

BITS, PILANI-DUBAI, ACADEMIC CITY, DUBAI

Second SEMESTER 2007-2008

CHE C332: Process Design Decisions

Comprehensive Examination

DATE: 02-06-2009

TOTAL DURATION: 3 hours

MAXIMUM MARKS: 80

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

**PART – A [35 Marks]**

Each of the following questions 1 to 8 carries ONE MARK each.

**Tick (✓) the correct option:**

In chemical plant preliminary cost estimation:

1. Start-up costs are taken as 10% of
  - a) Fixed capital
  - b) total investment
  - c) Working capital
  - d) raw material costs
2. Working capital is taken as 15% of:
  - a) Fixed capital
  - b) total investment
  - c) Direct costs
  - d) onsite
3. Off-site costs are taken as 45% of
  - a) Working capital
  - b) on-site costs
  - c) Direct costs
  - d) fixed capital

In a simplified investment model for a chemical plant:

4. Total investment is calculated as ..... times the fixed capital
  - a) 1.3
  - b) 2.0
  - c) 2.36
  - d) 3.5
5. The cost of royalties and patents is taken as .....% of total product cost
  - a) 0.5
  - b) 3
  - c) 10
  - d) 25
6. Tick the correct statement:
  - a) fixed charges are taken as 3% of the fixed capital
  - b) fixed charges are taken as 10% of the fixed capital
  - c) fixed charges are taken as 50% of the fixed capital
  - d) fixed charges and the fixed capital are the same thing

7. The cash flow in a company is equal to
- Total Inv – Fixed Cap
  - Profit after tax + Depreciation
  - Profit before tax – Depreciation
  - Revenue – raw material cost
8. In a heat exchanger network, irrespective of HRAT chosen,
- the sum of hot utility requirements (HU) and cold utility requirements (CU) remains constant
  - the difference of HU and CU remains constant
  - total heat duty remains constant
  - total heat exchange area remains constant
9. An amount triples in 10 years in an investment scheme. What is the annual compound rate of interest? [2 M]
10. Assuming nominal annual interest rate to be 6%, find the value of \$100 invested for 10 years with interest compounding continuously. [2 M]
11. In a retirement scheme, you invest \$500 every year for 25 years. At an annual interest rate of 8%, how much will you receive at the end of 25-year period? [2 M]
12. Some universities have endowed chairs for distinguished faculty, which need \$50000 per year in salaries. How much a sponsoring industry needs to establish a chair if prevailing interest rate is 8%? [2 M]
13. Between the Liquid Separation System and the Vapor Recovery System, which should be designed first and why? [2 M]
14. In Heat exchanger network (HEN) synthesis, what are the heuristics of stream-matching (a) above pinch, and (b) below pinch? [2 M]
15. 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? [2 M]

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

16. An equipment costs \$90000 and has 10 years service life with no salvage value. Calculate using double declining balance (DDB) method:
- a) depreciation charged in third year, [3 M]
  - b) Book value at the end of third year. [2 M]
17. Write any FOUR heuristics for distillation sequencing in a multi-component separation. Give one justification for each heuristic. [4 M]
18. 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? [4 M]

\*\*\* END OF PART A \*\*\*

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**PART – B [45 Marks]**

**Note: Part B is to be attempted in separate answer-sheet.**

1. A chemical process has three hot streams to be cooled and two cold streams to be heated. Assuming  $HRAT = 20^{\circ}\text{C}$  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, [08]
  - (b) Hot and cold pinch temperatures. [02]

Stream No.	Source Temperature ( $^{\circ}\text{C}$ )	Target Temperature ( $^{\circ}\text{C}$ )	Heat Capacity Flow rate ( $\text{kW}/^{\circ}\text{C}$ )
1	150	50	200
2	170	40	100
3	110	80	50
4	50	120	300
5	80	110	500

2. For the heat exchanger network synthesis problem given below, hot and cold utility requirements for  $HRAT = 10^{\circ}\text{C}$  are 250 MW and 525 MW, respectively. The pinch temperature is  $195^{\circ}\text{C}$ . [10]

Stream No.	Source Temperature ( $^{\circ}\text{C}$ )	Target Temperature ( $^{\circ}\text{C}$ )	Heat Capacity Flow rate ( $\text{MW}/^{\circ}\text{C}$ )
1	200	115	6.0
2	155	90	4.5
3	40	195	5.0

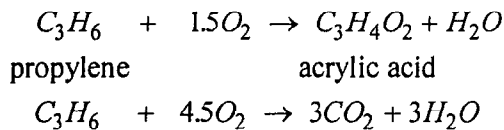
Synthesize an MER network featuring minimum number of units, and draw it on the grid diagram; clearly indicating heat exchanger loads and intermediate stream temperatures.

