

BITS, PILANI-DUBAI, ACADEMIC CITY, DUBAI

Second SEMESTER 2009-2010

CHE C332: Process Design Decisions

Comprehensive Examination

DATE: 25-05-2010

TOTAL DURATION: 3 hours

MAXIMUM MARKS: 40

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

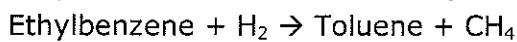
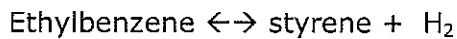
PART – A [20 Marks]

1. If an amount is doubled in 12 years, what is the annual compound rate of return? [1]
2. Assuming nominal annual interest rate to be 8%, find the value of \$1200 invested for 4 years with interest compounding quarterly. [1]
3. An amount of \$3,000.00 is deposited in a bank paying an annual interest rate of 3 %, compounded continuously.
 - (a) Find the balance after 4 years. [1]
 - (b) How long would it take for the money to double? [1]
4. In a retirement scheme, you invest \$1500 every year for 15 years. At an annual interest rate of 7.5%, how much will you receive at the end of 15-year period? [1]
5. Some universities have endowed chairs for distinguished faculty, which need \$60000 per year in salaries. How much a sponsoring industry needs to establish a chair if the interest rate is 6.25%? [1]
6. Between the Liquid Separation System and the Vapor Recovery System, which should be designed first and why? [1]
7. How is fixed capital different from fixed charges in a chemical plant cost estimation? [1]
8. In Heat exchanger network (HEN) synthesis, what are the heuristics of stream-matching (a) above pinch, and (b) below pinch? [1]
9. Suppose you want to invest in a bond costing \$15000 and promising to double the investment in 8 years. Before you make investment, central bank increases 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]

10. A piece of equipment with an original cost of \$12600 and no salvage value has a depreciation allowance of \$2400 during its third year of service, when depreciated by SOYD method. What recovery period has been used? [2]
11. If there are five components with their boiling points and destination codes as listed below, how many product streams will be there? What components each of these streams will contain? [1]

Component	Boiling Point °C	Destination Code
Hydrogen	-253	Recycle and Purge
Toluene	111	Recycle
Benzene	80	Primary Product
Methane	-161	Recycle and Purge
Diphenyl	253	Fuel

12. 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]

13. An equipment costs \$65000 and has 8 years service life with no salvage value. Calculate using double declining balance (DDB) method:
- a) depreciation charged in third year, [2]
 - b) Book value at the end of third year. [1]

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1. A chemical process has two hot streams to be cooled and three cold streams to be heated. Assuming $HRAT = 14^{\circ}\text{C}$ 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 ($\text{kW}/^{\circ}\text{C}$)
1	280	60	30
2	180	20	45
3	20	160	40
4	120	260	60

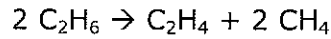
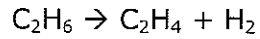
2. For the heat exchanger network synthesis problem given below, hot and cold utility requirements for $HRAT = 12^{\circ}\text{C}$ are 58 MW and 38 MW, respectively. The pinch temperature is 86°C . [6]

Stream No.	Source Temperature ($^{\circ}\text{C}$)	Target Temperature ($^{\circ}\text{C}$)	Heat Capacity Flow rate ($\text{MW}/^{\circ}\text{C}$)
1	180	60	3.0
2	150	30	1.0
3	20	135	2.0
4	80	140	4.5

- (a) 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.
- (b) Show the results in the form of following table (do not show utility exchangers).

Exchan ger No.	Exchan ger Load (MW)	Hot Stream			Cold Stream		
		Inlet Tempera ture ($^{\circ}\text{C}$)	Outlet Tempera ture ($^{\circ}\text{C}$)	CP (M W)	Inlet Tempera ture ($^{\circ}\text{C}$)	Outlet Tempera ture ($^{\circ}\text{C}$)	CP (M W)

3. A homeowner has a choice between a gas fuel heating system and a solar heating system. Both systems have a 20 years useful life. The initial cost for the fuel heating system is \$1200 and the annual fuel cost \$600. if the annual rate of interest is 8%, determine the capital cost of the solar system that will make it competitive with the gas fueled system. [4]
4. The main reactions for a process to produce ethylene via ethane cracking are:



