Scheme of courses & Syllabus

3rd – 8th Semester

B. Tech. 2023 Batch Onward

DEPARTMENT OF CHEMICAL ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY SRINAGAR, HAZRATBAL

JAMMU AND KASHMIR – 190006 (INDIA)

VISION OF THE DEPARTMENT

To be one of the leading chemical engineering departments in the Country, providing teaching, research and training to the students along with high moral values to solve the problems of chemical and allied industries and to meet the aspirations of the society.

MISSION OF THE DEPARTMENT

M1. To create and sustain strong foundation of chemical engineering education, research and innovation.

M2. To produce well qualified, innovative chemical engineers with entrepreneurial skills & leadership qualities to face and solve the problems of the industries, and the society at large.

M3. To make professional leaders, academicians and engineers with highest moral values and ethics.

PROGRAM EDUCATIONAL OBJECTIVES

PEO1: Providing broad-based engineering education on the solid foundation of basic sciences, engineering sciences, humanities & social sciences and management through choice-based credit systems.

PEO2: Enable the students to become future leaders in engineering practices for the overall betterment of society, and instil in them a work culture based on foundations of ethics, scientific temperament, and team work.

PEO3: Equip the students with knowledge, understanding and applications of chemical engineering tools that enable them to pursue innovative research.

PEO4: Attain excellence in engineering and design through education in the principles and practices of chemical engineering.

Consistency of PEOs with Mission of the Department

Mission → / PEOs ↓	M1	M2	M3
PEO1	3	2	3
PEO2	2	2	3
PEO3	3	2	2
PEO4	3	2	2

PROGRAM OUTCOMES (POs)

Engineering Graduates will be able to:

1. Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

2. Problem analysis: Identify, formulate, review research literature, and analyse complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

3. Design/development of solutions: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

4. Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

5. Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

6. The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

7. Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

8. Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

9. Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

10. Communication: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

11. Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one’s own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

12. Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

PROGRAM SPECIFIC OUTCOMES (PSOs)

Chemical Engineering Graduates will be able to:

PSO 1. Apply the principles and practices of Chemical Engineering discipline along with the basic sciences and humanities to solve the complex engineering problems concerning the issues of environment, safety, economics, culture and society etc.

PSO 2. Acquire and apply the new knowledge with professional responsibility and ethics towards the advancement of academic and research pursuits in chemical and allied disciplines in the societal contexts.

PSO 3. Design, develop and modify the chemical processes and to analyze these by applying the physicochemical and biological techniques.

Chemical Engineering Department: Implemented for Batch 2023 and onwards Total Required Credits: Minimum = 160 (1st + 2nd Semester = 42)

Semester	Course-1	Course-2	Course-3	Course-4	Course-5	Course-6	Course-7	Course-8	Course-9	Course-10	Course-11	Total Credits
III	Chemical Process Calculations	Process Fluid Mechanics	Mechanical Operations	Process Instrumentation	Chemical Engineering Thermodynamics-I	Engineering Ethics	Numerical Methods	Mechanical Operations Laboratory				
	3	3	3	3	3	3	3	1				22
	CET-201	CET-202	CET-203	CET-204	CET-205	HST-201	MAT-201	CEL-201				
IV	Chemical Reaction Engineering-I	Chemical Engineering Thermodynamics-II	Heat Transfer	Chemical Process Technology	Chemical Engineering Mathematics	Engineering Economics and Management	Energy Technology Laboratory	Fluid Mechanics Laboratory				
	3	3	3	3	3	3	1	1				20
	CET-250	CET-251	CET-252	CET-253	MAT-250	HST-250	CEL-250	CEL-251				
V	Process Equipment Design-I	Chemical Reaction Engineering-II	Mass Transfer-I	Biochemical Engineering	Elective-I	Elective-II	Heat Transfer Laboratory	Computer Simulation Laboratory				
	3	3	3	3	3	3	1	1				20
	CET-306	CET-307	CET-308	CET-309			CEL-302	CEL-303				
VI	Process Equipment Design-II	Chemical Process Safety	Process Dynamics and Control	Mass Transfer-II	Elective-III	Elective-IV	Chemical Reaction Engineering Laboratory	Mass Transfer Laboratory	Industrial / Research Training and Presentation	Seminar		
	3	3	3	3	3	3	1	1	1	1		22
	CET-354	CET-355	CET-356	CET-357			CEL-352	CEL-353	CEI-350	CES-350		
VII	Transport Phenomena	Process Economics and Plant Design	Elective-V	Elective-VI	Open Elective-I	Process Dynamics and Control Laboratory	Biochemical Engineering Laboratory	Pre-Project Work				
	3	3	3	3	3	1	1	2				19
	CET-410	CET-411			Open Elective-I	CEL-404	CEL-405	CEP-401				
VIII	Elective-VII	Elective-VIII	Open Elective-II	Project Work								
	3	3	3	6								15
				CEP-450								
												160

Chemical Engineering Department: Implemented for Batch 2023 and onwards Total Required Credits: Minimum = 180 (1st + 2nd Semester = 42)

Semester	Course-1	Course-2	Course-3	Course-4	Course-5	Course-6	Course-7	Course-8	Course-9	Course-10	Course-11	Total Credits
III	Chemical Process Calculations	Process Fluid Mechanics	Mechanical Operations	Process Instrumentation	Chemical Engineering Thermodynamics-I	Engineering Ethics	Numerical Methods	Mechanical Operations Laboratory				
	3	3	3	3	3	3	3	1				22
	CET-201	CET-202	CET-203	CET-204	CET-205	HST-201	MAT-201	CEL-201				
IV	Chemical Reaction Engineering-I	Chemical Engineering Thermodynamics-II	Heat Transfer	Chemical Process Technology	Chemical Engineering Mathematics	Engineering Economics and Management	Energy Technology Laboratory	Fluid Mechanics Laboratory				
	3	3	3	3	3	3	1	1				20
	CET-250	CET-251	CET-252	CET-253	MAT-250	HST-250	CEL-250	CEL-251				
V	Process Equipment Design-I	Chemical Reaction Engineering-II	Mass Transfer-I	Biochemical Engineering	Elective-I	Elective-II	Heat Transfer Laboratory	Computer Simulation Laboratory	Honors Elective-I			
	3	3	3	3	3	3	1	1	3			23
	CET-306	CET-307	CET-308	CET-309			CEL-302	CEL-303	MAT-002			
VI	Process Equipment Design-II	Chemical Process Safety	Process Dynamics and Control	Mass Transfer-II	Elective-III	Elective-IV	Chemical Reaction Engineering Laboratory	Mass Transfer Laboratory	Industrial / Research Training and Presentation	Seminar	Honors Elective-II	
	3	3	3	3	3	3	1	1	1	1	3	25
	CET-354	CET-355	CET-356	CET-357			CEL-352	CEL-353	CEI-350	CES-350	CET-021	
VII	Transport Phenomena	Process Economics and Plant Design	Elective-V	Elective-VI	Open Elective-I	Process Dynamics and Control Laboratory	Biochemical Engineering Laboratory	Pre-Project Work	Honors Elective-III	Honors Elective-IV		
	3	3	3	3	3	1	1	2	3	3		25
	CET-410	CET-411			Open Elective-I	CEL-404	CEL-405	CEP-401	CET-022	HST-023		
VIII	Elective-VII	Elective-VIII	Open Elective-II	Project Work	Honors Elective-V	Honors Elective-VI	Honors Elective-VII	Honors Elective-VIII				
	3	3	3	6	3	3	1	1				23
				CEP-450	CET-024	CET-025	CET-026	CET-027				
												180

Dean A/A 1/08/24 01/08/2024 1/8/24 1/8/24

2023 Batch Onwards

Scheme of Courses for B.Tech. Chemical Engineering (3rd to 8th Semester)

Table1: Overall credits for B. Tech and B. Tech Honours

	Credits	
Programme	**B-tech**	**B-tech (Honours)**
1st and 2nd Sem.	**42**	**42**
3rd to 8th Sem.	**118**	**138**
Total Credits	**160**	**180**

Table2: B. Tech courses credit distribution (3rd to 8th semester)

S.No		No. of Courses	No. of Credits
1.	**Core Courses**	28 (19 theory + 9 labs)	66 (57 + 9)
2.	**Professional Electives**	8	24
3.	**Open Electives**	2	6
4.	**B. Tech Honours**	8 (6 theory + 2 labs)	20 (18 + 2)
5.	**Pre Project**	1	2
6.	**Project**	1	6
7.	**Seminar**	1	1
8.	**ITP**	1	1
9.	**Humanities**	2	6
10.	**Basic Science**	2	6

3rd Semester						
S.No.	**Course No.**	**Subjects**	**L**	**T**	**P**	**Credits**
1.	CET-201	Chemical Process Calculations	2	1	0	3
2.	CET-202	Process Fluid Mechanics	2	1	0	3
3.	CET-203	Mechanical Operations	2	1	0	3
4.	CET-204	Process Instrumentation	2	1	0	3
5.	CET-205	Chemical Engineering Thermodynamics-I	2	1	0	3
6.	HST-201	Engineering Ethics	2	1	0	3
7.	MAT-201	Numerical Methods	2	1	0	3
8.	CEL-201	Mechanical Operations Laboratory	0	0	2	1
		Total	**14**	**7**	**2**	**22**
4th Semester						
S.No.	**Course No.**	**Subjects**	**L**	**T**	**P**	**Credits**
1.	CET-250	Chemical Reaction Engineering-I	2	1	0	3
2.	CET-251	Chemical Engineering Thermodynamics-II	2	1	0	3
3.	CET-252	Heat Transfer	2	1	0	3
4.	CET-253	Chemical Process Technology	2	1	0	3
5.	MAT-250	Chemical Engineering Mathematics	2	1	0	3
6.	HST-250	Engineering Economics and Management	2	1	0	3
7.	CEL-250	Energy Technology Laboratory	0	0	2	1
8.	CEL-251	Fluid Mechanics Laboratory	0	0	2	1
		Total	**12**	**6**	**4**	**20**
5th Semester						
S.No.	**Course No.**	**Subjects**	**L**	**T**	**P**	**Credits**
1.	CET-306	Process Equipment Design–I	2	1	0	3
2.	CET-307	Chemical Reaction Engineering-II	2	1	0	3
3.	CET-308	Mass Transfer -I	2	1	0	3
4.	CET-309	Biochemical Engineering	2	1	0	3
5.		Elective-I	2	1	0	3
6.		Elective-II	2	1	0	3
7.	CEL-302	Heat Transfer Laboratory	0	0	2	1
8.	CEL-303	Computer Simulation Laboratory	0	0	2	1
		Total	**12**	**6**	**4**	**20**
B. Tech Honours Elective-I						
9.	MAT-021	Applied Mathematics for Chemical Engineers	2	1	0	3
		Total	**14**	**7**	**4**	**23**
6th Semester						
S.No.	**Course No.**	**Subjects**	**L**	**T**	**P**	**Credits**
1.	CET-354	Process Equipment Design-II	2	1	0	3
2.	CET-355	Chemical Process Safety	2	1	0	3
3.	CET-356	Process Dynamics and Control	2	1	0	3
4.	CET-357	Mass Transfer -II	2	1	0	3
5.		Elective-III	2	1	0	3
6.		Elective-IV	2	1	0	3
7.	CEL-352	Chemical Reaction Engineering Laboratory	0	0	2	1
8.	CEL-353	Mass Transfer Laboratory	0	0	2	1
9.	CEI-350	Industrial/Research Training and Presentation	0	0	2	1
10.	CES-350	Seminar	0	0	2	1

		Total	**12**	**6**	**8**	**22**
B. Tech Honours Elective-II						
11.	CET-022	Membrane Science and Engineering	2	1	0	3
		Total	**14**	**7**	**8**	**25**
		7th Semester				
S. No.		**Subjects**	**L**	**T**	**P**	**Credits**
1.	CEP-401	Pre-project work	0	0	4	2
2.	CET-410	Transport Phenomena	2	1	0	3
3.	CET-411	Process Economics and Plant Design	2	1	0	3
4.		Elective-V	2	1	0	3
5.		Elective-VI	2	1	0	3
6.	CEL-404	Process Dynamics and Control Laboratory	0	0	2	1
7.	CEL-405	Biochemical Engineering Laboratory	0	0	2	1
8.		Open Elective – I				3
		Total	**8**	**4**	**8**	**19**
B. Tech Honours Elective-III &IV						
9.	CET-023	Risk Analysis and Hazards	2	1	0	3
10.	HST-024	Innovation Management	2	1	0	3
		Total	**12**	**6**	**8**	**25**
		8th Semester				
S. No.		**Subjects**	**L**	**T**	**P**	**Credits**
1.	CEP-450	Project Work	0	0	12	6
2.		Elective– VII	2	1	0	3
3.		Elective– VIII	2	1	0	3
4.		Open Elective – II				3
		Total	**4**	**2**	**12**	**15**
B. Tech Honours Elective-V to VIII						
5.	CET-025	Multi-Component Distillation	2	1	0	3
6.	CET-026	Heterogeneous Catalysis	2	1	0	3
7.	CEL-027	Advanced Computational Laboratory	0	0	2	1
8.	CEL-028	Instrumentation Laboratory	0	0	2	1
		Total	**8**	**4**	**16**	**23**
		Total Credits				**118 (138)**

PROFESSIONAL ELECTIVES

S. No.	5th Semester Elective Courses (Any Two)	L	T	P	Credit
MAT-001	Operation Research	2	1	0	3
CET-002	Material Science and Technology	2	1	0	3
CET-003	Cement Technology	2	1	0	3
CET-004	Energy Technology	2	1	0	3
CET-005	Polymer Science and Engineering	2	1	0	3
S. No.	**6th Semester Elective Courses (Any Two)**	**L**	**T**	**P**	**Credit**
CET-006	Industrial Pollution Abatement	2	1	0	3
CET-007	Petroleum Refining	2	1	0	3
CET-008	Instrumental Methods of Analysis	2	1	0	3
CET-009	Clean Technology in Process Industries	2	1	0	3
CET-010	Swayam Online Course				3
S. No.	**7th Semester Elective Courses (Any Two)**	**L**	**T**	**P**	**Credit**
CET-011	Nano-Science and Technology	2	1	0	3
CET-012	Microfluidics	2	1	0	3
CET-013	Advanced Separation Processes	2	1	0	3
CET-014	Process Heat Integration	2	1	0	3
CET-015	Swayam Online Course				3
S. No.	**8th Semester Elective Courses (Any Two)**	**L**	**T**	**P**	**Credit**
CET-016	Environmental Engineering	2	1	0	3
CET-017	Computational Fluid Dynamics	2	1	0	3
CET-018	Modeling and Simulation OF Chemical Process Systems	2	1	0	3
CET-019	Bioresource Technology	2	1	0	3
CET-020	Fuel Cell Technology	2	1	0	3

Nomenclature

CE	Chemical Engineering subject
MA	Mathematics Department subject
HS	Humanities and Social Sciences Department subject
T	Theory
L	Lab course
P	Project/Dissertation
S	Seminar
I	Industrial Training & Presentation

- The first numeral indicates the year of the course, except for elective courses, which are assigned a '0' (zero).
- The second and third numerals represent the unique course number for odd semester courses, starting from 01 to 49, and even semester courses, starting from 50 to 99.
- Online courses such as those on SWAYAM will be offered before the start of the semester and will be managed by a faculty mentor

3rd Semester

Chemical Process Calculations (CET-201)

<table>
<tr><td rowspan="3">Subject: Chemical Process Calculations (Code: CET-201)</td><td colspan="2" rowspan="3">Year & Semester: B. Tech Chemical Engineering 2nd Year & 3rd Semester</td><td colspan="3">Total Course Credit: 3</td></tr>
<tr><td>L</td><td>T</td><td>P</td></tr>
<tr><td>2</td><td>1</td><td>0</td></tr>
<tr><td>Evaluation Policy</td><td>Mid-Term (26 Marks)</td><td>Class Assessment (24 Marks)</td><td colspan="3">Final-Term (50 Marks)</td></tr>
</table>

Course Objective: To formulate and solve Material and Energy balances for Chemical process systems.

