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APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

B.Tech Degree S6 (R,S) / (WP), S4 (PT) Exam April 2025 (2019 Scheme)

Course Code: MET302

Course Name: HEAT AND MASS TRANSFER

Max. Marks: 100 **Duration: 3 Hours**

Use of Steam Table & Heat and Mass Transfer Data Book Permitted

PART A

Answer all questions, each carries 3 marks. Marks

1	Explain how a hot cup of coffee loses heat.	(3)
2	Describe the role of fins in electronic cooling systems.	(3)
3	Describe the concept of a hydrodynamic boundary layer with a sketch.	(3)
4	List three real-life examples of natural convection heat transfer.	(3)
5	Describe the differences between pool boiling and flow boiling.	(3)
6	Identify the main types of heat exchangers based on flow arrangement.	(3)
7	Explain Wien's displacement law and its importance.	(3)
8	Define radiation shape factor and its role in heat exchange calculations.	(3)
9	State Fick's first law of diffusion and its mathematical expression.	(3)
10	Differentiate stagnant diffusion and counter diffusion with examples	(3)

PART B

Answer any one full question from each module, each carries 14 marks.

Module I

11 a) A composite cylindrical pipe consists of three concentric layers made of different materials. The inner and outer radii of the first layer are 0.05 m and 0.08 m, respectively, with a thermal conductivity of 20 W/m·K. The second layer has an outer radius of 0.12 m and a thermal conductivity of 5 W/m·K, while the third layer extends to an outer radius of 0.18 m and has a thermal conductivity of 2 W/m·K. The inner surface temperature is maintained at 300°C, while the outer surface temperature is 100°C. Assuming steady-state one-dimensional radial heat conduction and neglecting contact resistance, determine the total thermal resistance, the heat transfer rate per meter length of the pipe, and the interface temperatures at r=0.08m and r=0.12m. (9)

b) Derive the expression for the critical radius of insulation for a cylindrical system. (5)

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OR

12 a) Derive the general three-dimensional heat conduction equation in Cartesian coordinates. (9)

b) A solid sphere made of copper (thermal conductivity k=400 W/m·K, density ρ=8933 kg/m³, specific heat c_p=385 J/kg·K) with a diameter of 5 cm is initially at 200°C. It is suddenly immersed in a large water bath maintained at 30°C. The convective heat transfer coefficient between the sphere and water is 120 W/m²·K. Using the lumped capacitance method, determine: (i) The time required for the sphere's temperature to drop to 90°C. (5)

Module II

13 a) Air at 30°C flows over a 1-meter-long flat plate with a velocity of 2 m/s. The plate is maintained at a surface temperature of 90°C. Assume that the flow is laminar over the entire plate. Given the properties of air at the film temperature: Thermal conductivity, k=0.026W/m· K, Kinematic viscosity, $\nu=1.5\times10^{-5}$, Prandtl number, Pr = 0.7, Density, ρ = 1.2 kg/m³. Determine: (i) The boundary layer thickness at the end of the plate. (ii) The total drag force exerted by the air on the plate per unit width. (iii) The total heat transfer rate from the plate per unit width. (9)

b) Explain the significance of the Prandtl number in convection heat transfer. (5)

OR

14 a) A 1-meter-high vertical plate with a surface temperature of 150°C is exposed to air at 50°C under natural convection. Given: Thermal conductivity of air, k= 0.03 W/m·K, Kinematic viscosity, $\nu=2.0\times10^{-5}$ m²/s, Prandtl number, Pr=0.72, Density, ρ=1.1 kg/m³. Determine: (i) The Rayleigh number, (ii) The average convective heat transfer coefficient. (iii) The total heat transfer rate from the plate per unit width. (9)

b) Discuss the role of Grashof number in natural convection heat transfer. (5)

Module III

15 a) Hot water enters a parallel flow heat exchanger at 90°C and exits at 60°C. Cold water enters at 30°C and exits at 50°C. The specific heat capacity of water is 4.18 kJ/kg·K, and the mass flow rate of both fluids is 2 kg/s. Determine: (i) The LMTD for the heat exchanger, (ii) The total heat transfer rate, (iii) The required heat exchanger area if the overall heat transfer coefficient is 300 W/m²·K. (9)

b) Differentiate between filmwise condensation and dropwise condensation. (5)

OR

16 a) Hot oil enters a counter flow heat exchanger at 150°C, while cold water enters at 30°C. The mass flow rate of hot oil is 3 kg/s, and that of cold water is 5 kg/s. The specific heat capacities are: Hot oil: $c_{p,h}$=2100 J/kg·K, Cold water: $c_{p,c}$==4180 J/kg·K, The overall heat transfer coefficient is 250 W/m²·K, and the heat exchanger area is 8 m². Determine: (i) The Number of Transfer Units (NTU), (ii) The effectiveness of the heat exchanger, (iii) The heat transfer rate. (9)

b) Explain the different regimes of the boiling curve with a labeled diagram. (5)

Module IV

17 a) A black body at 3000 K emits radiation. Calculate the following: i) Monochromatic emissive power at 7 μm wave length. ii) Wave length at which emission is maximum. iii) Emissive power at maximum wavelength iv) Total emissive power, v) Calculate the total emissive of the furnace if it is assumed as a real surface having emissivity equal to 0.85. (9)

b) Describe the use of radiation shields to reduce heat loss. (5)

OR

18 a) Two infinite parallel plates with emissivities $\varepsilon_1 = 0.7$ and $\varepsilon_2 = 0.5$ are maintained at temperatures $T_1 = 800$ K and $T_2 = 400$ K, respectively. The plates are separated by a vacuum and behave as gray surfaces. Determine: (i) The net radiation heat transfer per unit area between the plates, (ii) The % reduction in radiation heat flux if a radiation shield with $\varepsilon = 0.3$ is placed between them. Take Stefan-Boltzmann constant: $\sigma = 5.67\times10^{-8}$ W/m^{2}K^4 (9)

b) Explain Kirchhoff's law of thermal radiation with examples. (5)

Module V

19 a) A liquid layer of 8 mm thickness contains acetic acid diffusing through water at steady-state equimolar counter-diffusion conditions at 20°C. The concentration of acetic acid at one side of the layer is 2.5 kmol/m³, and at the other side, it is 0.5 kmol/m³. The diffusion coefficient of acetic acid in water is 1.3×10^{-9} m²/s. Find: (i) The molar flux of acetic acid in kmol/m²·s, (ii) The molar flux of water, (iii) The total volume (in liters) of acetic acid diffused in 8 hours, assuming a 1 m² area and that acetic acid has a density of 1.049 kg/L. (9)

b) Describe the differences between molecular diffusion and convective mass transfer. (5)

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OR

20 a) A wet paper sheet of 1.2 m^2 area is placed in an airflow at 20°C and 1 atm pressure. The mass transfer coefficient for water vapor in air is 0.03 m/s, and the saturation vapor pressure of water at 20°C is 2.34 kPa. The air has a humidity of 40%. Determine: (i) The rate of water evaporation in $kg/m^2 \cdot s$, (ii) The total amount of water evaporated in 2 hours. (9)

b) Describe the physical significance of Sherwood number in convective mass transfer. (5)

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