B.E. Chemical Engineering Third Year First Semester Examination 2019 (Old)

Process Heat Transfer

Time: 3 hours Marks: 100

Answer any **FIVE** questions

Assume any missing data

All the symbols have usual meaning

1. (a) Show that for conductive heat transfer through a thick walled hollow sphere, the mean area of heat transfer is equal to the square root of product of inside and outside area of the sphere. **[5]**

(b) Consider a large plane wall of thickness, $L = 0.4$ m, thermal conductivity, $k = 2.3$ W/m·°C, and surface area, $A = 20$ m^2. The left side of the wall is maintained at a constant temperature of 80°C while the right side loses heat by convection to the surrounding air at 15°C with a heat transfer coefficient of $h = 24$ W/m^2·°C. Assuming constant thermal conductivity and no heat generation in the wall, (*a*) express the differential equation and the boundary conditions for steady one-dimensional heat transfer through the wall, (*b*) obtain a relation of temperature in the wall by solving the differential equation, and (*c*) evaluate the rate of heat transfer through the wall. **[3+10+2]**

2. A tapered steel rod is perfectly insulated on the curved surface and it has end diameters of 0.08 m and 0.20 m respectively. It is 0.5 m long. The thicker end is maintained at 170°C whereas, the thinner end is maintained at 40°C. The thermal conductivity of steel is 15 W/m·°C. Assuming constant k and no heat generation in the rod, (*a*) obtain the differential equation for steady one-dimensional heat conduction through the rod, (*b*) express the variation of temperature as a function of length of the rod and (*c*) calculate the steady state rate of heat loss through the rod. **[10+8+2]**

3. (a) Air at 160°C flows over a 2-m-long flat plate at 10 m/s. The pressure is 1 atm and the ambient temperature is 20°C. (*a*) Express the local heat transfer coefficient as function of longitudinal position, (*b*) calculate the average heat transfer coefficient and (*c*) determine the rate of heat loss from the surface. **[8+5+2]**
Properties of air at the mean film temperature are: $\rho = 0.962$ kg/m^3, $v = 2.22 \times 10^{-5}$ m^2/s, $k = 0.031$ W/m·°C, $C_p = 1.01$ kJ/ kg·°C.

(b) A hot plate 30 cm length and 20 cm wide is horizontally exposed to the ambient air. The temperature of the hot plate is maintained at 100°C and that of the ambient air is 40°C. Find the heat loss from top surface of the plate. **[5]**
The properties of air at the mean film temperature of 70°C are: $k = 7.08 \times 10^{-3}$ cal/s·m·°C, $v = 2.0 \times 10^{-5}$ m^2/s, Pr = 0.964. Use the correlation: $(\mathrm{Nu})_{av} = 0.15(\mathrm{Gr}\cdot\mathrm{Pr})^{1/3}$

4. (a) What is fouling factor? **[2]**
(b) Why LMTD correction is needed in a multipass shell and tube heat exchanger? **[4]**

(c) Water enters a double-pipe heat exchanger at 25°C and leaves at 60°C by passing through inner tube. Air enters the heat exchanger at 120°C and is brought to 50°C by passing through the annulas opposite to the direction of water flow. If the air velocity is 25 m/s, determine the heat transfer area and the length of the pipe required. Neglect tube resistance and any fouling resistance. **[14]**

Data:

- Inner tube: ID = 10 mm, OD = 15 mm
- Outer Tube: ID = 25 mm, OD = 30 mm
- Water side heat transfer coefficient = 70 cal/s·m^2·°C.
- The properties of air at the mean temperature are: ρ = 2.87 kg/m^3, v = 2.22 × 10^{-5} m^2/s, k = 0.0075 cal/s·m·°C, C_p = 241 cal/kg·°C.

5. a) Define *film condensation* and *dropwise condensation.* **[4]**

b) What is the difference between *evaporation* and *boiling*? **[3]**

c) Draw the boiling curve and identify the different boiling regimes. Also, briefly explain the characteristics of each regime. **[5+8]**

6. a) What is steam economy and capacity in multiple-effect evaporator. **[5]**

b) A continuous single-effect evaporator is to be fed with 5000 kg/h of solution containing 1 wt% solute. The feed at a temperature of 30°C and it is to be concentrated to a solution of 1.65 wt%. The evaporation is at atmospheric pressure and the area of evaporation is 76.5 m^2. Saturated steam is supplied at 1.6 atm and 120°C for heating. Boiling point elevation of the solution is 4°C. Calculate the amounts of vapor and liquid product and the overall hear transfer coefficient. **[15]**

Data: Enthalpy of feed, vapor product, liquid product, saturated steam and condensate are 145.8 kJ/kg, 2676.0 kJ/kg, 509.0 kJ/kg, 2691.5 kJ/kg and 461.3 kJ/kg, respectively.