GUJARAT TECHNOLOGICAL UNIVERSITY

Bachelor of Engineering
Subject Code: 3170510
Semester – VII

Subject Name: Process Intensification

Type of course: Professional Elective Course

Prerequisite: Basics of heat transfer, mass transfer and reaction engineering

Rationale: Process intensification is the paths for development of more sustainable chemical processes. Process intensification leads to a substantially smaller, cleaner, safer, and more energy efficient technology. Process intensification concerns engineering methods and equipment only; development of a new chemical route or a change in composition of a catalyst is not covered under process intensification. Process intensification consists of the development of novel apparatuses and techniques to bring improvements in manufacturing and processing, substantially decreasing equipment size/production-capacity ratio, energy consumption, or waste production; ultimately resulting better sustainable technologies. Process intensifying equipment covers novel reactors, intensive mixers, and heat-transfer and mass-transfer devices. Process intensifying methods covers new or hybrid separations, integration of reactions and separations, heat exchange, phase transition and/or new process-control methods such as intentional unsteady-state operations.

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks				Total Marks
				Theory Marks		Practical Marks		
L	T	P	C	ESE (E)	PA (M)	ESE (V)	PA (I)	
3	0	0	3	70	30	0	0	100

Content:

Sr. No.	Content	Total Hrs
1	**Introduction to process Intensification** History of Process Intensification, Definitions and Interpretations of Process Intensification, Fundamentals of Process Intensification – Principles, Approaches, Domains, and Scales, Techniques of Process Intensification (PI) Applications, The philosophy and opportunities of Process Intensification, Main benefits from process intensification, Process Intensifying Equipment, Process intensification toolbox, Techniques for PI application.	5
2	**Novel Reactors:** Introduction to spinning disc reactor, Rotor stator reactors: the STT reactor, Taylor–Couette reactor, Rotating packed-bed reactors, Oscillatory baffled reactors (OBRs), Micro-reactors (The catalytic plate reactor (CPR), HEX-reactors), Hydrodynamic	8

	Cavitation Reactors	
3	**Intensive mixers:** Introduction to special types of mixers, Ultrasound mixers, Mixing in intensified equipment, Chemical Processing in High-Gravity Fields Atomizer, Ultrasound Atomization, Nebulizers, High intensity inline mixers reactors; Static mixers, Ejectors, Tee mixers, Impinging jets, Rotor stator mixers	**6**
4	**Structured Catalysts and Reactors:** Introduction to catalyst, Overview of structured reactors, Monolithic Catalysts and Reactors, Gauzes, Structured Packings, Foams, Three-Levels-of-Porosity (TLP) Reactors, Membrane-Enclosed Catalytic Reactor (MECR), Environmental Catalysis, Hydrodynamics and Mass Transfer in Monoliths	**7**
5	**Hybrid Separation :** Distillation – dividing wall columns, Short path distillation, Membrane distillation, Extractive distillation, Adsorptive distillation, Membrane absorption/stripping, Adsorptive membranes (membrane chromatography), Membrane extraction, Supercritical separation, Barriers and future prospects	**6**
6	**Integration of reaction and separation:** Heat Integrated Distillation Trains, Reactive distillation, Reactive extraction, Reactive absorption, Fundamentals of process modeling in integrated systems, Case studied such as Absorption of NOx, Coke Gas Purification, Methyl Acetate Synthesis, Synthesis of Methyl Tertiary Butyl Ether	**7**
7	**New Heat Exchangers:** Plate heat exchangers, Graphite plate heat exchangers, Spiral heat exchangers, Printed circuit heat exchangers, The Chart-flow heat exchanger, Flat tube-and-fin heat exchangers, Microchannel heat exchangers, Polymer film heat exchanger, Foam heat exchangers, Mesh heat exchangers, Selection of heat exchanger technology, Integrated heat exchangers in separation processes	**6**

Plasma

Suggested Specification table with Marks (Theory):

Distribution of Theory Marks					
R Level	U Level	A Level	N Level	E Level	C Level
5	10	25	15	10	5

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Legends: R: Remembrance; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Note: This specification table shall be treated as a general guideline for students and teachers. The actual distribution of marks in the question paper may vary slightly from above table.

Reference Books:

1. Process Intensification Engineering for Efficiency, Sustainability and Flexibility by David Reay, Colin Ramshaw, Adam Harvey. Elsevier Science, 2013
2. Reengineering the Chemical Process Plants, Process Intensification by Stankiewicz, A., Moulijn, (Eds.), Marcel Dekker, 2003.
3. Process Intensification for Green Chemistry, Engineering Solutions for Sustainable Chemical Processing by Kamelia Boodhoo, Adam Harvey, Willey 2013

Course Outcomes:

After successful completion of the course, student will be able to

Sr. No.	CO statement	Marks % weightage
CO-1	identify process intensification for the enhancement of chemical processes	15
CO-2	apply intensified reactors and/or separators in process industries	35
CO-3	analyze scale up issues in the process industries.	25
CO-4	solve process challenges using intensification technologies	25

List of Open Source Software/learning website:

- Students can refer to video lectures available on the websites including NPTEL lecture series.
- Students can refer to the CDs available with some reference books for the solution of problems using software/spreadsheets.
- Heat Exchanger Network synthesis, design and analysis can be performed in HINT open source software. Student can use DWSIM, COCO, ChemSep open source software also.
- Students can use recent research articles published in Chemical Engineering and Processing: Process Intensification, Elsevier.