Ref. No. : Ex/ChE/T/314/2019

B.E. CHEMICAL ENGINEERING THIRD YEAR FIRST SEMESTER – 2019

PROCESS HEAT TRANSFER

(50 marks for each part)

Time: Three Hours | **Use separate answer scripts for each part** | Full Marks: **100**

Part-I

(50 Marks)

Answer all questions

1. (a) Show the electrical analogy to heat flow.
   (b) 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?
   (c) What do you mean by temperature cross and what would be your recommendation if the value of temperature cross is higher?
   (d) What would be your recommendations for routing the fluids in a Shell-Tube heat exchanger if 1) the fluid is viscous and 2) the fluid flow rate is low?
   (e) Why temperature correction factor is used in a Shell-Tube heat exchanger?
   (f) Define steam economy of an evaporator and why backward feed operation is used in a triple effect evaporator when the product is highly viscous?
   (g) What is the main advantage of the basket type evaporator?
   (h) Define and classify the steam trap.
   (i) What do you mean by drop-wise condensation?
   (j) Define pool boiling and sub-cooled boiling. **1x10=10**

2. (a) Show that the rate of conduction heat transfer in a cylindrical shell is inversely proportional to the natural logarithm of the outer and inner radii.
   (b) Steam at 120°C is flowing through a wrought-iron (k=59 W/m K) tube of ID=5 cm and OD=7 cm which is covered with 1 cm thick asbestos (k=0.1105 W/m K) insulation. If the convection heat transfer co-efficients at the inner and outer surfaces of the tube are 200 W/m^2 K and 10 W/m^2 K, respectively, and the atmospheric air is at 25°C, estimate the rate of heat losses from steam per meter length of the tube. Assume that the steam in the tube is held at a constant temperature. **5+5=10**

3. (a) Derive an expression for critical insulation radius on a hollow cylinder in terms of thermal conductivity of the insulating material and convective heat transfer co-efficient outside the insulation.
   (b) It is proposed to use a 1 m long nickel (k=90 W/m K) rod as a heating element to dissipate 25 kW in a fluid at 30°C. If the convection heat transfer co-efficient between the rod and the fluid is 750 W/m^{2}K then determine the diameter of the rod if the maximum allowed temperature in the heating element is 900°C. **5+5=10**

4. (a) What do you mean by fin?
   (b) A plane wall is fitted with a copper (k= 204 W/m-K) pin fin of 1 cm diameter and 30 cm length. The fin base temperature is 300°C and the pin fin is in contact with air at 30°C. The convection heat transfer co-efficient between the fin surface and air is 10 W/m^2-K. Assuming that the fin is infinitely long, calculate the temperature at 5 cm, from the base.
   (c) Explain the backward and parallel feed operations of a triple effect evaporator. **1+4+5=10**

5. (a) What do you mean by lumped heat capacity system? Derive an equation for rate of heat flow in lumped heat capacity system.
   (b) A carbon-steel (k=54 W/m K; ρ=7833 kg/m^3; C=0.465 kJ/kg K) ball of 10 cm diameter which is initially at a uniform temperature of 625°C is suddenly immersed in a large quantity of oil at 25°C. If the convection heat transfer co-efficient between the steel ball and oil is 10 W/m^{2}K, estimate the time required for the ball to attain a temperature of 100°C. **5+5=10**

[Turn over

Ex/ChE/T/314/2019

B.E. CHEMICAL ENGINEERING THIRD YEAR FIRST SEMESTER EXAM 2019

PROCESS HEAT TRANSFER Time: Three Hours Full Marks: 100

Part- II
(50 marks for each part)
Use separate answer scripts for each part

Answer question 1 and any one from 2 & 3.
Assume any missing data.
Write all assumptions clearly.

HEAT EXCHANGER

1. (a) In a counter-current heat exchanger, an oil stream is cooled from 530 K to 450 K by water inlet and outlet temperatures of 300 K and 360 K respectively. The exchanger consists of a number of tubes of 1 m length each. It is now desired to cool the oil to 420 K (instead of 450 K) while maintaining the flow rate of oil, flow rate of water, inlet temperature of oil and water, and the number of tubes at the same values as before. Calculate the length of each tube required for this purpose. Assume that the physical properties remain unchanged.

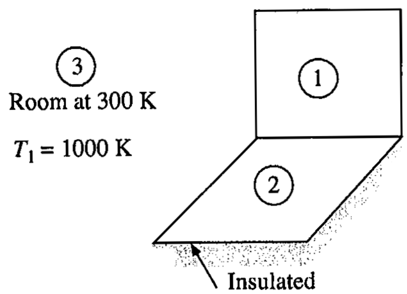
   (b) Derive an expression for LMTD for counterflow heat exchanger? If $\Delta T_l=\Delta T_2$ for a counterflow heat exchanger what will be your consideration? Draw temperature profile for a counterflow double pipe heat changer while water being heated using steam and gas stream being cooled by boiling water. **[10+15]**

CONVECTION & RADIATION

2. (a) Water at 20°C with a mass flow rate of 2.5kg/s enters a 3 cm ID tube with 100°C condensing steam at the outside of the tube. Calculate the length of the tube required to heat the water to 80°C. Mention all the assumptions clearly.

   Properties of water: ρ = 990 kg/m^3, c_p= 4181 J/kg. K, k = 0.644 W/ m.K, μ = 0.547x 10^{-3} kg/ m.s

   (b) Two rectangles 50 by 50 cm are placed perpendicularly with a common edge. One surface has T_1 = 1000 K, ε_1 = 0.6, while the other surface is insulated and in radiant balance with a large surrounding room at 300 K. Determine the temperature of the insulated surface and the heat lost by the surface at 1000 K. [Hints: Note that $J_3=E_{b3}$ because the room is large and $(1-\varepsilon_3)/\varepsilon_3 A_3$ approaches zero. Solve this problem using network method].

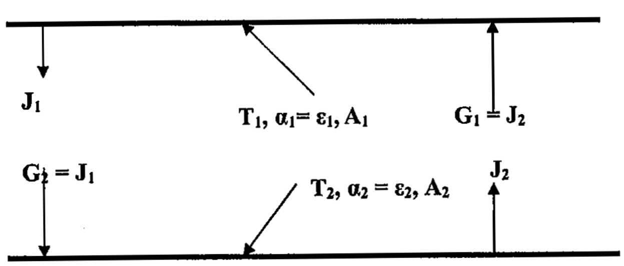


$F_{12} = 0.2 = F_{21}$

[10+15]

3. (a) Air at 27°C with a free stream velocity of 10m/s is used to cool electronic devices mounted on a printed circuit board. Each device, 4mm×4mm, dissipates 40mW, which is removed from the top surface. A turbulator is located at the leading edge of the board, causing the boundary layer to be turbulent. Estimate the surface temperature of the fourth device located 15 mm from the leading edge of the board.

(b) Derive an expression for heat exchange between two parallel infinite gray surfaces.



(c) Define radiosity, irradiance, and emissivity. **[10+10+5]**