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

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

PROCESS HEAT TRANSFER

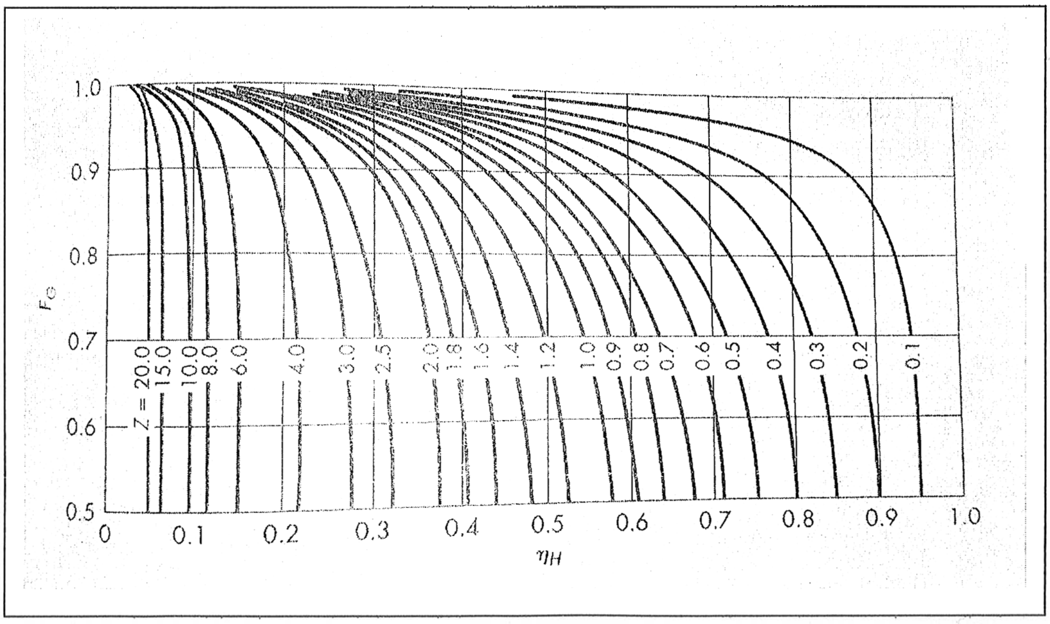
Part I

Answer any two questions
Assume any missing data

1. (a) Water flowing at 70 kg/s is heated from 35 °C to 75 °C in a 1-2 shell and tube heat exchanger by an oil (specific heat = 1.9 kJ/kg °C). The oil (flow rate = 225 kg/h) enters the exchanger at 110 °C. The heat transfer coefficient in the shell and tube side is 0.5 kW/m^2 °C and 1.0 kW/m^2 °C respectively. The tube wall (thermal conductivity = 50 W/ m °C) is 2.5 mm thick and the outer diameter of tube is 25 mm. Calculate
   (i) overall heat transfer coefficient based on inner area of tube
   (ii) temperature of oil exiting the exchanger.
   (iii) LMTD
   (iv) LMTD correction factor, F_G
   (v) outer heat transfer area of tubes required for heat exchange

   (4+2+3+4+4) [CO-5]

   The graph to obtain correction of LMTD, F_G is given below



(b) Sketch the heat flux versus temperature drop (difference between temperature of wire and boiling liquid) profile for boiling of water over an electrically heated wire. Identify the following regions in the diagram (i) pure convection regime (ii) individual bubble regime (iii) stable film boiling region (iv) Leidenfrost point. Explain why heat flux decreases when 'critical excess temperature' is exceeded. (8) [CO-4]

[Turn over

2. (a) A vertical tubular condenser is to be used to condense 20 kg/h of ethyl alcohol of ethyl alcohol which enters at atmospheric pressure. Colling water flows through the tubes at an average temperature of 30 °C. The tubes are 30 mm OD and 25 mm ID. The tubes are 1.5 m long. The water side heat transfer coefficient is 500 W/m^2 °C. Fouling factors and the resistance of tube wall may be neglected.
   (i) Assuming number of tubes in the condenser is 20, estimate the film heat transfer coefficient
   (ii) Verify whether 20 number of tubes is sufficient or in excess to obtain the desired condensate rate of 20 kg/h. (17) [CO-5]

The follow data is provided. The properties may be assumed constant.

