

BITS PILANI, DUBAI CAMPUS, ACADEMIC CITY, DUBAI
Second SEMESTER 2010-2011
CHE C332: Process Design Decisions
Comprehensive Examination

DATE: 29-05-2011

TOTAL DURATION: 3 hours

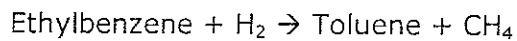
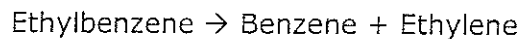
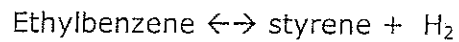
MAXIMUM MARKS: 40

Note: Attempt ALL questions. Part A contains 13 questions. Attempt Part A and Part B in separate answer sheets.

PART – A [20 Marks]

1. If an amount triples in 15 years, what is the annual compound rate of return? [1]
2. Assuming nominal annual interest rate to be 6%, find the value of \$1800 invested for 4 years with interest compounding quarterly. [1]
3. Assuming nominal annual interest rate to be 6%, find the value of \$100 invested for 10 years with interest compounding continuously. [1]
4. Some universities have endowed chairs for distinguished faculty, which need \$500,000 per year in salaries. How much a sponsoring industry needs to establish a chair if prevailing interest rate is 6.25%? [1]
5. In a retirement scheme, you invest \$2500 every year for 18 years. At an annual interest rate of 8.5%, how much will you receive at the end of 18-year period? [1]
6. Between the Liquid Separation System and the Vapor Recovery System, which should be designed first and why? [1]
7. In Heat exchanger network (HEN) synthesis, what are the heuristics of stream-matching (a) above pinch, and (b) below pinch? [1]
8. Suppose you want to invest in a bond costing \$14000 and promising to double the investment in 7 years. Before you make investment, central bank decreases the rate of interest for that bond by half percentage point. To give the same future value after 8 years, how much the bond will cost you now? [2]
9. A piece of equipment with an original cost of \$7000 and no salvage value has a depreciation allowance of \$1000 during its 4th year of service, when depreciated by SOYD method. What recovery period has been used? [2]

10. Styrene can be produced by the reactions



The reactions take place at 1115 °F and 25 psia. We want to produce 250 mol/h of styrene. Draw the a) recycle structure of the flowsheet, and b) discuss the effect of diluents on shifting equilibrium conversion in above process. [1 + 2 = 3]

11. An equipment costs \$90,000 and has 6 years' service life with no salvage value. Calculate using double declining balance (DDB) method depreciation charged in third year. [2]
12. Write any FOUR heuristics for distillation sequencing in a multi-component separation. Give one justification for each heuristic. [2]
13. When it is decided to install a vapor recovery system in a process, what are the possible locations (on the flow sheet) to place it? What are the heuristics that guide this decision? [2]

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PART – B [20 Marks]

Note: attempt ALL questions. Part B contains 4 questions. Part B is to be attempted in separate answer-sheet.

1. A chemical process has two hot streams to be cooled and two cold streams to be heated. Assuming $HRAT = 12\text{ }^{\circ}\text{C}$ for the stream data given below, carry out the energy integration analysis using Pinch Technology by determining the following:
- (a) Minimum hot and cold utility requirements based on second law, [3]
 (b) Hot and cold pinch temperatures, [1]

Stream No.	Source Temperature ($^{\circ}\text{C}$)	Target Temperature ($^{\circ}\text{C}$)	Heat Capacity Flow rate ($\text{MW}/^{\circ}\text{C}$)
1	285	60	30
2	190	25	45
3	20	160	40
4	120	265	60

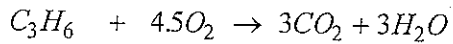
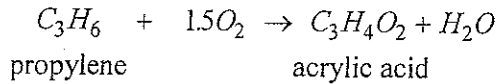
2. For the heat exchanger network synthesis problem given below, hot and cold utility requirements for $HRAT = 8\text{ }^{\circ}\text{C}$ are 4800 kW each. The pinch temperature is $104\text{ }^{\circ}\text{C}$. [5]

