Total No. of Questions : 8] *[Total No. of Printed Pages : 3*

Roll No ....

MECM-301(A)

M.E./M.Tech., III Semester Examination, June 2020

Data Base for Process Plant Design

Time : Three Hours

Maximum Marks : 70

Note : i) Attempt any five questions.
ii) All questions carry equal marks.
iii) Draw neat sketch and assume suitable data wherever you required.
iv) Write the answers in sequential order.

1. a) Explain Tube failures region within a heat exchanger.
   b) It is required to cool down 20 kg/s of an aqueous solution whose specific heat is 4,180 J/(kg.K) from an inlet temperature of 67°C to 37°C. The operation will be performed with cooling water available at 17°C. Determine the number of shell passes of the heat exchanger using a water mass flow of (i) 20kg/s and (ii) It is known that to achieve a reasonable value of the heat transfer coefficient when cooling a solution with the characteristics of that in above example a minimum fluid velocity of 1 m/s is necessary. In this case, the overall heat transfer coefficient will be about 1,300 W/(m^2.K). For cleaning considerations, the solution must circulate into the tubes. It is desired to design a heat exchanger to cool 20 kg/s of solution using 20 kg/s of cooling water. The heat exchanger must be constructed with 3/4 -in BWG 16 tubes that have an internal diameter of 0.0157m and an external diameter of 0.019 m. Suggest a preliminary design.

2. a) Explain design of a heat exchanger performed by the supplier, the purchaser, or an engineering company.
   b) A heat exchanger has 300 3/4-in BWG 16 tubes, 2m length, arranged in two passes. It is used to heat up 58kg/s of an oil whose properties are ρ = 790 kg/m^3, c = 2,100 J/(kg·K), k = 0.133W/(m·K) Viscosity as a Function of Temperature [kg/(m·s)]

T(°C)	57	67	77	147	177
μ[kg/(m·s)]	3.6×10^{-3}	3.02×10^{-3}	2.5×10^{-3}	7.4×10^{-4}	5.2×10^{-4}

3. a) How does Multiple Effect Evaporators Work?
   b) A triple effect forward-feed evaporator is being used to evaporate milk containing 10% solids to a condensed milk of 50% T.S. The boiling point rise of the milk (independent of pressure) can be estimated from BPR°C = $1.78x + 6.22x^2$, where x is weight fraction of T.S. in milk (K1). Saturated steam at 205.5 kPa (121.1°C saturation temperature) is being used. The pressure in the vapor space of the third effect is 13.4 kPa. The feed rate is 22680 kg/h at 26.7°C. The heat capacity of the milk is (K1) $C_p = 4.19 - 2.35x$ kJ/kg. K. The heat of milk is considered to be negligible. The coefficients of heat transfer have been estimated as $U_1 = 3123$, $U_2 = 1987$ and $U_3 = 1136$ W/m^2. K. If each effect has the same surface area, calculate the area, the steam rate used and the steam economy.

4. a) Advantages of multiple effect evaporators.
   b) Show that if the same total quantity is to be evaporated, then the heat transfer surface of each of the two effects must be the same as that for a single effect evaporator working between the same overall conditions.

5. a) Why the mist flow regime is avoided in reboiler design?
   b) Discuss Recirculating versus once-through operation of Thermosyphon reboiler. A kettle reboiler is being designed to generate 75,000 lb/h of vapor having a density of 0.40 lbm/ft^3. The liquid leaving the reboiler has a density of 41.3 lbm/ft^3 and a surface tension of 16 dyne/cm. The length of the tube bundle is 15 ft and the diameter plus clearance is 32 in.
   i) Calculate the vapor loading and dome segment area.
   ii) Calculate the diameter required for the enlarged section of the K-shell.
   iii) How many pairs of shell-side nozzles should be used?

6. a) Explain Jet Flood Safety factor and turndown ratio of tray design.
   b) A tray column is to be designed to reduce the water content in natural gas ($M_{methane}$ = 0.016kg mol^{-1}) from 0.10 to 0.02 mole % by absorption of water at 70°C and 40 bar in diethylene glycol (M_{DEG} = 0.106 kg mol^{-1}, ρ_{DEG} = 1100 kg m^{-3}) containing 2.0 mol% H_2O. The equilibrium constant $K = 5.0\cdot10^{-3}$ at this temperature. Preliminary calculations resulted in a slope of the operating line L/V = 0.010 and N_{ts} = 2.25.
   The column should have the capacity to treat $Q_V = 3m^3$ gas per unit time at this condition (40 bar, 70°C). Lab scale experiments showed that the overall mass transfer coefficient $k_{OV} = 3\cdot10^{-3}$ m s^{-1} at this gas load.
   The gas phase is assumed to obey the ideal gas law, $H_{spacing}$ = 0.5m, g = 9.81 m s^{-2}.

   Calculate:
   i) The minimum column diameter
   ii) The plate efficiency
   iii) The height of the column

7. a) Explain Flooding and Channeling in the packed absorption tower. How designer overcomes these problems?
   b) A packed tower is to be designed for absorption of SO_2 from air by contact with fresh water. The entering gas has a mole fraction of SO_2 of 0.10 and the exit gas must contain amole fraction of no greater then 0.005. The water flow rate used is to be 1.5 times the minimum, and the inlet airflow rate (on an SO_2 free basis) is 500 kg m^{-1} h^{-1}. The column is to be operated at 1 atm and 303K. Determine the height of the packed bed section.
   The following equilibrium data are available for SO_2 absorption in water at this temperature:

P_{SO_2} (mm Hg)	Conc. (g SO_2/100g H_2O)
0.6	0.02
1.7	0.05
4.7	0.10
11.8	0.20
19.7	0.30
36.0	0.50
52.0	0.70
79.0	1.00

   There also exist mass transfer coefficient correlations for SO_2 absorption in a column packed with 1-inch rings (at this temperature):

$$k_x a = 0.6634\bar{L}^{\,0.82} \qquad k_y a = 0.09944\bar{L}^{\,0.25}\bar{V}^{0.7}$$

   Where $\bar{L}$ and $\bar{V}$ are the liquid and gas mass fluxes, respectively, in kg m^{-2} h^{-1} and the units of $k_x a$ and $k_y a$ are kg-mol m^{-3} h^{-1} (mol fraction)$^{-1}$.

8. a) Discuss function of Weir and Down comer in plate type distillation column.

b) Design a sieve plate tower for the separation of a mixture of 60% (mole) of C_6H_6 and 40% (mole) of toluene by distillation at atm pressure. The feed at its boiling point. The annual throughput of 50,000 tonns corresponding to 1.65kg/sec after allowing an annual shut down. The rate of top product removal is to be 1.01 kg/sec and column operated with a reflux ratio of 2:1. The top and bottom product contains 95% and 5% C_6H_6 respectively. The air column gives rise to following data.

$T_{top} = 90°C$, $T_{bottom} = 110°C$, Avg liquid density = 695kg/m^3.

$\mu_{benzene} = 0.25cp$, $\mu_{toluene} = 0.28cp$

VLE data at atm pressure

X	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
y	0.23	0.38	0.51	0.63	0.70	0.78	0.86	0.90	0.97	1.0

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