Enrolment No./Seat No_____

GUJARAT TECHNOLOGICAL UNIVERSITY

BE - SEMESTER–VII EXAMINATION – SUMMER 2025

Subject Code:3170502 Date:21-05-2025

Subject Name:Process Equipment Design

Time:02:30 PM TO 05:00 PM Total Marks:70

Instructions:

1. **Attempt all questions.**
2. **Make suitable assumptions wherever necessary.**
3. **Figures to the right indicate full marks.**
4. **Simple and non-programmable scientific calculators are allowed.**

			MARKS
Q.1	**(a)**	Discuss merits and demerits of saturated steam over hot oil as a heating medium.	**03**
	(b)	Differentiate between jet flooding and downcomer flooding.	**04**
	(c)	Discuss criteria for the selection operating pressure in a distillation column.	**07**
Q.2	**(a)**	Suggest modifications to avoid temperature cross in shell and tube heat exchanger.	**03**
	(b)	Describe the effect of reflux ratio on operating, fixed cost and total cost of distillation column with the help of graph, qualitatively.	**04**
	(c)	Hexane at 40 ^{o}C is pumped through the system at a rate of 9.09 m^3/hr. The tank is at atmospheric pressure. Pressure at the end of discharge line is 345 kPa (g). The discharge head is 3.05 m and the suction lift is 1.22 m above the level of liquid in the tank. The friction loss in suction line is 3.45 kPa and that in discharge line is 37.9 kPa. The mechanical efficiency of the pump is 0.6. The density of hexane is 659 kg/m^3 and its vapor pressure at 40 ^{o}C is 33.71 kPa. Calculate (i) $(NPSH)_A$ and (ii) power required by centrifugal pump. Use following equation for calculation. $$P = \frac{Hq_v\delta}{3.67X10^5X\eta}$$ **OR**	**07**
	(c)	Calculate the differential pressure across orifice meter for the following data. Fluid = Chlorine gas, Flow rate = 1500 Nm^3/h, Operating pressure = 1.2 atm (a), Operating temperature = 30 ^{o}C, Viscosity of chlorine gas at 30 ^{o}C = 0.0145 cP, Pipe inside diameter = 154 mm, Specific heat ratio = 1.355, orifice to pipe inside diameter ratio = 0.5, type of pressure taps = corner taps. Use following equations for calculation purpose. $$C_0 = 0.5959 + 0.0312\beta^{2.1} - 0.184\beta^8 + 0.0029\beta^{2.5}\left(\frac{10^6}{Re_D}\right)^{0.75} + 0.09L_1\beta^4(1-\beta^4)^{-1} - 0.0337L_2\beta^3$$ $$Y = 1 - \left[\left(\frac{1-r}{k}\right)(0.41 + 0.35\beta^4)\right]$$ $$\dot{m} = C_0 Y A_0 \sqrt{\frac{2g_c(p_1-p_2)\delta}{1-\beta^4}}$$	**07**

Q.3 **(a)** Discuss the criteria for fluid allocation in shell and tube heat exchange. **03**

(b) Discuss criteria of selection between kettle type reboiler and thermosyphon reboiler. **04**

(c) Discuss stepwise design procedure for kettle type reboiler. **07**

OR

Q.3 **(a)** Discuss merits and demerits of shell and tube heat exchanger over plate type heat exchanger. **03**

(b) Explain Tinker's flow model with a neat diagram. **04**

(c) In design of vertical thermosyohon Reboiler recirculation ratio is determined via trial and error calculation. In calculation, one of the following hypothetical conditions arises for the assumed value of recirculation ratio. **07**

(i) $\Delta P_{av} \approx \Delta P_t$

(ii) $\Delta P_{av} > \Delta P_t$

(iii) $\Delta P_{av} << \Delta P_t$

Discuss how to find or fix the recirculation ratio in each of the above condition.

