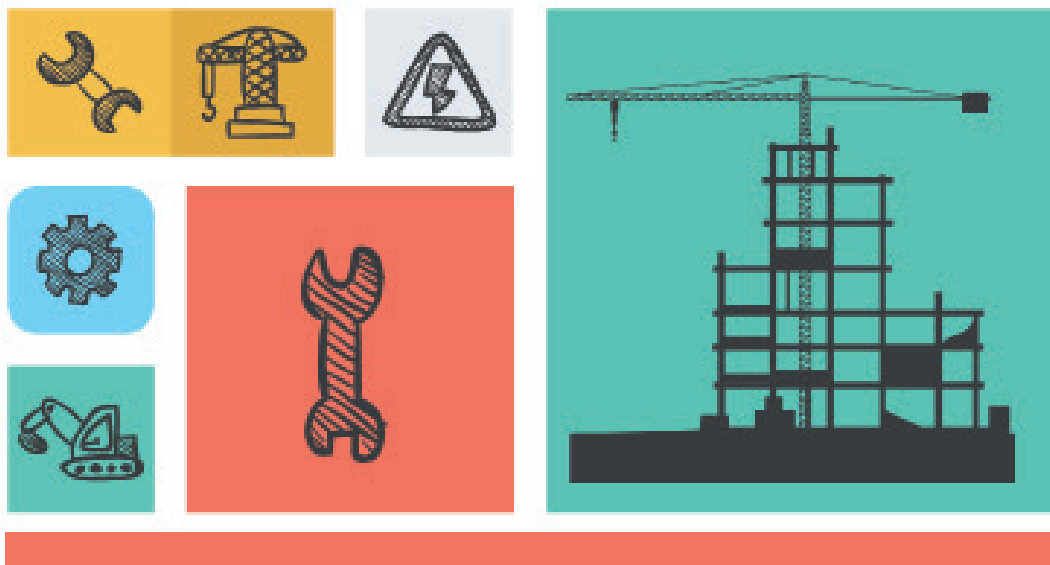


Engineering Fundamentals Exam

Study Guide For Chemical Engineering Exam



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1. Objectives

The aim of this manual is to provide guidelines for the examinees about the exam structure, timing, percentage of question coverage and distribution among various topic areas. In essence, the manual represents the bridge between the developed Chemical Engineering Standards and the actual phrased questions, which constitute the tests to be administered. It is designed to familiarize the examinees with the test questions formats and contents.

2. Contents

This study guide contains essential information for the examinees. Specifically, the following topics are presented in this manual:

- Exam structure, exam schedule and organization, exam type, eligibility for exam, and exam rules
- Organization of the exam framework
- Table of Specifications which includes an overview of the table, its structure and contents
- Sample of questions and solutions for the Chemical Engineering discipline

3. Exam Structure

The exam is conducted in two sessions and the duration of each session is 3 hours.

3.1 General Engineering Exam

The first session covers the General Engineering topics. These include the following fourteen topics:

1. Mathematics
2. Probability and Statistics
3. Computer Literacy
4. Statics and Dynamics
5. Chemistry
6. Thermodynamics



7. Fluid Mechanics
8. Materials Science and Engineering
9. Electricity and Magnetism
10. Engineering Drawing
11. Engineering Economics
12. Project Management
13. Ethics
14. General Skills
 - a. Use analytical thinking (logical deductions, statements and assumptions, cause and effect, verbal reasoning, analyzing arguments, statements and conclusions, break a complex problem into smaller problems and solve them)
 - b. Use effective communication in writing, orally, and graphically
 - c. Work cooperatively with other team members to deliver the required outcomes
 - d. Set goals and ways for personal development
 - e. Strive for ways to resolve conflicts while being sensitive to others opinions
 - f. Be able to use time and available resources in an efficient way
 1. Recognize and interpret environmental, social, cultural, political and safety considerations in engineering solutions.
 - g. Recognize decision making process
 - h. Recognize major engineering concepts outside the discipline.
 - i. Interpret uncertainties in measurements and calculations
 - j. Analyze and interpret data
 - k. Apply evaluation criteria and contemporary knowledge to select the optimum design from alternative solutions

3.2 Engineering Discipline Exam

The second session covers the Engineering Standards and is based on topics associated with one of the following engineering disciplines:

<i>Code</i>	<i>Discipline</i>
CE	Civil Engineering
CHE	Chemical Engineering
EE	Electrical Engineering
IE	Industrial Engineering



ME	Mechanical Engineering
SE	Structural Engineering

4. Exam Implementation

The exam consists of two sessions:

- The first session consists of General Engineering Exam. This session consists of 90 questions with a total time of 3 hours.
- The second session consists of Engineering Discipline Exam. This session consists of 50 questions with a total time of 3 hours.

