

JK LAKSHMIPAT UNIVERSITY, JAIPUR

INSTITUTE OF ENGINEERING AND TECHNOLOGY

End Term Examination (Regular/Backlog), April-May 2015

B. Tech in Chemical Engineering, Semester VI



Roll No.....

CHE 603: PROCESS EQUIPMENT DESIGN

Time: 3 hours

Max. Marks: 100

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.1A Objective type multiple choice questions (10 questions @ 1 mark) 10**
- i. Saddle support is most suitable for
 (a) horizontal vessels (b) tall vertical vessels
 (c) both (a) and (b) (d) none of these
 - ii. Longitudinal stress is of the circumferential stress
 (a) one half (b) two-third (c) three fourth (d) none of these
 - iii. Differentiate between light key component and heavy key component.
 - iv. Thickness of torispherical head is defined as:
 (a) $t = \frac{PL}{2\sigma E - 0.2P}$ (b) $t = \frac{PL}{0.2\sigma E + 2P}$ (c) $t = \frac{0.885PL}{2\sigma E - 0.1P}$ (d) $t = \frac{0.885PL}{\sigma E - 0.1P}$
 - v. If Reynolds number > 4000 , then tube side heat transfer coefficient is determined by:
 (a) $\frac{h_i d_i}{k_f} = C Re^{0.8} Pr^{0.33} \left(\frac{\mu}{\mu_w}\right)^{0.14}$ (b) $\frac{h_i d_i}{k_f} = C (Re^{0.8} Pr^{0.33})^{0.14}$
 (c) $\frac{h_i d_i}{k_f} = 1.86 (Re Pr \frac{d_i}{L})^{0.33} \left(\frac{\mu}{\mu_w}\right)^{0.14}$ (d) $\frac{h_i d_i}{k_f} = 1.86 (Re Pr \frac{d_i}{L})^{0.6} \left(\frac{\mu}{\mu_w}\right)^{0.14}$
 - vi. According to Lamé's equation, the thickness of cylinder is equal to
 (a) $r_i \left[\sqrt{\frac{\sigma_t + (1-2\mu)p}{\sigma_t - (1-2\mu)p}} - 1 \right]$ (b) $r_i \left[\sqrt{\frac{\sigma_t + (1-\mu)p}{\sigma_t - (1-\mu)p}} - 1 \right]$
 (c) $r_i \left[\sqrt{\frac{\sigma_t + p}{\sigma_t - p}} - 1 \right]$ (d) $r_i \left[\sqrt{\frac{\sigma_t}{\sigma_t - 2p}} - 1 \right]$
 - vii. In a thick cylindrical shell, the maximum radial stress at the outer surface of the shell is
 (a) zero (b) p (c) -p (d) 2p
 - viii. A cylinder is 300 mm mean diameter with a wall 2 mm thick. Calculate the maximum pressure difference allowed between the inside and outside if the stress in the wall must not exceed 150 MPa.
 (a) 5 MPa (b) 3 MPa (c) 2 MPa (d) 4 MPa
 - ix. Write name of methods to determine the number of theoretical stages in multicomponent distillation column.
 - x. Define bending moment.



Q.2	Short answer type questions (4 questions @ 2.5 marks)	10
i.	Discuss the phenomenon of "Entrainment Flooding" and "Weeping" briefly.	
ii.	A thin cylindrical pressure vessel of 500 mm diameter is subjected to an internal pressure of 2 N/mm ² . If the thickness of the vessel is 20 mm, find the hoop stress, longitudinal stress and the maximum shear stress.	
iii.	A material has stresses of 2 MPa in the x direction and 3 MPa in the y direction. Given the elastic constants $E = 205 \text{ GPa}$ and $\mu = 0.27$, calculate the strains in both direction.	
iv.	Write in brief about the types of plate in distillation column.	
Q.3A	Explain in which cases packed columns are preferred over plate columns.	05
Q.3B	Write a steps with formulation for the design of shell and tube heat exchanger.	05
Q.4A	Write note on various factors involved in the design of sieve tray distillation column.	05
Q.4B	Find the thickness for a tube of internal diameter 100 mm subjected to an internal pressure which is 5/8 of the value of the maximum permissible circumferential stress. Also find the increase in internal diameter of such a tube when the internal pressure is 90 N/mm ² . Take $E = 205 \text{ kN/mm}^2$ and $\mu = 0.29$. Neglect longitudinal strain.	05
Q.5A	Derive Lames's Equation.	05
Q.5B	A hydraulic cylinder is 100 mm internal diameter and 140 mm external diameter. It is pressurized internally to 100 MPa gauge. Determine the radial and circumferential stress at the inner and outer surfaces. Take $E = 250 \text{ GPa}$ and $\mu = 0.25$	05
Q.6A	Design a vertical thin shell pressure vessel according to the ASME Section 8 Div. 1 for the following input data: Pressure = 85 Pa Temperature = 90 °C Volume = 30 cubic meter $r/t = 225 \text{ mm}$ corrosion allowance, $c = 0.02 \text{ mm}$ weld efficiency = 85% Material for pressure vessel shell = AISI 304 SS Allowable stress for AISI 304 SS = 103 MPa Head Type = hemishperical Application = for storing high pressure hot water	15
Q.7A	(a) Derive the expression of thickness of thin spherical shell due to an internal pressure. (b) A seamless spherical shell, 900 mm in diameter and 10 mm thick is being filled with a fluid under pressure until its volume increases by $150 \times 10^3 \text{ mm}^3$. Calculate the pressure exerted by the fluid on the shell, taking modulus of elasticity for the material of the shell as 200 kN/mm ² and poisson's ratio as 0.3.	05 + 05 = 10

OR

- Q.7A Define failure mechanism of pressure vessel. Show that for excessive elastic deformation, bending moment is represented by 10

$$M = EI \frac{d^2 y}{dx^2}$$

- Q.8 A distillation column is to separate 4750 mol/h of feed composed of 37% n-butane, 32% iso-pentane, 21% n-pentane and 10% n-hexane. The column operates at an average pressure of 2 atm and will produce a distillate product containing 95% n-butane and 5% iso-pentane. The bottom product is allowed to contain no more than 570 mol/h of n-butane. Feed is 25% (by mole) vapour (means $q = 0.75$). Assume ideal vapor-liquid equilibrium. All compositions are mole %.

Component	Feed		Distillate		Residue		Average relative Volatility
	Mol %	Mol/hr	Mol %	Mol/hr	Mol %	Mol/hr	
n-butane (LK)	37	1757.5	95	1187.5	16.3	570.0	2.567
iso-pentane (HK)	32	1520.0	5	65.5	41.6	1457.5	1
n-pentane	21	997.5	-	-	28.5	997.5	0.762
n-hexane	10	475.0	-	-	13.6	475.0	0.236
Total	100	4750.0	100	1250.0	100	3500	

Find:

- (i) Minimum number of stages required by Fenske method
- (ii) Minimum reflux ratio by Underwood method (take $\theta = 1.6045$)
- (iii) Number of ideal stages at $R = 1.2 R_{min}$ by Gilliland Method or Erbar-Maddox Method.
- (iv) Also find the number of ideal stages at rectifying section and the stripping section at the operating reflux ratio and location of feed stage.

- Q.9 A lube oil cooler for 2MW steam turbine is to be designed for following operating conditions. Lube oil, conforming to ISO VG-46 grade, flows at the rate of 23463 kg/h and is to be cooled from 65° C to 45° C with cooling water. Allocate lube oil on shell side and water on tube side. Use 1 shell 4 tube passes. Select triangular pitch arrangement for shell and tube heat exchanger. Let clearance between shell ID and $D_b = 12.5$ mm. 15

Density of lube oil = 869 kg/m³

Specific heat of lube oil = 2.1413 KJ/(Kg °C)

Thermal conductivity of lube oil at 55° C = 0.13 W/(m °C)

Viscosity of lube oil at 55° C = 15×10^{-3} kg/(m s)

Density of water at 37° C = 993.328 kg/m³

Heat capacity of water = 4.2 KJ/Kg °C

Thermal conductivity of water at 37° C = 0.628 W/(m. °C)

Viscosity of water at 37° C = 0.73×10^{-3} kg/(m s)

Cooling water inlet temperature = 35 °C
Cooling water outlet temperature = 39 °C



Assume initially $U = 150-500 \text{ W}/(\text{m}^2 \cdot ^\circ\text{C})$

Inner diameter of tube = 13.3858 mm

Outer diameter of tube = 15.875 mm

Tube Length = 10 ft

Baffle spacing = $D_s/5$

h_{od} = fouling coefficient for shell side fluid = $3000 \text{ W}/(\text{m}^2 \cdot ^\circ\text{C})$

h_{id} = fouling coefficient for tube side fluid = $5000 \text{ W}/(\text{m}^2 \cdot ^\circ\text{C})$

Thermal conductivity of tube material $k_w = 50 \text{ W}/(\text{m} \cdot ^\circ\text{C})$

Calculate overall heat transfer coefficient (U_o) based on outside area of tubes $\text{W}/(\text{m}^2 \cdot ^\circ\text{C})$.

OR

- Q.9 Design a sieve plate continuous distillation column to recover acetone from 50 - 50 mol % acetone-water mixture available at 30°C. the feed stream flowrate is 25000 kg/h. the top product should contain at least 95 mol% acetone and the bottom product should contain 1% acetone by mole. Consider reboiler as equivalent to one stage. This column is operated at atmospheric pressure (top tray). Column efficiency of 60% and pressure drop per plate of 1.25 kPa may be assumed. You can take the minimum flow as 70% of the maximum rate above and below the feed plate. Reflux ratio is 2.5 times of $R_{\min}$. Other required data are given below:

Number of stages = 9

$R_{\min} = 0.67$

Mol. weight of acetone = 58

Mol. Weight of water = 18

Physical Properties:

Top section (56.3° C)	Bottom section (105° C)
$\rho_v = 2.08 \text{ kg}/\text{m}^3$	$\rho_v = 0.693 \text{ kg}/\text{m}^3$
$\rho_l = 744 \text{ kg}/\text{m}^3$	$\rho_l = 955 \text{ kg}/\text{m}^3$
Average molecular weight of liquid = 56	Average molecular weight of liquid = 18.4
Surface tension, $\sigma = 20 \times 10^{-3} \frac{\text{N}}{\text{m}}$	Surface tension, $\sigma = 58 \times 10^{-3} \frac{\text{N}}{\text{m}}$

Take downcomer area as 10% of total cross sectional area.

Plate spacing = 600 mm

Flooding = 80%

Weir length = 0.73 * Tower diameter

Weir height = 40 mm

Hole diameter = 12 mm

Plate thickness = 12 mm

***** GOOD LUCK *****