3. An experimental research station located in remote area must provide its own electricity. Two options are being considered: wind turbine and gasoline-powered generator. Determine the energy cost (cost of electricity produced) in \$/(kWh) for each proposed system. Following data are given:

System	Generating power (kW)	% Up time	Capital cost	Annual maintenance	Annual operating cost
Wind turbine	15	50%	\$15000	\$500	none
Gasoline generator	10	75%	\$500	\$500	\$2500

The time value of money is 15% and service life of both equipment is 20 years. [10]

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



Some of the results for the product distribution are

Component	C <sub>3</sub> H <sub>6</sub>	C <sub>3</sub> H <sub>4</sub> O <sub>2</sub>	CO <sub>2</sub>	H <sub>2</sub> O	O <sub>2</sub>
Yield pattern, mol%	13.99	0.56	0.06	42.60	42.79
	13.45	1.61	0.16	42.11	42.67
	12.50	3.40	0.38	41.29	42.42
	11.12	5.98	0.83	40.16	41.91
	9.47	8.86	1.81	39.07	40.79
	7.60	11.39	4.65	38.82	37.55
	5.28	12.16	13.65	41.65	27.25
	3.89	12.57	19.20	43.43	20.92
	3.26	12.95	21.23	43.96	18.59

Convert the data suitably to calculate conversion,  $x$  and selectivity,  $S$  and develop a correlation (using least squares regression) for the selectivity (moles of C<sub>2</sub>H<sub>4</sub> at the reactor exit per mole of C<sub>2</sub>H<sub>6</sub> converted). The

correlation will have following form:  $S = 1 - \frac{a}{(1-x)^b}$  [15]

\*\*\* END OF PART B \*\*\*

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**BITS, PILANI-DUBAI, ACADEMIC CITY, DUBAI**  
**Second SEMESTER 2008-2009**

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

DATE: 30.04.2009

DURATION: 50 MINUTES

MAXIMUM MARKS: 40

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.

- In acetone recovery from air-acetone stream with the absorption as a selected alternative, discuss the following: [3 X 5 = 15 Marks]
  - Advantages and disadvantages of using a solvent other than water.
  - If dissolved air is present in acetone-water stream leaving absorber and entering the distillation column, then how will it affect the efficiency of distillation column and suggest ways to overcome this problem?
  - Discuss the pros and cons of using high flow rate of water in the absorber.
  - What is the trade-off associated with recycling the bottom product from distillation column to the absorber as solvent?
  - The effect of decreasing solvent flow rate to the absorber on the utilities requirement and reflux ratio in the subsequent distillation column.
- If feed to the distillation column is not pre-heated to saturated liquid condition, how does it affect the distillation operation as a whole? [3]
- If there are five components with their boiling points and destination codes as listed below, how many product streams will be there? [2]

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

- Selectivity data for a process to produce B from A are given below:

<b>S</b>	0.644	0.572	0.514	0.446	0.384
<b>x</b>	0.50	0.60	0.70	0.80	0.90

Where Selectivity,  $S = \text{mol B at reactor exit} / \text{mol A converted}$ .

Develop a linear correlation for the data. Use your results to estimate the conversion corresponding to the maximum yield. [15 + 5]

**BITS, PILANI-DUBAI, ACADEMIC CITY, DUBAI**  
**Second SEMESTER 2008-2009**

**CHE C332: process Design Decisions**  
**Test – 1 (Open Book)**

**DATE: 22.03.2009**

**DURATION: 50 MINUTES**

**MAXIMUM MARKS: 40**

**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 two hot streams to be cooled and two cold streams to be heated. Assuming  $HRAT = 10^{\circ}C$  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 [2]
  - b) minimum hot and cold utility requirements based on second law [8]
  - c) Hot and cold pinch temperatures. [2]

Stream No.	Source temperature ( $^{\circ}C$ )	Target temperature ( $^{\circ}C$ )	Heat capacity flowrate ( $kW/^{\circ}C$ )
1	200	40	2.0
2	180	35	4.0
3	30	175	5.0
4	45	130	3.0

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
<b>Air-cooled</b>	\$30, 000	\$1, 500
<b>Water-cooled</b>	\$15, 000	\$3, 500

- Both pieces of equipment have service lives of 18 years. For an internal rate of return of 10% p.a., which piece of equipment represents the better choice? [7]  
 At what internal rate of return, both equipments will be equally attractive? [9]

3. Suppose a business has an asset with \$4,000 Original Cost, \$100 Salvage Value, and 5 years useful life. Calculate depreciation using SOYD and DDB methods and show the results in following tabular form (ledger entry, one table for each method): [6+6]

Book Value - Beginning of Year	Depreciation Rate	Depreciation Expense	Accumulated Depreciation	Book Value - End of Year
\$4,000 (Original Cost)	...	...	...	...
...	...	...	...	...

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**Surprise Quiz - III**

DATE: .../04/2009

DURATION: 20 MINUTES

MAXIMUM MARKS: 10

I.D. No.