5. Exam Type

The exam is initially paper-based and will become computer based in a later stage. The exam, in both sessions, is of a multiple choice type where each question has four choices for the answer. There is no negative marking for wrong answers.

6. Eligibility for the Exam

Bachelor degree holders in an Engineering discipline i.e., Chemical Engineering, Civil Engineering, Electrical Engineering, Industrial Engineering, Mechanical Engineering, and Structural Engineering.

7. Exam Rules

- Books, lecture notes, or any type of materials are not allowed in the exam. Necessary reference sheets, monographs, equations, relevant data from codes will be provided in the exam.
- Calculators approved by Exam authorities are allowed.
- Admission in the examination center will be only through authorized admission card
- Examinees are subjected to all the rules and procedures applied by National Center for Assessment in Higher Education (Qiyas)



8. Organization of the Exam Framework

The core topics constitute the basis of this Engineering Exam. Indicators are used to describe the knowledge to be tested in each topic. Each of these indicators is further subdivided into three major levels following the recent Bloom's taxonomy of learning levels (Remembering and Understanding; Applying and Analyzing; and Evaluating and Creating).

Example

Topic:	T2: Chemical Engineering Principles
Indicator:	CHE-T2-04: Perform material balances on nonreactive systems
Learning Level:	Applying and Analyzing (AA)

9. Table of Specifications

9.1 Overview

The Table of Specifications is a map which facilitates the transformation of the Engineering Standards for each Topic Area into balanced and coherent question sheets to be used in the proposed Exam. The Table of Specifications is essentially a tableau structure which distributes, vertically, the exam Questions among various Topic Areas in accordance with the applicable Engineering Standards and, horizontally, over various Learning Levels (Remembering and Understanding, Applying and Analyzing, Evaluating and Creating).

9.2 Structure and Contents

The table below constitutes the Table of Specifications for the Chemical Engineering Discipline. The Table of Specifications contains the following columns:

9.2.1 Topic Area

These are the widely recognized Topic areas, which are covered in the Chemical Engineering Discipline, namely:

1. Chemistry



2. Chemical Engineering Principles
3. Thermodynamics
4. Fluid Mechanics
5. Heat Transfer
6. Mass Transfer
7. Reaction Engineering
8. Process Control
9. Process Economics
10. Safety, Health and Environment

9.2.2 % of Test

This column summarizes the total percentage (of the total test) allocated for each Topic Area.

9.2.3 Suggested Number of Questions

This column indicates the number of questions to be allocated for each Engineering Standard. The total number of questions per test conforms to the general guidelines which govern the total duration of the test. In the present case, 50 questions are included in each Discipline.

9.2.4 Engineering Standards

This column lists the Engineering Standards to be addressed under each Topic Area.

Standards are coded **CHE-TJ** (where **CHE** denotes the Chemical Engineering Discipline, **TJ** denotes the Topic Number **J**), whereas the Indicators are coded **CHE-TJ-K** (where **K** denotes the Indicator number).

For example: **CHE-T2-5** is for the question in Chemical Engineering (CHE) that represents Topic 2 (Chemical Engineering Principles) and Indicator 5.

9.2.5 Assigned Allocations among Learning Levels

The three sub-columns (Remembering and Understanding, Applying and Analyzing, and Evaluating and Creating) under this main column specify the question distribution for the Topic among the three Learning Levels. For example, for the Chemical Engineering Principles (CHE-T2), there is one question assigned to Learning Level **RU**, five questions for **AA** and one question for **EC**.



It is to be noted that the Learning Levels used in the Table of Specifications represent the so-called cognitive levels/processes (levels of thinking) in the revised Bloom's taxonomy. Every two consecutive Learning Levels in Bloom's are combined as one level here.

It is also important to note that the distribution of questions among various Topic Areas follows a careful and rigorous question allocation process, which ensures that appropriate relative levels of coverage are maintained for the various Learning Levels. In the Chemical Engineering Discipline, the distribution of questions (for all Topics) among the three *Learning Levels* is 11 questions (22%) for Remembering and Understanding, 28 questions (56%) for Applying and Analyzing, and 11 questions (22%) for Evaluating and Creating.



