

JK LAKSHMIPAT UNIVERSITY, JAIPUR

INSTITUTE OF ENGINEERING AND TECHNOLOGY

End Term Examination (Regular), April-May 2018

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. Most of the codes used in India is
(a) IS:2825-1969 (b) BS: 1500 and 1515
(c) ASME section VIII (d) All of these
- ii. In a thick cylindrical shell, the maximum radial stress at the outer surface of the shell is
(a) zero (b) p (c) $-p$ (d) $2p$
- iii. Write name of methods to determine the number of theoretical stages in binary distillation column.
- iv. Skirt support is most suitable for
(a) small horizontal vessels (b) tall vertical vessels
(c) large horizontal vessels (d) none of these
- v. Bronze is an alloy of
(a) copper-zinc (b) copper-aluminium
(c) copper-tin (d) copper-nickel
- vi. In case of thick cylinders, the tangential stress across the thickness of cylinder is:
(a) maximum at the outer surface and minimum at the inner surface
(b) maximum at the inner surface and minimum at the outer surface
(c) maximum at the inner surface and zero at the outer surface
(d) maximum at the outer surface and zero at the inner surface
- vii. A thin spherical shell of internal diameter d is subjected to an internal pressure p . if σ_t is the tensile stress for the shell material, then thickness of the shell (t) is equal to
(a) $\frac{p \cdot d}{\sigma_t}$ (b) $\frac{p \cdot d}{2\sigma_t}$ (c) $\frac{p \cdot d}{3\sigma_t}$ (d) $\frac{p \cdot d}{4\sigma_t}$
- viii. Maximum tangential stress at the inner surface of the shell is defined as:
(a) $\sigma_{t(max)} = \frac{p[(r_o)^2 + (r_i)^2]}{(r_o)^2 + (r_i)^2}$ (b) $\sigma_{t(max)} = \frac{p[(r_o)^2 + (r_i)^2]}{(r_o)^2 - (r_i)^2}$
(c) $\sigma_{t(max)} = \frac{p[(r_o)^2 + (r_i)^2]}{r_o + r_i}$ (d) $\sigma_{t(max)} = \frac{p[(r_o)^2 + (r_i)^2]}{r_o - r_i}$

- ix. If the diameter of thin shell pressure tank is 800 mm, determine its thickness for 100% efficiency of the joint. Assume the allowable tensile stress as 50 MPa.
(a) 20 mm (b) 30 mm (c) 50 mm (d) 24 mm
- x. Can we use flat heads in high pressure vessel? Justify
- Q.2 Short answer type questions (4 questions @ 2.5 marks) 10
- Why we use spherical vessel for storage of gases?
 - What is the principle difference between wrought iron and cast iron?
 - A pipe of 400 mm internal diameter and 100 mm thickness contains a fluid at 8 MPa. Find the maximum and minimum hoop stress across the section
 - How can we allocate fluid in tube side and shell side of a heat exchanger?
- Q.3A Draw a neat sketch of a pressure vessel and describe its each component. 05
- Q.3B Derive the expression of thickness of thin spherical shell due to an internal pressure. 05
- Q.4A Write note on various factors involved in the design of sieve tray distillation column. 05
- Q.4B (a) Write the steps used for design of packed distillation column by the use of height of transfer unit concept. 03 + 02 =
(b) Determine the minimum reflux ratio for the binary distillation at standard atmospheric pressure based on the following data: 05
Feed = 100 kmol/h
Feed Mixture: Benzene-toluene
Mole fraction of benzene in distillate required = 0.99
Mole fraction of benzene in residue required = 0.02
Average relative volatility = 2.25.
- Q.5A Write a steps with formulation for the design of shell and tube heat exchanger. 05
- Q.5B A homogenous liquid phase reaction 05
$$A \rightarrow R$$

Takes place with 50% conversion in a CSTR. Its rate equation is
$$-r_A = \frac{dC_A}{dt} = kC_A^2$$

(a) What will be the conversion if this reactor is replaced by the one, 6 time's larger reactor and all else remaining unchanged?
(b) What will be the conversion if the original reactor is replaced by a plug flow reactor of equal size and all else remaining unchanged?
- Q.6 Define failure mechanism of pressure vessel. Show that for excessive elastic deformation, bending moment is represented by 10
$$M = EI \frac{d^2y}{dx^2}$$

- Q.7 For a binary system of heptane-ethylbenzene the equilibrium data are as follows: 10

x	0	0.08	0.185	0.251	0.333	0.487	0.651	0.788	0.914	1.0
y	0	0.233	0.428	0.514	0.608	0.729	0.834	0.904	0.963	1.0

A feed mixture composed of 42 mol% heptane and 58 mole% ethylbenzene is to be fractionated to yield an overhead product of 97 mol% heptane and a residue of 99 mol% ethylbenzene.