Stream No.	Source Temperature ($^{\circ}\text{C}$)	Target Temperature ($^{\circ}\text{C}$)	Heat Capacity Flow rate ($\text{kW}/^{\circ}\text{C}$)
1	200	100	200
2	180	60	150
3	100	140	500
4	80	170	200

Synthesize an MER network featuring minimum number of units, and draw it on the grid diagram; clearly indicating heat exchanger loads and intermediate stream temperatures.

3. A homeowner has a choice between a gas fuel heating system and a solar heating system. Both systems have a 10 years useful life. The initial cost for the fuel heating system is \$1800 and the annual fuel cost \$600. If the annual rate of interest is 4%, determine the capital cost of the solar system that will make it competitive with the gas fueled system. [4]

4. In acrylic acid production process, following reactions occur:



Some of the results of production distribution are given below.

Component	C ₃ H ₆	C ₃ H ₄ O ₂	CO ₂	H ₂ O	O ₂
Yield pattern, mol%	14.100	0.550	0.060	42.500	42.790
	13.450	1.610	0.160	42.110	42.670
	12.600	3.350	0.340	41.290	42.420
	11.120	5.980	0.830	40.160	41.910
	9.470	8.860	1.810	39.070	40.790
	7.600	11.390	4.650	38.820	37.550
	5.270	12.180	13.650	41.650	27.250
	3.880	12.590	19.100	43.460	20.970
	3.260	12.950	21.240	43.960	18.590

Convert the data suitably to calculate conversion, x and selectivity, S and develop a correlation (using least squares regression) for the selectivity (moles of C₂H₄ at the reactor exit per mole of C₂H₆ converted). The

correlation will have following form: $S = 1 - \frac{a}{(1-x)^b}$ [7]

*** END OF PAPER ***

BITS PILANI, DUBAI CAMPUS
ACADEMIC CITY, DUBAI
Second SEMESTER 2010-2011
CHE C332: Process Design Decisions
TEST 2 (OPEN BOOK)

DATE: 15 May 2011

DURATION: 50 MINUTES

MAXIMUM MARKS: 20

Note: Attempt ALL questions. This paper contains a total of 7 questions. Show the calculation steps and formula used clearly. Make suitable design decisions wherever necessary, and mention them clearly. Do not alter any given data.

1. In acetone recovery from air-acetone stream with the absorption as a selected alternative, discuss the following: [1.5+1.5+2=5]
 - a) Advantages and disadvantages of using a solvent other than water.
 - b) Discuss the pros and cons of using high flow rate of water in the absorber.
 - c) The effect of decreasing solvent flow rate to the absorber on the utilities requirement and reflux ratio in the subsequent distillation column.
2. If feed to the distillation column is not pre-heated to saturated liquid condition, how does it affect the distillation operation as a whole? [1]
3. In the table below, there are 10 components with their destination codes listed in order of their boiling points. Calculate how many product streams will be there? What will be their composition? [2]

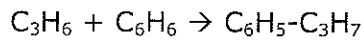
Component	Destination Code	Component	Destination Code
A	Recycle	F	Recycle
B	Waste	G	Recycle and Purge
C	Recycle	H	Recycle and Purge
D	Fuel	I	Primary Product
E	Recycle	J	Waste

4. Styrene is produced by the reaction:
$$\text{C}_6\text{H}_5\text{CH}_2\text{CH}_3 \leftrightarrow \text{C}_6\text{H}_5\text{CHCH}_2 + \text{H}_2$$

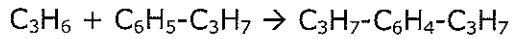
Ethylbenzene styrene

The reaction is reversible and is limited by equilibrium. We want to shift the equilibrium to the right to favor styrene production. Suggest how changing pressure can help accomplish this objective. [1]