Course Outcomes (COs): At the end of the course, students will be able to:

CO1.	Examine the basic concepts involved in material and energy balances of chemical processes.	BTL 4
CO2.	Solve the problems related to the ideal and real behavior of gases, vapors, and liquids.	BTL 3
CO3.	Perform and evaluate the material balances on chemical processes and non-conventional separation processes without and with reactions.	BTL 5
CO4.	Build and solve energy balances on chemical processes and non-conventional separation processes without and with reactions.	BTL6

Details of the Syllabus:

Module No.	Contents	Hours
Module I	Mole concept and mole fraction, weight fraction and volume fraction, the concentration of liquid solutions, molarity, molality, normality, ppm, density, and specific gravity, composition relationships, and Stoichiometry principles. Ideal and real gas laws, critical properties, properties of mixtures and solutions.	12
Module II	Mass balance of some prominent Unit Operations; Mass balance calculations of single and multistage unit operations like; Evaporation, Distillation, Crystallization, Drying, Mixing, Extraction, Absorption etc.	12
Module III	Mass Balance: Concepts of limiting and excess reactants, tie element, batch, stage-wise, and continuous operations in systems with and without chemical reactions.	10
Module IV	Recycle, Purge and Bypass and Energy Balance: Concepts, and calculation of enthalpy changes for systems with and without reactions. Energy balance, heat capacity, estimation of heat capacities, calculation of enthalpy changes (without phase change), enthalpy change for phase transitions, general energy balance, Hess's law of Summation- heat of formation, reaction, combustion, solution and mixing.	08

Books Recommended:

Text Books	1.	Himmelblau, D.M., "Basic Principles and Calculations in Chemical Engineering", 8thEdn., Prentice-Hall of India Ltd. (2012).
	2.	Felder, R.M., Rousseau, R.W., "Elementary Principles of Chemical Processes" Wiley, 3rdEdn., 2000.
	3.	Hougen, D.A., Watson, K.M., Ragatz, R.A., "Chemical Process Principles, Part-I ", 2ndEdn., John Wiley & Sons (1995).
	4.	Bhatt, B.I., Vora, S.M., "Stoichiometry", 5thEdn., Tata McGraw-Hill (2010).
Reference Books	1.	Narayanan, K. V., Lakshmikutty, B., "Stoichiometry and Process Calculations", Prentice Hall of India (2006).
	2.	Venkataramani, V., Anantharaman, N., Begum, K.M.M.S., "Process Calculations", PHI Learning Pvt. Ltd. 2nd Edition.
	3.	Gavhane, K. A., "Introduction to Process Calculations Stoichiometry", Nirali Prakashan, 2012.
	4.	Williams, E.T., Johnson, R.C., "Stoichiometry for Chemical Engineers", McGraw-Hill Book Company Ltd. (1958).

Process Fluid Mechanics (CET-202)

Subject: Process Fluid Mechanics (Code: CET-202)	**Year & Semester: B. Tech Chemical Engineering 2nd Year & 3rd Semester**		**Total Course Credit: 3**		
			L	T	P
			2	1	0
Evaluation Policy	Mid-Term (26 Marks)	Class Assessment (24 Marks)	Final-Term (50 Marks)		

Course Outcomes: Upon the successful completion of this course, the student will be able to:

CO1	Apply the principle of fluid statics for solving problems related to manometers.	BTL 3
CO2	Analyze fluid flow problems with the application of conservation laws.	BTL 4
CO3	Explain the function of flow measuring devices and apply Bernoulli equation to determine the performance of flow measuring devices.	BTL 5
CO4	Determine and analyze the performance aspects & characteristics of fluid machinery.	BTL 4

Detailed Syllabus:

Module No.	**Contents**	**Hours**
Module I	**Introduction:** Introduction to fluids and the concept of viscosity, Newtonian and non-Newtonian fluids. **Fluid Statistics:** Fluid forces and pressure measurement. **Kinematics:** Eulerian and Lagrangian description of fluid motion, concept of local and convective accelerations, steady and unsteady flows.	10
Module II	**Integral analysis:** Control volume analysis for mass, momentum and energy. **Differential analysis:** Differential equations of mass and momentum for incompressible flows: inviscid - Euler equation and viscous flows - Navier-Stokes equations, concept of fluid rotation, vorticity, stream function, Exact solutions of Navier-Stokes equation for Couette flow and Poiseuille flow.	10
Module III	**Inviscid flows:** Bernoulli's equation - assumptions and applications, potential function. Dimensional analysis and similitude. **Internal flows:** Fully developed pipe flow, empirical relations for laminar and turbulent flows: friction factor and Darcy-Weisbach relation. **Boundary layer theory:** Concept and assumptions, qualitative idea of boundary layer and separation, boundary layer equations, Blasius solution for laminar boundary layer, momentum-integral equation of boundary layer.	12
Module IV	**Flow measurements:** Basic ideas of flow measurement using venturimeter, pitot-static tube and orifice plate. Pumps, blowers and compressors. Characteristics and applications of pumps, blowers and compressors.	10

Books Recommended:

Text Books	1.	Shames, J.H., "Mechanics of Fluid", McGraw-Hill (1992).
	2.	Darby, R., "Chemical Engineering Fluid Mechanics", Marcel Dekker (1996).
	3.	Wilkes, J.O., "Fluid Mechanics for Chemical Engineers", Prentice-Hall International Series (1998).
Reference Books	4.	Streeter, V.L., Wylie E.B., Bedford, K.W. "Fluid Mechanics" McGrawHill Book Company, New York (1998).
	5.	Mc Cabe, W.L., Smith, J.C., Harriott, P., "Unit Operation of Chemical Engineering", McGraw-Hill (2004).

Mechanical Operations (CET-203)

Subject: Mechanical Operations (CET-203)	**Year & Semester: B. Tech Chemical Engineering 2nd Year & 3rd Semester**		**Total Course Credit: 3**		
			L	T	P
			2	1	0
Evaluation Policy	Mid-Term (26 Marks)	Class Assessment (24 Marks)	End-Term (50 Marks)		

Course outcomes (COs): Upon successful completion of the course, students will be able to:

CO1.	Apply the fundamentals to characterize, classify, conveying and storage of solids and mixing with liquids and gases	BTL 3
CO2.	Evaluate the power requirements and crushing efficiencies of size reduction equipment using laws of communition and understand the working of different size reduction equipment	BTL 5
CO3.	Analyze the screening results to estimate the screen effectiveness and acquire knowledge of screening mechanism and separation of solids from solids and gases	BTL 4
CO4.	Estimate the filtration time, specific cake and medium resistance of filtration processes and design the thickeners	BTL 6

Details of the Syllabus:

Module No.	**Contents**	**Hours**
Module I	**Introduction:** Properties of particulate solids, characterization of solid particles and mixed particle size. Storage and transportation of bulk solids (types of conveyers, their selection), Pneumatic and hydraulic conveying of solids, general characteristics and flow relations, mechanical conveyers. Agitation and mixing, theory of mixing, power consumption of mixer impellers.	12
Module II	**Crushing and Grinding**: Theory of Crushing. Laws of crushing-Rittingers' law, Kick's law, Classification of crushing and grinding machinery, Coarse Crushers (jaw crusher, gyratory crusher), intermediate crushers (roll, disc or cone crusher, edge runners, squired cage disintegrator, hammer mill), fine grinders-burhstones, roller mills, ball and tube mills.	12
Module III	**Solid-Solid and Gas-Solid Separation:** Principle of screening, screen analysis, types of screening equipment (grizzlies, trommels, shaking and vibrating screens), effectiveness of a screen, air separating method (cyclone separator, bag filters, electrostatic precipitator, scrubbers).	10
Module IV	**Solid-Liquid Separation: Settling:** Free and hindered settling, classification of classifiers (simple and mechanical), introduction to the design of continuous thickeners. **Filtration:** Classification of filters, effect of pressure on filtration, filter aids, constant pressure and constant rate filtration theory, membrane filtration.	08

Books Recommended:

Text books	**1.**	McCabe, W.I., Smith, J.C., "Unit Operations in Chemical Engineering", 7th Edn., McGraw-Hill (2011).
	2.	Swain, A.K., Patra, H., Roy, G.K., "Mechanical Operations" 1st Edn., McGraw-Hill (2010).
	3.	Badger, L.W., Banchero, T.J., "Introduction to Chemical Engineering", 3rd Edn., McGraw-Hill (1997).
Reference Books	**4.**	Coulson, J.M., Richardson, J.F., "Chem. Engineering, 2nd Vol.", Butterworth-Heinemann.
	5.	Foust, A. S., Wenzel, L. A., Clump, C. W., Maus, L., Andersen, L. B., "Principles of Unit Operations", 2nd Ed., Wiley-India (2008).
	6.	Perry, R.H., Green, D.W., "Perry's Chemical Engineers' Handbook", 7th Edn.", McGraw-Hill Book Company (2008).

Process Instrumentation (CET-204)

<table>
<tr><th rowspan="3">Subject: Process Instrumentation (CET-204)</th><th rowspan="3" colspan="2">Year & Semester: B. Tech Chemical Engineering
2nd Year & 3rd Semester</th><th colspan="3">Total Course Credit: 3</th></tr>
<tr><td>L</td><td>T</td><td>P</td></tr>
<tr><td>2</td><td>1</td><td>0</td></tr>
<tr><td>Evaluation Policy</td><td>Mid-Term
(26 Marks)</td><td>Continuous Assessment
(24 Marks)</td><td colspan="3">End-Term
(50 Marks)</td></tr>
</table>

Pre-requisites: None.

Course Objective: This course enables the students to know about the process principles and make the students knowledgeable in various types of measuring instruments used in chemical process industries.

Course Outcomes (COs): At the end of the course, the student will be able to:

CO1	Develop basic concepts of instrumentation, their principles, and applications.	BTL 3
CO2	Analyze Temperature measurement techniques.	BTL 4
CO3	Identify the measurement techniques for Pressure.	BTL 3
CO4	Identify the instruments for Flow and Level measurement.	BTL 3

Detailed Syllabus:

Module No.	Contents	Hours
Module I	**Introduction:** Measuring instruments and their function, elements of measurement, important characteristics of industrial measurement. Classification of Instruments: Recording and measuring types.	10
Module II	**Temperature measurement:** Classification of thermometers, and pyrometers, response of thermometers. Fluid filled expansion thermometers. Thermocouples: Resistance thermometers. Radiation and optical pyrometers.	10
Module III	**Pressure and vacuum measurement:** Classification. Manometers- Inverted well pressure gauges. Bourdon tube pressure gauges, diagram of pressure gauges. Special measuring devices: Pressure and vacuum, McLeod gauge. Thermal conductivity and ionization gauges.	12
Module IV	**Flow and Liquid Level Measurement:** Head and area flow meters-flow measuring devices, Visual indicators float motivation, liquid level instruments. Pressure differential type level gauge, Electrical contact type liquid level indicators.	10

Books Recommended:

<table>
<tr><td rowspan="4">Text books</td><td>1.</td><td>Dunn, W.C., “Fundamentals of Industrial Instrumentation and Process Control”, Tata McGraw-Hill (2009).</td></tr>
<tr><td>2.</td><td>Nakra B. C., Chaudhry K. K., “Instrumentation, Measurement and Analysis” Tata McGraw-Hill (2004).</td></tr>
<tr><td>3.</td><td>Andrew, W. G., “Applied Instrumentation in the Process Industries, Vol. I.", Gulf Publishing Company (1993).</td></tr>
<tr><td>4.</td><td>Liptek, B.G., “Instrument Engineers’ Handbook: Process Control and Optimization, Volume II", Taylor and Francis, CRC press (2006).</td></tr>
<tr><td>Reference books</td><td>1.</td><td>Johnson, C., “Process Control Instrumentation Technology”, Prentice Hall (2005).</td></tr>
</table>

Chemical Engineering Thermodynamics-1 (CET-205)

<table>
<tr><td rowspan="3">Subject: Chemical Engineering Thermodynamics-1 (CET-205)</td><td colspan="2" rowspan="3">Year & Semester: B. Tech Chemical Engineering 2nd Year & 3rd Semester</td><td colspan="3">Total Course Credit: 3</td></tr>
<tr><td>L</td><td>T</td><td>P</td></tr>
<tr><td>2</td><td>1</td><td>0</td></tr>
<tr><td>Evaluation Policy</td><td>Mid-Term
(26 Marks)</td><td>Continuous Assessment
(24 Marks)</td><td colspan="3">End-Term
(50 Marks)</td></tr>
</table>

