

JK LakshmiPat University Jaipur

INSTITUTE OF ENGINEERING AND TECHNOLOGY

End Term Examination, May, 2019

B. Tech. in Chemical Engineering, Semester Sixth

Roll No.....

Course Code : CHE603

Time: 3:00 hours

Max. Marks: 30

Course Name: Process Equipment Design

Instructions to students:

1. Do not write anything other than your roll number on question paper.
2. **Assume suitable data wherever required and mention it clearly.**
3. Writing appropriate units, nomenclature, and drawing neat sketches/schematics/ flow chart wherever, required are an integral part of the answer.

Q.1	Fill in the blanks. a) Sulfonation of naphthalene gives β-sulfonate and synthesis of cypermethrin are the industrial example of.....reactors. b) Some process steps like upstream and downstream processing of the reaction can also be performed in the c) Volume required by reactor is very much less than the same by reactor, particularly for a higher order reaction with higher desired conversion. d) Conversion of ammonia from the mixture of nitrogen and hydrogen, hydrolysis of ethylene oxide to ethylene glycol, and olefin production by steam cracking are the industrial examples of.....reactors. e) For highly viscous fluid or slurry solution, ...reactor provides higher heat transfer coefficient and mass transfer coefficient, compared to reactor.	5
Q.2	Acetic acid is to be separated from a process stream containing 80% acetic acid and 20% water by mass by continuous distillation at atmospheric pressure. Concentration of water in bottom product pure acetic acid should not greater than 50 ppm. Top product distillate contains 80% water and 20% acetic acid by mass. The feed is liquid at 30°C with 50% tray efficiency. The vapour-liquid equilibrium data at 101.325kPa are given in table-1. The density of the pure water and acetic acid at 100.64°C are 958 kg/m³ and 1010 kg/m³ respectively. The viscosity of pure water and acetic acid at 100.64°C are 0.28mPa.s and 0.48 mPa.s respectively. The contribution of CH₃ and COOH are 55.5 and 73.8 respectively. The actual velocity of the tower is 85% of flooding velocity. Diffusivity of acetic acid in water is 0.0000124 cm²/sec at 25° and at this temperature the viscosity of water is 0.95 mPa.s (a) Estimate the number of theoretical stage required.	15

	(b) Design a sieve tray tower for the distillation of acetic acid –water system at maximum feed flow rate is 12 000kg/h and minimum feed flow rate is 70% of the maximum at two different tray spacing 0.3 m and 0.45 m.	
Q.3	Butyl acetate formation is carried out in batch reactor at 90°C with sulphuric acid as a homogeneous catalyst. The feed contained 5.97 mole of n-butanol per mole of acetic acid and the catalyst concentration is 0.042% by mass as sulphuric acid. The rate equation for this reaction is $-r_A = kC_A^2$. Where, C_A is the concentration of acetic acid in mol/cm³ and k is rate constant 17.4 cm³/ (mol .min). Density of the reaction mixture at 90°C can be assumed constant and equal to 0.85g/cm³. $CH_3COOH(l) + C_4H_9OH(l) \leftrightarrow CH_3COOC_4H_9(l) + H_2O(l)$. Latent heat of vaporization of saturated steam and saturated steam side heat transfer coefficient at 120.23°C are 2201.6 kJ/kg and 6000 W/(m² °C) respectively. (a) Calculate the time required to obtained conversion of 70%. (b) Determine the size of reactor and the mass of reactants that must be charged to the reactor in order to produce ester at all average rate of 100 kg/h. conversion if 70%. Reactor will be shut down for 40 minute between batches for removal of product, cleaning and start-up. Assume that batch reactor is ideal. Also calculate the height and diameter of the reactor. (c) Determine the heat duty required and heat transfer area required for starting conditions of the reaction.	10

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Table-1: VLE Data for acetic acid-water system at 101.325kPa

Temperature, °C	Mole fraction of water in liquid, x	Mole fraction of water in vapour, y
118.3	0	0
110.6	0.1881	0.3063
107.8	0.3084	0.4467
105.2	0.4498	0.5973
104.3	0.5195	0.6580
103.5	0.5824	0.7112
102.8	0.6750	0.7797
102.1	0.7261	0.8239
101.5	0.7951	0.8671
100.8	0.8556	0.9042
100.8	0.8787	0.9186
100.5	0.9134	0.9409
100.2	0.9578	0.9708
100.0	1.0000	1.0000