Some of the results for the product distribution are

Component	Yield pattern, mol %					
H ₂	1.12	1.24	1.49	1.76	1.99	2.31
CH ₄	0.08	0.11	0.13	0.16	0.21	0.24
C ₂ H ₄	1.04	1.28	1.54	1.83	2.12	2.43
C ₂ H ₆	2.25	2.00	1.73	1.42	1.12	0.79

From these data, develop a correlation for the selectivity (moles of C₂H₄ at the reactor exit per mole of C₂H₆ converted) as a function of conversion, the following form:

$$1 - S = \frac{a}{(1 - x)^b} \quad [6]$$

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Second SEMESTER 2009-2010

CHE UC332: Process Design Decisions
Test - 2 (Open Book)

DATE: 02.05.2010

DURATION: 50 MINUTES

MAXIMUM MARKS: 20

Note: Attempt ALL 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 Marks]
 - 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. The operating conditions (temperature and pressure) of a set of reactions taking place in a chemical process plant are given below:

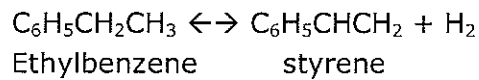
$A + B \rightarrow C$ (700 °C and 1 atm)
 $B + C \rightarrow D + E$ (500 °C and 1 atm)
 $D + A \rightarrow F + D$ (400 °C and 1 atm)
 $C + A \rightarrow F + G$ (400 °C and 2 atm)
 $C + D \rightarrow H + I$ (400 °C and 2 atm)

How many reactor systems are required at Level – 3 of conceptual design? [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? [3]

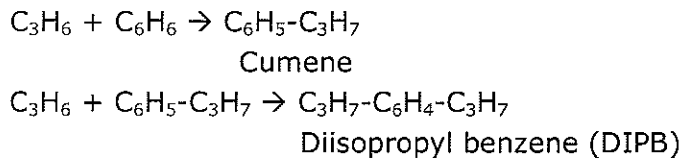
Component	Destination Code	Component	Destination Code
A	Recycle	F	Recycle and Purge
B	Waste	G	Recycle and Purge
C	Recycle	H	Primary Product
D	Fuel	I	Recycle
E	Fuel	J	Recycle

4. Styrene is produced by the reaction:



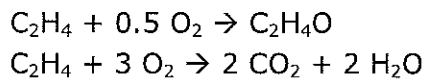
The reaction is reversible and is limited by equilibrium. We want to shift the equilibrium to the right to favor styrene production. Suggest how changing pressure can help accomplish this objective. [1]

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



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

6. Ethylene oxide (EO) is produced by the catalytic oxidation of ethylene over a silver-containing catalyst. A side-reaction oxidizes ethylene to carbon dioxide and water.



The reaction selectivity data are given below.

x	0.1	0.3	0.4	0.5	0.7	0.9
S	0.71	0.68	0.67	0.65	0.62	0.56

Where Selectivity, S = mol EO at reactor exit/ mol ethylene converted.
Develop a linear correlation between conversion x and selectivity S from above data.
Use your results to estimate the conversion corresponding to the maximum yield.

[7 + 2 = 9 Marks]

BITS, PILANI-DUBAI, ACADEMIC CITY, DUBAI
FIRST SEMESTER 2009-2010

CHE UC332: Process Design Decisions

TEST - 1
(Closed Book)

DATE: 21.03.2010

DURATION: 50 MINUTES

MAXIMUM MARKS: 20

Note: Attempt ALL questions. Make suitable design decisions wherever necessary, and mention them clearly. Do not alter any given data.

