Seat No.: _____ Enrolment No._____

# GUJARAT TECHNOLOGICAL UNIVERSITY

**BE – SEMESTER – VI EXAMINATION – WINTER 2015**

**Subject Code:160503** **Date:08/12/ 2015**

**Subject Name: Process Equipment Design-I**

**Time:2:30pm to 5:30pm** **Total Marks: 70**

**Instructions:**

1. **Attempt all questions.**
2. **Make suitable assumptions wherever necessary.**
3. **Figures to the right indicate full marks.**

**Q.1** **(a)** A centrifugal pump is drawing water from an overhead tank, exposed to atmosphere. Vertical distance between free surface of liquid in the tank and centre line of the pump is 10 m. Capacity of centrifugal pump is 10000 kg/h. Maximum operating temperature is 50 °C. Vapor pressure of water at 50 °C is 92.51 torr. Total length of suction pipe 10.5 m, having two 90 ° elbows. Material of pipe is carbon steel. Density of water = 1000 kg/m$^3$, Viscosity of water = 0.558 cP, K-Value for 90º elbow is 0.75. Surface roughness of carbon steel and friction factor are 0.0457 mm & 0.005 respectively. For the velocity of water in suction line 1 m/s, Determine (i) the size of suction pipe (ii) total frictional pressure drop in suction line (iii) (NPSH) of centrifugal pump. **07**

**(b)** What is jet flooding and downcomer flooding? Explain the design steps for the determination of total pressure drop in sieve tray distillation column. **07**

**Q.2** **(a)** Discuss the Process Design of Orifice meter. Also Explain various locations of pressure taps with neat sketch in orifice meter. **07**

**(b)** Discuss in detail about the various criteria of selection between horizontal and vertical condenser. **07**

**OR**

**(b)** Discuss in detail about criteria of selection between kettle type and thermosyphon reboiler. **07**

**Q.3** Lube oil is to be cooled from 65 °C to 45 °C by using cooling water in shell and tube heat exchanger having following data. **14**

Lube oil flow rate - 450 L/min
Density of lube oil - 869 kg/m$^3$
Specific heat of lube oil - 2.1413 kJ/kg °C
Thermal conductivity of lube oil - 0.13 W/m °C
Viscosity of lube oil - 15 cP
Cooling water inlet temperature - 35 °C
Cooling water outlet temperature - 39 °C
Specific heat of water - 4.1868 kJ/kg°C
Viscosity of water - 0.73 cP
Thermal conductivity of water - 0.628 W/m °C
Density of Water - 993.32 kg/m$^3$
Specification of fixed tube sheet heat exchanger:
Shell inside diameter – 418 mm
Tube O.D. - 15.875 mm
Type of baffle - 25% segmental
Tube I.D -13.3858 mm

Baffle spacing - 83.6 mm
Tube length - 3.048 m
Tube pitch - $1.25d_O$
Type of tube arrangement - Triangular
Nos. of tube side passes – 4
LMTD correction factor : 0.95
Assume overall heat transfer Coefficient = 400 W/m$^2$ °C
Fixed tube sheet type shell and tube heat exchanger is used for this duty. Take lube oil on shell side and water on tube side. Calculate (i) Number of tubes (ii) tube side heat transfer coefficient (iii) shell side heat transfer coefficient.
Use following correlation:
Shell side heat transfer coefficient. $\frac{h_o d_s}{k} = J_h R_e P_r^{1/3}$ , where $J_h = 10X$
X = 0.48856log10Re – 2.82393, $d_e = \frac{1.1}{d_o}(P_t^2 - 0.907 d_o^2)$
Tube Side Heat Transfer coefficient: $N_u = 0.023 R_e^{0.8} P_r^{0.33}$

**OR**

**Q.3** **(a)** State the merits and demerits of mixer-settler. Discuss the design steps for the process design of horizontal and vertical gravity settler. **07**