Table-2: All Required Data

Compound	$\Delta H_f^0, \frac{kJ}{mol}$ at 25°C	$C_{Li}, \frac{kJ}{kmol \cdot ^\circ C}$ at 57.5°C	$\lambda, \frac{kJ}{kg}$ at 89.4 °C	$\mu, \frac{mPa \cdot s}{}$ at 90°C	$C_{pi}, \frac{kJ}{(kg \cdot ^\circ C)}$	$k, \frac{W}{(m \cdot ^\circ C)}$	p_c, bar
Acetic Acid	-484.2	129.67		0.53	2.1855	0.1557	
Butanol	-327.3	215.41	625.39	0.65	2.8763	0.164	44.2
Water	-285.83	75.36	2284				220.5
Butyl Acetate	-522.766	267.12	330.2				31.4

Table-3: Pipe Roughness

Material	Absolute roughness, mm
Drawn tubing	0.0015
Commercial Steel Pipe	0.046
Cast Iron Pipe	0.26
Concrete Pipe	0.3 to 3.0

Table-4: Relationship of weir length and Down Comer Area

$\frac{Weir\ Length\ (l_w)}{ID\ of\ Tower\ (D_i)}$	$\frac{Down\ comer\ Area\ (A_d)}{Column\ Area\ (A_c)} \times 100$
0.600	5.25
0.650	6.80
0.700	8.80
0.705	9.00
0.715	9.50
0.727	10.00
0.745	11.00
0.770	12.00
0.780	13.00
0.800	14.00
0.815	15.00
0.826	16.00
0.840	17.00
0.850	18.00

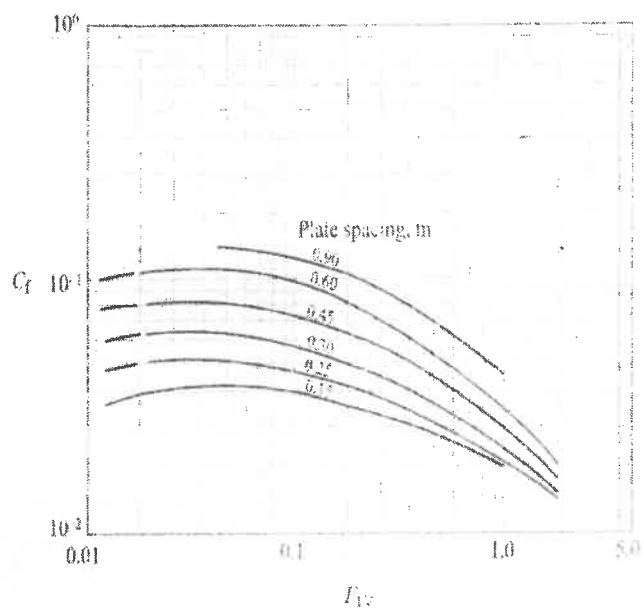


Figure-1: Flooding Velocity (Sieve Plates)

