Seat No.: ________ Enrolment No.___________

GUJARAT TECHNOLOGICAL UNIVERSITY

BE - SEMESTER–VII (NEW) EXAMINATION – WINTER 2021

Subject Code:3170502 Date:13/12/2021

Subject Name:Process Equipment Design

Time:10:30 AM TO 01:00 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.**

Q.1	**(a)**	Define schedule number, Equivalent length of pipe and NPSH.	**03**
	(b)	State the advantages and disadvantages of rotameter.	**04**
	(c)	It is proposed to pump 10,000 kg/h of saturated toluene at 114^{o}C and 1.1 atm a from the reboiler of a distillation tower to a second distillation unit without cooling. If the friction loss in the reboiler and pump is 7 kPa and density of toluene is 866 kg/m^3, how much liquid level in the reboiler is to be maintained to give a net suction head of 2.5 m? Calculate the power required to drive the pump if the pump is to elevate the toluene to 10 m to a second unit at atmospheric pressure. Assume friction loss in the discharge line to be 35 kPa. Pump efficiency is 62%.	**07**
Q.2	**(a)**	State the reasons for providing baffles in shell and tube heat exchanger.	**03**
	(b)	With neat diagram explain Tinker's flow model.	**04**
	(c)	Discuss the criteria of selection between horizontal and vertical condenser.	**07**
		OR	
	(c)	Discuss the design steps to calculate of shell and tube side heat transfer coefficient.	**07**
Q.3	**(a)**	State the advantages of vacuum distillation.	**03**
	(b)	What are the functions of downcomers? Briefly explain the different types of downcomers used for sieve tray distillation column.	**04**
	(c)	With suitable examples explain the concept of selection of operating pressure for distillation column.	**07**
		OR	
Q.3	**(a)**	Determine the minimum reflux ratio for the saturated binary liquid mixture of benzene – toluene at standard atmospheric pressure based on the following data. Feed – 100 kmol/h, Mole fraction of benzene in feed – 0.4, Mole fraction of benzene in distillate – 0.99, Mole fraction of benzene in residue – 0.02, Average relative volatility – 2.25	**03**
	(b)	Discuss in details the various factors considered for the selection of tray.	**04**
	(c)	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.4	**(a)**	What is flooding? Define flooding velocity and minimum wetting rate.	**03**
	(b)	Describe the selection criteria of tray tower type absorber.	**04**
	(c)	Discuss in detail the design steps to determine the diameter for the packed tower type absorber for physical absorption.	**07**
		OR	
Q.4	**(a)**	State the function of liquid distributors, packing support and hold down plate in packed tower type absorber?	**03**
	(b)	With neat sketch discuss any two types of random packing material used for packed	**04**

tower type absorber.

(c) Determine the fractional of solute removal in a venturi scrubber based on the following data. **07**

Volumetric flow rate of boiler flue gas - 24,000 Nm^3/h, Discharge pressure of gas from venture - Atmospheric, Temperature of gas - 80 to 90°C, SO_2 concentration in boiler flue gas - 4000 ppm (or mg/kg), Solvent - 1% lime solution, 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 constant (m) – 40.63

Q.5 **(a)** What is Radiography? How it is being carried out? **03**

(b) State the applications of various types of heads used for pressure vessel design. **04**

(c) Define internal and external design pressure. Discuss the different methods to calculate thickness of cylindrical shell subjected to external design pressure. **07**

OR

Q.5 **(a)** A low carbon steel cylindrical vessel having shell of 3 m outer diameter & 10 m length is to be designed for vacuum operation at 250°C. Shell thickness is 14 mm. Shell will be fabricated from carbon steel plate. Modulus of elasticity of plate material and poisson ratio is 19.5×10^5 kgf/cm^2 and 0.3 respectively. (i) What is the maximum allowable vacuum permitted in the vessel based on the given shell thickness without stiffener? (ii) Design the vessel for minimum number of equally spaced circumferential stiffeners to permit the use of full vacuum in the vessel with the given thickness of shell. (iii) Calculate the material saved by design of shell with stiffeners, compare to the same shell design without stiffeners for full vacuum. Weight of stiffener - 29.75 kg/m, area of cross section for stiffener - 31.81cm^2 and moment of inertia for the stiffening ring - 650 cm^4. Take 2 mm corrosion allowance. **14**

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Seat No.: ________ Enrolment No.___________