5. Cumene (isopropyl benzene) is produced by reacting propylene and benzene over an acid catalyst. The reactions are as follows:



Cumene



Diisopropyl benzene (DIPB)

We want to limit the amount of undesired by-product DIPB. Suggest one way to accomplish that objective. [1]

6. The reaction selectivity data for a reaction are given below.

x	0.1	0.2	0.3	0.4	0.5	0.6
S	0.8935	0.8714	0.8407	0.7962	0.7272	0.6100

Develop a best-fit correlation between conversion x and selectivity S from

above data, in the form: $S = 1 - \frac{a}{(1-x)^b}$. [7]

7. The relative volatilities of four components (A, B, C, and D) of a mixture are given below:

Component	Relative Volatilities
A	3.7
D	1.59
B	2.5
C	1.6

Draw the distillation train for the separation of above mixture. [3]

BITS PILANI, DUBAI CAMPUS
ACADEMIC CITY, DUBAI
Second SEMESTER 2010-2011
CHE C332: Process Design Decisions
TEST 1 (CLOSED BOOK)

DATE: 27 MARCH 2011

DURATION: 50 MINUTES

MAXIMUM MARKS: 20

NOTE: ATTEMPT ALL QUESTIONS. This paper contains a total of 4 questions.

1. For the heat exchanger network synthesis problem given below, hot and cold utility requirements for $HRAT = 10^\circ\text{C}$ are 2750 kW and 725 kW, respectively. The pinch temperature is 150°C . [6]

Stream No.	Source Temperature ($^\circ\text{C}$)	Target Temperature ($^\circ\text{C}$)	Heat Capacity Flow rate ($\text{kW}/^\circ\text{C}$)
1	180	75	70
2	155	90	45
3	40	220	50
4	60	170	30

Synthesize an MER network featuring minimum number of units, and draw it on the grid diagram; clearly indicating heat exchanger loads and intermediate stream temperatures.

2. In the final design stage of a project, the question has arisen as to whether to use a water-cooled exchanger or an air-cooled exchanger in the overhead condenser loop of a distillation tower. The information available on the two pieces of equipment is provided below:

	Initial Investment	Yearly Operating Cost
Air-cooled	\$45, 000	\$1, 500
Water-cooled	\$25, 000	\$3, 500

Both pieces of equipment have service lives of 12 years. For an internal rate of return of 10% p.a., which piece of equipment represents the better choice? [3]

At what internal rate of return, both equipments will be equally attractive? [4]

3. Compare two pension fund schemes: Investment scheme A requires you to deposit \$1000 per year for fifteen years, and then pays you \$3500 per year forever. Investment scheme B requires you to deposit \$2000 per year for 10 years, and then pays you \$3500 per year forever. Which investment scheme you consider to be better? Justify. [4]
4. A piece of equipment with an original cost of \$10000 and no salvage value has a depreciation allowance of \$1905 during its third year of service, when depreciated by SOYD method. What recovery period has been used? [3]

BITS, PILANI, DUBAI CAMPUS
DUBAI INTERNATIONAL ACADEMIC CITY, DUBAI
Second SEMESTER 2010-2011
CHE UC332: Process Design Decisions
Quiz - II (Closed Book)

DATE: 20.04.2011

DURATION: 20 MINUTES

MAXIMUM MARKS: 5

Note: Attempt ALL questions. Choose the best option from the choices given in each question.

Student's Name:

I.D.