Table of Specifications for Chemical Engineering Exam

Topic Area	% of Test	# Q	Engineering Standards	Assigned Allocations among Learning Levels		
				RU	AA	EC
T1- Chemistry	10%	5	CHE-T1	2	3	0
T2- Chemical Engineering Principles	14%	7	CHE-T2	1	5	1
T3- Chemical Engineering Thermodynamics	10%	5	CHE-T3	1	3	1
T4- Fluid Mechanics	10%	5	CHE-T4	1	3	1
T5- Heat Transfer	10%	5	CHE-T5	1	2	2
T6- Mass Transfer	12%	6	CHE-T6	1	3	2
T7- Reaction Engineering	12%	6	CHE-T7	1	4	1
T8- Process Control	6%	3	CHE-T8	1	1	1
T9- Process Economics	10%	5	CHE-T9	2	2	1
T10- Safety, Health and Environment	6%	3	CHE-T10	0	2	1
	100%	50		11 (22%)	28 (56%)	11 (22%)



10. Sample of Questions

A sample of questions is shown in the following tabular format in accordance with the following instructions.

1. For Learning Levels
 - RU for Remembering and Understanding
 - AA for Applying and Analyzing
 - EC for Evaluating and Creating
2. References sheets are denoted in the last column of the Table

Table of Sample Questions



Q. No.	Topic Area	Standard Code	Learning Level	Question Statement (Answer's Choices)	Key Answer	Expected Time (min)	supplied Reference
1	Chemistry	CHE-T1-07	AA	<p>Calculate the percentage equilibrium conversion at 300°C for the following reversible chemical reaction:</p> $2NO_2 \rightleftharpoons N_2O_4$ <p>The equilibrium constant based on mole fraction is 1.0. Initially 2 moles of NO₂ are present and no N₂O₄.</p> <p>a) 44.7 b) 55.3 c) 63.7 d) 72.3</p>	(b)	3 - 3.5	Reference #1
2	Chemical Engineering Principles	CHE-T2-13	AA	<p>Air that enters a dryer has a dry bulb temperature of 60°C and a dew point of 26.7°C. The humid volume (m³/kg dry air) is:</p> <p>a) 1.522 b) 1.066 c) 0.977 d) 0.833</p>	(c)	2.0 - 2.5	Reference #2



3	Chemical Engineering Thermodynamics	CHE-T3-01	AA	<p>Calculate the heat requirements (kJ/s) if 240 mol/min of ethane is heated from 20°C to 50°C. Ethane flows at steady state through a constant diameter horizontal pipe with no shaft work. Heat capacity of ethane (kJ/mol. K) is,</p> $C_p = 0.0494 + 13.92 \times 10^{-5}T$ <p>a) 5.4 b) 6.5 c) 7.3 d) 8.9</p>	(b)	1.5 – 2.0	Reference #3
4	Fluid Mechanics	CHE-T4-10	EC	<p>As an engineer, you are requested by your company to select a Schedule-40 steel pipe that allows 4.5 ft³/h of liquid to flow at the maximum velocity but without exceeding 1 ft/s to avoid liquid splash outside from the tank-car. Which nominal pipe size (inches) would you recommend?</p> <p>a) 1/4 b) 3/8 c) 1/2 d) 3/4</p>	(b)	2.0 – 2.5	Reference #4



5	Heat Transfer	CHE-T5-06	EC	<p>200 mol/s of a gas stream is cooled in a double-pipe heat exchanger from 160°C to 100°C by a co-current flow of a water stream. The water enters at 25°C and leaves at 80°C. The overall heat transfer coefficient (U) is 600 W/(m².°C). The heat capacity of the gas stream is 56 J/(mol.K). The required heat transfer area (m²) is:</p> <p>a) 18.6 b) 19.7 c) 20.6 d) 21.5</p>	(a)	2.0 – 2.5	Reference #5
6	Mass Transfer	CHE-T6-05	AA	<p>The Murphree Local efficiency (E_v) of a distillation tray can be given by the relationship: $E_v = 1 - e^{-N_{OG}}$ where N_{OG} is number of the overall transfer units.</p> <p>A tray in a distillation column receives liquid (L) at a rate of 85 moles per hour and vapor (V) at a rate of 120 moles per hour. The equilibrium relationship is given by:</p> $y_n = 1.5 x_n$ <p>The number of the individual transfer units are: $N_L=5$ and $N_G=7$. Calculate the Murphree overall tray efficiency for complete mixing conditions.</p> <p>a) 43.2 b) 66.7 c) 86.3 d) 82.9</p>	(d)	3.0 – 3.5	Reference #6