Pre-Requisites: None

Course Outcomes: At the end of the course, the student will be able to:

CO1	Apply the first and second laws of thermodynamics to chemical processes.	BTL 3
CO2	Compute the properties of ideal and real gas mixtures.	BTL 3
CO3	Estimate heat and work requirements for industrial processes.	BTL 5
CO4	Analyze refrigeration and liquefaction processes.	BTL 4

Detailed Syllabus:

Module No.	Contents	Hours
Module I	**Introduction and First Law of Thermodynamics:** First Law of Thermodynamics, Energy Balance for Closed Systems, Equilibrium, The Phase Rule, The Reversible Process, Internal energy, Enthalpy, Heat Capacity, Mass and Energy balances for Open Systems. Application of first law to non-flow isochoric, isobaric, isothermal, and adiabatic and polytropic processes. Volumetric Properties of Pure Fluids: General P-V-T Behaviour of Pure Substances, Virial Equations of State, The Ideal Gas, Application of the Virial Equations, Cubic Equations of State, Generalized Correlations for Gases, Generalized Correlations for Liquids.	12
Module II	**Second Law of Thermodynamics:** Statements of the Second Law, Heat Engines, Entropy, Entropy Changes of an Ideal Gas, Mathematical Statement of Second Law of Thermodynamics, Clausius inequality, Entropy as a property, Principle of increase of entropy, Calculation of Ideal Work, Lost Work. Thermodynamic Cycles: Carnot cycle, Otto, Diesel, Rankine cycles and their applications. Third Law of Thermodynamics.	12
Module III	**Thermodynamic Properties of Fluids:** Thermodynamic Property Relations for Single Phase Systems, Residual Property Relations, Residual Property Calculation by Equations of State, Two-Phase Systems, Thermodynamic Diagrams, Tables of Thermodynamic Properties, Generalized Property Correlations for Gases.	10
Module IV	**Refrigeration and Liquefaction:** Carnot Refrigerator, Vapor-Compression Cycle, Choice of Refrigerant, Absorption Refrigeration, Heat Pump, Liquefaction Processes.	08

Books Recommended:

Text books	1.	Introduction to Chemical Engineering Thermodynamics, Smith J. M, H. C. Van Ness and M. M. Abbott, Mc-Graw-Hill, 2018, 8th Edition.
	2.	Chemical Engineering Thermodynamics, K. V. Narayanan, PHI Learning Pvt. Ltd., 2013, 2nd Edition.
	3.	Engineering Thermodynamics, PK Nag, Mc-Graw Hill, 2017 6th Edition.
Reference books	1.	Thermodynamics and its Applications, J.W. Tester and M. Modell, Prentice Hall, 1999, 3rd Edition.
	2.	Thermodynamics, Wark, K., Mc-Graw Hill. 2001. 4th Edition.
	3.	Thermodynamics: An Engineering Approach, Çengel, Y.A., Boles, M.A., Mc-Graw-Hill (2008). 8th Edition.

Engineering Ethics (HST-201)

Subject: Engineering Ethics (HST--201)	**Year & Semester: B. Tech Chemical Engineering 2nd Year & 3rd Semester**		**Total Course Credit: 3**		
			L	T	P
			2	1	0
Evaluation Policy	Mid-Term (26 Marks)	Continuous Assessment (24 Marks)	Final-Term (50 Marks)		

COURSE OUTCOMES:

After completing this course, the student must demonstrate the knowledge and ability to:

CO1	Apply the principles of ethics and ethical decision-making to real-world scenarios	BTL 3
CO2	Examine the relevance of ethical theories to contemporary business organisations.	BTL 4
CO3	Appraise the value of Corporate Social Responsibility.	BTL 5
CO4	Investigate the applicability of Theories of Corporate Social Responsibility.	BTL 4

Detailed Syllabus:

Module No.	**Contents**	**Hours**
Module I	Nature and Significance of Business Ethics, Ethical Dilemmas, Personal Ethics: Morality, Religion, Etiquette, Professional Code, Moral and Non-moral Standards, Ethical Relativism, Moral Development and Moral Reasoning, Ethical Decision-Making Model, Globalization and Business ethics.	12
Module II	Business Ethical Principles, Role and Types of Ethical Theories: Teleological, Deontological and Virtue, Kant's Ethics: Rights and Duties, Ethics of care-Virtue Ethics, Ethical Dimensions of Marketing, Human Resource, Production and Financial Decisions.	10
Module III	Corporate Social Responsibility: Nature of Corporations, Corporation as Morally Responsible Agent, Nature and significance of Corporate Social Responsibility, Social Responsiveness and Social Performance.	10
Module IV	Corporate Philanthropy, Corporate Citizenship, Social Responsibility Model, Theories of CSR: Shareholders Theory, Stakeholders Theory and Social Contract Theory.	10

Books Recommended:

Text books	1.	Fernando, A.C. (2012). *Business Ethics and Corporate Governance*. Pearson India.
	2.	Ghosh, B.N. (2012). *Business Ethics and Corporate Governance*. Tata-McGraw-Hill Education Private Limited.
	3.	Shaw, W.H. (2016). *Business Ethics: A textbook with Cases*. Cengage Learning.
	4.	Velasquez, M.G. (2017). *Business Ethics: Concepts and Cases*. Pearson Education Limited.
Reference books	5.	McDonald, G. (2014). *Business Ethics: A Contemporary Approach.* Cambridge University Press.
	6.	Bharti, S. (2022). *Corporate Social Responsibility in India: Law, Regulation and Politics*. Palgrave Macmillan.

Numerical Methods (MAT-201)

Subject: Numerical Methods (MAT-201)	**Year & Semester: B. Tech Chemical Engineering 2nd Year & 3rd Semester**		**Total Course Credit: 3**		
			L	T	P
			2	1	0
Evaluation Policy	Mid-Term (26 Marks)	Continuous Assessment (24 Marks)	End-Term (50 Marks)		

Pre-requisites: A student should have basic knowledge of calculus.

Course Outcomes: At the end of the course, the student will be able to:

CO1	Determine the numerical solution of algebraic and transcendental equations.	BTL 4
CO2	Solve the problems related to inverse by various numerical methods.	BTL 3
CO3	Apply interpolating polynomials to approximate functions and determine intermediate values.	BTL 3
CO4	Apply numerical techniques for solving ordinary differential equations.	BTL 3

Detailed Syllabus:

Module No.	**Contents**	**Hours**
Module I	Floating-point form of numbers, Round-off, Algorithm, Stability, Programming errors, Errors of numerical results, Error propagation, Basic error principle, Loss of significant digits. Bolzano's bisection method, iteration method, Regula-Falsi method, Newton-Raphson method, numerical solution for system of equations. Gauss elimination method, Gauss-Jordan method, Computation of Inverse by Gauss's Method, LU decomposition, Gauss-Siedel iteration method, Jacobi method, The Eigen value problem	15
Module II	Interpolation Forward, Backward and Shift operators, Central differences, their relations, Existence, Uniqueness of interpolating polynomial, error of interpolation - unequally spaced data; Lagrange's formula.	07
Module III	Newton's divided difference formula. Equally spaced data: finite difference operators and their properties, Newton's forward and backward interpolation formulae, Gauss's forward and backward.	08
Module IV	Numerical differentiation using difference techniques, Trapezoidal, Simpson's 1/3 and Simpson's 3/8 rule, Truncation error, Romberg's method. Picard's method, Taylor series method, Euler and modified Euler method, Runge-Kutta method of 4th order, Predictor-Corrector methods (Adam's-Moulton method & Milne's method.	12

Books Recommended:

Text books	1.	S.S. Sastry, *Introductory methods in Numerical Analysis*, 5th Edition, Prentice Hall India learning Pvt Ltd, ISBN: 9788120345928, 9788120345928.
	2.	Kendall E. Atkinson, Han, *Elementary Numerical Analysis*, 3rd Edition, Wiley India Pvt Ltd, (2006).
	3.	J.B. Scarborough, *Mathematical Numerical Analysis*, 6th Edition, Oxford and IBH Publishers, (2020).

Mechanical Operations Lab. (CEL-201)

<table>
<tr><td rowspan="3">Subject: Mechanical Operations Lab. (CEL-201)</td><td rowspan="3">Year & Semester: B. Tech Chemical Engineering
2nd Year & 3rd Semester</td><td colspan="3">Total Course Credit: 1</td></tr>
<tr><td>L</td><td>T</td><td>P</td></tr>
<tr><td>0</td><td>0</td><td>2</td></tr>
<tr><td>Evaluation Policy</td><td>Continuous Assessment
(60 Marks)</td><td colspan="3">Final-Term
(40 Marks)</td></tr>
</table>

Course outcomes (COs): Upon successful completion of the course, students will be able to:

CO1.	Apply the knowledge of characterization and classification of solids to estimate the particle size	BTL 3
CO2.	Estimate the capacities and efficiencies of the size separation equipment	BTL 5
CO3.	Analyze the problems and results in conveying and size reduction of particles	BTL 4
CO4.	Design the solid-liquid separation equipment	BTL 6

<u>List of Experiments</u> (Total Contact hours:28)

S.No.	Name of the Experiment
1.	Particle Size Analysis by Sieves
2.	Determine the Efficiency of a Ball Mill
3.	Determine the Efficiency of a Vibrating Screen
4.	Find out the discharge at different angles of elevation of the Screw conveyor
5.	Study the settling Characteristics of Slurry
6.	Demonstration of Trommel
7.	Determine the Capacity of Belt Conveyor

Books Recommended:

<table>
<tr><td rowspan="3">Text books</td><td>1.</td><td>McCabe W. L., Jullian Smith C. and Peter Harriott - Unit operations of Chemical Engineering, 7th Edn., McGraw-Hill international edition (2005).</td></tr>
<tr><td>2.</td><td>Coulson J.M and Richardson. J.F, Chemical Engineering Volume I and II, 5th Edn., Elsevier India (2006).</td></tr>
<tr><td>3.</td><td>Swain, A.K., Patra, H., Roy, G.K., “Mechanical Operations” 1st Edn., McGraw-Hill (2010).</td></tr>
<tr><td rowspan="2">Reference books</td><td>1.</td><td>Foust, A. S., Wenzel, L. A., Clump, C. W., Maus, L., Andersen, L. B., “Principles of Unit Operations”, 2nd Ed., Wiley-India (2008).</td></tr>
<tr><td>2.</td><td>Kiran D. Patil, Mechanical Operations: Fundamental Principles and Applications, 3rd Edn., Nirali Prakshan (2012).</td></tr>
</table>

4th Semester

Chemical Reaction Engineering-I (CET-250)

<table>
<tr><td rowspan="3">Subject: Chemical Reaction Engineering-I (CET-250)</td><td colspan="2" rowspan="3">Year & Semester: B. Tech Chemical Engineering
2nd Year & 4th Semester</td><td colspan="3">Total Course Credit: 3</td></tr>
<tr><td>L</td><td>T</td><td>P</td></tr>
<tr><td>2</td><td>1</td><td>0</td></tr>
<tr><td>Evaluation Policy</td><td>Mid-Term
(26 Marks)</td><td>Class Assessment
(24 Marks)</td><td colspan="3">End-Term
(50 Marks)</td></tr>
</table>

Course outcomes (COs): Upon successful completion of the course, students will be able to:

CO1.	Determine the kinetics of chemical reaction from the data using integral, differential method of analysis	BTL 5
CO2.	Design the reactors for single and multiple reactions and the performances of different types of reactors	BTL 6
CO3.	Select the optimal sequence of reactors in multiple reactor systems and design the reactors for the maximum desired product formation in multiple reactions	BTL 3
CO4.	Analyze and size the reactors while accounting the non-isothermal conditions and non-ideal flow patterns	BTL 4

Details of the Syllabus:

Module No.	Contents	Hours
Module I	**Introduction:** Kinetics of homogeneous reactions, concentration dependent term and temperature dependent term of rate equation, interpretation of batch reactor: Constant volume batch reactor, integral method of analysis of data, series and parallel reactions, reversible reactions, variable volume batch reactor, differential methods of analysis, temperature and reactions rate.	12
Module II	**Introduction to Reactor Design:** Ideal batch reactor, mixed flow reactor, plug flow reactor, holding and space time, design for single reactions, size comparison (analytical and graphical methods), plug flow reactors in series and parallel, mixed flow reactors in series, different types of reactors in series, recycle reactors	10
Module III	**Design for Multiple Reactions:** Reactions in parallel, series and series-parallel in C.S.T.R, reactions in parallel, series and series-parallel reactions in plug flow reactor, yield and selectivity.	10
Module IV	**Temperature and Pressure Effect:** General design procedure, optimum temperature progression, adiabatic operation, non-adiabatic operation, semi batch reactors **Non-ideal Flow:** Residence time distribution (RTD) theory, role of RTD in determining reactor behaviour, age distribution (E) of fluid, experimental methods for finding E, relationship between E and F curve, models for non-ideal flow – single parameter and multi parameter models (axial dispersion, tanks in series), performance estimation of reactor using reactor models.	10

Books Recommended:

Text books	1.	Fogler H.S., Elements of Chemical Reaction Engineering, 5th Edn., PHI (2016).
	2.	Levenspiel O., Chemical Reaction Engineering, 3rd Edn., Wiley, India (2006).
	3.	Smith J.M., Chemical Engineering Kinetics, 2nd Edn., McGraw-Hill (1970).
Reference books	1.	E. Bruce Nauman., Chemical Reactor Design, Optimization and Scaleup, 2nd Edn., Wiley (2008).
	2.	Martin Schmal., Chemical Reaction Engineering: Essentials, Exercises and Examples, CRC Press, 1st Edn., (2014).

