20° C with a velocity of 1.4 m/s and leaves at 40° C. If the rate of cooling water supply is 55000 kg/h and the latent heat of condensation of steam at 80° C is 2304 kJ/kg, Calculate: a. The number of tubes, b. The length of each tube. For calculating the tube side heat transfer coefficient use the Dittus-Boelter equation and for the shell side heat transfer coefficient, the average value may be taken as 10760 W/m^2 K.	L3	2	16
			Or			
	b	i	A vertical cylinder 1.5 m height and 180 mm in diameter is maintained at 100° C in an atmosphere environment of 20° C. Calculate heat loss by free convection from the surface of the cylinder. Assume properties of air at mean temperature as, ρ = 1.06 kg/m^3, v = 18.97 x 10^{-6} m^2/s, C_p = 1.004 kJ/kg°C and k= 0.1042 kJ/mh°C.	L3	2	8
		ii	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 = 1/198 K^{-1}. Assume Nu = 0.12 (Gr. Pr)$^{1/3}$	L3	2	8
13.	a	i	Saturated steam at 120° C condenses on a 2 cm OD vertical tube which is 20 cm long. The tube wall is maintained at a temperature of 119° C. Calculate the average heat transfer coefficient and the thickness of the condensate film at the base of the tube. Assume Nusselt's solution is valid. p_{sat} = 1.985 bar, ρ_w = 943 kg/m^3, h_{fg} = 2202.2 kJ/kg, k_w = 0.686 W/m K, μ = 237.3 x 10^{-6} Ns/m^2.	L3	3	8
		ii	A vertical plate 500 mm high and maintained at 30° C is exposed to saturated steam at atmospheric pressure. Calculate the following: a. The rate of heat transfer, b. The condensate rate per hour per metre of the plate width for film condensation. The properties of water film at the mean temperature are: ρ = 980.3 kg/m^3, k =66.4 10^{-2} W/m°C, μ = 434 x 10^{-6} kg/ms and h_{fg} = 2257 kJ/hg. Assume vapour density is small compared to that of the condensate.	L3	3	8
			Or			
	b		16.5 kg/s of the product at 650° C (C_p = 3.55 kJ/kg°C), in a chemical plant, are to be used to heat 20.5 kg/s of the incoming fluid from 100°C (C_p = 4.2 kJ/kg°C). If the overall heat transfer coefficient is 0.95 kW/m^2°C and the installed heat transfer surface is 44 m^2, Calculate the fluid outlet temperatures for the counter-flow and parallel flow arrangements.	L3	3	16

14.	a		A long cylindrical heater 25 mm in diameter is maintained at 660° C and has surface resistivity of 0.8. The heater is located in a large room whose walls are at 27° C. How much will the radiant heat transfer from the heater be reduced if it is surrounded by a 300 mm diameter radiation shield of aluminium having an emissivity of 0.2? What is the temperature of the shield?	L4	4	16
			Or			
	b		Two parallel plates of size 1.0 m x 1.0 m spaced 0.5 m apart are located in a very large room, the walls of which are maintained at a 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.	L4	4	16
15.	a	i	Hydrogen gas at 25° C and 2.5 atmosphere flows through a rubber tubing of 12 mm inside radius and 24 mm outside radius. The binary diffusion coefficient of hydrogen is 2.1×10^{-8} m^2/s and the solubility of hydrogen is 0.055 m^3 of hydrogen per m^3 of rubber at 1 atmosphere. If the gas constant for hydrogen is 4160 J/kg K and the concentration of hydrogen at the outer surface of tubing is negligible, calculate the diffusion flux rate of hydrogen per metre length of rubber tubing.	L3	5	8
		ii	Air is contained in a tyre tube of surface area 0.5 m^2 and wall thickness 10 mm. The pressure of air drops from 2.2 bar to 2.18 bar in a period of 6 days. The solubility of air in the rubber is 0.072 m^3 of air per m^3 of rubber at 1 bar. Determine the diffusivity of air in rubber at the operating temperature of 300 K if the volume of air in the tube is 0.028 m^3.	L3	5	8
			Or			
	b	i	A 30 mm deep pan is filled with water to a level of 15 mm and is exposed to dry air at 40° C. Assuming the mass diffusivity as 0.25×10^{-4} m^2/s, calculate the time required for all the water to evaporate.	L3	5	8
		ii	Due to accidental opening of a valve, the water has been split out on the floor of an industrial plant. The water level is 1.2 mm and temperature 25° C. The temperature and pressure of air are 25° C and 1 bar respectively. The specific humidity of air is 1.8 g/kg of dry air. Assuming $D = 0.25 \times 10^{-4} m^2/s$ and the evaporation takes place by molecular diffusion through an air film 6 mm thick, determine the time required to evaporate the water completely.	L3	5	8