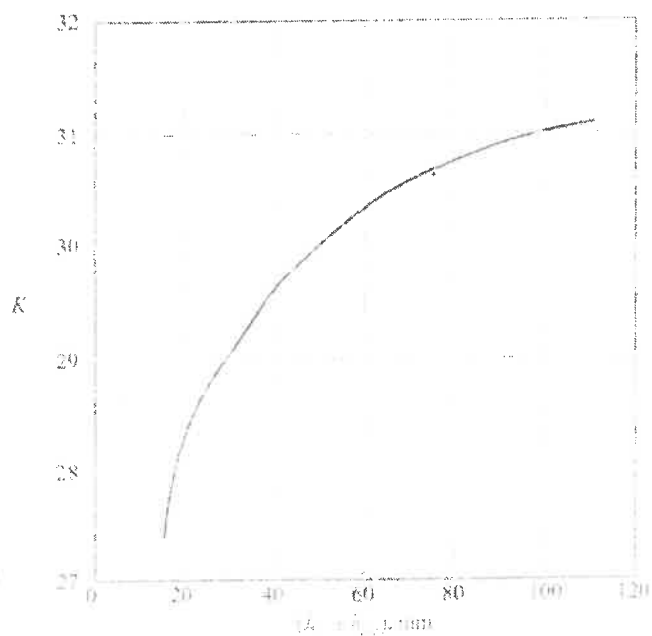


Figure-2: Weep-Point Correlation

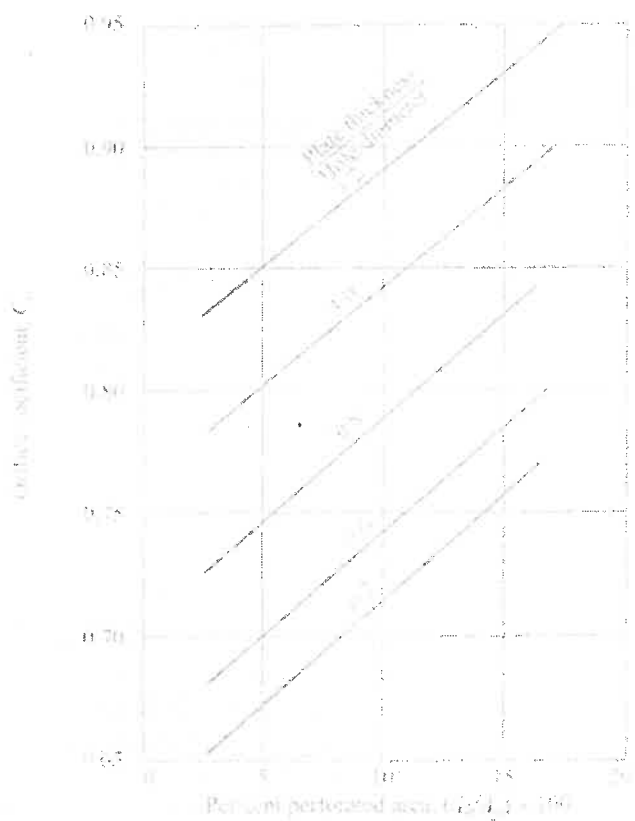


Figure-3: Discharge Coefficient (Sieve Plates)



Figure-4: Entrainment Correlation for Sieve Plates

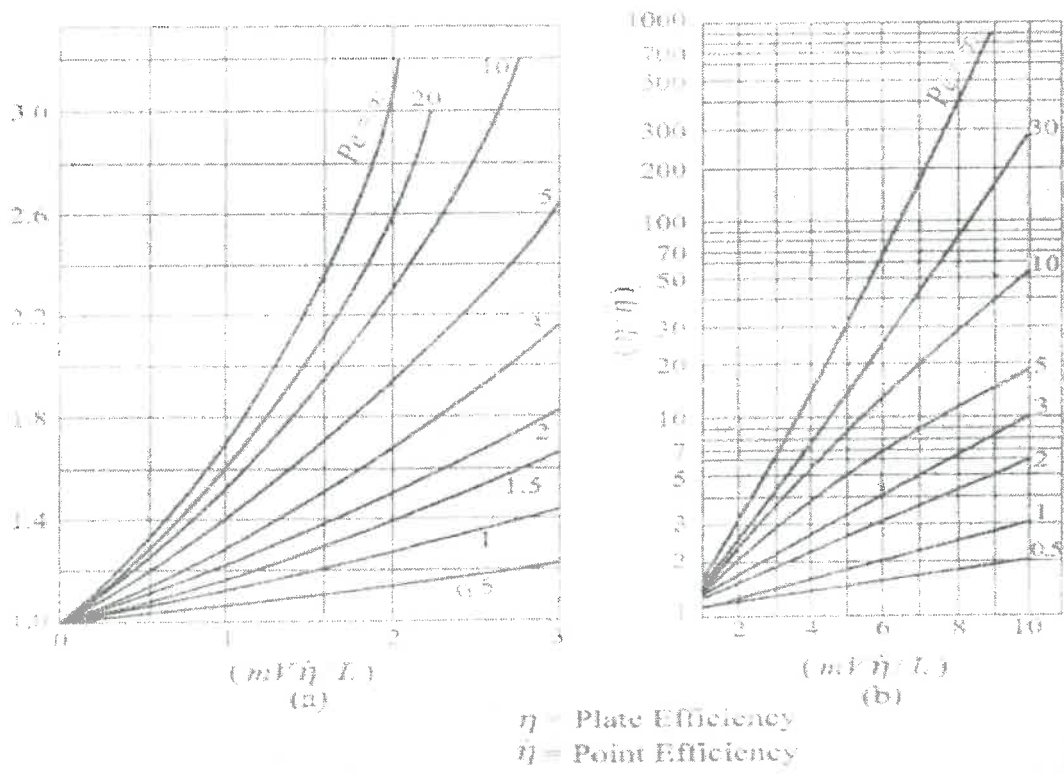


Figure-5: Relationship between Plate and Point Efficiencies

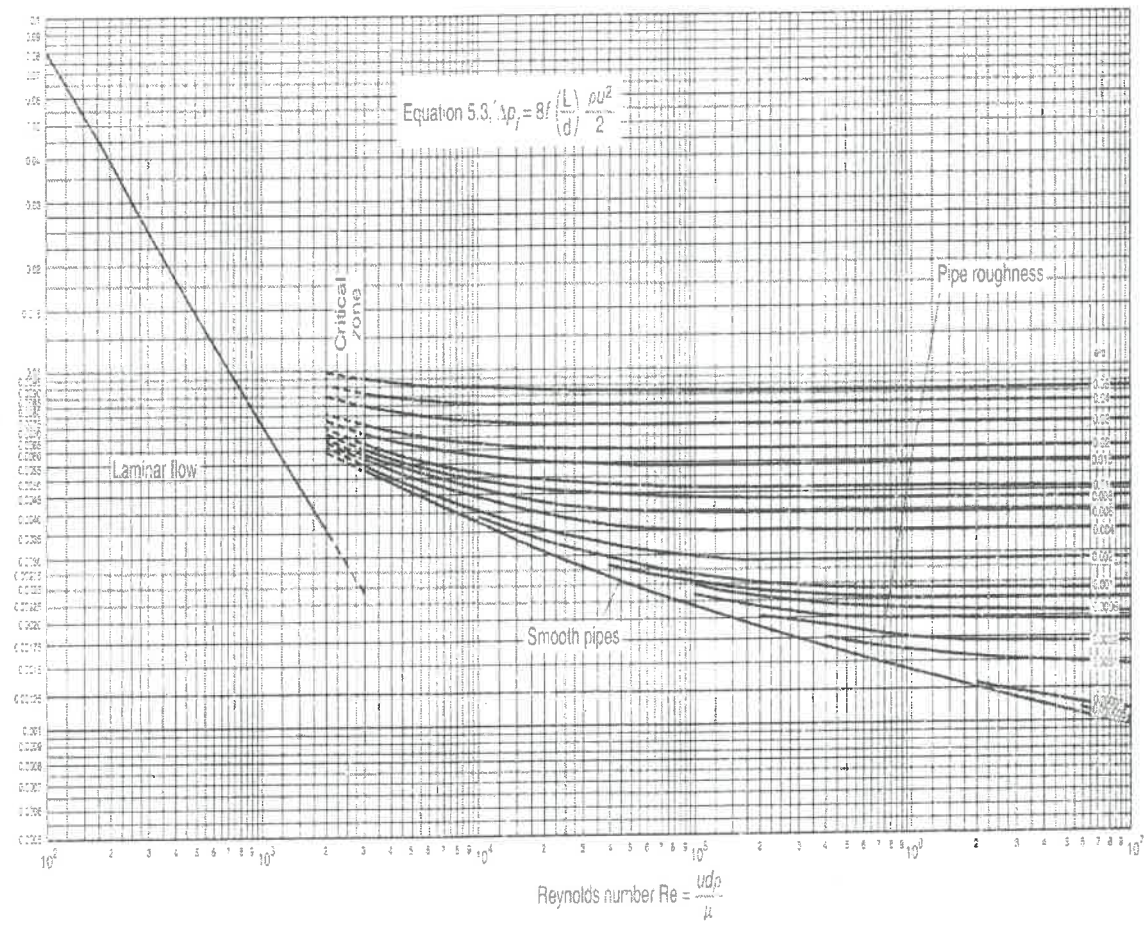


Figure -6: Pipe friction versus Reynolds number and relative roughness

