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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: IV**
Branch: Aerospace Engineering **Duration: 3 hrs.**
Course Code: 23AS4PCHMT / 22AS4PCHMT **Max Marks: 100**
Course: Heat and Mass Transfer

Instructions: 1. Answer any FIVE full questions, choosing one full question from each unit.
2. Missing data, if any, may be suitably assumed.
3. Heat and Mass Transfer data hand book is permitted

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 - I	***CO***	***PO***	**Marks**
1	a)	Derive the three-dimensional heat conduction equation in Cartesian coordinates for material with constant thermal conductivity. Clearly state the assumptions involved in the derivation.	*CO1*	*PO1, PO2*	**08**
	b)	A wall is constructed of several layers. The first layer consists of brick (k = 0.66 W/m-K), 25 cm thick, the second layer 2.5 cm thick mortar (k = 0.7 W/m-K), the third layer 10 cm thick limestone (k = 0.66 W/m-K) and outer layer of 1.25 cm thick plaster (k = 0.7 W/m-K). The heat transfer coefficients on interior and exterior of the wall fluid layers are 5.8 W/m^2-K and 11.6 W/m^2-K, respectively. Find, (i) Overall thermal resistance per m^2, (ii) Overall heat transfer coefficient, (iii) Rate of heat transfer per m^2, if the interior of the room is at 26°C while outer air is at – 7°C, (iv) Temperature at the junction between mortar and limestone.	*CO2*	*PO1, PO3*	**12**
		OR			
2	a)	Describe the significance of critical thickness of insulation. Using appropriate assumptions, derive the expression for critical insulation thickness for a cylinder.	*CO1*	*PO1, PO2*	**10**
	b)	The two long rods A and B, equivalent in every respect except that one is fabricated from material of known thermal conductivity of k_A while other of material of unknown thermal conductivity k_B, are attached to a surface of fixed temperature T_0, and are exposed to a fluid at T_∞, with convection coefficient h. These rods are instrumented with thermocouples to measure the temperature at a fixed distance x_1 from the heat source. If the standard material is of aluminium with k_A = 200 W/m-K and measurements reveal T_A	*CO2*	*PO1, PO3*	**10**

			= 75°C and T_B = 60°C at x_1 when T_0 is 100°C and T_∞ is 25°C. Assume infinitely long fin. What is the thermal conductivity of the test material B ?			
			UNIT - II			
	3	a)	Define Biot number and Fourier number. State their physical significance in the study of transient heat transfer.	*CO2*	*PO1, PO3*	**08**
		b)	A slab of aluminium 10 cm thick is initially at temperature of 500°C. It is suddenly immersed in a liquid bath at 100°C resulting in a heat transfer coefficient of 1200 W/m^2-K. Determine the temperature at the centerline and surface 1 min after the immersion. Also calculate the total thermal energy removed per unit area of the slab during this period. The properties of the aluminium for given conditions are: $\alpha = 8.4 \times 10^{-5}$ m^2/s, k = 215 W/m-K, ρ = 2700 kg/m^3, Cp = 0.9 kJ/kg-K.	*CO2*	*PO1, PO3*	**12**
			OR			
	4	a)	What is lumped system? Derive an expression for the temperature distribution in case of lumped system in terms of dimensionless parameters as shown below. $$\frac{T - T_\infty}{T_i - T_\infty} = e^{Bi \times Fo}$$	*CO2*	*PO1, PO3*	**12**
		b)	A solid steel ball 5 cm in diameter and initially at 450°C is quenched in a controlled environment at 90°C with convection coefficient of 115 W/m^2-K. Determine the time required for the centre of the ball to reach a temperature of 150°C. Take thermos-physical properties as, C = 420 J/kg-K, ρ = 8000 kg/m^3, k = 46 W/m-K.	*CO2*	*PO1, PO3*	**08**
			UNIT - III			
	5	a)	Define the Reynolds, Prandtl, Nusselt, Grashof, and Rayleigh numbers commonly used in convection heat transfer. Discuss the physical significance of each.	*CO1*	*PO1, PO2*	**10**
		b)	Air at velocity of 3 m/s and at 20°C flows over a flat plate along its length. The length, width and thickness of the plate are 100 cm, 50 cm, and 2 cm, respectively. The top surface of the plate is maintained at 100°C. Calculate the heat lost by the plate and temperature of bottom surface of the plate for the steady state conditions. The thermal conductivity of the plate may be taken as 23 W/m.K.	*CO3*	*PO2, PO9*	**10**
			OR			