- (i) Using reflux ratio of 1.5, find the number of equilibrium stages needed for saturated liquid feed and a bubble point reflux by the McCabe-Thiele method.
(ii) Find the minimum reflux ratio.

OR

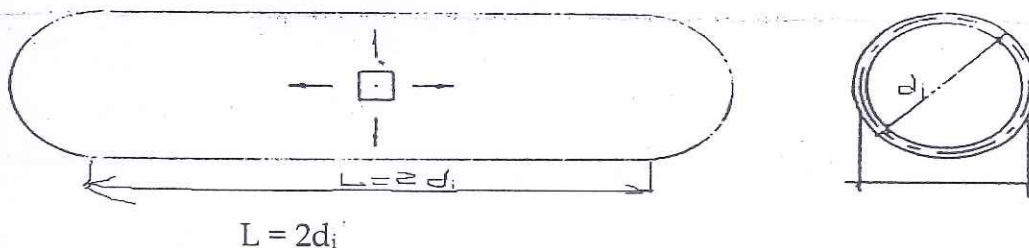
- Q.7 A butane-pentane splitter defined by the compositions given in the table below. 10
The column will operate at a pressure of 8.3 bar, with a reflux ratio of 2. The feed is at its boiling point.

	α_i	f_i	d_i	b_i
C_3	5	5	5	0
iC ₄	2.6	15	14.9	0.1
nC ₄ (LK)	2.0	25	24	1
iC ₅ (HK)	1	20	1	19
nC ₅	0.85	35	0.4	34.6
		100	$D = 45.3$	$B = 54.7$

Find:

- (i) Minimum number of stages required by Fenske method
(ii) Minimum reflux ratio by Underwood method (take $\theta = 1.35$)
(iii) Number of ideal stages 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.8 An air receiver consisting of a cylinder closed by hemispherical ends is shown in Figure below. It has a storage capacity of 0.25 m³ and an operating internal pressure of 5 MPa. It is made of plain carbon steel 10C4 with maximum allowable stress 85 MPa. Weld efficiency of the seam is represented as 85% and corrosion allowance is 0.02 mm. Design a vertical thin shell pressure vessel according to the ASME Section 8 Div. 1 15



- Q.9 1.2 kg/sec of an organic liquid is to be cooled from 45°C to 20°C. The organic liquid is cooled by chilled water from a refrigeration unit at a temperature of 5°C and can be heated upto 10°C. Properties of organic liquid and water are: 15

	Organic Liquid	Water
Specific heat J/kgK	2150	4180

Viscosity N-s/m ²	0.25 x 10 ⁻³	0.8 x 10 ⁻³
Density kg/m ³	716	1000
Thermal conductivity W/mK	0.133	0.61

Design a suitable heat exchanger by using given data:

Fouling resistance for organic liquid = $0.0002 \frac{m^2 K}{W}$

Fouling resistance for water = $0.0004 \frac{m^2 K}{W}$

Steel tubes are to be used. Thermal conductivity of steel tube = 45 W/mK.

Assume overall heat transfer coefficient = 590 W/m²K

Inside diameter of tubes = 12mm

Wall thickness of tubes = 2mm

Length of tubes = 1.5 m

Equivalent diameter = 0.011 m

Shell diameter = 0.25m

Baffle spacing = 6cm

Tubes are arranged on triangular pitch. Use two pass arrangement.

Calculate the overall heat transfer coefficient and heat transfer area required.

OR

Q.9 Design an exchanger using Kern's method to sub-cool condensate from a 15

methanol condenser from 95°C to 40°C. Flow-rate of methanol 100,000 kg/h.

