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B.M.S. College of Engineering, Bengaluru-560019

Autonomous Institute Affiliated to VTU

June 2025 Semester End Main Examinations

Programme: B.E. **Semester: VI**

Branch: Mechanical Engineering **Duration: 3 hrs.**

Course Code: 23ME6PCHTR / 22ME6PCHTR / 20ME6DCFHT **Max Marks: 100**

Course: Heat Transfer / Fundamentals of Heat Transfer

Instructions: 1. Answer any FIVE full questions, choosing one full question from each unit.
2. Use of Heat Transfer data handbook may be permitted.
3. Missing data, if any, may be suitably assumed.

		UNIT - I	*CO*	*PO*	Marks
1	a)	Define the three modes of heat transfer. For each mode, explain the physical mechanism involved and provide any 2 real-life example.	*CO1*	*PO1*	**06**
	b)	Starting from the general heat diffusion equation in Cartesian coordinates, derive the one-dimensional transient heat conduction equation assuming constant thermal conductivity and no internal heat generation.	*CO1*	*PO1*	**06**
	c)	A solid rectangular block of dimensions L= 0.2 m, W= 0.1 m, and H= 0.05 m is made of a homogeneous material with thermal conductivity k= 45 W/m K. The temperature on one face (x = 0) is maintained at 100 °C, and the opposite face (x = 0.2 m) is maintained at 50 °C. All other surfaces are insulated. Assume, steady-state one-dimensional heat conduction. i) Write down the simplified form of the heat conduction equation and solve for the temperature distribution. ii) Calculate the rate of heat transfer through the block.	*CO2*	*PO2*	**08**
		OR			
2	a)	Differentiate between long fin, short fin with insulated tip, and short fin with convective tip. Illustrate with temperature profile.	*CO1*	*PO1*	**06**
	b)	Define fin efficiency and fin effectiveness. Under what conditions is the use of a fin considered desirable or ineffective? Justify with equations and physical reasoning.	*CO2*	*PO2*	**06**
	c)	A small copper sphere (diameter D=10 mm) is suddenly exposed to air at T_∞=30 °C. The initial temperature of the sphere is T_i=300 °C. The convective heat transfer coefficient is h=120 W/m^2 K, and the sphere's properties are: ρ=8950 kg/m^3, C_p=385 J/kg K, k=401 W/m K. Check the validity of the lumped system analysis. Estimate the temperature of the sphere after 15 seconds.	*CO3*	*PO2*	**08**

Important Note: Completing your answers, compulsorily draw diagonal cross lines on the remaining blank pages. Revealing of identification, appeal to evaluator will be treated as malpractice.

			UNIT - II			
	3	a)	Define and discuss the significance of Reynolds number, Prandtl number, and Nusselt number in convective heat transfer.	*CO1*	*PO2*	**06**
		b)	Write the Blasius solution for the local and average Nusselt numbers over a flat plate with isothermal conditions in laminar flow. Describe the transition from laminar to turbulent boundary layer and provide approximate Reynolds number range for this transition.	*CO1*	*PO2*	**06**
		c)	Air at 25°C flows over a flat plate maintained at 75°C. The free stream velocity is U_∞=5 m/s, and the plate length is 1 m. If the properties of air: ρ=1.18 kg/m^3, μ=1.84x10^{-5} Pa-s, C_p=1005 J/kg-K, k=0.026 W/m-K. Assume laminar flow and calculate: i) Local convective heat transfer coefficient at x = 0.5 m. ii) Average heat transfer rate per unit width over the entire plate of length L=1 m.	*CO1*	*PO2*	**08**
			OR			
	4	a)	Define the hydrodynamic and thermal entry lengths and fully developed regions for the laminar flow in a circular tube with necessary sketches.	*CO4*	*PO1*	**06**
		b)	Define the mean fluid temperature T_m how the rate of heat transfer 'q' is calculated in fully developed internal laminar flow when the surface temperature is constant?	*CO4*	*PO1*	**06**
		c)	Water enters a circular tube of diameter 10 mm and length 2 m at a temperature of 20°C. The wall is maintained at 60°C. The mass flow rate of water is m = 0.01 kg/s. Given properties at mean temperature 40°C: C_p=4178 J/kg, k=0.63 W/m-K, ρ=992.2 kg/m^3, μ=6.53×10−4 Pa-s. Assume laminar, fully developed flow and constant surface temperature. Calculate: i. Reynolds number and confirm flow regime. ii. Heat transfer coefficient using constant wall temperature assumption. iii. Outlet temperature of water.	*C41*	*PO2*	**08**
			UNIT - III			
	5	a)	List any four assumptions considered in deriving the boundary layer equations for laminar free convection. Write the simplified boundary layer equations for continuity, momentum, and energy for a vertical plate.	*CO4*	*PO1*	**06**
		b)	What is Grashof number and write its mathematical equation? Defend the point that, Grashof number is the Reynold's number for the free convection condition.	*CO4*	*PO1*	**06**
		c)	A vertical plate 30 cm high and 1 m wide and maintained at a uniform temperature of 120^{o}C is exposed to quiescent air at 30^{o}C. Calculate the average heat transfer coefficient and the total heat transfer rate from the plate to air.	*CO4*	*PO2*	**08**

