Ref. No.: Ex/Che/PC/B/T/314/2024(S)

B.E. Chemical Engineering 3rd year 1st Semester Supplementary Exam, 2024

Process Heat Transfer

Time : Three hours | Full Marks : 100

(50 Marks for each Part)

Use separate answer script for each Part

PART I (50 Marks)

Answer all questions
Assume any missing data

1. (a) Carbon tetrachloride flowing at the rate of 400 kg/min through the annulus in a double-pipe heat exchanger is to be cooled from 80 °C to 45 °C using cooling water entering the inner pipe at 20 °C and flow rate of 300 kg/min. The inner diameter and thickness of the inner pipe of the heat exchanger consists is 25 mm and 5 mm respectively whereas the inner diameter of outer pipe is 45 mm. The heat transfer coefficient for carbon tetrachloride and water is 1250 W/m^2-°C and 1800 W/m^2-°C respectively. The specific heat for carbon tetrachloride and water is 0.24 and 1.0 kcal/kg-°C respectively. The thermal conductivity of the wall of the inner pipe is 45 W/m-°C.
   (i) Calculate the design overall heat transfer coefficient based on outer surface are of inner pipe.
   (ii) What is the required heat transfer area if the liquids are flowing counter-currently?

   (b) Explain with reasons whether the concept of log mean temperature difference would be valid if a reacting fluid (exothermic reaction) was flowing through a heat exchanger. [16 + 4]

2. (a) A single effect evaporator is used to concentrate 20 wt% solution of NaOH (flow rate = 12000 kg/h) entering at 60 °C to 50 wt%. Saturated steam is available to 172.4 kpa abs is used in the heat exchanger. The evaporator pressure is 11.7 kPa abs. The overall heat transfer coefficient is 1560 W/m2-K. Calculate the amount of steam used, steam economy and the heat transfer area.
   Data:
   The saturation temperature and latent heat of saturated steam at 172.4 kPa abs. is 115.6 °C and 2215 kJ/kg respectively.
   The boiling point of water at 11.7 kPa abs and 50% NaOH solution is 49 °C and 89 °C respectively.
   The enthalpies of 20% NaOH at 60 °C, 50% NaOH at 89 °C and superheated water vapor leaving the evaporator at 11.7 kPa and 89 oC is 210 kJ/kg, 500 kJ/kg and 2660 kJ/kg respectively.
   (b) Explain with reasons whether steam economy will be greater or lower in multi effect evaporator as compare to single effect evaporator [16 + 4]

[Turn over

3. (a) State the dimensionless groups/numbers important for the flow of heat in cases of (i) unsteady state conduction (ii) Natural convection (iii) forced convection in laminar flow (iv) forced convection in turbulent flow (v) film type condensation in a vertical tube

   (b) Explain with reasons whether the rate of condensation in condensers would increase or decrease if condensable vapor is mixed with non-condensing gas [5 + 5]

Ref. No.: Ex/Che/PC/B/T/314/2024(S)

B.E. CHEMICAL ENGINEERING THIRD YEAR FIRST SEMESTER SUPPLEMENTARY EXAM 2024

PROCESS HEAT TRANSFER

Part-II
Marks: 50

Q. No	CO No.	Question	Marks
1.	CO1	**a)** What is the critical thickness of insulation? **b)** Derive an expression for critical insulation radius on a hollow sphere in terms of thermal conductivity of the insulating material and convective heat transfer co-efficient outside the insulation. **c)** What would be your recommendations if the value of critical insulation radius is greater than the outer radius of the steam pipe and insulation of a steam pipe is wetted? **d)** A hollow spherical vessel of ID=19 cm and OD=20 cm contains a hot fluid. The fluid is to be cooled by exposing the vessel to a surrounding cold fluid when the outside film co-efficient is 10 W/m^2-K. If the vessel is to be insulated by mica steel (k=0.5815 W/m-K), determine the thickness of insulation so that the rate of heat transfer from the hot fluid is maximum.	1+4+2+3= 10
2.	CO2	**a)** What do you mean by fin? **b)** Draw (with figure caption) the different types of fins used in chemical industry. **c)** A plane wall is fitted with a copper (k= 420 W/m-K) pin fin of 1 cm diameter and 50 cm length. The fin base temperature is 350°C and the pin fin is in contact with air at 25°C. The convection heat transfer co-efficient between the fin surface and air is 25 W/m^2-K. Assuming that the fin is infinitely long, calculate the temperature at 10 cm, from the base.	2+3+5=10
3.	CO3	**a)** What do you mean by lumped heat capacity system? **b)** What is the difference between Biot (Bi) number and Nusselt (Nu) number? **c)** A constant wire (k=22.7 W/m-K; $\alpha=0.612\times10^{-5}$ m^2/s) of 1 mm diameter originally at 25°C is suddenly exposed to air at 250°C. If the convection heat transfer co-efficient is 3 W/m^2-K, determine the time required for the wire to reach a temperature of 225°C.	3+2+5=10
4.	CO4	**a)** What do you mean by temperature cross? What would be your recommendation if the value of temperature cross is higher? **b)** What would be your recommendations for routing the fluids in Shell-Tube heat exchanger if 1) the fluid is viscous and 2) the fluid flow rate is low? **c)** What are the empirical equations generally used for determination of convective heat transfer coefficients for tube and shell side fluids in	2+2+2+4 =10

		laminar and turbulent flows? **d)** In a double pipe heat exchanger hot fluid is entering at 220°C and leaving at 115°C. Cold fluid enters at 10°C and leaves at 75°C. Mass flow rate of hot fluid 100 kg/hr, C_p of hot fluid 1.1 kcal/kg °C, C_p of the cold fluid 0.95 kcal/kg °C. Calculate LMTD, 1.If the flow is parallel, 2.If the flow is counter current, 3.The mass flow rate of cold fluid if the heat loss during the exchange is 5 %.	
5.	CO5	**a)** What do you mean by steam economy of an evaporator? **b)** Briefly explain the backward feed arrangement in multi-effect evaporator. **c)** How does radiation heat transfer work? **d)** How do you differentiate gray body from black body? **e)** Briefly explain the Wein's Diplacement law and show that the wavelength is inversely proportional to the temperature.	1+3+1+1+4=10