1. A chemical plant has one hot stream to be cooled and two cold streams to be heated. Assuming $HRAT = 10^{\circ}\text{C}$ for the stream data set given below, carry out the process synthesis using Pinch Technology by determining the following:
 - a) net amount of heat available in the streams based on first law [1]
 - b) minimum hot and cold utility requirements based on second law [4]
 - c) Hot and cold pinch temperatures. [1]
 - d) Create a heat exchanger network featuring MNU and show it using a grid diagram. On the grid diagram, clearly mention intermediate temperatures and heat exchanger duties. [5]

Stream No.	Source temperature ($^{\circ}\text{C}$)	Target temperature ($^{\circ}\text{C}$)	Heat capacity flowrate ($\text{kW}/^{\circ}\text{C}$)
1	200	50	40
2	60	150	30
3	80	180	50

2. Compare two pension fund schemes: Investment scheme A requires you to deposit \$1000 per year for twenty years, and then pays you \$4000 per year forever. Investment scheme B requires you to deposit \$2000 per year for 13 years, and then pays you \$4000 per year forever. Which investment scheme you consider to be better? Justify. [5]
3. A piece of equipment with an original cost of \$10000 and no salvage value has a depreciation allowance of \$2381 during its second year of service, when depreciated by SOYD method. What recovery period has been used? [4]

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Second SEMESTER 2009-2010

CHE UC332: Process Design Decisions

Quiz - II

DATE: 04/05/2010

DURATION: 20 MINUTES

MAXIMUM MARKS: 07

I.D. No.

Name:

Note: Attempt all questions. Questions 1 through 8 carry ½ marks each. Questions 9 carries 2 marks and question 10 carries 1 mark.

1. We process the inerts rather than eliminating them before reaction when
 - a) Catalyst is adversely affected by the inerts
 - b) Large exothermic heat must be removed
 - c) Nearly pure products are required
 - d) all of the above
2. Byproducts from reversible side reactions are
 - a) Purged
 - b) recycled
 - c) Recovered in separators
 - d) all of the above 3 can be considered
3. In the design of a process at the screening stage, it is desirable to recover more than % of valuable components
 - a) 75
 - b) 95
 - c) 99
 - d) 80
4. In process design, the heuristic to choose the solvent flow rate for an isothermal, dilute gas absorber is
 - a) $L = 1.4$,
 - b) $L = 1.4 G$,
 - c) $L = mG$,
 - d) $G = 1.4 L$
5. A batch reactor is
 - a) Suitable for gas-phase reactions on commercial scale
 - b) Suitable for liquid-phase reactions involving small production rate
 - c) Least expensive to operate for a given rate
 - d) Most suitable for very large production rate
6. 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

7. The gas recycle and purge stream is used in a process, if the light reactant is boiled at boiling point lower than the boiling point of:
a) ethylene, b) propylene, c) propane, d) ethane
8. To separate a 4-component mixture by distillation, how many alternative distillation sequences are possible:
a) 3 b) 5 c) 14 d) 24
9. The selectivity versus conversion relationship for a particular reaction system is given as: $S = 1 - 1.25x$. Find out the conversion corresponding to maximum yield.
10. What are the 4 locations to place a vapor recovery system?

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Second SEMESTER 2009-2010
CHE UC332: Process Design Decisions
Quiz - I (Closed Book)

DATE: 08.03.2010

DURATION: 20 MINUTES

MAXIMUM MARKS: 8

Note: Attempt ALL questions.

Student's Name: _____ I.D. _____

1. For the stream data set given below:

Stream No.	Supply Temperature ($^{\circ}\text{C}$)	Target Temperature ($^{\circ}\text{C}$)	CP (MW/ $^{\circ}\text{C}$)
1	200	115	30
2	155	60	60
3	40	195	50

- a) Find out the hot and cold pinch temperatures, [1]
b) Find out the hot and cold utility requirements, HRAT = 10°C . [2]

Hot pinch temperature =

Cold pinch temperature =

Hot utility required =

Cold utility required =

Show the heat cascade on the reverse of this sheet. [1]

2. You want to buy an ordinary annuity that will pay you \$800 a year for the next 8 years. You expect annual interest rates to be 8 percent over that time period. Calculate the maximum price you would be willing to pay for the annuity.

Price of the annuity =

3. An amount of \$9000 is deposited in a bank paying an annual interest rate of 9 %, compounded continuously.
(a) Find the balance after 9 years. [1]
(b) How long would it take for the money to double? [1]

Balance after 9 years =

Time required for doubling the money =

4. An equipment costs \$90000 and has 10 years service life with no salvage value. Calculate using SOYD method depreciation charged in third year.

Depreciation charged in third year =