Name:

1. If we double the tower pressure in an isothermal dilute gas absorber, the number of plates required in absorber
  - a) Increases
  - b) decreases
  - c) remains constant
  - d) can not say
2. In acetone recovery from air-acetone stream with the absorption as the selected alternative, if we double 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) can not say
3. In process design, the heuristic to choose the solvent flow rate for an isothermal, dilute gas absorber is
  - a)  $L = 1.4$ ,
  - b)  $L = 1.4 \text{ mG}$ ,
  - c)  $L = 1.4/\text{mG}$ ,
  - d)  $G = 1.4 \text{ L}$
4. We normally do not use distillation to split adjacent components when
  - a)  $\alpha > 1.1$ ,
  - b)  $\alpha < 1.1$ ,
  - c)  $\alpha = 1.1$ ,
  - d)  $\alpha = 1.4$
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. 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.



7. In Level-2 decisions, with reference to feed condition, if the feed impurity is present as an azeotrope with reactant than the better option is to **process/separate** the impurity.
8. 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
9. 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.
10. Byproducts from reversible side reactions are
  - a) purged
  - b) recycled
  - c) recovered in separators
  - d) all of the above 3 can be considered

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**BITS, PILANI-DUBAI, ACADEMIC CITY, DUBAI**  
**Second SEMESTER 2008-2009**  
**CHE UC332: Process Design Decisions**  
**Surprise Quiz - II**

DATE: 17.03.2009

**DURATION: 30 MINUTES**

**MAXIMUM MARKS: 10**

**Note: Attempt ALL questions. Show calculations overleaf.**

**Student's Name:** \_\_\_\_\_

**I.D.** \_\_\_\_\_

1. I invest money in a savings account that pays a nominal interest of 6% p.a. compounded monthly. I open the account with a deposit of \$1000 and then deposit \$50 at the end of each month for a period of two years followed by a monthly deposit of \$100 for the following 3 years. What will be the value of my savings account at the end of the five-year period? [2]

**Answer:**

2. Assuming interest is compounding continuously, estimate the future value of 41,000 invested for 22 years at 5%, then re-invested for 7 years at 10%. [2]

**Answer:**

3. You have 5 options for constructing an apartment building on a site. Your MARR (minimum acceptable rate of return) is 10%. Which options are acceptable and which option is the best? (Assume that net rents continue indefinitely, with no inflation). [6]

A	5 story building, no frills: \$1 million investment, annual net income from rent \$0.11 million
B	5 story building, with pools and gardens: \$1.5 million investment, annual net income from rent \$0.12 million
C	10 story building, no frills: \$2 million investment, annual net income from rent \$0.21 million
D	10 story building, upscale: \$2.5 million investment, annual net income from rent \$0.25 million
E	15 story building, upscale: \$3.3 million investment, annual net income from rent \$0.35 million

**Answer:**

Option A	Acceptable/ Unacceptable	.....
Option B	Acceptable/ Unacceptable	.....
Option C	Acceptable/ Unacceptable	.....
Option D	Acceptable/ Unacceptable	.....
Option E	Acceptable/ Unacceptable	.....

**BITS, PILANI-DUBAI, ACADEMIC CITY, DUBAI**

**Second SEMESTER 2008-2009**

**CHE UC332: Process Design Decisions**

**Surprise Quiz - I**

**DATE: 23.02.2008**

**DURATION: 30 MINUTES**

**MAXIMUM MARKS: 10**

**Note: Attempt ALL questions.**

**Student's Name:**

**I.D.**

1. For the stream data set given below:

<b>Stream No.</b>	<b>Supply Temperature (°C)</b>	<b>Target Temperature (°C)</b>	<b>CP (MW/°C)</b>
1	190	30	3.0
2	170	50	4.0
3	20	135	3.5
4	70	140	7.0

- a) Find out the hot and cold pinch temperatures, [2]  
b) Find out the hot and cold utility requirements, HRAT = 10 °C. [4]

Hot pinch temperature =

Cold pinch temperature =

Hot utility required =

Cold utility required =

2. You want to buy an ordinary annuity that will pay you \$4,000 a year for the next 20 years. You expect annual interest rates to be 8 percent over that time period. The maximum price you would be willing to pay for the annuity is closest to

- a) 32, 000      b) 39, 272      c) 40, 000      d) 80, 000

3. With monthly compounding at 10 percent nominal for 30 years, the future value of an initial investment of \$2,000 is closest to

- a) 34, 898      b) 39, 675      c) 164, 500      d) 328, 282

4. Find the future value of an annuity of \$600 per year for 8 years if the interest rate is 12 per cent

- a) 7373.42      b) 7379.82      c) 7388.08      d) 7392.22

5. An investment scheme doubles an amount in 11 years. What is the annual rate of interest?

Answer: