K. K. Wagh Institute of Engineering Education and Research, Nashik

(Autonomous wef AY 2022-23)

Syllabus B. Tech Chemical Engineering (Honors/Minors)

Pattern: 2023 Pattern
(wef AY 2023-24)

B. Tech with Honors Degree with Multidisciplinary Minor (2023 Pattern) Honors in Process Engineering																	
Sem	**Course Type**	**Course Code**	**Title of Course**	**Teaching Scheme**			**Evaluation Scheme and Marks**						**Credits**			
				TH	**TU**	**PR**	**INSEM**	**ENDSEM**	**CCE**	**TW**	**PR/OR**	**TOTAL**	**TH**	**TU**	**PR/OR**	**TOTAL**
V	PCC	2307381	Process Intensification	04	-	-	20	60	20	-	-	100	04	-	-	04
	PCC	2307382	Lab Course in Process Intensification	-	-	02	-	-	-	25	50	75	-	-	01	01
	CEP/FP	2307383	Seminar	-	-	02	-	-	-	50	-	50	-	-	01	01
VI	PCC	2307384	Process Technology	04	-	-	20	60	20	-	-	100	04	-	-	04
	PCC	2307385	Lab Course in Process Technology	-	-	02	-	-	-	25	50	75	-	-	01	01
	CEP/FP	2307386	Mini Project	-	-	02	-	-	-	50	-	50	-	-	01	01
VII	PCC	2307481	Mass Transfer with Reactions	04	-	-	20	60	20	-	-	100	04	-	-	04
	PCC	2307482	Process Utilities	02	-	-	-	-	50	-	-	50	02	-	-	02
	Total			**14**	**-**	**08**	**60**	**180**	**110**	**150**	**100**	**600**	**14**	**-**	**04**	**18**

Dr. S. N. Jain
Chairman, BoS

Dr. K. N. Nandurkar
Director

Semester V (TY - B. Tech.) Chemical Engineering 2307381: Process Intensification		
Teaching Scheme: Theory: 04 hrs/week	**Credit Scheme:** 04	**Examination scheme:** **In Semester Exam:** 20 marks **End Semesters Exam:** 60 marks **Continuous Comprehensive Evaluation:** 20 marks **Total:** 100 Marks

Prerequisite: Unit Operations and Unit Processes. Chemical Reaction Engineering, Process Control and Instrumentation.

Course Objectives:

1. Understand the concepts, principles, and significance of Process Intensification (PI).
2. Apply PI concepts to heat transfer, mass transfer, mixing, and reaction systems.
3. Analyze equipment and processes such as microreactors, RPBs, SDRs, and DWCs for performance enhancement.
4. Evaluate energy-based PI methods like sonochemistry, microwave-assisted processes, and membrane reactors.
5. Relate PI applications to improved material, energy efficiency, and sustainability goals in chemical industries

Course Outcomes: On completion of the course, students will be able to–

Sr. No.	Course Outcomes	Bloom's Level
CO1	Interpret PI principles, tools, and advantages over conventional processes.	2 – Understand
CO2	Apply intensified heat and mass transfer equipment in chemical processes.	3-Apply
CO3	Analyze advanced mixing and microreactor technologies for process enhancement.	4-Analyze
CO4	Evaluate reactive separations and energy-based intensification methods for sustainable and efficient processes.	5-Evaluate

Course Contents:

Unit I	**Introduction of Process Intensification**	**(L06)**	**COs Mapped: CO1**

Definition and historical development, PI for sustainability, economic efficiency, and safety, Principles and domains of PI, Benefits of PI compared to conventional processes, Process synthesis, design approaches, miniaturization, multifunctional reactors, PI Toolbox: Active and passive methods.

Unit II	**Intensified Heat and Mass Transfer**	**(L08)**	**COs Mapped: CO1, CO2**

Heat transfer intensification, Microchannel and compact heat exchangers, Plate heat exchangers, spiral heat exchangers, Introduction to mass transfer intensification, Rotating Packed Beds (RPBs/HiGee), Membrane-based processes for separation, Applications in chemical industries.

Unit III	**Advanced Mixing and Microreactor Technologies**	**(L08)**	**COs Mapped: CO2, CO3**

Microfluidics, static mixers, coalescence devices, Spinning Disc Reactors (SDRs), High-

pressure homogenization, Confined Impinging Jet Reactors (CIJR), Membrane reactors integrating reaction and separation, Microstructured (microchannel) reactors.			
Unit IV	**Reactive Separation Techniques**	**(L08)**	**COs Mapped: CO3, CO4**
Reactive distillation, Dividing-Wall Columns (DWCs), Reactive extraction, Reactive absorption, Reactive membrane separations, Centrifugal extractors, Comparison with conventional separation processes.			
Unit V	**Energy-Based PI Methods**	**(L10)**	**COs Mapped: CO2, CO4**
Sonochemistry – applications and mechanism, Microwave-assisted reactors – principles and advantages, Plasma-assisted reactors, Photocatalytic reactors for reaction and pollution control, Evaluation of energy savings and process efficiency, Sustainable design using energy-based PI approaches.			

Reference Books

1. Process Intensification: Engineering for Efficiency, Sustainability and Flexibility, D. Reay, C. Ramshaw, and A. Harvey, 2nd Edition, Butterworth-Heinemann.
2. Process Intensification Technologies for Green Chemistry, K. Boodhoo, and A. Harvey, John Wiley & Sons.
3. Re-Engineering the Chemical Processing Plant: Process Intensification, A. Stankiewicz, and J.A. Moulijn, Marcel Dekker.
4. Modeling of Process Intensification, F. J. Keil, WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim.
5. The Fundamentals of Process Intensification, Andrzej Stankiewicz, Tom van Gerven, Georgios Stefanidis, Wiley VCH.

Guidelines for Continuous Comprehensive Evaluation of Theory Course

Sr. No.	Components for Continuous Comprehensive Evaluation	Marks Allotted
1	Three Assignments on unit-1, unit-2, unit-3 & 4	10
2	Group Presentation on unit-5	05
3	Test on each unit	05
	Total	**20**

K. K. Wagh Institute of Engineering Education and Research, Nashik

(Autonomous from Academic Year 2022-23)

<table>
<tr><td colspan="3">Semester V (TY - B. Tech.) Chemical Engineering
2307382: Lab Course in Process Intensification</td></tr>
<tr><td>Teaching Scheme:
Practical: 02 hrs/week</td><td>Credit : 01</td><td>Examination scheme:
TW: 25 marks
Oral: 50 marks
Total: 75 Marks</td></tr>
<tr><td colspan="3">Prerequisite: Fundamentals of Chemical Engineering, Unit Operation and Unit Processes.</td></tr>
<tr><td colspan="3">Course Objectives:
1. Understand the principles and applications of ultrasound in process intensification
2. Investigate the principles and operation of reactive distillation
3. Explore the utilization of microwave-assisted processes for enhanced chemical reactions
4. Study the design and operation of microreactors for intensified chemical processes</td></tr>
<tr><td colspan="3">Course Outcomes: On completion of the course, students will be able to–</td></tr>
<tr><td>Sr. No.</td><td>Course Outcomes</td><td>Bloom's Level</td></tr>
<tr><td>CO1</td><td>Apply the principles of ultrasound, reactive distillation, microwave-assisted processes, and microreactors in laboratory experiments to demonstrate process intensification.</td><td>3-Apply</td></tr>
<tr><td>CO2</td><td>Analyze experimental data from intensified processes to assess performance improvements over conventional operations.</td><td>4-Evaluate</td></tr>
<tr><td>CO3</td><td>Evaluate and compare different process intensification techniques to recommend suitable approaches for sustainable chemical engineering applications.</td><td>5-Evaluate</td></tr>
<tr><td colspan="3">List of Laboratory Experiments / Assignments</td></tr>
<tr><td>Sr. No</td><td>List of experimets</td><td>CO Mapping</td></tr>
<tr><td>1</td><td>Study of Ultrasonication.</td><td>CO1, CO2, CO3</td></tr>
<tr><td>2</td><td>Study of Reactive Distillation</td><td>CO1, CO2, CO3</td></tr>
<tr><td>3</td><td>Study of Microwave-Assisted Processes</td><td>CO1, CO2, CO3</td></tr>
<tr><td>4</td><td>Study of Micro-reactors</td><td>CO1, CO2, CO3</td></tr>
<tr><td>5</td><td>Study of Compact Heat Exchangers</td><td>CO1, CO2, CO3</td></tr>
<tr><td>6</td><td>Study of Solar Detoxification</td><td>CO1, CO2, CO3</td></tr>
<tr><td>7</td><td>Study of Photocatalytic oxidation.</td><td>CO1, CO2, CO3</td></tr>
<tr><td>8</td><td>Study of Enhanced Mixing Efficiency in Stirred Tanks</td><td>CO1, CO2, CO3</td></tr>
<tr><td colspan="3">Guidelines for Termwork Assessment</td></tr>
<tr><td colspan="3">Term work assessment is to be based on overall performance of students, which includes the following parameters: timely completion of tasks, performance quality, punctuality, participation, and contribution in the experiments. Students will be evaluated based on the experiment, report and presentation.</td></tr>
</table>