Viscosity(μ) = 5x10^{-4} Pa.s; specific heat (C_p) = 2.44x10^3 J/kg K; thermal conductivity (k)= 0.48 W/m K; density (ρ)= 769 kg/m^3; latent heat of vaporization = 856x10^3 J/kg; boiling point of ethanol = 78.4 °C.
The heat transfer coefficient for the condensate film (h) may be calculated from

$$Re \leq 30 \qquad h\left(\frac{\mu^2}{k^3\rho^2 g}\right)^{0.33} = 1.47Re^{-0.33}$$

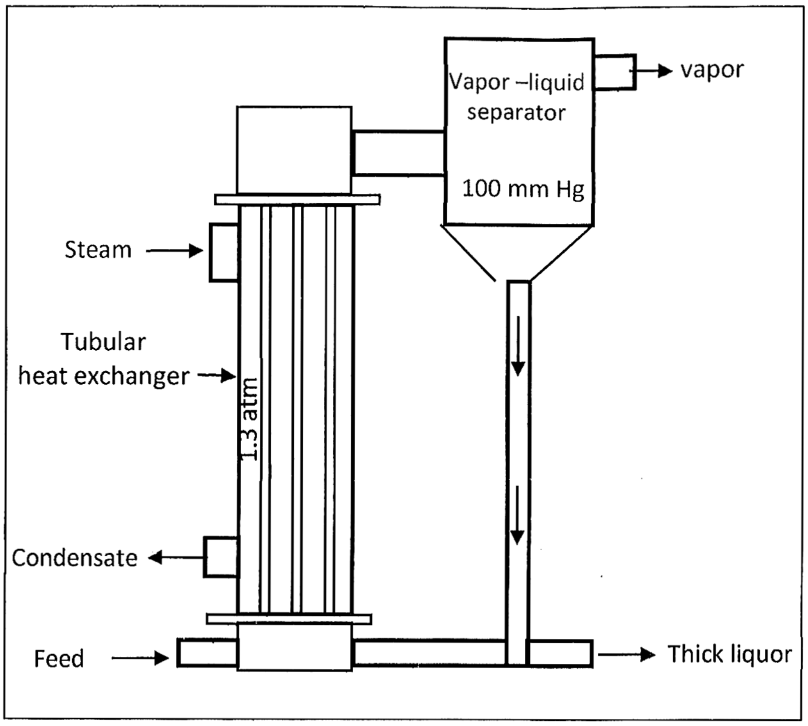
$$Re > 1800 \qquad \frac{h}{k}\left(\frac{\mu^2}{\rho^2 g}\right)^{(0.33)} = (Re^{-0.44} + 5.82x10^{-6}Re^{0.8}Pr^{1.3})^{0.5}$$

Where *Re* is the Reynold's number and *Pr* is the Prandtl number.

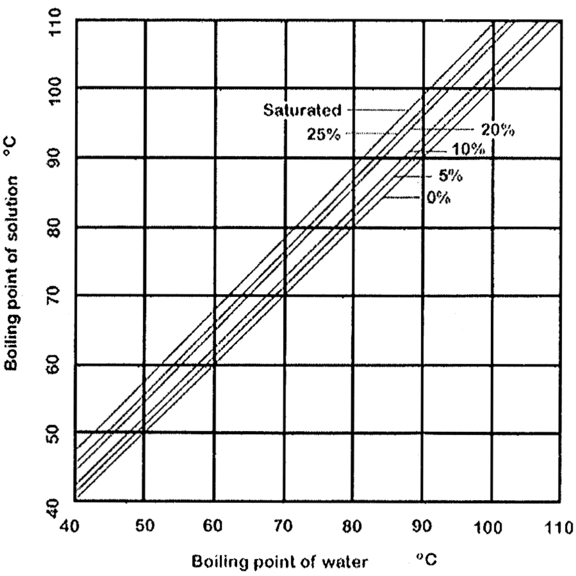
(b) Suggest two techniques for increasing heat transfer rate for laminar flow inside tubes. Also explain the reason why augmentation would occur with these techniques (5) [CO-2]

© Estimate the exchange of radiant energy per unit area between two large parallel plates. The temperature and emissivity of plate 1 is 300 °C and 0.56 and that of plate 2 is 25 °C and 0.90. The magnitude of Stefan-Boltzmann constant is 5.67x10^{-8} Wm^{-1} K^{-4} (3) [CO-3]