7	Reaction Engineering	CHE-T7-10	EC	<p>Consider the following <u>elementary</u> liquid phase reaction,</p> $A \rightarrow 2B$ <p>that takes place in an isothermal continuous stirred tank reactor (CSTR) at 127°C. The activation energy is 8000 J/mol and the frequency (pre-exponential) factor is 252 h⁻¹. Calculate the reactor volume (m³) for 82% conversion of A. The initial concentration and molar flow rate of A are 2 mol/m³ and 1 mol/min respectively.</p> <p>a) 3.1 b) 4.0 c) 5.1 d) 6.0</p>	(d)	2.5 – 3.0	Reference #7
8	Process Control	CHE-T8-03	RU	<p>The process static gain and time constant for the following first order process,</p> $G_p(s) = \frac{3}{2s + 5}$ <p>are:</p> <p>a) 3 and 5 b) 3 and 2 c) 0.6 and 0.4 d) 1.5 and 0.5</p>	(c)	1.0 – 1.5	Reference #8

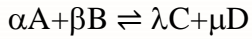


9	Process Economics	CHE-T9-02	RU	<p>The salvage value of a plant after 15 years is 50 million Saudi Riyals (SR). If the purchase price of the plant was 500 million SR. what will be the value of the plant (million SR) after 5 years if it depreciates linearly?</p> <p>a) 350 b) 450 c) 550 d) 650</p>	(a)	1.5 – 2.0	Reference #9										
10	Safety, Health and Environment	CHE-T10-04	AA	<p>Given the lower flammability limit (LFL) of the following gases:</p> <table border="1" data-bbox="871 646 1442 778"> <thead> <tr> <th>Gas</th> <th>H₂</th> <th>C₂H₄</th> <th>C₂H₆</th> <th>C₃H₆</th> </tr> </thead> <tbody> <tr> <td>LFL (%)</td> <td>4.0</td> <td>2.75</td> <td>3.0</td> <td>2.0</td> </tr> </tbody> </table> <p>A gas mixture consists of H₂=15%, C₂H₄=26%, C₂H₆=21% and the balance is propylene (C₃H₆). Calculate the LFL (%) for the gas mixture.</p> <p>a) 3.55 b) 3.25 c) 2.85 d) 2.55</p>	Gas	H ₂	C ₂ H ₄	C ₂ H ₆	C ₃ H ₆	LFL (%)	4.0	2.75	3.0	2.0	(d)	2.0 – 2.5	Reference #10
Gas	H ₂	C ₂ H ₄	C ₂ H ₆	C ₃ H ₆													
LFL (%)	4.0	2.75	3.0	2.0													



Reference #1

For a reversible reaction



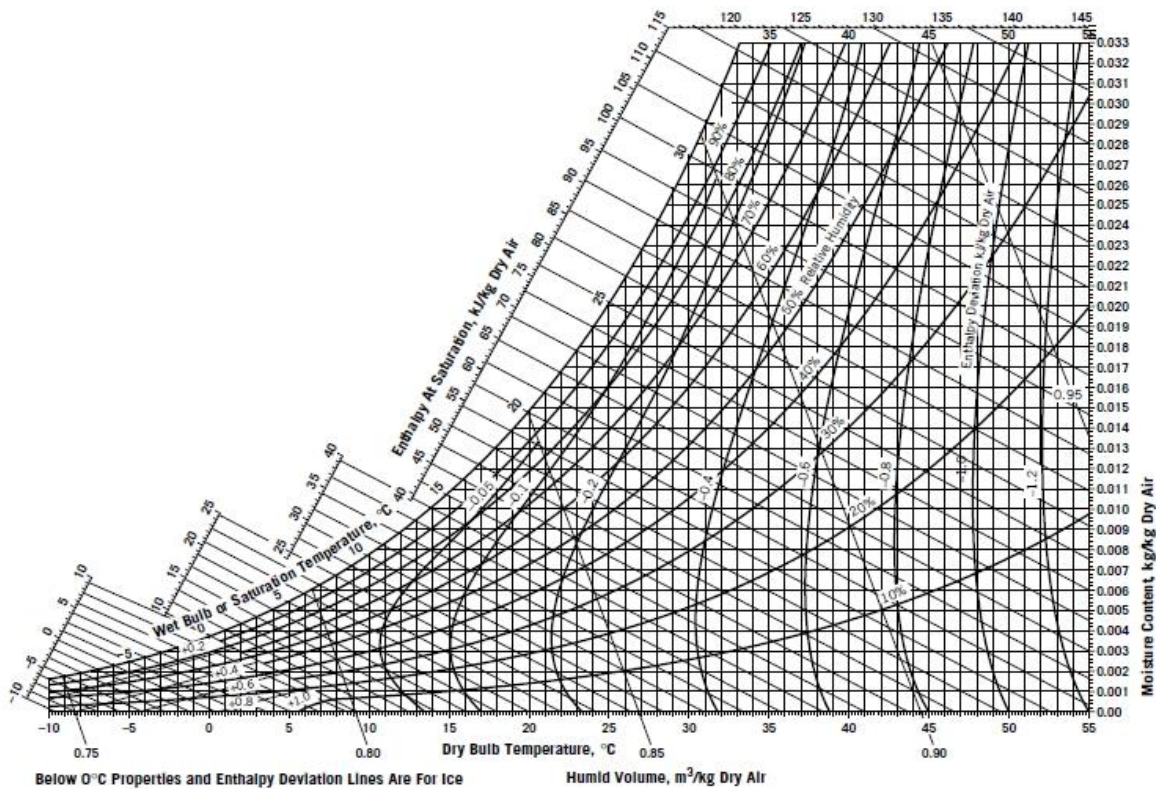
The equilibrium constant (K) based on mole fraction is:

$$K = \frac{(y_C)^\lambda (y_D)^\mu}{(y_A)^\alpha (y_B)^\beta}$$

Where y_i is the molar fraction of species (i)

Reference #2

$$v_H \left(\frac{m^3}{kg \text{ dry air}} \right) = (2.83 \times 10^{-3} + 4.56 \times 10^{-3} \times H) \times T(K)$$



Reference #3

The first law of thermodynamics for a steady state, steady flow process is:

$$Q + W_s = \Delta H + \Delta E_k + \Delta E_p$$

$$\int_{T_1}^{T_2} (a + b \times T) dT = a(T_2 - T_1) + \frac{b}{2}(T_2^2 - T_1^2)$$



Reference #4

1ft =12 in

Schedule 40 steel pipe dimensions

Nominal Pipe size, in	Outside diameter, in	Inside diameter, in
1/8	0.405	0.269
1/4	0.540	0.364
3/8	0.675	0.493
1/2	0.840	0.622
3/4	1.050	0.824
1	1.315	1.049
5/4	1.660	1.380
6/4	1.990	1.610

Flow rate = cross sectional area \times velocity

Reference #5

$$Q = U \times A \times \Delta T_{lm}$$

$$\Delta T_{lm} = \frac{\Delta T_2 - \Delta T_1}{\ln(\Delta T_2 / \Delta T_1)}$$

Reference #6

$$\lambda = \frac{mV}{L}$$

$$N_{OG} = \left(\frac{1}{N_G} + \lambda \cdot \frac{1}{N_L} \right)^{-1}$$

Reference #7

$$V = \frac{(F_{Ao} - F_A)}{-r_A}$$

$$k = k_o e^{-\frac{E}{R.T}}$$

$$C_A = C_{Ao} (1 - \text{conversion})$$

$$F_A = F_{Ao} (1 - \text{conversion})$$

$$R=8.314 \text{ J/mol.K}$$



Reference #8

The transfer function of a first order process is

$$G_p(s) = \frac{K_p}{\tau_p s + 1}$$

Reference #9

Depreciation per year (linear) = $\frac{\text{original value} - \text{salvage value}}{\text{years}}$

Reference #10

$$LFL_{mix} = \frac{100}{\sum_1^n \left(\frac{y(i)}{LFL(i)} \right)}$$



11. Solution of the Sample Questions

Question # 1

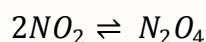
Topic Area: Chemistry

Learning Level: Applying & Analyzing

Indicator: CHE-T1-07 Calculate reactant conversion and equilibrium conversion

Question Statement:

Calculate the percentage equilibrium conversion at 300°C for the following reversible chemical reaction:



The equilibrium constant based on mole fraction is 1.0. Initially 2 moles of NO₂ are present and no N₂O₄.

