PROCESS INTEGRATION
(CHEN 4232)

Time Allotted : 2½ hrs **Full Marks : 60**

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and any 4 (four) from Group B to E, taking one from each group.

Candidates are required to give answer in their own words as far as practicable.

Group – A

1. Answer any twelve: **12 × 1 = 12**

Choose the correct alternative for the following

(i) The hierarchical structure of process design is shown by
(a) Process flow sheet
(b) Piping diagram
(c) Onion Diagram
(d) None of the above

(ii) In synthesis step:
(a) A HEN that satisfied the target for utility consumption is designed
(b) The design starts where the process is more constrained
(c) Both (a) and (b)
(d) None of the above

(iii) An example of a constant temperature utility is
(a) Cooling water
(b) Flue gases
(c) Chilled water
(d) Condensing steam

(iv) The ΔT_{cont} value for liquid-liquid heat exchange is
(a) 5°C
(b) 25°C
(c) 10°C
(d) 15°C

(v) The pinch signifies
(a) Maximum heat transfer
(b) Minimum driving force for heat transfer
(c) Minimum cost
(d) Maximum Energy requirement

(vi) For maximum energy recovery, no utility cooling should be used
(a) Below the pinch
(b) Above the pinch
(c) At the pinch
(d) At the cold stream starting level

(vii) For a badly designed plant, the scope of energy cost reduction per year is around
(a) 5-10%
(b) 40-50%
(c) 60%
(d) >70%

(viii) A connection between the hot and cold utility through streams and exchangers is called a
(a) Path
(b) Loop
(c) Curve
(d) Boundary

(ix) A closed path through a network is called a
(a) Domain
(b) Loop
(c) Path
(d) Circuit

(x) For a reversible heat engine, the mechanical efficiency is
(a) 20%
(b) 50%
(c) 1%
(d) 100%

Fill in the blanks with the correct word

(xi) In a chemical plant, the onion model design strategy starts with the _____.

(xii) If the hot utility load in a network increases by 20 kW, then the cold utility load increases by _____ kW.

(xiii) Capacity is the product of _____ and specific heat.

(xiv) Stream splitting is used to satisfy the _____criteria.

(xv) Liquid streams are assigned a ΔT_{cont} value of _____.

Group - B

2. (a) State and explain the three stages of a HEN synthesis used in chemical engineering. *[(CO1)(Analyse/IOCQ)]*

(b) Explain briefly the three stages of the pinch design. *[(CO1)(Analyse/IOCQ)]*

6 + 6 = 12

3. Consider the plant shown in figure 1 below where decisions regarding reaction path, reactors and separation have been made. The process does not have any material recycles.

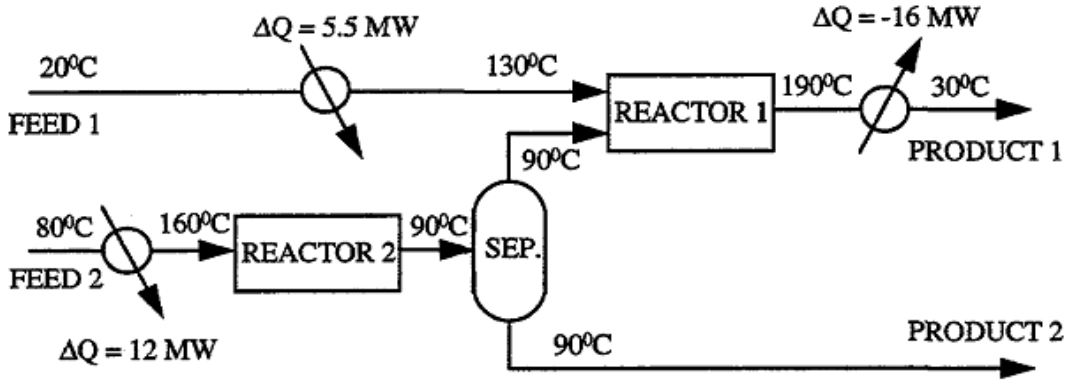

Fig. 1

The two feed streams require heating and PRODUCT 1 requires cooling. Table below gives the data necessary for considering heat recovery between these three streams. Note that the classification of hot and cold streams is based on whether a stream requires cooling or heating, it does not depend on temperature.

Stream Name	Stream No.	T_S, ^{0}C	T_t, ^{0}C	C_P. MW / ^{0}C
PRODUCT I	Hot 1(H1)	190	30	0.10
FEED 2	Cold 1(C1)	80	160	0.15
FEED 1	Cold 2 (C2)	20	130	0.05

(i) Suggest a possible Heat Exchanger Network for this system. *[(CO1) (Analyse/IOCQ)]*

(ii) Suggest the complete process including the HEN to show how HEN may influence the dynamics of the overall plant. *[(CO1) (Evaluate/HOCQ)]*

(6 + 6) =12

Group - C

4. (a) By a simple example, explain how you can reduce the heating and cooling loads for a reactor operating at a high temperature, producing a product that needs to be cooled for storage. *[(CO1)(Apply/IOCQ)]*

(b) Draw the hot composite curve for the following data:

Table 1

Stream No	Capacity (kW/K)	T_s (°C)	T_t (°C)
1	3	25	140
2	4	175	65
3	5	75	145
4	2.5	150	25

[(CO1)(Apply/IOCQ)]

4 + 8 = 12

5. (a) For the data given in Table 1, prepare the problem table algorithm. *[(CO1)(Apply/IOCQ)]*

(b) Calculate the hot and cold utility requirements, as well as the pinch temperatures for the hot and cold streams. *[(CO 1, 2)(Apply/IOCQ)]*

8 + 4= 12

Group - D

6. (a) Normally, we allocate a ΔT_{cont} value slightly higher than $\Delta T_{min}/2$ to account for changes in stream properties or fouling. But in some particular cases the contributed ΔT may be less than $\Delta T_{min}/2$. Can you suggest such a possible case? *[(CO 2, 3)(Evaluate/HOCQ)]*

   (b) What is the utility of supertargeting? *[(CO 2, 3)(Understand/LOCQ)]*

6 + 6 = 12

7. (a) What is the utility of stream splitting? *[(CO 2, 3)(Analyse/IOCQ)]*

   (b) Write the algorithms for stream splitting above the pinch and below the pinch. *[(CO 2, 3)(Understand/LOCQ)]*

4 + 8 = 12

Group - E

8. (a) What is the principle behind combined heat and power plants? *[(CO 4)(Analyse/IOCQ)]*

   (b) Show that, for a CHP plant, as the hot utility temperature rises, the power generated falls. *[(CO 4)(Analyse/IOCQ)]*

5 + 7 =12

9. (a) How can energy integration be achieved in a distillation column? *[(CO 4)(Evaluate/HOCQ)]*

   (b) Define (i) Carnot efficiency (ii) COP. *[(CO 4)(Understand/LOCQ)]*

8 + 4 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	18.75	54.17	27.08

Course Outcome (CO):

After the completion of the course students will be able to

1. Perform pinch analysis on a given Heat exchange system to identify non-optimal arrangements.
2. Design a Heat Exchanger Network (HEN) for a given heat exchange problem.
3. Analyze and optimize a HEN with respect to cost, energy requirement, area requirement etc.
4. Design energy-integrated process systems for distillation, chemical reaction, evaporation, refrigeration and cogeneration.

**LOCQ: Lower Order Cognitive Question; IOCQ: Intermediate Order Cognitive Question; HOCQ: Higher Order Cognitive Question.*