Brackish water will be used as the coolant, with a temperature rise from 25°C to 40°C. Coolant is corrosive, so assign to tube-side.

Heat capacity methanol = 2.84 kJ/kg°C

Heat capacity water = 4.2 kJ/kg°C

Use one shell pass and two tube passes

Assume U = 600 W/m²°C

Choose 20 mm o.d., 16 mm i.d., 4.88-m-long tubes, cupro-nickel.

L = 4.83 m ; use 1.25 triangular pitch

bundle diametrical clearance = 68 mm,

Thermal conductivity of cupro-nickel alloys = 50 W/m°C.

Tube side fluid property:

Density water = 995 kg/m³

Viscosity of water = 0.8 mNs/m²

Thermal conductivity = 0.59 W/m°C

Equivalent diameter = 14.4 mm

Shell side fluid property:

Methanol density = 750 kg/m³

Viscosity = 0.34 mNs/m²

Heat capacity = 2.84 kJ/kg°C

Thermal conductivity = 0.19 W/m°C

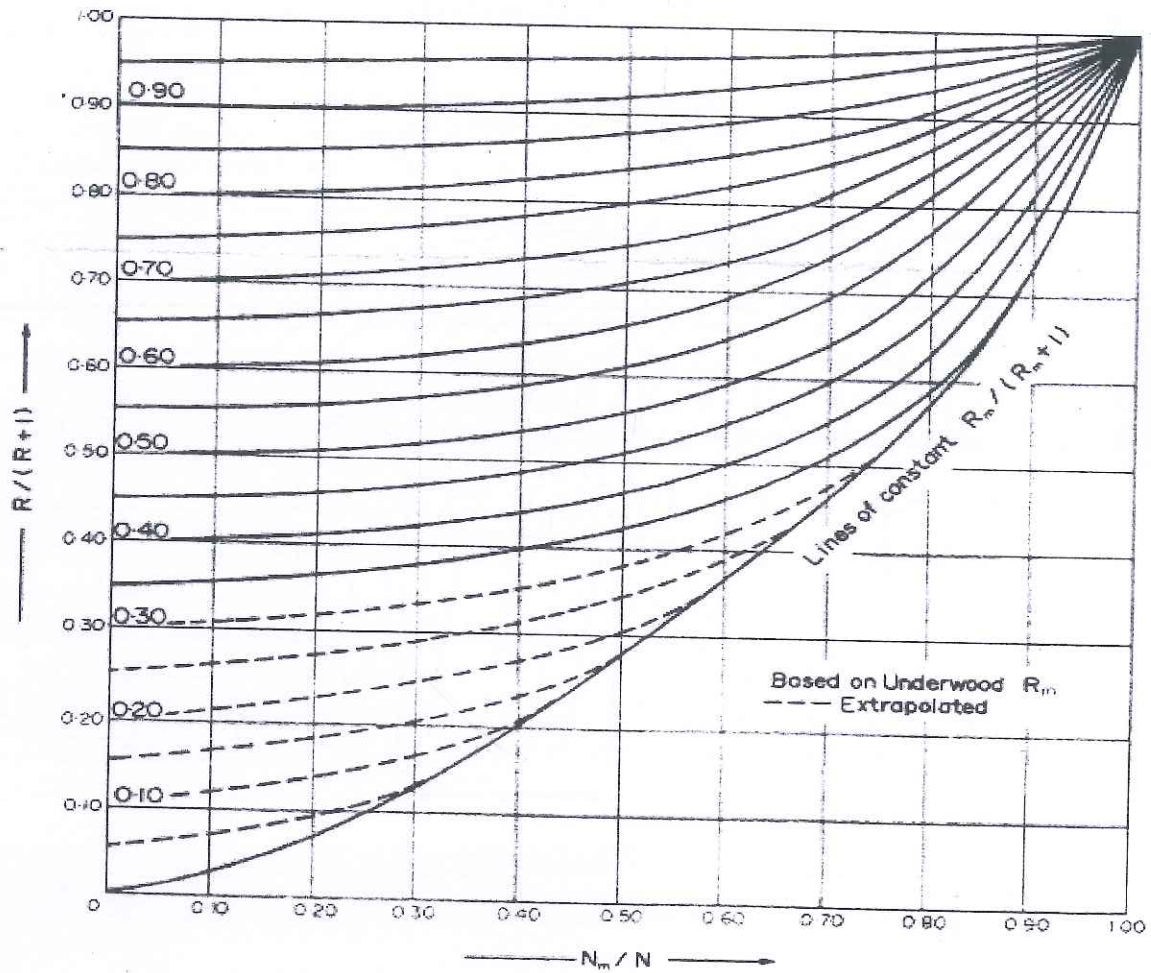
Take the fouling coefficients as; methanol (light organic) 5000 Wm⁻²°C⁻¹,
brackish water (sea water), take as highest value, 3000 Wm⁻²°C⁻¹