- a) 44.7
- b) 55.3
- c) 63.7
- d) 72.3

Answer:

(b)

Supplied Reference: Reference #1

Estimated Solution Time by Examinee: 3.0 – 3.5 minutes

Remarks: The objective of this question is to ensure that the examinee can define, formulate, and use the equilibrium constant to calculate conversion.

Solution:

The equilibrium constant = $K_y = \frac{y_{\text{N}_2\text{O}_4}}{y_{\text{NO}_2}^2} = 1$ (1)

Let 2α be the moles of NO₂ converted at equilibrium, then

	NO ₂	N ₂ O ₄
at t=0	2	0
moles change at equilibrium	-2 α	α
Component moles at equilibrium	(2 - 2 α)	α
Total # of moles at equilibrium	(2 - α)	
mole fraction (y _i)	$\frac{(2 - 2\alpha)}{(2 - \alpha)}$	$\frac{\alpha}{(2 - \alpha)}$

Substituting the mole fractions into Equ. (1) → $5\alpha^2 - 10\alpha + 4 = 0$

→ $\alpha = 0.553$ or $\alpha = 1.447$ (impossible)

% equilibrium conversion = $\frac{2 \times 0.553}{2} \times 100 = 55.3\%$



Question # 2

Topic Area: Chemical Engineering Principles

Learning Level: Applying & Analyzing

Indicator: CHE-T2-13 Use and interpret psychrometric charts

Question Statement:

Air that enters a dryer has a dry bulb temperature of 60°C and a dew point of 26.7°C. The humid volume (m³/kg dry air) is:

- a) 1.522
- b) 1.066
- c) 0.977
- d) 0.833

Answer:

(c)

Estimated Solution Time by Examinee: 2.0 – 2.5 minutes

Remarks: The objective of this question is to ensure that the examinee knows how use the psychrometric chart

Supplied Reference: Reference #2

Solution:

From the chart, we obtain the humidity $H=0.0225$ kg H₂O/kg dry air

Using the eq. given in the reference and substituting $T=60+273$ and $H=0.0225$

$$v_H \left(\frac{m^3}{kg \text{ dry air}} \right) = (2.83 \times 10^{-3} + 4.56 \times 10^{-3} \times H) \times T(K)$$

gives $v_H=0.977$ m³/kg dry air



Question # 3

Topic Area: Chemical Engineering Thermodynamics

Learning Level: Remembering & Understanding

Indicator: CHE-T3-01 State and apply the first law of thermodynamics

Question Statement:

Calculate the heat requirements (kJ/s) if 240 mol/min of ethane is heated from 20°C to 50°C. Ethane flows at steady state through a constant diameter horizontal pipe with no shaft work.

Heat capacity of ethane (kJ/mol. K) is,

$$C_p = 0.0494 + 13.92 \times 10^{-5}T$$

- a) 5.4
- b) 6.5
- c) 7.3
- d) 8.9

Answer:

(b)

Estimated Solution Time by Examinee: 1.5 – 2.0 minutes

Remarks: The objective of this question is to ensure that the examinee knows how to state and apply the first law of thermodynamics.

Supplied Reference: Reference #3

Solution:

Write the first law of thermodynamics:

$$Q - W_s = \Delta H + \Delta E_k + \Delta E_p$$

No moving part $\rightarrow W_s = 0$

Horizontal pipe $\rightarrow \Delta E_p = 0$

Constant diameter pipe $\rightarrow \Delta E_k = 0$

$$Q = \Delta H = n \int_{20}^{50} C_p \cdot dT \rightarrow Q = (240/60) \times 1.628 = 6.513 \text{ kJ/s}$$



Question # 4

Topic Area: Fluid Mechanics

Learning Level: Evaluating & Creating

Indicator: CHE-T4-10 Choose and apply codes and standards in the design.

Question Statement:

As an engineer, you are requested by your company to select a Schedule-40 steel pipe that allows 4.5 ft³/h of liquid to flow at the maximum velocity but without exceeding 1 ft/s to avoid liquid splash outside from the tank-car. Which nominal pipe size (inches) would you recommend?

- a) 1/4
- b) 3/8
- c) 1/2
- d) 3/4

Answer:

(b)

Supplied reference: Reference #4

Estimated solution time by examinee: 2.0- 2.5 minutes

Remarks: The question tests the ability of the student in designing simple flow systems under constraints using codes and standards.

