P4–RT–Exam.–Oct.–12–2–22

Con. 10506–12. **KR–5456**

(3 Hours) **[Total Marks : 100**

N.B. : (1) Question No. **1** is **compulsory**.
(2) Answer any **four** out of the **remaining** questions.

1. Explain any **four** of the following in brief :– **20**
   (a) Lumped Parameter analysis.
   (b) Hydrodynamic and Thermal boundary layer.
   (c) Significance of Nusselt, Reynolds and Grashoff Number in convection heat transfer.
   (d) Shape factor algebra.
   (e) Correction factor for LMTD.
   (f) Fouling of heat exchangers.

2. (a) A 3 mm diameter stainless steel wire (K = 20 W/m°C) resistivity, P = $10 \times 10^{-8} \Omega$m, 100 meters long has a Voltage of 100 V impressed on it. The outer surface of the wire is maintained at 100°C. Calculate the centre temperature of the wire. If the heated wire is submerged in a fluid maintained at 50°C, find the heat transfer co-efficient on the surface of the wire. **10**

   (b) A thermocouple junction is in the form of 8 mm diameter sphere. Properties of the material are : C = 420 J/kg°C, P = 8000 kg/m^3, K = 40 W/m°C and h = 40 W/m^2°C. This junction is initially at 40°C and inserted in a stream of hot air at 300°C. Find (i) Time constant of the thermocouple (ii) the thermocouple is taken out from the hot air after 10 seconds and kept in still air at 30°C. Assuming the heat transfer coefficient in air 10 W/m^2°C, find the temperature attained by the junction 20 seconds after removing from hot air. **10**

3. (a) What do you understand by critical thickness of insulation ? What is its practical significance ? Derive an expression for critical radius of insulation for a spherical surface with usual notations. **8**

   (b) Two long rods of the same diameter one made of brass (K = 85 W/m°C) and the other made of copper (K = 375 W/m°C) have one of their ends inserted into the furnace. Both of the rods are exposed to the same environment. At a distance of 105 mm away from the furnace end, the temperature of the brass rod is 120°C. At what distance from the furnace end the same temperature would be reached in the copper rod ? Assume the rod to be infinitely long fin. Solve the problem starting from basic differential equation. **12**

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4. (a) Define Buckingham π theorem and derive the following expression for forced convection heat transfer, $Nu = C(Re)^m (Pr)^n$. **10**

   (b) An electric wire of 0.25 mm diameter, $\in = 0{\cdot}4$ is placed within a tube of 2.5 mm diameter, $\in = 0.6$ having negligible thickness. This tube in turn is placed concentrically within a tube of 5 mm diameter, $\in = 0.7$. Annular spaces can be assumed to be evacuated completely. If the surface temperature of the outer tube is maintained at 5°C, what must be the temperature of wire so as to maintain the temperature of inner tube at 120°C ? **10**

5. (a) Derive with usual notations an expression for radiant heat exchange between two infinitely long parallel plane surfaces, assuming the surface to be grey. State the assumptions. **10**

   (b) Air at 30°C flows with a velocity of 2.8 m/s over a plate 1000 mm (length) × 600 mm (width) × 25 mm (thickness). The top surface of the plate is maintained at 90°C. If the thermal conductivity of the plate material is 25 W/m°C, calculate : (i) Heat lost by the plate, (ii) Bottom temperature of the plate for the steady state condition. The Thermo-physical properties of air at mean film temp. at 60°C are : $\rho = 1.06$ kg/m^3, $C_p = 1.005$ kJ/kg K, K = 0.02894 W/m°C, $\nu = 18.97 \times 10^{-6}$ m^2/s, Pr = 0.696. Choose the appropriate relation from the following : **10**

   $$\overline{Nu} = 0{\cdot}664\,(Re_L)^{1/2}\,(Pr)^{1/3} \text{ – for Laminar flow.}$$

   $$\overline{Nu} = 0{\cdot}036\,(Re_L)^{0{\cdot}8}\,(Pr)^{1/3} \text{ – for turbulent flow.}$$

6. (a) Derive an expression for LMTD of counter flow heat exchanger. **10**

   (b) A Chemical having specific heat of 3.3 KJ/kg K flowing at the rate of 20000 kg/h enters a parallel flow heat exchanger at 120°C. The flow rate of cooling water is 50000 kg/h with an inlet temperature of 20°C. The heat transfer area is 10 m^2 and the overall heat transfer coefficient is 1050 W/m^2 K. Find (i) the effectiveness of the heat exchanger (ii) the outlet temperature of water and chemical. Take for water, specific heat is 4.186 KJ/kg K. **10**

7. (a) State and explain Fick's law of diffusion. **5**

   (b) Define Schmidt and Sherwood Number with respect to mass transfer. **5**

   (c) An open tank 5.5 m in diameter contains 1 mm deep layer of benzene (molecular weight = 78) at its bottom. The vapour pressure of benzene in the tank is 0.13 bar. The diffusion of benzene takes place through a stagnant air film 2.8 mm thick. The system is operating at 1 atm and 20°C and under these conditions the diffusivity of benzene is 8.3×10^{-6} m^2/s. Assuming the density of benzene as 880 kg/m^3 calculate the time taken for the entire benzene to evaporate. **10**