**(b)** For the separation of dimethylformamide (DMF) from its dilute solution having a flow rate of 1000 kg/h and containing 20 % DMF by mass is to be counter currently extracted with methylene chloride to reduce the DMF concentration to 1 % in the final raffinate. Determine (i) the minimum amount of solvent which can be used and (ii) the number of theoretical stages if actual amount of solvent is double than the minimum required. Phase equilibrium equation is given by $Y = 0.5555\,X$ at 25 ºC where, Yand X are mass fractions of solute. **07**

**Q.4** **(a)** Discuss about the determination minimum reflux ratio for binary distillation. **07**

**(b)** Aqueous solution of ethanol contains 6 % by mass ethanol. It is to be concentrated in the distillation column to 30 % by mass. Open steam, saturated at 80 kPa gauge pressure will be used for the distillation column. Feed flow rate is 5000 kg/h and it is saturated liquid at its bubble point. Residue should not contain more than 0.02 mass percent ethanol. Sparging steam flow rate is 0.2 kg of feed. Calculate the number of theoretical stages required for the desired separation. The equilibrium data for ethanol-water system at 101.3 kPa is as follows. **07**

| | | | | | |
|---|---|---|---|---|---|
| x | 0.019 | 0.0721 | 0.0966 | 0.1238 | 0.1661 |
| y | 0.170 | 0.3891 | 0.4375 | 0.4704 | 0.5089 |

**OR**

**Q.4** Isopropyl alcohol (IPA) forms a minimum boiling azeotrope with water at 80.4 ºC and 101.325 kPa, having a composition of 31.47 mole % water. A feed consisting of 50 mass % IPA under saturated liquid condition is to be distilled to give 67.5 mole % IPA as distillate (near azeotrope) and 0.1 mole % (0.0033 mass %) IPA in the bottom. Using McCabe-Thiele technique and for R = 3, find the number of theoretical stages, required for the separation at 1 atmospheric and locate the feed introduction stage. To find the nonideal behaviour of IPA-water system, use of van Laar equation can be used. Assume the vapour fugacity to be unity at low pressure. The vapour pressure of IPA can be calculated using Antoine equation. **14**

$$\log p_v = 6.8651 - \frac{1359.50}{(T - 75.65)}$$

Where, $p_v$ = Vapour pressure, kPa and T = Saturation temperature, K

**Q.5** **(a)** Discuss the function of Liquid distributors, Liquid redistributors, Packing support and Hold-down plate used for packed tower type absorber. **07**

**(b)** With neat sketch explain the various types of packing arrangement used in packed column. **07**

**OR**

**Q.5** Venturi scrubber is planned for absorbing $SO_2$ gases from the exist gas stream of boiler flue gas by using 1% lime Solution (by mass). The data for the scrubber is as follows. **14**

Volumetric flow rate of exist gas stream = 24000 $Nm^3/h$
Discharge pressure of gas from venturi = Atmospheric
Temperature of gas mixture, entering the venturi scrubber = 90 °C
$SO_2$ concentration in the boiler flue gas = 4000 ppm (or mg/kg)
Solvent to gas ratio = 1.4 $L/m^3$
Throat velocity of gas phase = 100 m/s
Average molar mass of flue gas = 29.48 kg/kmol
Density of 1% lime Solution = 1012.5 $kg/m^3$
Equilibrium mass of $SO_2$ per 100 mass of $H_2O$ = 0.035
Determine: (i) throat diameter of venturi scrubber (ii) % removal $SO_2$ gases (iii) consumption of lime and (iv) pressure drop in venturi scrubber.
Use following correlation:

Fractional solute removal = $\dfrac{y_1 - y_2}{y_1} = \eta \dfrac{(1 - mx_2 / y_2)}{\left(1 + \dfrac{mG_M}{L_M}\right)}$

Mass transfer efficiency = $\eta = 1 - e^{-N_G}$

Number of overall gas-phase mass transfer units $N_G = (K_G aRT / p_t) / \theta_c$

Venturi pressure drop $\Delta P = 2.584 \times 10^{-3} v_G{}^2 \rho_G A_{th}{}^{0.133} (L' / G')^{0.78}$

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