Calculate overall heat transfer coefficient (U_o)

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

Additional Data

Distillation Column



Erbar-Maddox correlation (Erbar and Maddox, 1961)

Heat Exchanger

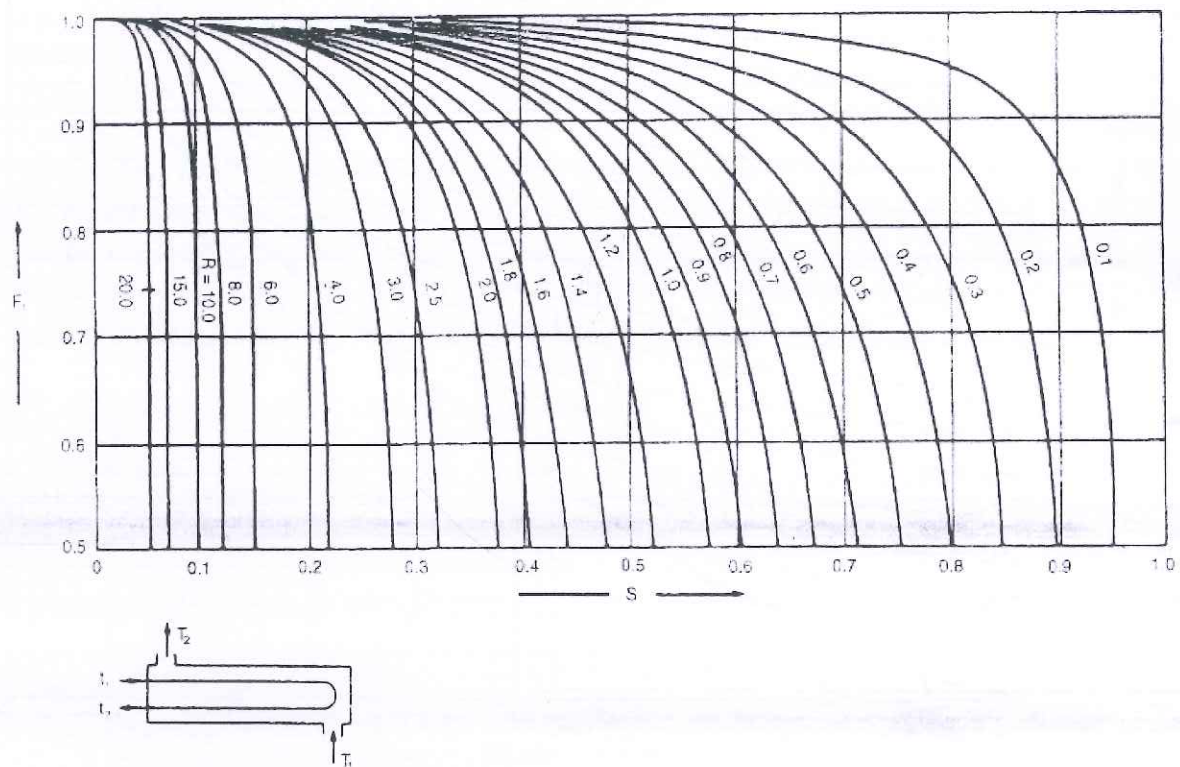


Figure 12.19. Temperature correction factor: one shell pass; two or more even tube passes

Triangular pitch, $p_t = 1.25d_o$					
No. 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
Square pitch, $p_t = 1.25d_o$					
No. passes	1	2	4	6	8
K_1	0.215	0.156	0.158	0.0402	0.0331
n_1	2.207	2.291	2.263	2.617	2.643