Solution:

Flow rate = 4.5/3600 = 0.00125 ft³/s

Area of pipe (at 1 ft/s velocity) = A = 0.00125/1 = 0.00125 ft²

Diameter of pipe = $\sqrt{\frac{4A}{\pi}} = \sqrt{\frac{4 \times 0.00125}{\pi}} = 0.04 \text{ ft} = 0.48 \text{ in}$

The closest nominal diameter from the reference sheet is 3/8 in which meets the splash constraints (≤ 1 ft/s); it gives a velocity of 0.94 ft/s (the highest permissible velocity that fills the tank in the shortest time).



Question # 5

Topic Area: Heat Transfer

Learning Level: Evaluating & Creating

Indicator: CHE-T5-06 Determine the heat transfer area considering flow configuration

Question Statement:

200 mol/s of a gas stream is cooled in a double-pipe heat exchanger from 160°C to 100°C by a co-current flow of a water stream. The water enters at 25°C and leaves at 80°C. The overall heat transfer coefficient (U) is 600 W/(m².°C). The heat capacity of the gas stream is 56 J/(mol.K). The required heat transfer area (m²) is:

- a) 18.6
- b) 19.7
- c) 20.6
- d) 21.5

Answer:

(a)

Supplied Reference: Reference #5

Estimated Solution Time by Examinee: 2.5 to 3 minutes

Remarks: The objective of this question is to ensure that the examinee can recognize the effect of flow pattern on the design of heat exchangers.

Solution:

$$\text{Heat load} = q = n C_p \Delta T = 200 \times 56 \times (160 - 100)$$

$$q = 672000 \text{ J/s}$$

For co-current flow:

$$\Delta T_2 = 160 - 25 = 135^\circ\text{C}$$

$$\Delta T_1 = 100 - 80 = 20^\circ\text{C}$$

The log mean temperature difference is given by:

$$\Delta T_{\log} = \frac{\Delta T_2 - \Delta T_1}{\ln(\Delta T_2 / \Delta T_1)} = 60.22^\circ\text{C}$$

$$\text{Area} = \frac{q}{U \times \Delta T_{\log}} = \frac{672000}{600 \times 60.22} = 18.6 \text{ m}^2$$



Question # 6

Topic Area: Mass Transfer

Learning Level: Applying & Analyzing

Indicator: CHE-T6-05 Determine various efficiencies (local, Murphree ...etc)

Question Statement:

The Murphree Local efficiency (E_v) of a distillation tray can be given by the relationship:

$E_v = 1 - e^{-N_{OG}}$ where N_{OG} is number of the overall transfer units.

A tray in a distillation column receives liquid (L) at a rate of 85 moles per hour and vapor (V) at a rate of 120 moles per hour. The equilibrium relationship is given by:

$$y_n = 1.5 x_n$$

The number of the individual transfer units are: $N_L=5$ and $N_G=7$. Calculate the Murphree overall tray efficiency for complete mixing conditions.

- a) 43.2
- b) 66.7
- c) 86.3
- d) 82.9

Answer:

(d)

Supplied Reference: Reference # 6

Estimated solution time by examinee: 3-3.5 minutes

Remarks: The question evaluates the understanding of mass transfer relationships and the effect of the degree of mixing on tray efficiency.

Solution:

Given: $L = 85$; $V = 120$; $m = 1.5$; $N_L = 5$; $N_G = 7$

$$\lambda = \frac{mV}{L} = \frac{1.5 \times 120}{85} = 2.12$$

$$N_{OG} = \left(\frac{1}{N_G} + \lambda \cdot \frac{1}{N_L} \right)^{-1} = 1.766$$

$$E_v = 1 - e^{-N_{OG}} = 0.829$$

For complete mixing, tray efficiency is equal to point efficiency ($E_{OG} = E_v$)

i.e., $E_{OG} = 0.829$ or 82.9%



Question # 7

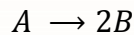
Topic Area: Reaction Engineering

Learning Level: Evaluating & Creating

Indicator: CHE-T7-10 Design a Continuous Stirred Tank Reactor (CSTR)

Question Statement:

Consider the following elementary liquid phase reaction



that takes place in an isothermal continuous stirred tank reactor (CSTR) at 127°C. The activation energy is 8000 J/mol and the frequency (pre-exponential) factor is 252 h⁻¹. Calculate the reactor volume (m³) for 82% conversion of A. The initial concentration and molar flow rate of A are 2 mol/m³ and 1 mol/min respectively.

- a) 3.1
- b) 4.0
- c) 5.1
- d) 6.0

Answer:

(d)

Supplied Reference : Reference #7

Estimated solution time by examinee: 2.5 - 3 minutes

Remarks: The question tests the ability of the student in designing a CSTR considering phase effect.