	6	a)	With neat sketches, explain the formation of hydrodynamic and thermal boundary layers over a flat plate in the context of convection heat transfer.	*CO1*	*PO1, PO2*	**10**
		b)	A vertical plate 15 cm high and 10 cm wide is maintained at 140°C. Calculate the maximum heat dissipation rate from the both sides of the plate in an ambient of at 20°C. Use relation, $$Nu_L = 0.59\,(Gr \times \mathrm{Pr})^{1/4}$$ For air at 80°C, take $\nu = 21.09 \times 10^{-6}$ m^2/s, Pr = 0.692, k_f = 0.03 W/m.K.	*CO3*	*PO2, PO9*	**10**
			UNIT - IV			
	7	a)	With a neat sketch, explain the concept of a blackbody.	*CO1*	*PO1, PO2*	**05**
		b)	With a neat sketch, explain the concept of a radiation shield and its role in reducing net radiative heat transfer between two surfaces.	*CO1*	*PO1, PO2*	**05**
		c)	Two large parallel plates at temperature 1000 K and 600 K have emissivity of 0.5 and 0.8 respectively. A radiation shield having emissivity 0.1 on one side and 0.05 on the other side is placed between the plates. Calculate the heat transfer rate by radiation per square meter with and without radiation shield.	*CO3*	*PO2, PO9*	**10**
			OR			
	8	a)	State and explain the following fundamental laws of thermal radiation: i. Stefan–Boltzmann Law ii. Planck's Law iii. Wien's Displacement Law iv. Kirchhoff's Law v. Lambert's Cosine Law	*CO1*	*PO1, PO2*	**10**
		b)	Define the following terms related to radiation heat transfer: Emissivity, Absorptivity, Reflectivity and Transmissivity.	*CO1*	*PO1, PO2*	**04**
		c)	A cubical room 4 m by 4 m by 4 m is heated through the ceiling by maintaining it at uniform temperature of 350 K, while walls and the floor are at 300 K. Assuming that the all surfaces have an emissivity of 0.8, determine the rate of heat loss from ceiling by radiation.	*CO3*	*PO2, PO9*	**06**
			UNIT - V			
	9	a)	Derive an expression for the logarithmic mean temperature difference (LMTD) for a parallel-flow heat exchanger.	*CO3*	*PO2, PO9*	**10**
		b)	A double pipe heat exchanger is constructed of a stainless steel (k = 15.1 W/m.K) inner tube of inner diameter of 1.5 cm and outer diameter of 1.9 cm. It is concentric to an outer tube of diameter 3.2 cm. The inside and outside heat transfer coefficients are 800 and 1200 W/m^2.K, respectively. Due to continuous operation of the heat exchanger, the inner and outer surfaces of tube are fouled	*CO3*	*PO2, PO9*	**10**

			and respective fouling factors are 0.0004 m^2.K/W and 0.0001 m^2. K/W. Calculate: i. Thermal resistance of heat exchanger per unit length, and ii. Overall heat transfer coefficient based on inner and outer surface areas of the tube.			
			OR			
	10	a)	With a neat sketch, explain the boiling curve of water. Describe the different regimes of boiling represented in the curve.	*CO4*	*PO3*	**10**
		b)	An electric wire of 1.5 mm diameter and 20 cm long is laid horizontally and submerged in water at atmospheric pressure. The current flowing through the wire is 40A, while voltage drop is 16V. Calculate the heat flux, heat transfer coefficient and excess temperature. Use correlation: $h = 1.54 (Q/A)^{3/4} = 5.58(\Delta Te)^3$.	*CO4*	*PO3*	**10**

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