GUJARAT TECHNOLOGICAL UNIVERSITY

Program Name: Master of Engineering
Level: PG
Branch: Chemical Engineering
Subject Code: ME02030061
Subject Name: Process Design Synthesis

w. e. f. Academic Year:	2024-25
Semester:	2
Category of the Course:	Professional Elective Course

Prerequisite:	Basics of heat transfer, mass transfer and reaction engineering
Rationale:	For sustainable industrial activity, processes should use raw materials as efficiently as is economic and practicable, both to prevent the production of waste that can be environmentally harmful and to preserve the reserves of raw materials as much as possible. Processes should use as little energy as economic and practicable. Water must also be consumed in sustainable quantities. Chemical Process Synthesis requires the selection of a series of processing steps and their integration. Extensive applications of computer softwares, simulators and optimization tools in the process industries have made it mandatory to understand computer aided design tools.

Course Outcome:

After Completion of the Course, Student will able to:

No	Course Outcomes
01	Analyze alternative processes and equipment
02	Synthesize a chemical process flow sheet that would approximate the real process
03	Design best process flow sheet for a given product
04	Perform economic analysis related to process design and evaluate project profitability

Teaching and Examination Scheme:

Teaching Scheme(in Hours)			Total Credits L+T+ (PR/2)	Assessment Pattern and Marks				Total Marks
				Theory		Tutorial / Practical		
L	T	PR	C	ESE (E)	PA / CA (M)	PA/CA (I)	ESE (V)	
3	0	2	4	70	30	20	30	150

Course Content:

Unit No.	Content	No. of Hours	% of Weightage
1.	**Introduction:** Introduction to fundamental concepts and principles of process synthesis and design and use of flow sheet simulators to assist process design. Process Flow sheet models: An Introduction to Design, Chemical process synthesis, analysis and optimization. Introduction to commercial process design software such as HYSYS, Aspen plus etc., Chemical Process (reactor, heat exchanger, distillation etc) analysis using commercial software	**4**	**9**
2.	**Product design and developments:** Process engineering economics and project evaluation Life Cycle Assessments of process: From design to product development, Engineering Economic Analysis of Chemical Processes, Project costing and performance analysis, Environmental concerns, Green engineering, Engineering ethics, Health and safety	**6**	**13**
3.	**Reactor Networks:** Geometry of mixing and basic reactor types, The Attainable Region (AR) approach, AR in higher dimensions & for other processes, Reactive Separation processes, Fundamental behavior and problems, Separation through reactions. Reactive Residue Curve Maps	**6**	**13**
4.	**Synthesis of Separation Trains:** Criteria for selection of separation methods, select ion of equipment: Absorption, Liquid-liquid extraction Membrane separation, adsorption, leaching, drying, crystallization, Ideal distillation – Column and sequence fundamentals, Sharp splits & sequencing Phase diagrams for 2, 3 and 4 components, Feasibility and vapor flow rates for single columns, Residue curve basics, Non-ideal Distillation – Azeotropic systems; detecting binary azeotropes, Residue curve maps for azeotropic systems, Topological analysis, Feasibility for single azeotropic columns, Binary VLLE and pressure swing separation, Non-ideal distillation synthesis. Equipment sequencing: VLE + VLLE, Detailed Residue Curve Maps, Residue curve maps: Interior structure	**12**	**27**
5.	**Heat Exchanger Network Synthesis:** Minimum heating and cooling requirements, Minimum Energy Heat Exchanger Network, Loops and Paths, Reducing Number of Exchangers, HENS basics & graphics, The pinch point approach, Stream Splitting, Performance targets, trade-off & utilities, Heat & power integration, HENS as mathematical programming	**11**	**25**
6.	**Mass Integration:** Introduction, Minimum Mass Separating Agent	**6**	**13**

	(MSA), Mass Exchanger Networks Minimum External MSA, Minimum Number of Mass Exchangers		
	Total	**45**	**100**

Suggested Specification Table with Marks (Theory):

Distribution of Theory Marks					
R Level	**U Level**	**A Level**	**N Level**	**E Level**	**C Level**
7	12	35	10	6	0

Where R: Remember; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create (as per Revised Bloom's Taxonomy)

References/Suggested Learning Resources:

(a) Books:

1. Conceptual Design of Chemical Processes by Douglas, J., New York, NY: McGraw-Hill Science/ Engineering / Math, 1988. ISBN: 0070177627.
2. Product and Process Design Principles: Synthesis, Analysis, and Evaluation by Seider, W. D., J. D. Seader, and D. R. Lewin, 2nd ed. New York, NY: Wiley, 2004. ISBN: 0471216631.
3. Systematic Methods of Chemical Process Design by Biegler L.T., Grossmann I.E. and Westerberg A.W., Prentice Hall, 1997

(b) Open source software and website:

1. Students can refer to video lectures available on the websites including NPTEL lecture series.
2. Students can refer to the CDs available with some reference books for the solution of problems using softwares/spreadsheets.

Suggested Course Practical List:

1. Determine minimum utility requirements for the given process stream information.
2. Calculate pinch point and utility requirements for given process data.
3. Solution of linear programming model for determination of pinch point using tools like GAMS / MATLAB / SCILAB / Excel.
4. Solution of MILP model for determination of pinch point using tools like GAMS / MATLAB / SCILAB / Excel.

5. Analyze optimum approach temperature and parameters influencing it for the heat exchanger network synthesis using given stream information.
6. Estimate the area and cost of heat exchangers required for the given process plant data.
7. Optimize utilities, number of heat exchangers and average area of heat exchangers in a heat exchange network design assignment using sequential optimization.
8. Optimize utilities, number of heat exchangers and average area of heat exchangers in a heat exchange network design assignment using simultaneous optimization.
9. Plotting of Attainable Region for reactor networks.
10. Pinch point and utility requirement calculation for mass exchanger network synthesis.
11. Determine the best sequence of distillation column for multi-component system.
12. Course project by each student with analysis of HENS for industrial case study.

Major Softwares: MS Excel, HINT, GAMS, MATLAB, SCILAB

List of Laboratory/Learning Resources Required:

- Computer Lab

Suggested Project List:

- Design a sustainable cracking process with a heat recovery system.
- Synthesis gas production for renewable energy applications.
- Hybrid systems combining thermal and reverse osmosis processes.

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