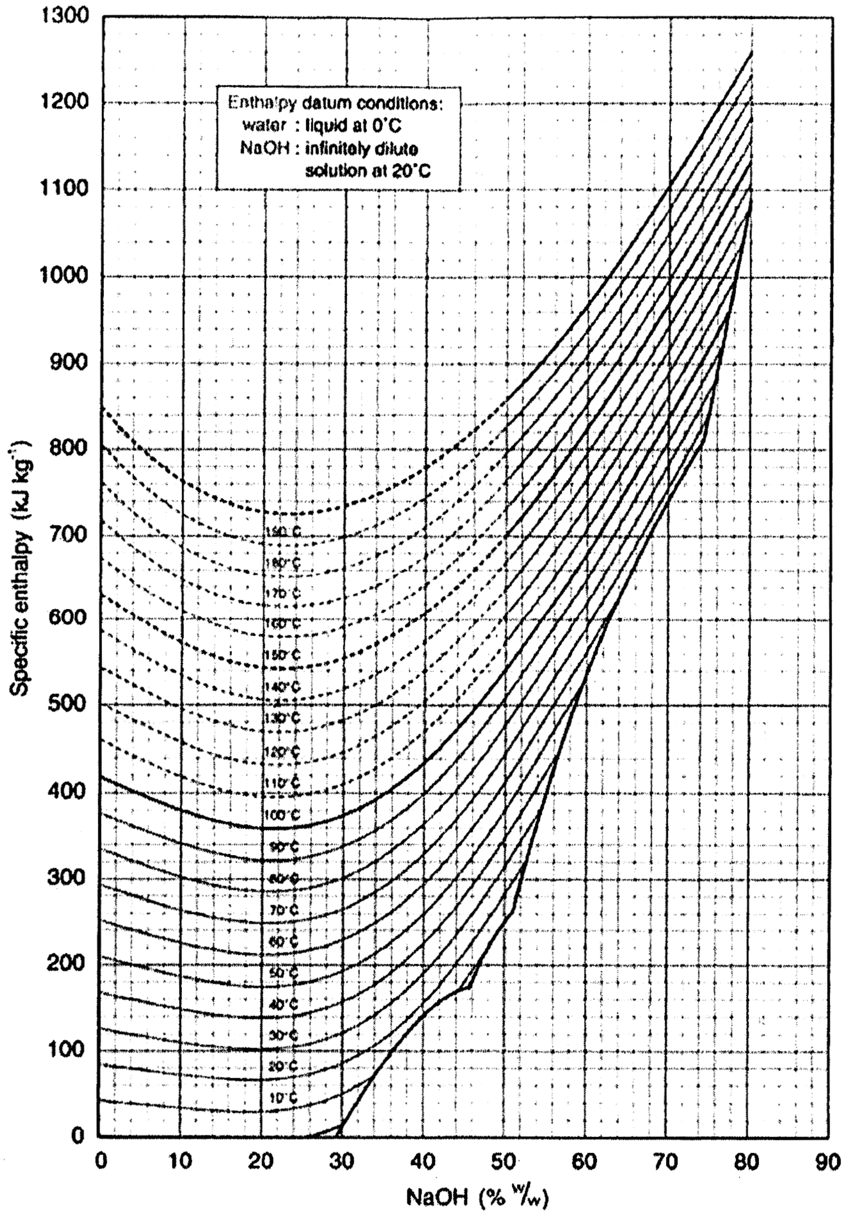
3. A single-effect evaporator is used to concentrate 25,000 kg/h of a 5 percent solution of sodium hydroxide to 20 percent solids. The gauge pressure of the steam is 1.5 atm. The absolute pressure in the vapor space is 100 mm Hg. The overall heat transfer coefficient is 1.25 kW/m^2 °C. The feed temperature is 40 °C. Calculate (a) amount of vapor generated (b) boiling point elevation (c) steam economy (d) area of heating surface required. (20) [CO-6]



Data:
Boiling point of water at 100 mm Hg = 51 °C.
The latent heat of vaporization and temperature of saturated steam at 1.5 atm is 2180 kJ/kg and 127.6 °C respectively.
Enthalpy of vapor exiting vapor-liquid separator = 2500 kJ/kg



Duhring diagram



Enthalpy concentration diagram for sodium hydroxide solution

Ref. No.: Ex/Che/PC/B/T/314/202

PART-II
Marks: 50
Use separate answer scripts
Answer all questions

B.E. CHEMICAL ENGINEERING THIRD YEAR FIRST SEMESTER EXAM 2024
Subject: PROCESS HEAT TRANSFER

Year: **Semester:**
Exam Roll No.:

Signature of Invigilator:

Date:

	CO-1	CO-2	CO-3	CO-4	CO-5	CO-6	Total
Marks Allotte							
Marks Obtained							

Signature of Examiner:

Q. No	CO No.	Questions	Marks
1.	CO1	1(a) Show that the rate of conduction heat transfer in a cylindrical shell is inversely proportional to the natural logarithm of the ratio of the outer and inner radii. (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 25°C. If the convection heat transfer co-efficient between the rod and the fluid is 750 W/ m^2K, then determine the diameter of the rod if the maximum allowed temperature in the heating element is 1000°C.	5+5=10
2.	CO1	2(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+5+1+3=10
3.	CO2	3(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
4.	CO2	4(a) What do you mean by lumped heat capacity system? Derive an equation for rate of heat flow in lumped heat capacity system. (b)What is the difference between Biot (Bi) number and Nusselt (Nu) number? (c) 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^2K, estimate the time required for the ball to attain a temperature of 100°C.	4+2+4 = 10
5.	CO3	5(a) How does radiation heat transfer work? (b) Discuss the different types of radiation intensity. (c) Briefly explain the exchange of energy between any source and any receiver.	2+3+5= 10