Chemical Engineering Thermodynamics-II (CET-251)

<table>
<tr><td rowspan="3">Subject: Chemical Engineering Thermodynamics-II (CET-251)</td><td rowspan="3" colspan="2">Year & Semester: B. Tech Chemical Engineering
2nd Year & 4th Semester</td><td colspan="3">Total Course Credit: 3</td></tr>
<tr><td>L</td><td>T</td><td>P</td></tr>
<tr><td>2</td><td>1</td><td>0</td></tr>
<tr><td>Evaluation Policy</td><td>Mid-Term
(26 Marks)</td><td>Continuous Assessment
(24 Marks)</td><td colspan="3">End-Term
(50 Marks)</td></tr>
</table>

Pre-requisites: Chemical Engineering Thermodynamics-I

Course Outcomes: At the end of the course, the student will be able to:

CO1	Determine thermodynamic properties and Evaluate heat effects involved in industrial chemical processes	BTL 5
CO2	Estimate Bubble-P & T, Dew-P & T for binary and multi-component systems	BTL 6
CO3	Calculate vapor-liquid equilibrium (VLE) composition for ideal and non-ideal systems	BTL 3
CO4	Determine equilibrium constant and composition of product mixture for single and multiple reactions	BTL 5

Detailed Syllabus:

Module No.	Contents	Hours
Module I	**Solution Thermodynamics:** Fundamental property relation, Chemical potential, Partial properties, The ideal gas mixture model, Fugacity and fugacity coefficient, The ideal solution model, Excess properties.	10
Module II	**Applications of Solution Thermodynamics:** Liquid phase properties from VLE data, Activity coefficient, Excess Gibbs Energy, Models for the excess Gibbs energy, Property changes of mixing, Heat effects of mixing process.	10
Module III	**Phase Equilibria and Heat Effect**: The nature of equilibrium, Criteria of equilibrium, The phase rule, Duhem's theorem, Raoult's law, Henry's law, Modified Raoult's law, Dew point and bubble point calculations, Relative volatility, Flash calculations. Heat Effects: Sensible heat effects, Temperature dependency of heat capacity, Latent Heat of pure substance, Standard heats of reaction, formation and combustion, Heat effects of industrial reactions.	12
Module IV	**Chemical Reaction Equilibria:** The reaction coordinate, Equilibrium criteria to chemical reactions, Gibbs free energy change, Equilibrium constant, Effect of temperature on equilibrium constant, Evaluation of equilibrium constants, Relation of equilibrium constant to composition, Equilibrium conversions for single reactions, Phase rule and Duhem's theorem for reacting systems, Multireaction equilibria.	10

Books Recommended:

Text books	1.	Introduction to Chemical Engineering Thermodynamics, Smith J. M, H. C. Van Ness and M. M. Abbott, Mc-Graw-Hill, 2018, 8th Edition.
	2.	Chemical Engineering Thermodynamics, K. V. Narayanan, PHI Learning Pvt. Ltd., 2013, 2nd Edition.
	3.	Engineering Thermodynamics, PK Nag, Mc-Graw Hill, 2017 6th Edition.
Reference books	1.	Thermodynamics and its Applications, J.W. Tester and M. Modell, Prentice Hall, 1999, 3rd Edition.
	2.	Thermodynamics, Wark, K., Mc-Graw Hill. 2001. 4th Edition.
	3.	Thermodynamics: An Engineering Approach, Çengel, Y.A., Boles, M.A., Mc-Graw-Hill (2008). 8th Edition.

Heat Transfer (CET-252)

<table>
<tr><td rowspan="3">Subject: Heat Transfer (CET-252)</td><td colspan="2" rowspan="3">Year & Semester: B. Tech Chemical Engineering
2nd Year & 4th Semester</td><td colspan="3">Total Course Credit: 3</td></tr>
<tr><td>L</td><td>T</td><td>P</td></tr>
<tr><td>2</td><td>1</td><td>0</td></tr>
<tr><td>Evaluation Policy</td><td>Mid-Term
(26 Marks)</td><td>Continuous Assessment
(24 Marks)</td><td colspan="3">End-Term
(50 Marks)</td></tr>
</table>

Course Outcomes: Upon the successful completion of this course, the student will be able to:

CO1	Identify, formulate, analyze & solve problems involving steady state heat conduction in simple geometries.	BTL 3
CO2	Evaluate heat transfer coefficients for natural & forced convection.	BTL 5
CO3	Estimate radiation heat transfer between black body surfaces & grey body surfaces and explain heat transfer involving phase change.	BTL 6
CO4	Design heat exchanger using LMTD and effectiveness method for parallel and counter flow arrangement.	BTL 6

Detailed Syllabus:

Module No.	Contents	Hours
Module I	**Introduction:** Modes of heat transfer. Thermal conductivity of material. Effect of temperature on thermal conductivity of different solids, liquids and gases. Derivation of generalized heat conduction equation in Cartesian, cylindrical and spherical coordinates and its reduction to specific cases, general laws of heat transfer.	10
Module II	**Conduction**: Fourier's law, steady state conduction through flat wall, multi-layer wall, cylinders and hollow spheres. Lagging of pipes and optimum lagging thickness. **Heat transfer from extended surface:** Types of fin, heat flow through rectangular fin, infinitely long fin, fin insulated at the tip and fin losing heat at the tip, efficiency and effectiveness of fin.	10
Module III	**Convection:** Natural and forced convection, Newton's law of cooling, dimensional analysis applied to forced and free convection, dimensionless numbers and their physical significance, empirical correlations for free and forced convection, continuity, momentum and energy equations, thermal and hydrodynamic boundary layer. **Heat transfer with phase change**: Boiling of liquids, Pool boiling curve, different types of pool boiling, condensation of vapor. Film wise & drop wise condensation. **Radiation:** Emissivity, absorptivity, black body and grey body radiation, view factors, radiation between various types of surfaces.	12
Module IV	Heat exchanger: Classification, heat exchanger analysis, LMTD for parallel and counter flow exchanger, condenser and evaporator, overall heat transfer coefficient, fouling factor, correction factors for multi pass arrangement, effectiveness and number of transfer unit for parallel and counter flow heat exchanger, introduction of heat pipe and compact heat exchanger.	10

Books Recommended:

<table>
<tr><td rowspan="3">Text Books</td><td>1.</td><td>McCabe, W.L., Smith, J.C., "Unit Operation of Chemical Engineering", 7th Edn., McGraw-Hill (2011).</td></tr>
<tr><td>2.</td><td>Holman, J.P., "Heat Transfer", 10th Edn., McGraw-Hill (2009)</td></tr>
<tr><td>3.</td><td>Bergman, T.L., Lavine, A.S., Incropera, F.P., DeWitt, D.P., "Introduction to Heat Transfer", 6th Edn., Wiley (2011).</td></tr>
<tr><td rowspan="2">Reference Books</td><td>4.</td><td>Kreith, F., Manglik, R.M., Bohn, M., "Principles of Heat Transfer", 7th Edn., Cengage Learning (2010).</td></tr>
<tr><td>5.</td><td>Hewitt, G.F., Shires, G.L., Bott, T.R., "Process Heat Transfer", Begell House (1995). Kern, D.Q., "Process Heat Transfer", McGraw- Hill (2001).</td></tr>
</table>

Chemical Process Technology (CET-253)

Subject: Chemical Process Technology (CET-253)	**Year & Semester: B. Tech Chemical Engineering 2nd Year & 4th Semester**		**Total Course Credit: 3**		
			L	T	P
			2	1	0
Evaluation Policy	Mid-Term (26 Marks)	Continuous Assessment (24 Marks)	End-Term (50 Marks)		

Course Outcomes: At the end of the course, the student will be able to:

CO1	Analyze the processes used by chemical process industries for the production of various chemical products.	BTL 4
CO2	Application of process flow diagram for the chemical process industries.	BTL 3
CO3	Ability to deal with apparatus, unit operations, and chemical economics.	BTL 3
CO4	To enable chemical Engineering solutions to meet the needs of process industry while conserving environment.	BTL 6

Detailed Syllabus:

Module No.	**Contents**	**Hours**
Module I	Technology of Water: Classification of water, industrial and municipal purposes, methods for obtaining fresh water from sea water. Basic Chemical Industries: Common salt, its uses, economics and manufacture. Soda ash, its uses, raw materials, manufacture by Solvay process and its modification. Caustic soda-chlorine types of cells, raw materials, reactions, uses and manufacture.	12
Module II	Synthetic ammonia: Uses, reactions, manufacturing process, concentration of nitric acid. Nitrogenous Fertilizers: Ammonium sulphate, ammonium nitrate and urea, their methods of production. Phosphate Industries: Phosphorous, uses and manufacture; phosphoric acid, uses and types of manufacturing procedures; phosphate fertilizers, raw materials and uses. Manufacture of super-phosphates, granular super phosphate and triple super-phosphate	10
Module III	Pulp & Paper: Sulphite and Kraft processes for manufacture of paper. Oils, fats, soaps and detergents: Classification of vegetable oils and fats, production of edible oil and fats, purification, hydrogenation of oils, Sugar and Starch: Manufacture of raw sugar crystals from sugar cane, refining operations,	10
Module IV	Coal and Coal Tars: Cola chemicals, law temperature and high temperature carbonization, chemicals from coal tar. Cement: History, various types of cements, raw materials, manufacture of Portland cement. Sulphuric acid: Raw materials, method of manufacture by contact process.	10

Books Recommended:

Text Books	**1.**	Rao, M.G., Sittig, M., "Dryden's Outlines of Chemical Technology for the 21st Century", East-West Press, New Delhi (2002).
	2.	Austin, G.T., "Shreve's Chemical Process Industries", 5thEdn., McGraw Hill Book Company (1984).
	3.	Moulijn, J. K., Makkee, M., Van Diepen, A., "Chemical Process Technology", Wiley (2001).

Chemical Engineering Mathematics (MAT-250)

Subject: Chemical Engineering Mathematics (MAT-250)	Year & Semester: B. Tech Chemical Engineering 2nd Year & 4th Semester		Total Course Credit: 3		
			L	T	P
			2	1	0
Evaluation Policy	Mid-Term (26 Marks)	Continuous Assessment (24 Marks)	End-Term (50 Marks)		

Course Outcomes: At the end of the course, the student will be able to:

CO1	Evaluate Laplace transform of various functions.	BTL 5
CO2	Evaluate Inverse Laplace transform of various functions and solution of ODE by Laplace transform.	BTL 5
CO3	Solve problems related to moments, correlation, regression, conditional probability.	BTL 3
CO4	Apply the concepts of various probability distributions to various engineering problems.	BTL 3

Detailed Syllabus:

Module No.	Contents	Hours
Module I	Laplace transform, Condition for the existence of Laplace transform, Laplace transform of some elementary functions, Properties of Laplace transform, Differentiation and Integration of Laplace transform. Laplace transforms of periodic functions and other special functions, Unit Impulse function, Dirac-delta function and its Laplace transform.	10
Module II	Inverse Laplace transform, Convolution theorem and properties of Convolution, Heaviside's expansion theorem. Use of Laplace transforms in the solution of ordinary linear differential equations with constant and variable coefficients.	10
Module III	Introduction to basic statistics, moments, correlation, regression, method of least square. Introduction to basic probability, Conditional probability, Independent events, Baye's theorem and Law of Total probability and allied problems.	10
Module IV	Random variable, Probability density function, Mode and median of distribution of a random variable, Probability distribution function and its properties, Mathematical expectation, Laws of expectation, Mean, Variance, Moments, Moment generating function, Binomial, Poisson and normal Distributions and their applications.	12

Books Recommended:

Text Books	**1.**	Integral Transforms and their Applications, L. Debnath and D. Bhatta, Second Edition, CRC press, 2007.
	2.	Schaum's Outlines Laplace Transforms, Murray R. Spiegel, Tata Mc-Graw Hill Edition, 2005.
	3.	Advanced Engineering Mathematics, R.K Jain and S.R.K Iyengar, Third Edition, Narosa Pub. House, 2008.
Reference Books	**4.**	Introduction to Probability and Statistics for Engineers and Scientists, Sheldon M. Ross, 4th Edition, Academic Foundation, ISBN: 978-8-190-93568-5.
	5.	Applied Statistics and Probability for Engineers, Douglas C. Montgomery, 5th Edition, , Wiley India, ISBN: 978-8-126-53719-8.

Engineering Economics and Management (HST-250)

<table>
<tr><td rowspan="3">Engineering Economics and Management (HST-250)</td><td colspan="2" rowspan="3">Year & Semester: B. Tech Chemical Engineering 2nd Year & 4th Semester</td><td colspan="3">Total Course Credit: 3</td></tr>
<tr><td>L</td><td>T</td><td>P</td></tr>
<tr><td>2</td><td>1</td><td>0</td></tr>
<tr><td>Evaluation Policy</td><td>Mid-Term
(26 Marks)</td><td>Continuous Assessment
(24 Marks)</td><td colspan="3">End-Term
(50 Marks)</td></tr>
</table>

COURSE OUTCOMES:

After completing this course, the student must demonstrate the knowledge and ability to:

CO1	Apply the management concepts within the engineering domain.	BTL 3
CO2	Analyze the various functions of management	BTL 4
CO3	Appraise the importance of economics in the engineering context	BTL 5
CO4	Discuss the operation of different forms of markets and their competitive strategies.	BTL 6

Detailed Syllabus:

Module No.	Contents	Hours
Module I	**Basics of Management:** Definition, Functions, Process and Significance of Management; Evolution of management thought; Theories of Management.	12
Module II	**Functions of Management:** Planning; Organizing; Staffing; Directing and Controlling. Nature and Significance of functions of management.	10
Module III	**Basics of Economics and Consumer Behaviour:** Economics- Meaning, Divisions and Importance (Engineering Context); Demand- Concept and Law, Elasticity of demand-types, measurement, and importance.	10
Module IV	**Market and Economic Policies:** Markets- Features, type; Perfect Competition, Monopoly, Monopolistic Competition, Duopoly and Oligopoly; Introduction to concepts of inflation, GDP, fiscal policy and monetary policy.	10

Books Recommended:

<table>
<tr><td rowspan="4">Text books</td><td>1.</td><td>Ahuja, H. L. (2016). Advanced Economic Theory: Microeconomic analysis (Ed. 21st). S. Chand.</td></tr>
<tr><td>2.</td><td>Keat, P. G., College, d., Erfle, S., Banerjee, S., & Young, P. K. Y. (2018). Managerial Economics (Ed. 7th). Pearson.</td></tr>
<tr><td>3.</td><td>Dessler, G., & Varrkey, B. (2020). Human Resource Management (16th ed.). Pearson.</td></tr>
<tr><td>4.</td><td>Koontz, H., Weihrich, H., & Cannice, M. V. (2020). Essentials of Management (Ed. 11th). McGraw Hill, New Delhi.</td></tr>
<tr><td rowspan="2">Reference books</td><td>5.</td><td>Pindyck, R. S., Rubinfeld, D. L., & Banerjee, S. (2022). Microeconomics (Ed. 9th). Pearson Education.</td></tr>
<tr><td>6.</td><td>Koontz, H., Weihrich, H., & Cannice, M. V. (2020). Essentials of Management (11th ed.). McGraw-Hill.</td></tr>
</table>

Energy Technology Laboratory (CEL-250)

Energy Technology Laboratory (CEL-250)	**Year & Semester: B.Tech. Chemical Engineering 2nd Year & 4thSemester**	**Total Course Credit: 3**		
		L	T	P
		0	0	2
Evaluation Policy	Total Marks (100)			

Course Objectives

This laboratory aims to perform various experiments on solid and liquid fuels and their characteristics.