Semester V (TY - B. Tech.) Chemical Engineering 2307383: Seminar		
Teaching Scheme: Practical: 02 hrs/week	**Credit : 01**	**Examination Scheme: Term Work: 50 Marks Total: 50 Marks**

Course Outcomes: On completion of the course, students will be able to:

	Course Outcomes	**Bloom's Level**
CO1	Apply process intensification principles to identify and select emerging techniques in chemical industries.	3-Apply
CO2	Analyze research, case studies, and industrial applications to assess their impact on process performance.	4 - Analyze
CO3	Evaluate and present innovative process intensification strategies through effective technical communication.	5 - Evaluate

Course Structure:

Week	**Activity**	**Description**
Week 1	Introduction to Seminar Course	Guidelines on seminar topics, presentation structure, evaluation rubrics.
Week 2-3	Topic Selection & Research	Students select the process engineering topics and conduct literature research.
Week 4-10	Seminar Presentations	Students present their topics weekly. Peer discussions and Q&A sessions follow each presentation.
Week 11-12	Panel Discussion & Case Studies	Group discussions on industrial case studies, challenges, and future trends.
Week 13	Course Review & Feedback	Reflection on learnings, feedback on presentations, and final assessment.

Format of the Seminar report preparation:

1. The Seminar report should be based on a detailed study of any relevant topic to Chemical Engineering. The typing shall be with normal spacing and on one side of the paper.
2. The report should be submitted in spiral bound format.
3. Front cover: This shall have the following details.
   - Title of the seminar report.
   - The name of the candidate with roll number / examination seat number at the middle.
   - Name of the guide below the candidate's details.

- The name of the institute and year of submission on separate lines at the bottom.

4. The format of the text of the seminar reports:
    - The report shall be presented in the form of a technical paper. The introduction should be followed by literature survey.
    - The Result-discussion and conclusions shall form the last part of the text. Nomenclature and symbols should be added. References should be written in the standard format after the conclusion.
    - The total number of typed pages, excluding cover shall be about 25 to 30. All the pages should be numbered. This includes figures and diagrams.
    - Two copies of the seminar report shall be submitted to the Institute. The candidate shall present the seminar through power point presentation. The total duration of presentation and discussion should be about 30 minutes max.