Q.4 Estimate minimum reflux ratio and minimum number of ideal stages needed for the feed defined by the compositions given in table below. Also investigate effect of reflux ration on number of theoretical stages. The desired recovery of the light key component O in the distillation is 94.48%. The recovery of heavy key component P in the bottoms is 95.39%. Feed is at its bubble point. Total feed flow rate is 100 kmol/hr. Assume components lighter than the light key do not appear in bottom and components heavier than the heavy key do not appear in distillate. **14**

Component	Feed mole fractions	Average relative volatility, α_i
M	0.10	2.30
N	0.13	1.75
O (LK)	0.25	1.45
P (HK)	0.23	1.00
Q	0.15	0.90
R	0.08	0.83
S	0.06	0.65

Useful equations for calculation,

$$\sum \frac{\alpha_i x_{id}}{\alpha_i - \vartheta} = R_m + 1$$

$$\sum \frac{\alpha_i z_{if}}{\alpha_i - \vartheta} = 1 - q$$

$$N_m = \frac{log\left[\left(\frac{x_{LK}}{x_{HK}}\right)_d \left(\frac{x_{HK}}{x_{LK}}\right)_b\right]}{log\alpha_{LK}}$$

$$f(N) = \frac{N - N_m}{N + 1} = 1 - \exp\left[\left(\frac{1 + 54.4\psi}{11 + 117.2\psi}\right)\left(\frac{\psi - 1}{\psi^{0.5}}\right)\right]$$

$$\psi = \frac{R - R_m}{R + 1}$$

OR

Q.4 10900 kg/h of pure saturated methyl ethyl ketone (MEK) vapour at 13.73 kPa g is to be condensed by cooling water which is available in pant at 32 °C. Calculate required area of condenser to perform said duty. Use following data for calculation purpose. **14**

Orientation of condenser = Horizontal
Latent heat of vaporization of MEK = 438.27 kJ/kg
Condensation temperature of MEK vapor at 13.73 kPa= 83.87 °C
Heat capacity of cooling water = 4.18 kJ/kg°C
Cooling water outlet temperature = 40 °C
Initial assumption for overall heat transfer coefficient = 800 W/m^2°C
Tube length = 2m
Tube outside diameter = 19.05 mm
Tube inside diameter = 15.748 mm
Thermal conductivity of tube material = 16.3 W/m°C
Number of tube side passes = 4
Constant k_1 = 0.175
Constant n_1 = 2.285
Cooling water = tube side
P_t/d_o = 1.25
Cooling water viscosity = 0.72 cP
Cooling water thermal conductivity = 0.6228 W/m°C
Cooling water density = 992.9 kg/m^3
Thermal conductivity of MEK liquid = 0.173 W/m°C
Density of MEK liquid = 805 kg/m^3
Density of MEK vapour = 2.79 kg/m^3
Viscosity of MEK liquid = 0.32 cP
MEK side fouling coefficient = 10000 W/m^2°C
Water side fouling coefficient = 4000 W/m^2°C
Use following equations for calculation purpose.

$$Nu = 0.023Re^{0.8}Pr^{0.33}\left(\frac{\mu}{\mu_w}\right)^{0.14}$$

$$h_{co} = 0.95k_L\left(\frac{\delta_L(\delta_L - \delta_V)g}{\mu_L\tau_h}\right)^{1/3}.Nr^{-1/6}$$

$$Nr = \frac{2}{3}\left(\frac{D_b}{P_t}\right)$$

$$\tau_h = \frac{W_c}{LN_t}$$

Q.5 **(a)** Explain the function of liquid distributors, liquid re-distributor and packing support in packed tower absorber. **03**

(b) Discuss about different types of heads in pressure vessel and their applications. **04**

(c) Explain the graphical method to determine thickness of vessel subjected to external pressure with and without stiffening ring. **07**

OR

Q.5 **(a)** Discuss about Radiography test and its types in brief. **03**

(b) Discuss about stress-strain curve in detail. **04**

(c) Discuss stepwise procedure to calculate tower diameter of a sieve tray distillation column. **07**

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