Course Outcomes (COs)

CO1.	Experiment with different types of energy sources.	BTL 3
CO2.	Analyse the proximate analysis parameters of fuels.	BTL 4
CO3.	Identification of various fuel properties.	BTL 3
CO4.	Experiment with unconventional energy sources like briquetted fuel.	BTL 3

Details of the Syllabus (Total Contact hours:28)

Experiments	1: To determine the Proximate analysis Parameters of coal and other solid fuels. 2. Determination of calorific value of solid fuels. 3. Test for cloud and pour point of petroleum products. 4. Determination of flash point, fire point and specific gravity of petroleum products. 5. To find the Smoke point of a liquid fuel. 6. To study the briquetting/pelletization of biomass

Books Recommended

1	Sarkar, S. “Fuel and Combustion” (2000).
2	Griswold, J. , “Fuels, Combustion and Furnaces”
3	S. Van Loo, "Handbook of Biomass Combustion and Co-Firing"

Fluid Mechanics Lab. (CEL-251)

<table>
<tr><td rowspan="3">Subject: Fluid Mechanics Lab. (Code: CEL-251)</td><td rowspan="3">Year & Semester: B. Tech Chemical Engineering 2nd Year & 4thSemester</td><td colspan="3">Total Course Credit: 1</td></tr>
<tr><td>L</td><td>T</td><td>P</td></tr>
<tr><td>0</td><td>0</td><td>2</td></tr>
<tr><td>Evaluation Policy</td><td>Mid-Term/Class Assessment
(50 Marks)</td><td colspan="3">Final-Term
(50 Marks)</td></tr>
</table>

Course Objective: To develop skills in designing and conducting experiments related to applications of principles of fluid mechanics and mechanical operations.

Course outcomes (COs): At the end of the course, students will be able to:

CO1.	Experiment with velocity measurements using flow meters	BTL 3
CO2.	Examine the laminar and turbulent flow behavior	BTL 4
CO3.	Measure the viscosity by Stokes Apparatus	BTL 5
CO4.	Analyze Bernoulli's principle and pipe fittings	BTL 4

<u>**List of Experiments and Equipments**</u> **(Total Contact hours:28)**

S.No.	Name of the Experiment	Name of the Equipment
1	Measurement of liquid viscosity by Stokes Method	Stokes Apparatus
2	Reynolds Experiment to demonstrate laminar and turbulent flow	Reynolds Apparatus
3	Verification of Bernoulli's Principle	Bernoulli's Apparatus
4	Flow through Orifice meter	Orifice meter
5	Flow through Venturimeter	Venturi meter
6	Flow through Rotameter	Rotameter
7	Pipe Fittings	---

Books Recommended:

1.	McCabe W. L., Jullian Smith C. and Peter Harriott - Unit operations of Chemical Engineering, 7thEdn., McGraw-Hill international edition, 2005.
2.	Coulson J.M and Richardson. J.F, Chemical Engineering Volume I and II, 5thEdn., Elsevier India, 2006.

5th Semester

Process Equipment Design-I (CET-306)

<table>
<tr><td rowspan="3">Subject: Process Equipment Design-I (CET-306)</td><td colspan="2" rowspan="3">Year & Semester: B.Tech. Chemical Engineering 3rd year & 5th Semester</td><td colspan="3">Total Course Credit: 3</td></tr>
<tr><td>L</td><td>T</td><td>P</td></tr>
<tr><td>2</td><td>1</td><td>0</td></tr>
<tr><td>Evaluation Policy</td><td>Mid-Term
(26 Marks)</td><td>Continuous Assessment
(24 Marks)</td><td colspan="3">Final-Term
(50 Marks)</td></tr>
</table>

Course Objectives

The aim of the course is to provide basic knowledge of design parameters and their applications in the design of equipment such as pressure vessels, storage tanks, and tall towers used in the process industries along with the flanges and supports.

Course Outcomes (COs)

CO1.	Develop a foundational understanding of the mechanics of materials.	BTL 3
CO2.	Apply knowledge of pressure vessel codes in practical contexts.	BTL 3
CO3.	Analyze and construct the mechanical design of pressure vessels, tall towers, and storage tanks.	BTL 4
CO4.	Utilize knowledge of flanges and supports in design and applications.	BTL 3

Details of the Syllabus

Module No.	Contents	Hours
Module I	**Mechanics of Materials:** Stress, strain, biaxial stress, stress-strain relationship for elastic bodies, theories of failure, thermal stresses, membrane stresses in shells of revolution, thin and thick cylinder.	10
Module II	**Pressure Vessel:** Selection of type of vessels, material of construction selection and design considerations. Introduction of codes for pressure vessel design, classification of pressure vessels as per codes. Design of cylindrical and spherical shells under internal pressure; Pipe thickness calculation under internal pressure; Selection and design of closures and heads. Compensation of openings. Inspection and testing of pressure vessels.	12
Module III	**Flanges and Supports:** Selection of gaskets, selection of standard flanges, optimum selection of bolts for flanges, design of flanges. Design of lug, leg and saddle supports.	10
Module IV	**Tall Tower Design:** Design of shell used at high wind and seismic conditions. Introduction of bearing-plate and anchor bolts for tall tower. **Storage Tanks:** Classification of storage tanks; Filling and breathing losses; optimum length to diameter ratio, design of liquid storage tanks with and without floating roof.	10

Books Recommended

<table>
<tr><td rowspan="4">Text Books</td><td>1</td><td>Brownell, L. E., Young, H. E., “Process Equipment Design”, John Wiley (2004).</td></tr>
<tr><td>2</td><td>Bhattacharya, B. C., “Introduction of Chemical Equipment Design”, CBS Publisher (2003).</td></tr>
<tr><td>3</td><td>I.S.:2825-1969, “Code for Unfired Pressure Vessels”, (1969).</td></tr>
<tr><td>4</td><td>I.S.:803-1974, “Code of Practice for Design, Fabrication and Erection of Vertical Mild Steel Cylindrical Welded Oil Storage Tanks”, (1984).</td></tr>
<tr><td>Reference Books</td><td>1</td><td>Moss, D. R., "Pressure Vessel Design Manual”, 3rd Edn., Gulf (2004).</td></tr>
</table>

Chemical Reaction Engineering-II (CET-307)

<table>
<tr><td rowspan="3">Subject: Chemical Reaction Engineering-II (CET-307)</td><td colspan="2" rowspan="3">Year & Semester: B. Tech Chemical Engineering
3rd Year & 5th Semester</td><td colspan="3">Total Course Credit: 3</td></tr>
<tr><td>L</td><td>T</td><td>P</td></tr>
<tr><td>2</td><td>1</td><td>0</td></tr>
<tr><td>Evaluation Policy</td><td>Mid-Term
(26 Marks)</td><td>Continuous Assessment
(24 Marks)</td><td colspan="3">End-Term
(50 Marks)</td></tr>
</table>

Course outcomes (COs): Upon successful completion of the course, students will be able to:

CO1.	Derive the rate law and determine the surface area and pore size of catalyst.	BTL 4
CO2.	Design reactors for the homogenous and heterogeneous catalysed reactions, and understand their effect on performance equations of catalytic reactors.	BTL 6
CO3.	Determine the internal and overall effectiveness factors.	BTL 5
CO4.	Analyze the fluid particle reactions	BTL 4

Details of the Syllabus:

Module No.	Contents	Hours
Module I	**Catalytic reactors:** Catalysts, steps in a catalytic reaction, synthesizing a rate law, mechanism and rate limiting step, heterogeneous data analysis for reactor design, reactor design.	10
Module II	**Solid Catalysts**: Determination of surface area, void volume and solid density, pore volume distribution, theories of heterogeneous catalysis, classification of catalysts, catalyst preparation, promoter and inhibitors, catalysts deactivation.	10
Module III	**Internal and External Diffusions:** Internal diffusion: quantitative aspects of pore diffusion-controlled reactions (single cylindrical pore), effective diffusivity, mole balance for the elementary slice of catalyst pore, Thiele Modulus and internal effectiveness factor, overall effectiveness factor. External diffusion: Concept of external diffusion control, external resistance to mass transfer, mass transfer to a single particle, mass transfer limited reaction in a packed bed, shrinking core model (catalyst regeneration).	12
Module IV	**Fluid-Particle Reactions**: Selection of model, unreacted core model for spherical particles, diffusion through gas film control and diffusion through ash layer control, chemical reaction control, design.	10

Books Recommended:

Text books	**1.**	Fogler H.S., Elements of Chemical Reaction Engineering, PHI (2010).
	2.	Levenspiel O., Chemical Reaction Engineering, Wiley, India (2007).
	3.	Smith J.M., Chemical Engineering Kinetics, McGraw-Hill (1970).

Mass Transfer-I (CET-308)

<table>
<tr><td rowspan="3">Subject: Mass Transfer-1 (CET-308)</td><td colspan="2" rowspan="3">Year & Semester: B. Tech Chemical Engineering
3rd Year & 5th Semester</td><td colspan="3">Total Course Credit: 3</td></tr>
<tr><td>L</td><td>T</td><td>P</td></tr>
<tr><td>2</td><td>1</td><td>0</td></tr>
<tr><td>Evaluation Policy</td><td>Mid-Term
(26 Marks)</td><td>Continuous Assessment
(24 Marks)</td><td colspan="3">End-Term
(50 Marks)</td></tr>
</table>

Course Outcomes (COs):

CO1	Analyze the principles and applications of mass transfer operations	BTL 4
CO2	Acquire knowledge and apply principles of interphase mass transfer and mass transfer coefficients	BTL 3
CO3	Exhibiting basic understanding and analysis of gas absorption and understanding of equipment's used.	BTL 4
CO4	Analyze humidification and drying processes, including equipment knowledge and application to practical problems.	BTL 4

Details of the Syllabus

Module No.	Contents	Hours
Module I	**Principles of Mass Transfer, Steady and Unsteady States:** Molecular diffusion in fluids, diffusivities of fluids, applications of molecular diffusion- analogies and mass transfer coefficients in laminar flow, concepts of effective diffusivity. Eddy diffusion, mass transfer in turbulent flow, models of mass transfer operations.	12
Module II	**Interphase Mass Transfer:** Interphase mass transfer-diffusion between phases, two phases mass transfer coefficients, individual and overall coefficients, stage wise process. Concurrent and counter current processes.	10
Module III	**Gas Absorption:** Equilibrium relationships. Material balances for co-current and counter current multistage equipment. Dilute system. HETP, HTU and NTU individual and overall coefficients. Equipment: General characteristics of tray towers, efficiencies, wetted wall towers, packed towers, characteristics of packed towers, mass transfer coefficients in packed towers.	10
Module IV	**Humidification:** General theory, psychometric chart, fundamental concepts in humidification and dehumidification. Cooling towers and related equipment. **Drying:** Equilibria, drying rate curve definitions. Batch and continues drying. Mechanism of drying. Calculation of batch and continuous drying. Drying Equipments	10

Books Recommended

Text Books	**1.**	Unit Operation of Chemical Engineering, McCabe, W.L., Smith, J.C., McGraw-Hill (2011), 7th Edition
	2.	Mass Transfer Operations, Treybal R.E., McGraw-Hill, 1981, 3rd Edition.
	3.	Principles of Mass Transfer and Separation Processes, Binay K. Dutta, Prentice-Hall India, 2007, 2nd Edition.
	4.	Mass Transfer – Theory and Applications, K V Narayanan and B Lakshmikutty, CBS Publishers & Distributors pvt. ltd., 2014.
Reference books	**1.**	Mass Transfer and Separation Processes: Principles and Applications Basmadjian, D., CRC Press (2007).
	2.	Principles of Unit Operations, Foust, A. S., Wenzel, L. A., Clump, C. W., Maus, L., Andersen, L. B., Wiley-India (2008), 2nd Edition
	3.	Separation Process Principles, Ernest J. Henley, J. D. Seader, D. Keith Roper, Wiley, 2011, 3rd Edition.
	4.	Diffusion – Mass transfer in fluid systems, E. L. Cussler, Cambridge University Press, 2009, 3rd Edition.
	5.	Transport processes and Separation Process Principles, Geankoplis C.J., Prentice-Hall India, 2003, 4th Edition.