Evaluation Rubrics for Seminar Presentation:

Criteria	Excellent (10-9)	Good (8-7)	Satisfactory (6-5)	Needs Improvement (4-0)	Weightage (%)
Technical Content	Depth of research, accuracy, and relevance to Industrial Automation.	Well-researched but minor gaps.	Basic understanding with some errors.	Lacks depth, many inaccuracies.	**30%**
Presentation Skills	Clear, confident, engaging delivery.	Good, but minor hesitation.	Some difficulties in explanation.	Poor clarity and engagement.	**20%**
Visual Aids (Slides, Diagrams, etc.)	Well-structured, professional, easy to read.	Good but minor formatting issues.	Acceptable but lacks clarity.	Disorganized, difficult to follow.	**10%**
Q&A and Discussion	Answers all questions clearly and logically.	Addresses most questions satisfactorily.	Struggles with some answers.	Unable to answer relevant questions.	**20%**
Peer Interaction & Feedback	Actively engages in discussions and provides insightful feedback.	Provides useful comments but limited engagement.	Minimal participation in discussions.	No engagement in peer discussions.	**10%**

Overall Professionalism	Well-prepared, confident, maintains eye contact, follows time limits.	Mostly prepared but slight timing issues.	Somewhat disorganized and rushed.	Unprepared and exceeds/under utilizes time.	**10%**

Semester VI (TY - B. Tech.) Chemical Engineering
2307384: Process Technology

Teaching Scheme:	Credit :	Examination Scheme:
Theory : 04hrs/week	**04**	**Continuous Comprehensive Evaluation: 20 Marks** **InSem Exam: 20 Marks** **EndSem Exam: 60 Marks** **Total: 100 Marks**

Prerequisite: Basic knowledge of chemical process calculations, thermodynamics, heat and mass transfer, reaction engineering, and unit operations.

Course Objectives:

1. Provide knowledge of process flow diagrams (PFDs) and piping and instrumentation diagrams (P&IDs) as essential tools for process design and development.
2. Develop the ability to integrate safety, environmental, and economic aspects into holistic process development.
3. Familiarize students with recent advancements in organic, inorganic, polymer, and catalytic processes.
4. Introduce the principles of green technologies, sustainable process practices, and circular economy concepts.
5. Explore bio-refinery technologies for conversion of biomass into biofuels, bio-chemicals, and bio-materials, including relevant industrial applications.

Course Outcomes: On completion of the course, students will be able to

	Course Outcomes	Bloom'sLevel
CO1	Apply the fundamentals of process design to develop process flow diagrams (PFDs) and piping and instrumentation diagrams (P&IDs).	**3-Apply**
CO2	Analyze chemical process technologies to assess their efficiency, sustainability, and industrial relevance.	**4 -Analyze**
CO3	Examine the principles of green chemistry, sustainability, and circular economy to identify opportunities for waste minimization, energy efficiency, and resource recovery in process industries.	**4 -Analyze**
CO4	Analyze bio-refinery processes and advanced process technologies through case studies to recommend sustainable and innovative solutions for chemical engineering applications.	**4 -Analyze**

COURSE CONTENTS

Unit I	Process Development	(08hrs)	CO1

Flow Sheet Development: Fundamentals of process design, process flow diagrams (PFDs), piping and instrumentation diagrams (P&IDs). **Holistic Process Development:** Integration of environmental, safety, and economic considerations in process design.

Unit II	**Recent Advancements in Process Technologies**	**(08hrs)**	**CO2**
Organic Processes: Innovations in the production of organic chemicals, pharmaceuticals, and polymers. **Catalysis in Organic Synthesis:** Green catalysis, biocatalysts, photo-catalysis, transition metal catalysts, and electro-catalysis. **Polymer Chemistry and Technology:** Biodegradable polymers, recyclable and circular polymers, 3D printing of polymers, smart polymers, and nanopolymers. **Inorganic Processes:** Technological advancements in metallurgy, fertilizers, cement, and inorganic chemical production.			
Unit III	**Green Technology**	**(08hrs)**	**CO3**
Introduction to Green Technologies: Definitions, principles, and applications in process industries. **Green Chemistry and Sustainable Processes:** Atom economy, solvent-free reactions, carbon capture and utilization (CCU), waste minimization, and reuse. **Industrial Applications:** Case studies on energy-efficient and low-emission process technologies.			
Unit IV	**Sustainability and Circular Economy**	**(08hrs)**	**CO3**
Concept of Sustainability: Overview of sustainable practices in the process industries. **Circular Economy Principles:** Reduce, reuse, and recycle approaches, with a focus on the sugar industry. **Case Study: Sugar Industry:** Implementation of sustainability and circular economy strategies in sugar production, recycling, and waste utilization.			
Unit V	**Bio-Refinery Processes**	**(08hrs)**	**CO4**
Introduction to Bio-Refinery: Concepts, biomass conversion processes, and value-added products. Bio-Refinery Technologies: Biomass conversion into biofuels, bio-chemicals, and bio-materials. Discussion on feedstock selection and process design. Industrial Applications: Case studies of bio-refineries in the food, energy, and chemical industries.			

