Reg. No.										

MANIPAL INSTITUTE OF TECHNOLOGY

MANIPAL

(A constituent unit of MAHE, Manipal)

I SEMESTER M.TECH. (CHEMICAL ENGINEERING)

END SEMESTER EXAMINATIONS, NOV/DEC 2023

SUBJECT: PROCESS DESIGN OF CHEMICAL EQUIPMENT [CHE 5117]

REVISED CREDIT SYSTEM
(09/12/2023)

Time: 3 Hours MAX. MARKS: 50

Instructions to Candidates:

- Answer **ALL** the questions.
- Missing data may be suitably assumed.
- The use of data sheets is allowed in the examinations.

1.A.	A vapour mixture of 20% methane (1), 30% ethane (2) and 50% propane (3) at constant temperature of 30°C is available. Evaluate the dew point pressure and the composition of the first drop of condensate formed. (Use K-factor chart)	5
1.B	Estimate the gas phase diffusivity of carbon dioxide (CO_2) in air at 20°C and atmospheric pressure. $$D_v = \frac{1.013\times10^{-7}T^{1.75}\left(\frac{1}{M_a}+\frac{1}{M_b}\right)^{1/2}}{P\left[(\sum_a v_i)^{1/3}+(\sum_b v_i)^{1/3}\right]^2}$$ D_v diffusivity, m^2/s, T temperature, K Ma and Mb molecular weight of components a and b, P is total pressure, bar $(\sum_a v_i)$ and $(\sum_b v_i)$ are summation of special diffusion volume coefficients for components a and b	5

2.	Diethyl ether vapour at a rate of 5000 lit/hr at 90°C and 1.5 bar is to be condensed by chilled water at 20°C and the water may be heated up to 80°C. Design the required size of the horizontal condenser. Calculate the heat transfer area, number of tubes and diameter of the shell. The physical properties at the average temperature are given below. Latent heat of diethyl ether can be assumed to be that of ethyl ether. The tubes are of 1″ OD and 18 BWG. The length of the tubes is 8 ft. Assume that the tubes are arranged in triangular pitch. The number of passes is 8. The heat transfer coefficient for the horizontal condenser is given as $h_o = 0.725 \left(\frac{k^3 \rho^2 g \lambda}{\Delta t_o d_o N^{2/3} \mu}\right)^{1/4}$ Δt_o =Bulk hot fluid temp −Avg temp of cold fluid N=6	10
3.A.	For the heat exchanger condenser problem (question number 2), calculate the pressure drop on both the sides.	4
3.B.	Explain the various factors (any three) to be considered while allocating fluids in the inside pipe and annulus side of the double pipe heat exchanger.	3
3.C.	Explain with the diagrams, how the optimum cost, total heat transfer area and steam flow rate varies with respect to the number of effects in multiple effect evaporator.	3
4.A.	A Swenson Walker crystallizer is used to produce crystals of Na_2SO_4 by cooling a solution from 27°C to 17°C with the help of cooling water which enters at 8°C and leaves at 17°C. The solution contains 40 kg of Na_2SO_4 / 100 kg of water at 27°C and 14 kg of Na_2SO_4 / 100 kg of water at 17°C. The feed enters at a rate of 2000 kg/hr. The molecular weight of Na_2SO_4 is 120. Heat capacity of the solution is 2.93 kJ/kg K The heat of the solution: -13.31×10^3 kJ/kg mol Assume U= 520 W/m^2 K Calculate the area of the crystallizer.	8
4.B.	Explain the terms: bone dry material, wet bulb temperature	2

Properties of fluid	Diethyl ether	Water
Specific heat, J/kg K	1980.45	4187
Density, kg/m^3	708	988.03
Thermal conductivity, W/mK	0.1350	0.6284
Viscosity, kg/ms	0.13×10^{-3}	0.59×10^{-3}

5.	A binary mixture of methanol (30% by weight) and ethanol (70% by weight) is to be separated by fractionation to obtain 95% purity of methanol by weight in the distillate and 95% purity of ethanol by weight in the bottom product. The feed is a saturated vapour. For the equilibrium data calculations, consider the arithmetic average of relative volatility value. Molecular weight of methanol is 32 Molecular weight of ethanol is 46 Relative volatility α is defined as vapour pressure of more volatile component to vapour pressure of less volatile component.	10

Temperature, °C	64	67	70	73	76	78
Methanol, mm Hg	760	820	920	1020	1150	1260
Ethanol, mm Hg	420	430	470	610	690	760

The system follows Raoult's law and the vapour pressure data are available.

Calculate the number of theoretical plates required for the distillation column.