Biochemical Engineering (CET-309)

Subject: Biochemical Engineering (CET-309)	Year & Semester: B. Tech Chemical Engineering 3rd Year & 5th Semester		Total Course Credit: 3		
			L	T	P
			3	0	0
Evaluation Policy	Mid-Term (26 Marks)	Continuous Assessment (24 Marks)	End-Term (50 Marks)		

Course Outcomes (COs):

CO1	Develop fundamental understanding of the subject based on various conversion routes.	BTL 3
CO2	Acquire basic knowledge about microbiology and biochemistry.	BTL 3
CO3	Exhibit knowledge for analysis of the bioprocess and the Module operations used.	BTL 3
CO4	Able to analyze the data and their application for bioprocess development.	BTL 4

Details of the Syllabus:

Module No.	Contents	Hours
Module I	**Evolution of modern biochemical processes**. Role of biochemical engineer in the development of modern fermentation processes. Status of biochem. engg. in the fermentation industry.	12
Module II	**Types of Microorganism:** Bacteria, fungi, viruses, algae, protozoa. Cell types and structure (Eucaryotic and Procaryotic).	10
Module III	**Chemicals of Life:** Carbohydrates, fats, proteins, RNA and DNA (structure, uses and functions). Understanding Enzymes: Naming and classification, specificity of enzyme action, active cites, factors affecting enzyme-catalyzed reactions. Kinetics of enzyme-catalysed reactions (Michaelis-Menten equation and Lineweaver Burk Plot).	10
Module IV	**Sterilization.** Aerobic and anaerobic fermentation. Requirement for growth and media formation. Growth cycle phases for batch cultivation. Parameters of growth and analysis of growth data. Growth kinetics. Aeration and agitation. Scale-up. Bio-reactors. Bio separation processes.	10

Books Recommended

Text Books	**1.**	Shijie, L., "Bioprocess Engineering-Kinetics, Sustainability and Reactor Design", 2nd Edn., Elsevier (2017).
	2.	Shuler, M., Kargi, F., "*Bioprocess Engineering, Basic Concep*", 2nd Edn., Prentice Hall of India Pvt. Ltd. (2004).
	3.	Bailey, J. E., Ollis, D. F., "*Biochemical Engg. Fundamentals*", 2nd Edn., McGraw-Hill Book Company, New York (1985).
	4.	Paul A. Belter, E.L. Cussler, Wei-Shou Hu, "*Bioseparations, Downstream Processing for Biotechnology*", 2nd Edn., Wiley-India (1988).
Reference Books	**1.**	Pelczar, M.J., Chan, E.C.S., Krieg, N.R., "*Microbiology*", 5th Edn. McGraw-Hill Book Company (1986).
	2.	Fairley, J.L., Kilgour, G. L., "*Essentials of Biological Chemistry*", 2nd Edn., Van Nestrond Reinhold Publishing Corporation (1966).
	3.	Palmer, T., "*Understanding Enzymes*". Ellis Horwood Limited, Halsted Press, a division of John Wiley & Sons (1985).
	4.	Pirt, S.J., "Principles of Microbe and Cell Cultivation", 1stEdn., Blackwell Scientific Publications, 1975
	5.	McCabe, W., Smith, J. and Harriott, P., "Module Operations of Chemical Engineering", 7th Edn.McGraw-Hill (2017).

Heat Transfer Lab. (CEL-302)

<table>
<tr><td rowspan="3">Subject: Heat Transfer Lab. (CEL-302)</td><td rowspan="3">Year & Semester: B. Tech Chemical Engineering 3rd Year & 5th Semester</td><td colspan="3">Total Course Credit: 1</td></tr>
<tr><td>L</td><td>T</td><td>P</td></tr>
<tr><td>0</td><td>0</td><td>2</td></tr>
<tr><td>Evaluation Policy</td><td>Continuous Assessment
(60 Marks)</td><td colspan="3">Final-Term
(40 Marks)</td></tr>
</table>

Course outcomes (COs): Upon successful completion of the course, students will be able to:

CO1	Demonstrate the modes of heat transfer	BTL 3
CO2	Estimate the thermal conductivity of a composite slab and verify the Fourier's law of heat conduction	BTL 5
CO3	Evaluate the Heat transfer coefficient for Forced convection, Natural Convection and parallel and counter flow heat exchangers	BTL 5
CO4	Determine the emissivity of any body and verify Stefan Boltzmann's Law	BTL 5

List of Experiments (Total Contact hours:28)

S.No.	Name of the Experiment
1.	Study of Heat Transfer by Natural Convection
2.	Study of Heat Transfer by Forced Convection
3.	Study of Heat Transfer by Filmwise and Dropwise Condensation
4.	Determination of Thermal resistance and thermal conductivity of Composite Wall
5.	Determination of emissivity of a Grey Surface at different temperatures
6.	Performance study of Finned Tube Heat Exchanger
7.	Study of Heat Transfer in Shell and Tube Heat Exchanger

Books Recommended:

Text books	1.	McCabe W. L., Jullian Smith C. and Peter Harriott - Unit operations of Chemical Engineering, 7thEdn., McGraw-Hill international edition, 2005.
	2.	Theodore L. Bergman, Adrienne S. Lavine, Incropera F. P. and DeWitt. D. P - Fundamentals of Heat and Mass Transfer. 7th Edn., John Wiley and Sons, New York, 2011.
	3.	Holman. J. P - Heat Transfer. 10th Edn., McGraw–Hill, New York, 2010.
Reference books	1.	Cengel Y.A. and Ghajar A.J, Heat Transfer: A Practical Approach, 4th Edn., McGraw Hill, 2003.
	2.	Kern D. Q., Process Heat Transfer, 1st Edn., Tata McGraw Hill Education Pvt. Ltd., 2001.

Computer Simulation Laboratory (CEL-303)

Subject: Computer Simulation Laboratory (Code: CEL-303)	**Year & Semester: B. Tech Chemical Engineering 3rd Year & 5th Semester**	**Total Course Credit: 1**		
		L	T	P
		0	0	2
Evaluation Policy	Mid-Term/Class Assessment (50 Marks)	Final-Term (50 Marks)		

Course Objective: The objective of the lab is to introduce students to solving process simulation problems using software.

Course outcomes (COs): At the end of the course, students will be able to:

CO1	Utilize the basics of software	BTL 3
CO2	Model development of the chemical engineering process systems	BTL 3
CO3	Solve the model equations of individual equipment through simulation	BTL 3
CO4	Analyse and solve the Flow Sheeting problems	BTL 4

Details of the Syllabus (Total Contact hours:28)

A basic background in Numerical Methods and Chemical Engineering is expected, though all the key concepts required for the lab will be reviewed during the course of the semester. Basics of software, key computational techniques relevant to software and use them for simulation and analysis, Simulation of individual equipment and Simulation of flow sheets, and Simulation of case studies related to chemical engineering applications.

Books Recommended:

1.	Nayef Ghasem, "Modeling and Simulation of Chemical Process Systems", CRC Press, Taylor & Francis Group (2019).
2.	Amiya K Jana, "Chemical Process Modelling and Computer Simulation", 2nd Edition, PHI Learning Private Limited, (2011).
3.	http://courses.washington.edu/overney/ChemE435.html.

B. Tech Honours

Applied Mathematics for Chemical Engineers (MAT-021)

Subject: Applied Mathematics for Chemical Engineers (MAT-302)	Year & Semester: B. Tech Chemical Engineering 3rd Year & 5th Semester		Total Course Credit: 3		
			L	**T**	**P**
			2	1	0
Evaluation Policy	Mid-Term (26 Marks)	Continuous Assessment (24 Marks)	Final-Term (50 Marks)		

Pre-requisites: A student should have basic knowledge of calculus.

Course Outcomes: At the end of the course, the student will be able to:

CO1	Analyse the complex functions for continuity, differentiability and analyticity.	BTL 4
CO2	Solve the problems related to complex Integration	BTL 3
CO3	Solve problems related to series expansion of complex functions	BTL 3
CO4	Classify the singularities and calculation of residues of complex functions.	BTL 4

Detailed Syllabus:

Module No.	Contents	Hours
Module I	Function of a Complex variable, Limit, Continuity and Differentiability of complex function. Cauchy-Riemann Equations, Polar Coordinates, Analytic function, Harmonic functions and Properties of Analytic functions, Elementary function.	12
Module II	Derivatives of functions w(t), Definite Integrals of functions w(t), Contours and Contour Integrals, ML Theorem, Cauchy Integral Theorem, Antiderivatives and Definite Integrals.	10
Module III	Cauchy Integral Formula, Cauchy Integral formula for Derivatives, Evaluation of Improper Definite Integrals by Contour Integration, Liouville's Theorem and its consequences.	10
Module IV	Taylor Series, Laurant Series, Classification of Singularities, Residues, Cauchy's Residue Theorem and its Applications, Zeros of Analytic functions, Rouche's Theorem and its consequences.	10

Books Recommended:

Text books	1.	M. K. Jain, S. R. Iyengar & R.K. Jain, *Numerical Methods for Scientists and Engineering,* 7th Edition, Wiley Eastern Ltd New age international publishers, (2019).
	2.	J. W. Brown and R.V Churchill, Complex Variables and Applications, Eighth Edition, 2009, , Mc-Graw Hill International Edition
	3.	S. R. Iyengar & R.K. Jain, Advanced Engineering Mathematics, Third Edition, Narosa Pub. House, 2008.

6^{th} Semester

Process Equipment Design-II (Process Aspect) (CET-354)

<table>
<tr><td rowspan="3">Subject: Process Equipment Design-II (Process Aspect) (Code: CET-354)</td><td rowspan="3" colspan="2">Year & Semester: B. Tech Chemical Engineering 3rd Year & 6th Semester</td><td colspan="3">Total Course Credit: 3</td></tr>
<tr><td>L</td><td>T</td><td>P</td></tr>
<tr><td>2</td><td>1</td><td>0</td></tr>
<tr><td>Evaluation Policy</td><td>Mid-Term (26 Marks)</td><td>Continuous Assessment (24 Marks)</td><td colspan="3">Final-Term (50 Marks)</td></tr>
</table>

Course Objective: To design and analyze the process equipment of heat and mass transfer

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

CO1	Apply and classify the process equipment based on heat and mass transfer	BTL 3
CO2	Design and evaluate the double-pipe heat exchanger	BTL 6
CO3	Design and analyze the shell and tube heat exchanger	BTL 6
CO4	Design and examine the evaporator, Crystallizer	BTL 6

Details of the Syllabus:

Module No.	Contents	Hours
Module I	Process Design, Chemical equipment design, Concept of a chemical Industry, equipment to be designed, classification of heat and mass transfer equipment, classification of heat exchanger equipment, plate type heat exchanger, basic design parameters, Overall heat transfer coefficients, Dirt factor, mean temperature difference, F_T correction factor, temperature approach, and temperature cross. Double pipe Heat exchanger, series and parallel configuration of hairpins, over the surface and over design, Design procedure of double pipe heat exchanger, Pressure drop calculations.	12
Module II	Basic design procedure of Shell and Tube heat exchanger equipment, overall heat transfer coefficient and fouling factors, Scope of shell and tube heat exchanger, Classification of shell & tube heat exchangers, heat exchanger standards and codes, tube dimensions, tube arrangements, tube passes, shell diameter, shell arrangements, shell baffles, tube sheet, mean temperature difference, general design considerations, tube-side heat transfer coefficient and pressure drop, shell-side heat transfer coefficient and pressure drop, design methods.	10
Module III	Introduction to evaporation, Performance of evaporators, Capacity and Economy of the evaporators, Boiling point elevation, Types of evaporators, Operation of evaporators, Open cattle or Pan evaporator, Horizontal tube natural circulation evaporator, Vertical type natural circulation evaporator, Long tube vertical type evaporator, Falling film type evaporator, forced circulation type evaporator, Agitated film evaporator, Difference between rising and falling film evaporator, Methods of the feeding of evaporators, Material and energy balance of single effect evaporator, Design of multiple effect evaporator.	10
Module IV	Crystallization, Seven general crystal systems, the process of production of crystals, Saturation, and Supersaturation, solid-liquid phase equilibrium, Solubility curve, Nucleation and crystal growth, Primary nucleation, Homogeneous nucleation, Heterogeneous nucleation, secondary nucleation, Types and equipment of crystallizer, Design of Crystallizer.	10

Books Recommended:

Text Books	**1.**	Towler, G., Sinnott, R. K., "Chemical Engineering Design: Principles, Practice and Economics of Plant and Process Design", Butterworth-Heinemann (2012).
	2.	Process Heat Transfer, Donald Q. Kern, Tata McGraw-Hill Education, Indian Edition, 2017.
	3.	Brownell, L. E., Young, H. E., "Process Equipment Design", John Wiley (2004).
	4.	Bhattacharya, B. C., "Introduction of Chemical Equipment Design", CBS Publisher (2003).
Reference Books	**1.**	I.S.:2825-1969, "Code for Unfired Pressure Vessels", (1969).
	2.	I.S: 4503-1967, "Indian Standard Specification for Shell & Tube Type Heat Exchangers", (1983)
	3.	Hewitt, G.F., Shires, G. L., Bott T. R., "Process Heat Transfer", Begell House (1994).

Chemical Process Safety (CET-355)

Subject: Chemical Process Safety (CET-355)	Year & Semester: B. Tech Chemical Engineering 3rd Year & 6th Semester		Total Course Credit: 3		
			L	T	P
			2	1	0
Evaluation Policy	Mid-Term (26 Marks)	Continuous Assessment (24 Marks)	End-Term (50 Marks)		

Course outcomes (COs): Upon successful completion of the course, students will be able to:

CO1	Appraise the strategies for anticipation, recognition, investigation and evaluation of the hazardous conditions and practices which affect the masses, their properties and the environment.	BTL 5
CO2	Develop and evaluate appropriate strategies designed to mitigate risk by understanding the importance of plant safety and safety regulations, different types of plant hazards and their measurement, control, principles and procedures of safety audit.	BTL 6
CO3	Discuss the importance of physical, chemical and physico-chemical transformations of the material in process industries with respect to safety	BTL 3
CO4	Analyze the hazards and assess the risk and undertake appropriate preventive steps to address the need of safety.	BTL 4

Details of the Syllabus:

Module No.	Contents	Hours
Module I	**Introduction:** Introduction, safety program, engineering ethics, concept of loss prevention, acceptable risks, accident and loss statistics, nature of accident process, inherent safety, accident investigations-case histories	12
Module II	**Toxicology:** UN and other classification of chemicals, toxicants entry route, acute and chronic exposure effects, Dose versus response, models for dose and response curves, TLV and PEL, Industrial Hygiene.	10
Module III	**Basics of Fires and Explosion:** Fire triangle, definitions, flammability characteristics of liquid and vapours, LOC and inerting, types of explosions, Designs for fire prevention.	10
Module IV	**Hazard Identification:** Work permit systems, color coding of chemical pipelines, HAZCHEM Code, Hazard survey, checklist, HAZOP, safety reviews, what if analysis **Risk Assessment:** Probability theory, event tree, fault tree, QRA and LOPA, Dow's fire and explosion index, Mond's index, Dow's Chemical release model.	10

Books Recommended:

Text books	1.	D. A. Crowl and J.F. Louvar, Chemical Process Safety: Fundamentals with Applications, Prentice Hall, NJ 1990.
	2.	V.C. Marcel, Major Chemical Hazard, Ellis Hawood Ltd., Chi Chester, UK, 1987.
	3.	B. Skeleton, Process Safety Analysis, Institution of Chemical Engineers, U.K., 1997.
Reference books	1.	K.S.N. Raju, Chemical process Industry Safety, McGraw Hill Education Private Limited, India, 2014.
	2.	Roy E. Sanders, Chemical Process Safety learning from case histories, Butterworth-Heinemann, UK, 2015.