Reference Books

1. Process Systems Analysis and Control, D.R. Coughanowr, McGraw-Hill Education, 3rd Edition, 2009.
2. Unit Operations of Chemical Engineering, Warren McCabe, Julian Smith, Peter Harriott, McGraw-Hill Education, 7th Edition, 2005.
3. Green Chemistry and Engineering: A Practical Design Approach, Concepción Jiménez-González, Wiley, 1st Edition, 2011.
4. The Circular Economy: A User's Guide, Walter R. Stahel, Routledge, 1st Edition, 2019.

Guidelines for Continuous Comprehensive Evaluation of Theory Course

Sr. No.	**Components for Continuous Comprehensive Evaluation**	**Marks Allotted**
1	Three Assignments on unit-1, unit-2, unit-3 & 4	10
2	Group Presentation on unit-5	05
3	Test on each unit	05
	Total	**20**

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Semester VI (TY - B. Tech.) Chemical Engineering 2307385: Lab work in Process Technology		
Teaching Scheme: **Practical: 02 hrs/week**	**Credit :** **01**	**Examination Scheme:** **Practical: 50 Marks** **Term Work: 25 Marks** **Total:100 Marks**

Course Outcomes: On completion of the course, students will be able to

	Course Outcomes	Bloom'sLevel
CO1	Apply the fundamentals of process design to develop process flow diagrams (PFDs) and piping and instrumentation diagrams (P&IDs).	**3-Apply**
CO2	Analyze chemical process technologies to assess their efficiency, sustainability, and industrial relevance.	**4 -Analyze**
CO3	Examine the principles of green chemistry, sustainability, and circular economy to identify opportunities for waste minimization, energy efficiency, and resource recovery in process industries.	**4 -Analyze**
CO4	Analyze bio-refinery processes and advanced process technologies through case studies to recommend sustainable and innovative solutions for chemical engineering applications.	**4 -Analyze**

List of Laboratory Experiments/ Assignments

Sr. No.	Laboratory Experiments/Assignments	CO Mapped
1.	Development of process flow diagrams (PFDs) or piping and instrumentation diagrams (P&IDs) using DWSIM/ Aspen Plus/UniSim	**CO1**
2.	Case study on a selected chemical process.	**CO2**
3.	Synthesis and characterization of biodegradable polymers.	**CO3**
4.	Synthesis of catalyst and its applications using photocatalytic reactor	**CO2**
5.	Waste minimization and case studies on zero waste discharge	**CO3**
6.	Case study on Energy-efficient process analysis in chemical reactions.	**CO2**
7.	Recycling and reuse of industrial by-products (case study utilization on any industry).	**CO3**
8.	Water and energy conservation techniques in process industries.	**CO3**
9.	Conversion of biomass into biofuels (Biodiesel production from vegetable oils or waste oils).	**CO4**
10.	Bio-based chemical production and analysis.	**CO4**

Guidelines for Laboratory Conduction

1. Experiments should be performed in a group of two students only.

2. Avoid contacting circuits with weth and sor wet materials. 3. Double check circuits for proper connections and polarity prior to applying the power. 4. Observe polarity when connecting polarized components or test equipment. 5. Make sure test instruments are set for proper function and range prior to taking measurement.
Guidelines for Student's Lab Journal
Student's lab journal should contain following related things- Title,Objectives,Hardware/Softwarerequirement,Theory,CircuitDiagram,Observationtable,Graph, Calculations, Results, Conclusion and Assignment questions
Guidelines for Practical and Termwork Assessment
• R1: Timely completion of experiment (10 Marks) • R2: Understanding of experiment (10 Marks) • R3: Presentation /clarity of journal writing (10 Marks) Total 30 marks for each experiment and average marks of all experiments will be converted into 25 marks of Term work

