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APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY
SIXTH SEMESTER B.TECH DEGREE EXAMINATION, APRIL 2018

Course Code: ME 302

Course Name: HEAT AND MASS TRANSFER (MA, ME, AU)

Max. Marks: 100

Duration: 3 Hours

(Use of heat and mass transfer data book permitted.)

PART A

Answer any three full questions, each carries 10 marks.

Marks

- 1 a) Derive the general heat conduction equation in cylindrical coordinates. (6)
b) Explain the significance of critical radius of insulation. (4)
- 2 A hollow aluminium sphere, with an electrical heater in the centre, is used in tests to determine the thermal conductivity of insulating materials. The inner and outer radii of the sphere are 0.15 and 0.18 m, respectively, and testing is done under steady-state conditions with the inner surface of the aluminium maintained at 250°C. In a particular test, a spherical shell of insulation is cast on the outer surface of the sphere to a thickness of 0.12 m. The system is in a room for which the air temperature is 20°C and the convection coefficient at the outer surface of the insulation is 30 W/m² K. If 80 W are dissipated by the heater under steady-state conditions, what is the thermal conductivity of the insulation? (10)
- 3 a) Discuss the importance of non-dimensional numbers in heat transfer problems. (3)
b) A square (10 mm x 10 mm) silicon chip is insulated on one side and cooled on the opposite side by atmospheric air in parallel flow at $u_{\infty} = 20$ m/s and $T_{\infty} = 24^{\circ}\text{C}$. When in use, electrical power dissipation within the chip maintains a uniform heat flux at the cooled surface. If the chip temperature may not exceed 80°C at any point on its surface, what is the maximum allowable power? (7)
- 4 A vertical plate 1m wide and 20 cm high is at a temperature of 100 °C and rests in still air at 1 bar and 20°C. Determine (i) the boundary layer thickness at 10 cm from the leading edge. (ii) the local heat transfer coefficient at 10cm from the leading edge and (iii) the average heat transfer coefficient over the entire length of the plate. (10)

PART B

Answer any three full questions, each carries 10 marks.

- 5 Steel balls 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 $T_{\infty} = 325$ K and heat transfer coefficient, $h = 20$ W/m² K. Assume the properties of the steel to be the following. Thermal conductivity is 40W/mK, density is 7800 kg/m³, and specific heat is 600 J/kg K, estimate the time required for the cooling process. (10)

- 6 a) Distinguish between fin efficiency and fin effectiveness. (4)
- b) A rectangular aluminium fin of thermal conductivity 200 W/mK, 3mm thick and 7.5 cm long protrudes out from a wall. The fin base is maintained at a temperature of 300°C and the ambient temperature is 50°C with heat transfer coefficient 10W/m²K. The tip of the fin is insulated. Calculate the heat transfer from the fin per unit depth of material. (6)
- 7 a) Derive an equation for the effectiveness of a counter flow heat exchanger. (7)
- b) Explain the terms fouling factor and LMTD correction factor. (3)
- 8 Water at the rate of 4 kg/s is heated from 40°C to 55°C in a shell and tube heat exchanger. On the shell side one pass is used with water as the heating fluid and at a mass flow rate of 2kg/s, and entering the heat exchanger at 95°C. The overall heat transfer coefficient is 1500 W/m²K. and the average water velocity in the 2 cm diameter tubes is 0.5m/s. Because of space limitations, the tube length must not exceed 3 m. Calculate the number of tube passes, the number of tubes per pass and the length of the tubes, keeping in mind the design constraints (10)

PART C

Answer any four full questions, each carries 10 marks.

- 9 Distinguish radiation from other modes of heat transfer. Also describe the laws governing radiation heat transfer (10)
- 10 Explain the term view factor. Derive an expression for view factor for two arbitrarily oriented surfaces. (10)
- 11 Two large plates, one at 800K and other at 600K have emissivities 0.5 and 0.8 respectively. A radiation shield having an emissivity 0.1 on one side and emissivity 0.05 on the other side is placed between the plates. Calculate the heat transfer by radiation per square meter with and without the radiation shield. (10)
- 12 a) Explain equimolar counter diffusion. (4)
- b) Gaseous hydrogen is stored at elevated pressure in a rectangular steel container of 10mm wall thickness. The molar concentration of hydrogen in steel at the inner surface is 2kg mol/m³, while the concentration of hydrogen in steel at the outer surface is 0.5 kgmol/m³. The binary diffusion coefficient for hydrogen in steel is 0.26 x 10⁻¹²m²/s. What is the mass flux of hydrogen through the steel? (6)
- 13 a) Define Schmidt number, Lewis number, Sherwood number and explain their significance. (6)
- b) Discuss Reynolds analogy. (4)
- 14 Air at 35 °C flows over a wet flat plate 50cm long with a velocity of 30 m/s. Calculate the mass transfer coefficient of water vapour in air at the end of the plate. (10)