Process Dynamics and Control (CET-356)

Subject: Process Dynamics and Control (CET-356)	Year & Semester: B.Tech. Chemical Engineering 3rd year & 6th Semester		Total Course Credit: 3		
			L	T	P
			2	1	0
Evaluation Policy	Mid-Term (26 Marks)	Internal Assessment (24 Marks)	Final-Term (50 Marks)		

Pre-requisites: A student should have basic knowledge of the Laplace Transformations.

Course Outcomes: At the end of the course, the student will be able to:

CO1	Develop the basic control problem.	BTL 3
CO2	Determine the dynamics of a First order system.	BTL 5
CO3	Solve the dynamics of a Second order system.	BTL 3
CO4	Differentiate in between the dynamics of various controllers	BTL 4

Detailed Syllabus:

Module No.	Contents	Hours
Module I	Introductory concepts of process control. The chemical process industrial perspective of a typical process control problem, variables of a process. Use of Laplace transformation in control systems.	12
Module II	Feedforward, feedback systems, block diagrams. Linear open loop system transfer function. Derivation of the Transfer function and study of the transient response of a First Order system towards different inputs	10
Module III	Study of 1st order systems in series. Transfer function and Study of transient response and of 2nd order system. Study of parameters of 2nd order under damped response	10
Module IV	Components of a control system. Negative versus positive feedback. Study and behavior of different controllers, such as Proportional controllers, PD Controllers, and PID Controllers. Derivation of Closed loop transfer functions for physical systems. Transient response of simple control systems for Servo and Regulatory cases. Stability criterion, Routh test	10

Books Recommended:

Text books	**1.**	Coughanowr, D.R., LeBlanc, S., "Process System Analysis and Control", 3rd Edn., McGraw-Hill (2017).
	2.	Stephanopoulos G. "Chemical Process Control – An Introduction to Theory and Practice", 1st Edition, Prentice-Hall of India (2015).
	3.	Carlos A. Smith, Armando B. Corripio "Principles and Practices of Automatic Process Control, 3rd Edition, Wiley ,2023.
Reference books	**1.**	B.W. Bequette, Process Control: Modeling, Design and Simulation,1st Edition PHI, 2006.
	2.	S. Bhanot, Process Control: Principles and Applications, Oxford University Press, 1st Edition 2008.

Mass Transfer – II (CET-357)

Subject: Mass Transfer – II (CET-357)	B.Tech. Chemical Engineering 3rd year & 6th Semester		Total Course Credit: 3		
			L	T	P
			2	1	0
Evaluation Policy	Mid-Term (26 Marks)	Internal Assessment (24 Marks)	Final-Term (50 Marks)		

Course Objectives

The aim of the course is to provide fundamental knowledge of certain mass transfer operations – distillation, liquid-liquid extraction, adsorption and leaching, leading to the modelling and design of these processes by solving the operating equations and optimization of various design parameters.

Course Outcomes (COs)

CO1	Develop a fundamental understanding of distillation, design and thermodynamics involved, tray calculations for binary systems.	BTL 3
CO2	Analyze liquid-liquid equilibria, liquid systems, and perform stage-wise calculations for liquid extraction.	BTL 4
CO3	Analyze adsorption mechanisms and the operational equipment involved.	BTL 4
CO4	Analyze the leaching process, its stage-wise applications, and the equipment utilized.	BTL 4

Details of the Syllabus

Module No.	Contents	Hours
Module I	**Distillation:** Vapour-liquid equilibria, solutions deviation from ideality, Enthalpy concentration diagram, Flash vaporization, Partial condensation, Differential distillation for binary systems. Fractionation, McCabe-Thiele and Ponchon-Savarit methods for multistage operations, Reflux ratio and optimum reflux ratio. Reboilers. Total and partial condensers. Tray efficiencies and Azeotropic distillation	12
Module II	**Extraction:** Fields of usefulness, Liquid-Liquid equilibria, System of liquids with one and two pair possibility, Design calculation of single stage, multistage operations, Extraction equipment's	10
Module III	**Adsorption:** Adsorbents and its application, characteristics and properties, Equilibria, Selection, specific area of adsorbents, Adsorption equipment's, Adsorption operations for single and multi stages,	10
Module IV	**Leaching:** principles and Applications, continuous counter current Decantation process, classifier, Kennedy and Bollman extractor, Equilibria, single stage and multistage leaching.	10

Books Recommended:

Text Books	1	Mass Transfer Operations, Treybal R.E., McGrawHill, 1981, 3rd Edition.
	2	McCabe, W.L., Smith, J.C., Harriott, P., “Unit Operations of Chemical Engineering”, 7th Edn. McGraw-Hill Book Company (2011).
		Principles of Mass Transfer and Separation Processes, Binay K. Dutta, Prentice-Hall India, 2007, 2nd Edition.
	3	Heat and Mass Transfer, Yunus A. Cengel
	4	Mass Transfer – Theory and Applications, K V Narayanan and B Lakshmikutty, CBS Publishers & Distributors pvt. ltd., 2014.
Reference books	1.	Mass Transfer and Separation Processes: Principles and Applications Basmadjian, D., CRC Press (2007).
	2.	Principles of Unit Operations, Foust, A. S., Wenzel, L. A., Clump, C. W., Maus, L., Andersen, L. B., Wiley-India (2008), 2nd Edition
	3.	Separation Process Principles, Ernest J. Henley, J. D. Seader, D. Keith Roper, Wiley, 2011, 3rd Edition.
	4.	Diffusion – Mass transfer in fluid systems, E. L. Cussler, Cambridge University Press, 2009, 3rd Edition.
	5.	Transport processes and Separation Process Principles, Geankoplis C.J., Prentice-Hall India, 2003, 4th Edition.

Chemical Reaction Engineering Lab. (CEL-352)

Subject: Chemical Reaction Engineering Lab. (CEL-352)	**Year & Semester: B. Tech Chemical Engineering 3rd Year & 6th Semester**	**Total Course Credit: 1**		
		L	T	P
		0	0	2
Evaluation Policy	Continuous Assessment (60 Marks)	Final-Term (40 Marks)		

Course outcomes (COs): Upon successful completion of the course, students will be able to:

CO1	Demonstrate the performance of Batch, Plug flow and Mixed flow reactors	BTL 3
CO2	Determine the chemical kinetics of the given reaction by conducting experiments in a CSTR, batch and PFR	BTL 5
CO3	Compare theoretical and experimental conversions in a CSTR and PFR	BTL 4
CO4	Estimate RTD model parameters in packed bed and CSTR	BTL 6

List of Experiments

S.No.	Name of the Experiment
1.	Determination of the second order reaction rate constant for saponification reaction between NaOH and ethyl acetate in a plug flow reactor
2.	RTD Studies in CSTR using a pulse input
3.	Determination of the pseudo first order reaction rate constant for the saponification reaction in a constant volume isothermal batch reactor
4.	Determination of the pseudo first order reaction rate constant for the saponification reaction in a constant volume adiabatic batch reactor
5.	Study of a non-catalytic homogeneous second order liquid phase reaction in a CSTR under ambient conditions.
6.	RTD studies in Packed Bed Reactor

Books Recommended

Text books	1	Fogler H.S., Elements of Chemical Reaction Engineering, 5th Edn., PHI (2016).
	2	Levenspiel O., Chemical Reaction Engineering, 3rd Edn., Wiley, India (2006).
	3	Smith J.M., Chemical Engineering Kinetics, 2nd Edn., McGraw-Hill (1970).
Reference books	1.	E. Bruce Nauman., Chemical Reactor Design, Optimization and Scaleup, 2nd Edn., Wiley (2008).
	2.	Martin Schmal., Chemical Reaction Engineering: Essentials, Exercises and Examples, CRC Press, 1st Edn., (2014).

Mass Transfer Laboratory (CEL-353)

Subject: Mass Transfer Laboratory (CEL-353)	B.Tech. Chemical Engineering 3rd year & 6th Semester	Total Course Credit: 1		
		L	T	P
		0	0	2
Evaluation Policy	Total Marks (100) *Based on written examination and viva-voce. External examiner from the department to be nominated by H.O.D.			

Pre-requisites: None.

Course Objective: The purpose of the course is to impart fundamental understanding with respect to the experimental determination of physical parameters, such as diffusivity, heat and mass transfer coefficients, and their significance in mass transfer operations, and in chemical reactions.

Course Outcomes (COs): At the end of the course, the student will be able to:

CO1	Apply fundamental techniques for determining gas and liquid diffusivities.	BTL 3
CO2	Experimental determination of heat and mass transfer coefficients using wetted wall column.	BTL 3
CO3	Experimental determination of heat and mass transfer coefficients using cooling tower.	BTL 3
CO4	Create a drying rate curve using wet solids.	BTL 3

Details of the Experiments: (Total Contact hours:28)

Exp-I	To determine the diffusion coefficient of organic vapor in air.
Exp-II	To determine diffusivity of ionic salt in water at different temperatures.
Exp-III	To determine the mass transfer and heat transfer coefficient in wetted wall column.
Exp-IV	To determine effectiveness/efficiency and heat and mass transfer coefficient of cooling tower.
Exp-V	To produce drying rate curve for wet solid being dried with air of fixed temperature and humidity.

Books Recommended:

1.	Treybal, R.E., "Mass Transfer Operations" 3rd Edn., McGraw-Hill Book Company (1980).
2.	McCabe, W.L., Smith, J.C., Harriott, P., "Module Operations of Chemical Engineering", 7th Edn., McGraw-Hill Book Company (2011).
3.	Basmadjian, D., "Mass Transfer and Separation Processes: Principles and Applications", CRC Press (2007).
4.	Foust, A. S., Wenzel, L. A., Clump, C. W., Maus, L., Andersen, L. B., "Principles of Module Operations", 2nd Edn., Wiley-India (2008)

Industrial/Research Training & Presentation (CEI-350)

<table>
<tr><td rowspan="3">Subject: Industrial/Research Training & Presentation (CEI-350)</td><td rowspan="3">B. Tech. Chemical Engineering
3rd Year & 6th Semester</td><td colspan="3">Total Course Credit: 1</td></tr>
<tr><td>L</td><td>T</td><td>P</td></tr>
<tr><td>0</td><td>0</td><td>2</td></tr>
<tr><td colspan="5">Evaluation Policy (Total Marks: 100)</td></tr>
</table>

**Based on presentations by each of the students before a panel of examiners nominated by H.O.D with due weightage to the report submitted.*

Course Objective:
To gain practical experience in Industry or research organization.

Course Outcomes (COs): At the end of the course, students will be able to:

CO1	Correlate classroom learning to real industrial/research applications.	BTL 4
CO2	Development of written and oral communication skills.	BTL 6
CO3	Ability to be a multi-skilled engineer with good practical knowledge.	BTL 3
CO4	Development of management, leadership, and entrepreneurship skill	BTL 6

Seminar (CES-350)

Subject: Seminar (CES-350)	**B.Tech. Chemical Engineering 3rd year & 6th Semester**	**Total Course Credit: 1**		
		L	T	P
		0	0	2
Evaluation Policy Total Marks (100)				

*Based on presentations by each of the students before a panel of examiners nominated by H.O.D with due weightage to the report submitted

Course Outcomes: At the end of the course, the student will be able to:

CO1	Carry out up-to-date and effective literature study on a selected topic	BTL 4
CO2	Report writing and submission under the guidance of a faculty member of the Department	BTL 5
CO3	Enhancement in communication skills through seminar presentation	BTL 3
CO4	Able to find research gap of assigned topic	BTL 4

Details of the Syllabus

Each student in the batch will be assigned a topic pertaining to the Chemical Engineering field. He /she will carry out an up-to-date literature survey regarding the topic under the guidance of a faculty member. Evaluation will be carried out towards the end of the semester by a committee of faculty members nominated by the HOD. The evaluation will be based on

- i) Report writing (format and originality)
- ii) Presentation skill
- iii) Understanding and finding a solution to the problem/topic assigned.

B. Tech Honours

Membrane Science and Engineering (CET-022)

Subject: Membrane Science and Engineering (CET-358)	Year & Semester: B. Tech Chemical Engineering 3rd Year & 6th Semester		Total Course Credit: 3		
			L	T	P
			2	1	0
Evaluation Policy	Mid-Term (26 Marks)	Continuous Assessment (24 Marks)	End-Term (50 Marks)		

Objective: The course will enable students to develop necessary skills to design appropriate membrane-based separation technique as per the need.

Course outcomes (COs): Upon successful completion of the course, students will be able to:

CO1.	Develop expertise in membrane separation mechanisms, transport models, membrane types, modules, and their applications	BTL 6
CO2.	Develop skills in applying transport models for the calculation of membrane permeability, flux, and the extent of separation for various membrane separation systems.	BTL 3
CO3.	Be able to determine the types of experimental data needed for the calculation of membrane permeability parameters.	BTL 4
CO4.	To be able to calculate membrane process performance and analyze membrane separation characteristics.	BTL 4

Details of the Syllabus:

Module No.	Contents	Hours
Module I	Introduction to membranes, types of membranes, membrane processes, and applications.	12
Module II	General transport theories. Membrane preparation and their characterization.	10
Module III	Principles of various membrane processes such as reverse osmosis, microfiltration, ultrafiltration, dialysis, liquid membrane, pervaporation, etc.	10
Module IV	Applications of various membrane processes in different industries.	10

Books Recommended:

Text books	**1.**	Sun-Tak-Hwang and Karl Kammermeyer, "Membranes in Separations", John Wiley & Sons,
	2.	Coulson J.M. and Richardson J.F., "Chemical Engineering: Particle Technology and Separation Processes", Vol. 2, 4th Edition, Asian Books Pvt. Ltd. New Delhi, 1998.
	3.	Christie J. Geankoplis, "Transport Processes and Unit Operations", 4th Edition, Prentice Hall of India Pvt. Ltd., New Delhi, 2004.
Reference books	**1.**	Strathmann H., Giorno L. and Drioli E., "An Introduction to Membrane Science and Technology", Institute of Membrane Technology, CNR-ITM, University of Clabria, Italy, 2006.