Semester VI (TY - B. Tech.) Chemical Engineering 2307386:Mini project		
Teaching Scheme: **Practical: 02 hrs/week**	**Credit :** **01**	**Examination Scheme:** **Term Work:50 Marks** **Total: 100 Marks**

Course Outcomes: On completion of the course, students will be able to–

	Course Outcomes	Bloom's Level
CO1	Identify a process engineering challenge and formulate a structured mini-project proposal.	3-Apply
CO2	Design and develop a small-scale process system using engineering principles and simulation tools.	4 - Analyze
CO3	Analyze and optimize process parameters for efficiency, safety, and sustainability.	4 - Analyze
CO4	Document and present the mini-project with technical justification and proposed improvements.	5-Evaluate

Course Structure:

Week	Activity	Description
Week 1	Introduction & Problem Identification	Overview of process engineering challenges, brainstorming, and topic selection.
Week 2-3	Project Proposal Submission & Approval	Define objectives, identify key process parameters, develop process flow diagrams, and finalize a proposal.
Week 4-6	Process Design & Equipment Selection	Identify suitable equipment, design process layouts, perform material and energy balance calculations.
Week 6-9	Implementation & Experimental Setup	Develop a lab-scale or simulated process model, incorporate relevant process monitoring instruments, and establish key operational control parameters.
Week 10-11	Process Optimization & Performance Analysis	Evaluate system efficiency, optimize key parameters, and validate process performance.

Week 12-13	Documentation & Report Writing	Prepare detailed project reports including methodology, results, analysis, and conclusions.
Week 13	Final Presentation & Demonstration	Present the project with live demonstration and Q&A session.

Evaluation Rubrics for Mini Project

Criteria	Excellent (10-9)	Good (8-7)	Satisfactory (6-5)	Needs Improvement (4-0)	Weightage (%)
Problem Identification & Proposal	Clearly defined problem, innovative solution, well-structured proposal.	Problem well-identified, minor gaps in proposal.	Basic problem definition, lacks detailed planning.	Poor problem definition, unclear proposal.	**15%**
Design & Implementation	Exemplary design with innovative solutions, precise calculations, and flawless execution.	Good design, minor errors in integration.	Acceptable design but lacks optimization.	Poor design, major errors in implementation.	**25%**
Process Optimization & Performance Evaluation	All key parameters are effectively optimized and validated using quantitative data.	Good testing and optimization with minor unresolved issues.	Optimization is attempted, but data validation lack depth and consistency.	Optimization is poorly executed, resulting in subpar performance and unclear validation.	**20%**
Documentation & Report	Comprehensive report with methodology, results, and future scope.	Well-structured but missing minor details.	Basic report, lacks depth in analysis.	Incomplete or poorly written report.	**15%**
Final Presentation & Demonstration	Confident delivery, clear visuals, logical explanation.	Good delivery, some minor issues.	Presentation lacks clarity and confidence.	Poor presentation, difficult to understand.	**15%**
Teamwork & Collaboration	Active participation, clear role distribution, excellent teamwork.	Good teamwork, minor coordination issues.	Acceptable teamwork, some members less active.	Lack of coordination and contribution.	**10%**

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Semester VII (TY - B. Tech.) Chemical Engineering 2307481:Mass Transfer with Reactions		
Teaching Scheme: **Theory :04hrs/week**	**Credit: 04**	**Examination Scheme:** **Continuous Comprehensive Evaluation: 20 Marks** **InSem Exam: 20 Marks** **EndSem Exam: 60 Marks** **Total: 100 Marks**

Prerequisites: Basics of thermodynamics, reaction engineering, mass transfer, and fluid mechanics.

