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APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

B.Tech Degree S6 (R, S) / S4 (PT) (R, S) Examination May 2024 (2019 Scheme)

Course Code: MET302

Course Name: HEAT & MASS TRANSFER

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

PART A

Answer all questions, each carries 3 marks. Marks

1	Define thermal diffusivity and give its physical explanation.	(3)
2	What is meant by lumped heat capacity analysis? What is the criterion to decide whether heat transfer problem can be analysed using Lumped heat capacity model?	(3)
3	Show that Nusselt number represents the enhancement of heat transfer in convection relative to that in conduction by the fluid.	(3)
4	Sketch the velocity boundary layer that forms in flow over a flat plate and mark important flow regions in it.	(3)
5	When do we prefer Effectiveness-NTU method over LMTD method in heat exchanger analysis?	(3)
6	What is the relevance of Critical Heat Flux in boiling heat transfer?	(3)
7	How do we see colour of things? Explain it with basic concepts of radiation.	(3)
8	What is Kirchhoff's law of radiation? How the concept of grey surface is relevant in the context of it?	(3)
9	Which are the nondimensional numbers in mass transfer, which are analogous to Prandtl number and Nusselt numbers in heat transfer?	(3)
10	What is Fick's law of diffusion? How does the nature of diffusion coefficient of gases differ from that of liquids and solids?	(3)

PART B

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

Module I

11 a) A spherical tank of 3 m diameter contains LPG at -60°C. Insulation with thermal conductivity of 0.06 W/m.K and thickness 250 mm is applied to the tank to reduce heat gain. Ambient air temperature is 20°C and the convection coefficient on the (7)

outer surface is 6 $W/m^2.K$. Determine the radial position in the insulation layer at which the temperature is 0°C.

b) Steel balls of 12 mm in diameter are annealed by heating to 1150 K and then slowly cooling to 400 K in an air environment for which temperature T_∞ = 325 K and heat transfer coefficient, h =20 W/m^2 K. Assume the properties of the steel to be the following: Thermal conductivity is 40 W/mK, density is 7800 kg/m^3, and specific heat is 600 J/kg K. Estimate the time required for the cooling process. (7)

OR

12 a) Steam at 230°C is flowing through a steel pipe (k=15.1 W/m°C) whose inner and outer diameters are 9 cm and 10 cm, respectively. The pipe is insulated with a 5 cm thick fibre glass insulation (k=0.035 W/m °C). Outside temperature is 13°C. If heat transfer coefficients on the inside and outside of the pipe are 170 W/m^2 °C and 30 W/m^2 °C, respectively, find the heat loss per meter length of the pipe. (7)

b) A 1 mm diameter wire is maintained at a temperature of 400°C and exposed to a convection environment at 40°C, with heat transfer coefficient of 120 W/m^2K. Calculate the thermal conductivity which will just cause an insulation thickness of 0.2 mm to make a critical radius. How much of this insulation must be added to reduce the heat transfer by 75% from that which would be experienced by the bare wire? (7)

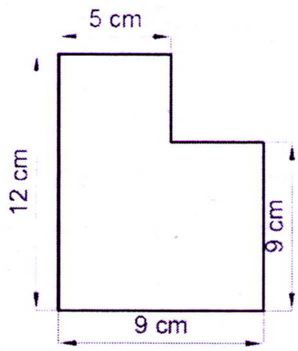
Module II

13 a) Atmospheric air at 60°C flows over a flat square plate of size $0.5\,m \times 0.5\,m$, maintained at 10°C. What must be the velocity of the air so that the total convective heat transfer from the air to plate is 215 W? (7)

b) A 3 m long circular cylinder with a diameter of 4 cm is exposed to the crossflow of 20°C atmospheric air at a velocity of 6m/s. If the surface temperature of the cylinder is 85°C, find the convective heat transfer from the cylinder. (7)