Solution:

The volume of the CSTR (V) is given by: $V = \frac{(F_{A0} - F_A)}{-r_A}$

Elementary reaction → first order → rate is given by: $-r_A = k \cdot C_A$

For liquid phase reaction, volume changes are negligible

Rate constant (k) = $k = k_0 e^{-\frac{E}{R.T}} = \left(\frac{252}{60}\right) e^{-\frac{8000}{8.314 \times 400}} = 0.379 \text{ min}^{-1}$

$C_A = C_{A0} (1 - \text{conversion}) = 2 * (1 - 0.82) = 0.36 \text{ mol/m}^3$

$F_A = F_{A0} (1 - \text{conversion}) = 1 \times (1 - 0.82) = 0.18 \text{ mol.min}^{-1}$

Rate = $-r_A = 0.379 * 0.36 = 0.136$

Volume = $V = \frac{(F_{A0} - F_A)}{-r_A} = \frac{(1 - 0.18)}{0.136} = 6.03 \text{ m}^3$



Question # 8

Topic Area: Process Control

Learning Level: Remembering & Understanding

Indicator: CHE-T8-03 Obtain transfer functions for open loops.

Question Statement:

The process static gain and time constant for the following first order process,

$$G_p(s) = \frac{3}{2s + 5}$$

are:

- a) 3 and 5
- b) 3 and 2
- c) 0.6 and 0.4
- d) 1.5 and 0.5

Answer:

(c)

Supplied Reference: Reference #8

Estimated Solution Time by Examinee: 1.0 to 1.5 minutes

Remarks: The objective of this question is to ensure that the examinee knows the first order transfer function

Solution:

Divide the numerator and denominator of the transfer function $G_p(s)$ by 5,

$$\text{Write } G_p(s) = \frac{3}{2s+5} = \frac{3/5}{(\frac{2}{5})s+1} = \frac{0.6}{0.4s+1}$$



Question # 9

Topic Area: Process Economics

Learning Level: Applying & Analyzing

Indicator: CHE-T9-02 Define terms used in engineering economy, e.g., profit, depreciation, profitability, cash flow, present value, alternative investment, break-even point, payback period, grass roots, battery limit, off-site facilities, etc.

Question Statement:

The salvage value of a plant after 15 years is 50 million Saudi Riyals (SR). If the purchase price of the plant was 500 million SR. what will be the value of the plant (million SR) after 5 years if it depreciates linearly?

- a) 350
- b) 450
- c) 550
- d) 650

Answer:

(a)

Supplied Reference: Reference #9

Estimated Solution Time by Examinee: 1.0 to 1.5 minutes

Remarks: The objective of this question is to ensure that the examinee knows basics of process economics.

Solution:

Initial cost = 500 M SR

Salvage value = 50 M SR

Depreciation per year (linear) = $\frac{(500-50)}{15} = 30 \text{ M SR}$

Price of plant after 5 years = $500 - 30 \times 5 = 350 \text{ M SR}$



Question # 10

Topic Area: Safety, Health and Environment

Learning Level: Applying & Analyzing

Indicator: CHE-T10-04 Calculate the lower flammability limit (LFL) and higher flammability limit (HFL)

Question Statement:

Given the lower flammability limit (LFL) of the following gases:

Gas	H ₂	C ₂ H ₄	C ₂ H ₆	C ₃ H ₆
LFL (%)	4.0	2.75	3.0	2.0

A gas mixture consists of H₂=15%, C₂H₄=26%, C₂H₆=21% and the balance is propylene (C₃H₆). Calculate the LFL (%) for the gas mixture.

- a) 3.55
- b) 3.25
- c) 2.85
- d) 2.55

Answer:

(d)

Supplied Reference: Reference #10

Estimated Solution Time by Examinee: 2.0 to 2.5 minutes

Remarks: The objective of this question is to ensure that the examinee knows how to calculate LFL and the effect of gas composition on LFL.

Solution:

Calculate % propylene = $100 - (15 + 26 + 21) = 38\%$

Apply the equation:

$$LFL_{mix} = \frac{100}{\sum_1^4 \left(\frac{y(i)}{LFL(i)} \right)} = \frac{100}{\left(\frac{15}{4} + \frac{26}{2.75} + \frac{21}{3} + \frac{38}{2} \right)} = \frac{100}{39.2}$$

$$LFL_{mix} = 2.55\%$$