Course Objectives:

1. Provide knowledge of fundamentals of mass transfer in reactive systems and their role in chemical reaction engineering.
2. Develop understanding of diffusion and reaction mechanisms in gases, liquids, and solids.
3. Analyze heterogeneous mass transfer with reaction in different reactor systems and catalytic processes.
4. Explore reactive separations, micro-reactors, and applications of mass transfer with reaction in sustainable and green technologies.

Course Outcomes: On completion of the course, students will be able to

	Course Outcomes	Bloom'sLevel
CO1	Apply mass transfer and reaction principles to analyze reactive systems.	3-Apply
CO2	Analyze diffusion and reaction mechanisms in gases, liquids, and solids.	4-Analyze
CO3	Analyze heterogeneous reactions in reactors and evaluate effectiveness factors.	4-Analyze
CO4	Evaluate reactive separations, micro-reactors, and green technology for sustainable solutions.	5-Evaluate

COURSE CONTENTS

Unit I	**Fundamentals of Mass Transfer with Chemical Reactions**	**(08hrs)**	**CO1**

Basics of mass transfer in reactive systems, Role of interface mass transfer in chemical reactions,· Classification: Homogeneous & Heterogeneous reactions, Theories of mass transfer (Film theory, Penetration theory, Surface renewal theory), Dimensionless numbers relevant to mass transfer with reaction

Unit II	**Diffusion and Reaction Mechanisms**	**(08hrs)**	**CO2**

Diffusion models: Fick's Law, Maxwell-Stefan diffusion, Diffusion in gases, liquids, and solids with reaction, Enhancement factors and film theories in diffusion-controlled reactions, Applications in absorption with chemical reaction (e.g., CO_2 absorption in amine solutions).

Unit III	**Mass Transfer with Heterogeneous Reactions**	**(08hrs)**	**CO3**

Mass transfer across phase boundaries, Effectiveness factor and Thiele modulus, Modeling of gas-

solid and liquid-solid reactions, Slurry reactors, trickle-bed reactors, and fluidized bed reactors, Catalyst pore diffusion and reaction.			
Unit IV	**Reactive Separations**	**(08hrs)**	**CO3, CO4**
Reactive distillation, Study of reactive separation columns, Equilibrium and rate-based modeling of reactive separations, Membrane reactors, Role of catalysts in mass transfer-reaction systems.			
Unit V	**Applications and Advanced Topics**	**(08hrs)**	**CO4**
Micro-reactors and intensified reactive mass transfer, Green chemistry applications (Hydrogen production, Biofuel synthesis), Applications in environmental engineering (e.g., pollutant removal).			

ReferenceBooks

1. Mass Transfer Operations, R.E. Treybal, McGraw-Hill, 3rd Edition, 1981.
2. Chemical Reaction Engineering, Octave Levenspiel, John Wiley & Sons, 3rd Edition, 1999.
3. Elements of Chemical Reaction Engineering, H. Scott Fogler, Prentice Hall, 5th Edition, 2016.
4. Mass Transfer with Chemical Reactions, J. M. Coulson and J. F. Richardson, Chemical Engineering Series, Elsevier, 6th Edition, 2005.
5. Process Intensification in Chemical Engineering, Andrzej Stankiewicz, Tom Van Gerven, Wiley-VCH, 2008.
6. Handbook of Heterogeneous Catalysis, G. Ertl, H. Knözinger, F. Schüth, J. Weitkamp, Wiley-VCH, 2nd Edition, 2008.
7. hemical Engineering Design: Principles, Practice and Economics of Plant and Process Design, J.M. Coulson, J.F. Richardson, R.K. Sinnott, Elsevier, 6th Edition, 2005.

Guidelines for Continuous Comprehensive Evaluation of Theory Course

Sr. No.	Components for Continuous Comprehensive Evaluation	Marks Allotted
1	Three Assignments on unit-1, unit-2, unit-3 & 4	10
2	Group Presentation on unit-5	05
3	Test on each unit	05
	Total	**20**

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Semester VII (TY - B. Tech.) Chemical Engineering 2307482: Process Utilities		
Teaching Scheme: Theory :02hrs/week	**Credit : 02**	**Examination Scheme: Continuous Comprehensive Evaluation: 50 Marks Total: 50 Marks**

Prerequisites: Basics of thermodynamics, fluid mechanics, heat transfer, and unit operations.