OR

14 a) A horizontal plate, with top view as shown in figure, has a surface temperature of 200°C and it is exposed to atmospheric air at 20°C. Its bottom side is insulated. Find the convective heat transfer from the plate. (7)



b) Water at 25°C flows through a tube of 50 mm diameter. The flow rate is 0.0575 kg/s. The tube is provided with a nichrome heating element on its internal surface and it provides a constant heat flux of 800 W per metre length of the tube. Determine the average heat transfer coefficient between the tube and water. Also, determine the length of the tube required for the rise of bulk water temperature to 50°C. (7)

Module III

15 a) In a parallel flow heat exchanger, hot fluid enters the heat exchanger at a temperature of 150 °C and a mass flow rate of 3 kg/s. The cooling medium enters the heat exchanger at 30^{0}C with a mass flow rate of 0.5 kg/s and leaves at a temperature of 70 °C. The specific heat capacities of hot and cold fluid are 1150 J/kg.K and 4180 J/kg. K, respectively. The convection heat transfer coefficients on the inner and outer side of the tube are 300 W/m^2 K and 800 W/m^2 K, respectively. For fouling factors of 0.0003 m^{2}K/W inside the tube and 0.0001 m^{2}K/W on the outer surface of the tube, determine a) The overall heat transfer coefficient b) The exit temperature of hot fluid c) Surface area of the heat exchanger. (10)

b) With simple sketches, explain Dropwise condensation and Film wise condensation on a vertical surface. Which among them has the better heat transfer coefficient and why? (4)

OR

16 a) Water enters a counter flow, double pipe heat exchanger at 15°C, flowing at the rate of 1300kg/h. It is heated by oil (c_p=2000 J/kgK) flowing at the rate of 550 kg/h, with an inlet temperature of 94°C. For an area of 1 m^2 and for an overall heat transfer coefficient of 1075W/m^{2}K, determine the total heat transfer and the outlet temperature of water and oil. (9)

b) Give a description on the classification of heat exchanger on the basis of flow arrangement and construction. (5)

Module IV

17 a) Two circular discs of diameters 20 cm each are placed 2 m apart. Calculate the net heat exchange between these plates, if they are maintained at 800°C and 300°C, respectively. Their corresponding emissivity are 0.3 and 0.5. (7)

b) A hemispherical furnace of radius 1m has the inner surface (emissivity =1) of its roof maintained at 800 K, while its floor (emissivity=0.5) is kept at 600 K. Calculate the net heat transfer from the roof to the floor. (7)

OR

18 a) A hollow enclosure is formed between two infinitely long concentric cylinders of radii 1 m and 2 m, respectively. Radiative heat transfer takes place between inner surface of the larger cylinder (*surface 2*) and the outer surface of the smaller cylinder (surface *1*) The radiating surfaces are diffuse and the medium present in between is non-participating. Calculate the fraction of the thermal radiation leaving the larger surface and striking itself. (10)

b) Explain Wein's displacement law. (4)

Module V

19 a) Oxygen gas at 25°C and a pressure of 2 bar is flowing through a rubber pipe of inside diameter 25 mm and wall thickness of 2.5 mm. The diffusivity of oxygen through rubber is 0.21×10^{-2} m²/s and the solubility of oxygen in rubber is 3.12×10^{-3} kmol/m³bar. Find the rate of loss of oxygen by diffusion per metre length of the pipe. (10)

b) Explain the phenomenon of equimolar counter diffusion. (4)

OR

20 a) CO_2 and air experience equimolar counter diffusion in a circular tube, whose diameter and length are 1 m and 50 ~~mm~~, respectively. The system is at a total pressure of 1 atm and a temperature of 25°C. The ends of the tubes are connected to large chambers, where the species concentrations are kept at fixed values. The partial pressure of CO_2 at one end of the tube is 190 mm of Hg, while that at the other end is 95 mm of Hg. The diffusion coefficient for CO_2-air combination is $D_{AB}=0.16\times 10^{-4}$ m²/S. Estimate the mass transfer of CO_2 and air through the tube. (10)

b) Give a briefing on different modes of mass transfer. (4)

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