GUJARAT TECHNOLOGICAL UNIVERSITY

BE - SEMESTER–VII (NEW) EXAMINATION – SUMMER 2022

Subject Code:3170502 Date:03/06/2022

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.**

Q.1	**(a)**	Define: 1. The capacity of pump 2. NPSH 3. Schedule number	**03**
	(b)	What are the functions of baffles in shell and tube heat exchangers? Discuss in brief types of baffles.	**04**
	(c)	Discuss with a neat sketch the pressure tapes in the orifice meter.	**07**
Q.2	**(a)**	Give the full name for TEMA, BEM, and HTRI in the context of shell and tube heat exchangers.	**03**
	(b)	State the advantages and disadvantages of plate-type heat exchangers.	**04**
	(c)	Benzene at 37.8 ^oC is pumped through the system at a rate of 9.09 m^3/h with the help of a centrifugal pump. The reservoir is at atmospheric pressure. Pressure at the end of a discharge line is 345 kPa g. The discharge head is 3.05 m and the pump suction head is 1.22 m above the level of liquid in the reservoir. The friction loss in the suction line is 3.45 kPa and that in the discharge line is 37.9 kPa. The mechanical efficiency of the pump is 0.6. The density of benzene is 865 kg/m^3 and its vapor pressure at 37.8 ^oC is 26.2 kPa. Calculate (i) $(NPSH)_A$ (ii) Power required by a centrifugal pump.	**07**
		OR	
	(c)	A three-stage reciprocating compressor is used to compress 306 Sm^3/h of methane from 0.95 atm a to 61.3 atm a. The inlet temperature is 26.7 C Specific heat ratio of methane, k =1.31. Calculate the power required for compression, if mechanical efficiency is 80% and discharge temperature of gas after 1st stage.	**07**
Q.3	**(a)**	What is the significance of the temperature correction factor? How to calculate?	**03**
	(b)	Discuss the downcomer design in the tray column.	**04**
	(c)	Explain the design steps to calculate the tower diameter of the packed bed absorption column.	**07**
		OR	
Q.3	**(a)**	Discuss the types of flooding in a distillation column.	**03**
	(b)	Discuss the criteria of selection between kettle type reboiler and thermosyphon reboiler.	**04**
	(c)	Discuss the significance of following in a packed bed tower design. 1. Flooding velocity 2. Minimum wetting rate 3. The minimum amount of solvent required.	**07**
Q.4	**(a)**	What is the function of packing support? Explain in brief its types.	**03**
	(b)	In the design of vertical thermosyphon Reboiler recirculation ratio is determined via trial and error calculation. Discuss how to find or fix the recirculation ratio in case if $\Delta Pav >> \Delta Pt$	**04**

(c) The feed and product composition for distillation column is given as below. Determine the number of theoretical stages required for R=3, by FUG method. The design equations are provided below. Take α_{LK} = 2.567, R_m=1.4509 **07**

Component	Feed	Distillate	Residue
n-butane	37	95	16.3
iso-pentane	32	05	41.6
n-pentane	21	--	28.5
n-hexane	10	--	13.6

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

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

OR

Q.4 **(a)** With an example explain the guideline to choose the material of construction for any pressure vessel. **03**

(b) Compare the various types of trays for tray columns. **04**

(c) What is design pressure? Explain various methods to calculate the thickness of cylindrical pressure vessels **07**

Q.5 **(a)** Calculate tube side and shell side heat transfer coefficient for the design of a 1-2 shell-and-tube exchanger for the following duty. What modifications are required to do for design? **14**

20,000 kg/h of kerosene (42° API) leaves the base of a kerosene side-stripping column at 200°C and is to be cooled to 90°C by exchange with 70,000 kg/h light crude oil (34° API) coming from storage at 40°C. The kerosene enters the exchanger at a pressure of 5 bar and the crude oil at 6.5 bar. A pressure drop of 0.8 bar is permissible on both streams. Allowance should be made for fouling by including a fouling factor of 0.0003 (W/m^2 °C)$^{-1}$ on the crude stream and 0.0002 (W/m^2 °C)$^{-1}$ on the kerosene stream.

Property	kerosene	light crude oil
Specific heat, kJ/kg K	2.47	2.01
Density	730	820
Thermal conductivity	0.132	0.134
Viscosity	0.43	3.2

k_1 and n_1 for tube bundle diameter: (For triangular pitch pt=1.25dO)

No of the tube side passes	1	2	4	6	8
k_1	0.319	0.249	0.175	0.0743	0.0365
n_1	2.142	2.207	2.285	2.499	2.675

Crude is taken through the tubes and the kerosene in the shell. Use 19.05 mm (3/4 inch) outside diameter, 14.83 mm inside diameter, 5 m Long tubes on a triangular pitch (pitch/dia. = 1.25). Assumed value of the overall heat transfer coefficient is 300 W/m^2 °C for calculation.

OR

Q.5 **(a)** Define and explain the significance of joint efficiency factor and maximum allowable stress. **03**

(b) Write a short note on types of heads and their applications. **04**

(c) Discuss the design steps to calculate the number of theoretical stages in binary distillation column. **07**

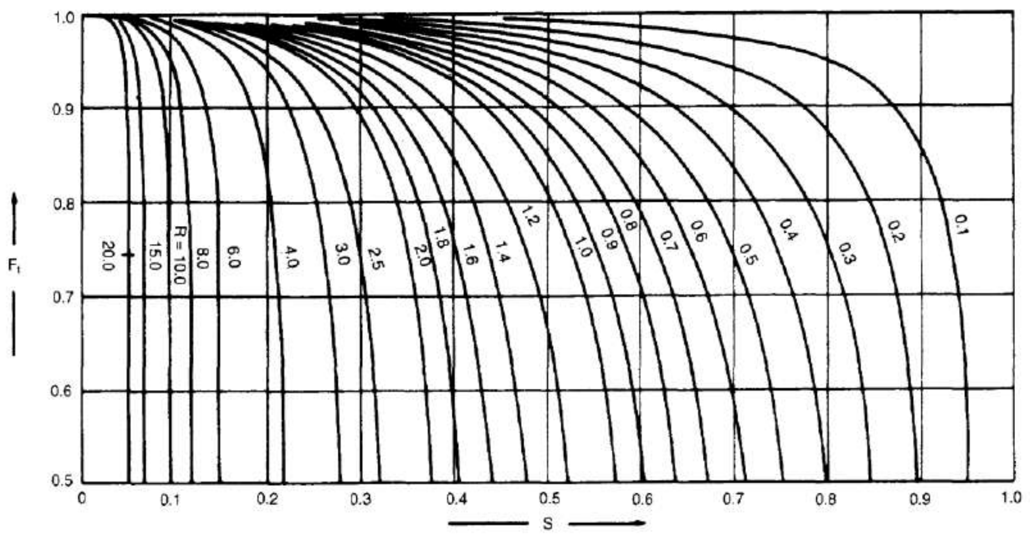

Figure1: Temperature correction factor for one pass shell and two ore more passes of tubes.