Course Objectives:

1. Provide knowledge of various process utilities and their role in chemical process industries, including classification, identification, and economic impact.
2. Understand water and steam systems, including water treatment, boiler feed water, steam generation, and utilization in process plants.
3. Study non-steam heating systems such as hot oils, thermic fluids, and fired heaters, including their properties, selection, and industrial applications.
4. Explore other utilities such as compressed air, inert gases, vacuum systems, chilling plants, refrigeration, and electrical power systems in process industries.

Course Outcomes: On completion of the course, students will be able to

	Course Outcomes	**Bloom'sLevel**
CO1	Apply knowledge of process utilities and assess their economic impact.	3-Apply
CO2	Analyze water and steam systems for efficient utilization.	4-Analyze
CO3	Examine non-steam heating and other utility systems for industrial applications.	4-Analyze
CO4	Evaluate and optimize utility systems for efficiency, sustainability, and reliability.	5-Evaluate

COURSE CONTENTS

Unit I	**Introduction of utilities:**	**(04hrs)**	**CO1**

Role of Process Utilities in process industries, Classification of process utilities, Impact on Project economics, Colour codes used for identification of process utilities.

Unit II	**Water**	**(05hrs)**	**CO2**

Water characteristics, conditioning and treatment methods of water for process industries, water softening techniques, De-mineralized Water, Applications of water, Process water, and boiler feed water (BFW) and its characteristics, cooling Water, recycling aspects of water from blow downs

Unit III	**Steam**	**(05hrs)**	**CO2, CO4**

Properties of steam, Characteristics properties, classification, selection and industrial applications Steam calculations, application of steam systems in chemical process plants, design of

efficient steam heating systems, Superheated steam, condensate utilization, flash steam, steam traps, Steam generators, classification, construction features, Boiler Accessories and Mountings, Economiser, super-heater, pre-heater			
Unit IV	**Non-steam heating systems**	**(05hrs)**	**CO3**
Hot Oil/Specialized Heat Transfer Fluids/Thermic Fluids, Mineral oils, Dowtherm - Synthetic Organic Fluids, Dowcal - Inhibited Glycols, Syltherm - Silicone Fluids, Characteristics properties, classification, selection and industrial applications Fuels, Fired heaters			
Unit V	**Other utilities**	**(05hrs)**	**CO3, CO4**
Air: Necessity, process air, instrument air, compressed air, air-water vapour mixture, psychrometry, Characteristics properties, classification, selection and industrial applications, Characteristics of air and air receivers, Inert gases, Inert gas generation Electrical Power: HT/LT, Emergency power. Inverters, DG sets. Etc. Vacuum system engineering, Chilling plant, refrigeration, Emergency Drives Identification			

ReferenceBooks

1. Chemical Plant Utilities, Sathiyamoorthy Manickkam, LAP LAMBERT Academic Publishing, 1st Edition, 2016.
2. A Textbook of Thermal Engineering, R.S. Khurmi, J.K. Gupta, S. Chand Publishing, 1st Edition, 2010.
3. Chemical Engineering, Vol. 6: Chemical Engineering Design, J.M. Coulson, J.F. Richardson, R.K. Sinnott, Elsevier Butterworth-Heinemann, 6th Edition, 1999.
   Steam Generators and Waste Heat Boilers: For Process and Plant Engineers, V. Ganapathy, CRC Press, 1st Edition, 2017.
4. Fuels and Combustion, Samir Sarkar, Orient BlackSwan, 1st Edition, 2009.

Guidelines for Continuous Comprehensive Evaluation of Theory Course		
Sr. No.	**Components for Continuous Comprehensive Evaluation**	**Marks Allotted**
1	Three Assignments on unit-1, unit-2, unit-3 & unit-4	40
2	Group Presentation on unit-5	10
	Total	**50**