			OR			
	6	a)	Derive the momentum equation for the natural convection heat transfer for vertical plate configuration.	*CO1*	*PO1*	**08**
		b)	With a neat sketch show the velocity and temperature profile inside the boundary layer of a vertical plate and briefly explain the profiles.	*CO1*	*PO1*	**04**
		c)	A 50 mm diameter, 1.5 m long vertical tube at a uniform temperature of 100^oC is exposed to quiescent air at 20^oC. calculate the rate of heat transfer from the surface to air. What would be the heat transfer rate if the tube were kept horizontally?	*CO1*	*PO2*	**08**
			UNIT - IV			
	7	a)	Explain the physical significance of Planck’s Law, Wein’s Displacement Law, and Stefan–Boltzmann Law. How do these laws help describe blackbody radiation?	*CO6*	*PO1*	**08**
		b)	Define and differentiate emissivity, absorptivity, reflectivity, and transmissivity. Write appropriate relation.	*CO6*	*PO1*	**06**
		c)	Two large parallel grey plates (ε = 0.6 for both) maintained at temperatures of 1000 K and 500 K respectively are facing each other. Calculate the net radiation heat exchange per unit area between the plates. Take Stefan–Boltzmann constant: $\sigma = 5.67 \times 10^{-8}$ W/m^{2}K^4.	*CO6*	*PO2*	**06**
			OR			
	8	a)	Define the following: i. Shape factor ii. Solid angle	*CO1*	*PO1*	**04**
		b)	Calculate the heat flux emitted due to thermal radiation from a black surface at 6000^{0}C. Determine the maximum wave length and corresponding maximum monochromatic emissive power.	*CO6*	*PO1*	**08**
		c)	A furnace is shaped like a long equilateral triangular duct. The width of each side is 1m. The base surface has an emissivity of 0.7 and is maintained at a uniform temperature of 600 K. The heated left-side surface closely approximates a blackbody at 1000 K. The right-side surface is well insulated. Determine the rate at which heat must be supplied to the heated side externally per unit length of the duct in order to maintain these operating conditions.	*CO6*	*PO2*	**08**
			UNIT - V			
	9	a)	How does a cross-flow heat ex-changer differ from a counter-flow one? Discuss.	*CO5*	*PO1*	**02**
		b)	Obtain an expression for LMTD for a counter flow heat ex-changer. State the assumptions made.	*CO5*	*PO1*	**08**
		c)	Water at 25^oC and a velocity of 1.5 m/s enters a brass condenser tube 6 m long, 13.4 mm ID, 15.8 mm OD and k = 110 W/m K. Steam is condensing on the outer surface of the tube with a heat transfer coefficient of 12,000 W/m^2 K. The fouling factors for the inner and outer surfaces are both equal to 0.00018 m^2 K/W.	*CO5*	*PO2*	**10**

			Calculate the overall heat transfer coefficient based on (i) the inside surface area and (ii) the outside surface area.			
			OR			
	10	a)	Explain how you can evaluate the outlet temperatures of the cold and hot fluids in a heat exchanger after its effectiveness is determined.	*CO5*	*PO1*	**02**
		b)	Derive an expression for effectiveness of a parallel flow heat exchanger.	*CO5*	*PO1*	**08**
		c)	The following data refer to a heat exchanger. Mass flow rate of the hot fluid = 4 kg/min. Mass flow rate of the cold fluid = 8 kg/min. Specific heat of hot fluid = 4.20 kJ/kg-K. Specific heat of the cold fluid = 2.52 kJ/kg-K. Inlet temperature of hot fluid = 100 ^{o}C. Inlet temperature of cold fluid = 20 ^{o}C. Determine the effectiveness and outlet temperatures if the arrangement is (i) parallel flow and (ii) counter flow? And write your comment.	*CO5*	*PO3*	**10**

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