1. In acetone recovery from air-acetone stream with the absorption as the selected alternative, if we increase the tower pressure in an isothermal dilute gas absorber, the number of plates required in absorber
 - a) Increases
 - b) decreases
 - c) Remains constant
 - d) cannot say

2. In acetone recovery from air-acetone stream with the absorption as the selected alternative, if we increase the tower pressure in an isothermal dilute gas absorber, then the diameter of the distillation column would
 - a) Increase
 - b) decrease
 - c) Remains constant
 - d) cannot say

3. In acetone recovery from air-acetone stream with the absorption as the selected alternative, solvent flow rate is a design variable. By increasing solvent flow rate,
 - a) Number of plates in absorber will increase, while number of plates in distillation column will decrease
 - b) Number of plates in absorber will decrease, and number of plates in distillation column will decrease
 - c) Number of plates in absorber will decrease, while number of plates in distillation column will increase
 - d) Number of plates in absorber will increase, and number of plates in distillation column will increase

4. Byproducts from reversible side reactions are
 - a) Purged
 - b) recycled
 - c) Recovered in separators
 - d) all of the above 3 can be considered

5. If an impurity in a liquid feed stream is a product or by-product
 - a) As a first guess process the impurity
 - b) Feed the process through the separation system
 - c) Remove it after reaction
 - d) None of the above

6. Which of the following group of streams is not included in counting number of product streams?
- a) Recycle and reactants b) recycle and purge
c) Vent and waste d) primary and secondary products
7. We provide purge stream
- a) To provide exit for feed impurities when they are small in quantities
b) To exit undesired product resulting from irreversible side reaction
c) To exit impurities in reactants when they are difficult to separate
d) all of the above.
8. The Kremser's equation can be used to calculate the number of plates required in the gas absorber for
- a) Isothermal, dilute systems
b) Adiabatic, dilute systems
c) Isothermal, concentrated systems
d) Adiabatic, concentrated systems
9. In deciding between batch versus continuous process, which of the following favor the choice of a batch process?
- a) Large production rate, seasonal product, fast reactions
b) Small production rate, multi-product plant, slow reactions
c) Small production rate, fast reactions, long product life
d) Large production rate, multi-product plant, fouling material
10. Consider the reaction system, $A \rightarrow B \rightarrow C$ where B is the desired product. The selectivity is given by,
- a) $S = \frac{\text{moles of B produced}}{\text{moles of A consumed}}$ c) $S = \frac{\text{moles of B produced}}{\text{moles of C produced}}$
b) $S = \frac{\text{moles of B produced}}{\text{moles of A fed to reactor}}$ d) $S = \frac{\text{moles of C produced}}{\text{moles of B consumed}}$

**BITS, PILANI, DUBAI CAMPUS
DUBAI INTERNATIONAL ACADEMIC CITY, DUBAI
Second SEMESTER 2010-2011
CHE UC332: Process Design Decisions
Quiz - I solution**

DATE: 02.03.2011

DURATION: 20 MINUTES

MAXIMUM MARKS: 5

Note: Attempt ALL questions. Do rough calculations on the back of this question paper.

Student's Name: _____

I.D. _____

1. For the stream data set given below:

Stream No.	Supply Temperature (°C)	Target Temperature (°C)	CP (MW/°C)
1	185	60	35
2	155	40	25
3	20	195	45

- a) Find out the pinch temperature, [0.5]
 b) Find out the hot and cold utility requirements, HRAT = 10 °C. [2]

Answer: Pinch temperature = 150

Hot utility required = 1200

Cold utility required = 575

2. An investment scheme doubles an amount in 7 years. What is the annual rate of interest? [0.5]

Answer: Annual rate of interest = 10.4%

$$2 = (1 + i)^7 \quad i = 2^{1/7} - 1 = 2^{0.14286} - 1 = 0.104 = 10.4\%$$

3. Suppose you want to invest in a bond costing \$1000 and promising to double the investment in 9 years. Before you make investment, central bank decreases the rate of interest for that bond by half percentage point. To give the same future value after 9 years, how much the bond will cost you now? [2]

Answer: New cost of the bond =

$$2 = (1 + i)^9 \quad i = 2^{1/9} - 1 = 0.08 = 8\%$$

New interest rate = 7.5%

$$2000 = P(1.075)^9 = 1.9172P$$

Or P = 1043.19