7th semester

Pre-Project Work (CEP-401)

<table>
<tr><td rowspan="3">Subject: Pre-project work (CEP-401)</td><td colspan="2" rowspan="3">Year & Semester: B. Tech Chemical Engineering 4th Year & 7th Semester</td><td colspan="3">Total Course Credit: 2</td></tr>
<tr><td>L</td><td>T</td><td>P</td></tr>
<tr><td>0</td><td>0</td><td>4</td></tr>
<tr><td>Evaluation Policy</td><td>Mid-Term
(20 Marks)</td><td>Supervisor
(40 Marks)</td><td colspan="3">End-Term
(40 Marks)</td></tr>
</table>

*Based on presentations by each/group of the student(s) before a panel of examiners nominated by H.O.D as per UG manual as per the rubrics.

Course outcomes (COs): Upon successful completion of the course, students will be able to:

CO1	Survey the existing literature related to a particular research topic	BTL 4
CO2	Categorize and appraise the literature to find the research gaps	BTL 4
CO3	List the objectives of the research	BTL 4
CO4	Plan and develop the methods and conduct the research on the specific topic	BTL 6

Note: There is no course content fixed. The collection of information, survey and appraisal of the existing literature, finding the research gaps, defining the objectives and the procurement of materials including chemicals/software during the pre-project work shall be evaluated based on the quality of the report, presentations and viva-voice examination by the examiners as per UG manual.

Transport Phenomena (CET-410)

Subject: Transport Phenomena (CET-410)	Year & Semester: B. Tech. Chemical Engineering 4th year & 7th Semester		Total Course Credit: 3		
			L	T	P
			2	1	0
Evaluation Policy	Mid-Term (26 Marks)	Internal Assessment (24 Marks)	Final-Term (50 Marks)		

Course Outcomes: At the end of the course, the student will be able to:

CO1	To develop the Molecular Transport of momentum, mass and heat with emphasis on momentum transport by the use of vectors /tensors.	BTL 3
CO2	To generate the Momentum Transport by shell balance and Equations of Sate.	BTL 6
CO3	To determine the Energy Transport by shell Energy balance.	BTL 5
CO4	To evaluate the Mass Transport by some suitable examples.	BTL 5

Detailed Syllabus:

Module No.	Contents	Hours
Module I	**Introduction of Transport phenomena (Mass/Heat/Momentum).** Emphasing the transport momentum with in depth details of transport Newton's Law of Viscosity (Molecular Momentum) Transport) Momentum Flux. Generalization of Newton's Law of Viscosity. Vector and Tensor calculations	12
Module II	Shell Momentum Balances and Velocity Distributions in Laminar Flow, The Equations of Change for Isothermal Systems, The Equation of Continuity Normal Stresses at Solid Surfaces for Incompressible Newtonian Fluids, The Equation of Motion, The Bernoulli Equation for the Steady sate case Use of the Equations of Change to Solve Flow of Various typical cases	10
Module III	Shell Energy Balances and Temperature Distributions. Heat Conduction in various typical cases like a Nuclear Heat Source, Viscous Heat Source, Chemical Heat source and through Composite Walls etc.	10
Module IV	Mass Transport Diffusivity and the Mechanisms of Mass Transport Molecular Mass Transport Temperature and Pressure Dependence of Diffusivities Mass and Molar Transport by Convection Mass and Molar Fluxes Concentration Distributions in Solids and Laminar Flow Shell Mass Balances of some selected cases.	10

Books Recommended:

Text books	**1.**	Bird, R.B., Stewart, W.D., Lightfoot, E.W., "Transport Phenomena", 2nd Edn., John Wiley & Sons (2006).
	2.	Deen, W. M., "Analysis of Transport Phenomena", 2nd edition, Oxford University Press (2011).
	3.	Brodkey R. S. and Hershey H. C., "Basic Concepts of Transport Phenomena", Vol. 1 and 2nd dn. Brodkey Publishing (2001).
Reference books	**1.**	Convective Heat and Mass Transfer; Kays, Crawford, Weigand; 4th Edn. McGraw Hill (2017)
	2.	Boundary Layer Theory; Schlichting and Gersten; Ed. 9 Springer (2016)

Process Economics and Plant Design (CET-411)

<table>
<tr><td rowspan="3">Subject: Process Economics and Plant Design (CET-411)</td><td colspan="2" rowspan="3">B.Tech. Chemical Engineering
4th year & 7th Semester</td><td colspan="3">Total Course Credit: 3</td></tr>
<tr><td>L</td><td>T</td><td>P</td></tr>
<tr><td>2</td><td>1</td><td>0</td></tr>
<tr><td>Evaluation Policy</td><td>Mid-Term
(26 Marks)</td><td>Internal Assessment
(24 Marks)</td><td colspan="3">Final-Term
(50 Marks)</td></tr>
</table>

Course Objective: The objective of the course is to provide basic concepts in engineering economics, plant design, safety features and its importance for chemical engineering.

Course Outcomes (COs): At the end of the course, student will be able to:

CO1	Explanation of time value of money in process economics in terms of profit.	BTL 3
CO2	Assessment of cost estimation and various depreciation methodologies,	BTL 5
CO3	Apply various optimization techniques for plant design for analyzing cost and production.	BTL 3
CO4	Selection of site and plant location with layout and scale up of plant.	BTL 5

Details of the Syllabus:

Module No.	**Contents**	**Hours**
Module I	**Time Value of Money**: Interest and its related terms, Types of Interests: Simple, compound and continuous. **CFD:** Cash Flow Diagram and types with mathematical expressions. **Profitability:** Methods that do not consider time value of money and methods that consider time value of money, Annualized cost method. Inflation and its types, Favourable and unfavourable effects of inflation on profitability.	12
Module II	**Cost Estimation:** Capital Investment and classification, capitalized cost, Factors Affecting Investment and Production Costs, Cost indices, Estimation of Total Product Cost, Net Profit and Annual Cash Flow. **Depreciation:** Basic definitions and important terms, Straight Line Method, Declining Balance method, Double Declining Balance Method, Sum-of-the years-digit method, Sinking Fund Method.	10
Module III	**Optimum Design and Strategy:** Procedure with one, two and more variables; Optimum Production Rates in Plant Operation; Application of Lagrange Multipliers; Method of Steepest Ascent or Descent. Factors affecting economic design of plant.	10
Module IV	**Plant Location:** Factors for Selection of Plant Location; factor rating methods, cost-volume profit analysis. **Plant Layout**: Basics, objectives, determinants, principles, and types. **Pilot plant and Scale-Up:** Basics, objectives, requirements, **Similarity:** Principle of Similarity; Regime Concept: Static Regime, Dynamic Regime; Similarity Criteria.	10

Recommended Books:

Text Books	**1.**	Peters, M. S., Timmerhaus, K. D. and West, R. E., "Plant Design and Economics for Chemical Engineers", McGraw Hill, (2002).
	2.	Towler, G., Sinnott, R. K., "Chemical Engineering Design: Principles, Practice and Economics of Plant and Process Design", Butterworth-Heinemann, (2012).
	3.	Couper, J. R., "Process Engineering Economics (Chemical Industries)", CRC Press, (2003).
Reference Books	**4.**	Zlokarnik, M., "Scale-up in Chemical Engineering", Wiley-VCH, (2006).
	5.	Silla H., "Chemical Process Engineering: Design and Economics", Marcel Dekker (2003).

Process Dynamics and Control Laboratory (CEL-404)

<table>
<tr><td rowspan="3">Subject: Process Dynamics and Control Laboratory (CEL-404)</td><td rowspan="3">Year & Semester: B. Tech. Chemical Engineering 4th year & 7th Semester</td><td colspan="3">Total Course Credit: 1</td></tr>
<tr><td>L</td><td>T</td><td>P</td></tr>
<tr><td>0</td><td>0</td><td>2</td></tr>
<tr><td>Evaluation Policy</td><td>Continuous Assessment (60 Marks)</td><td colspan="3">Final-Term (40 Marks)</td></tr>
</table>

Pre-Requisites: Process Dynamics and Control

Course Outcomes: At the end of the course, the student will be able to:

CO1	Identify the dynamics of first order, second order, interacting and non-interacting processes	BTL 4
CO2	Implement PID controller on a level control, pressure control and temperature control trainer	BTL 3
CO3	Evaluate the characteristics of I-P and P-I converters	BTL 4
CO4	Determine control valve characteristics	BTL 4

List of Experiments: (Total Contact hours:28)

S. No.	Name of the Experiment
1.	Dynamics of non-interacting process
2.	Dynamics of interacting process
3.	Dynamics of first and second order processes
4.	Study the different types of temperature sensor for characteristics and time constants.
5.	Study the temperature control trainer
6.	Study the level control trainer
7.	Study the pressure control trainer
8.	Study the multi process control trainer
9.	Characteristics of I&P and P&I converters
10.	Control valve characteristics

Books Recommended

Text books	1.	Coughanowr D.R., Process System analysis and Control, McGraw Hill, 2012, 3rd Edition.
	2.	Jean-Pierre Corriou, Process Control: Theory and Applications, Springer, 2018. 2nd Edition.
	3.	Seborg, D. E., Edgar, T. F., Millechamp, D. A., Doyle III, F. J., Process Dynamics and Control, Wiley, 2014, 3rd Edition.
Reference books	1.	Raghunathan Rengaswamy, Babji Srinivasan, Nirav Pravinbhai Bhatt, Process Control Fundamentals: Analysis, Design, Assessment, and Diagnosis, CRC Press, 2020.
	2.	Bequette, B.W., Process Control: Modeling, Design and Simulation, 2007.

BIOCHEMICAL ENGINEERING LAB (CEL-405)

Subject: Biochemical Engineering Lab (CEL-405)	**B.Tech. Chemical Engineering 4th year & 7th Semester**	**Total Course Credit: 1**		
		L	T	P
		0	0	2
Evaluation Policy	Total Marks (100)			

Course Outcomes (COs)

CO1	Develop basic understanding of various equipments used in biochemical engineering lab.	BTL 3
CO2	Apply techniques with respect to sterilization, preparation of solid and liquid media, culture growth and preservation.	BTL 3
CO3	Methods to estimate biomass, substrate and product concentrations.	BTL 4
CO4	Generate and analyze data for design and development of bioprocess.	BTL 4

List of Experiments (Total Contact hours:28)

S.No.	Experiments
1.	Study the fundamentals of bioreactor, shaking incubator, spectrophotometer, HPLC, laminar flow chamber, autoclave, centrifuge. w.r.t. its construction, function (application) and principle of operation.
2.	To prepare basic solid media as agar slants and agar plates.
3.	Study of sterilization by application of a steam autoclave.
4.	Quantitative estimation of glucose concentration by DNS colorimetric method or by phenol-sulfuric acid method.
5.	Estimation of cell concentration.
6.	Determination of volumetric mass-transfer co-efficient of O_2 by static method.
7.	Determination of volumetric mass-transfer co-efficient of O_2 by dynamic method.
8.	To study the kinetics of alcohol (ethyl alcohol) fermentation by using baker's yeast (*Saccharomyces cerevisae*) in a batch bioreactor.

Books Recommended:

Text Books	**1.**	Shuler, M., Kargi, F., "*Bioprocess Engineering, Basic Concep*", 2nd Edn., Prentice Hall of India Pvt. Ltd. (2004).
	2.	Bhattacharya, R.N., "Experiments with Microorganisms", Emkay Publications, Delhi (1986).
	3.	Aneja, K.R., "Experiments in Microbiology, Plant Pathology, Tissue Culture and Mushroom Cultivation", VishwaPrakashan (New Age International (P) Limited), New Delhi (1996).
	4.	Experiments Handouts (Departmental)

B. Tech Honours

Risk Analysis and Hazards (CET-023)

Subject: Risk Analysis and Hazards (CET-412)	Year & Semester: B. Tech Chemical Engineering 4th Year & 7th Semester (Honors)		Total Course Credit: 3		
			L	T	P
			3	0	0
Evaluation Policy	Mid-Term (26 Marks)	Class Assessment (24 Marks)	End-Term (50 Marks)		

Course outcomes (COs): Upon successful completion of the course, students will be able to:

CO1	Analyze the risk, targets, contingencies and risk mitigation strategies.	BTL 4
CO2	Identify hazards and affects in chemical industries.	BTL 4
CO3	Develop the skills to estimate risks and apply a control measure hierarchy to control risks.	BTL 3
CO4	Assess and produce safe operational working procedure in industries and research laboratories.	BTL 5

Details of the Syllabus:

Module No.	Contents	Hours
Module I	Introduction, quantitative risk assessment, rapid risk analysis, comprehensive risk analysis, emission and dispersion, leak rate calculation, single- and two-phase flow dispersion model for dense gas, flash fire, plume dispersion, toxic dispersion model and evaluation of risk, radiation tank on fire flame length, radiation intensity calculation and its effect on plant, people and property, radiation VCE,	12
Module II	Overall risk analysis, generation of meteorological data, ignition data, population data, consequence analysis and total risk analysis, overall risk analysis, overall risk contours for different failure scenarios,	10
Module III	Disaster management plan, emergency planning, onsite and off, site emergency planning, risk management, ISO 14000, EMS models case studies, marketing terminal, gas processing complex, refinery.	10
Module IV	Hazard identification safety audits, checklist, 'what if' analysis, vulnerability models event tree analysis, fault tree analysis, hazard past accident analysis, Flixborough, Mexico, Madras, Vizag, Bhopal analysis, hazop guidewords, parameters, deviation, cause, consequences, recommendation, coarse hazop study, case studies, pumping system, reactor, mass transfer system.	10

Books Recommended:

Text books	1.	K.V. Raghavan and A.A. Khan, Methodologies in Hazard identification and assessment, Manual, CLRI publication 1990.
	2.	V.C. Marcel, Major Chemical Hazard, Ellis Hawood Ltd., Chi Chester, UK, 1987.
	3.	B. Skeleton, Process Safety Analysis, Institution of Chemical Engineers, U.K., 1997.
	4.	D. A. Crowl and J.F. Louvar, Chemical Process Safety: Fundamentals with Applications, Prentice Hall, NJ 1990.

Innovation Management (HST-024)

Subject: Innovation Management (HST-402)	Year & Semester: B. Tech Chemical Engineering, 4th Year & 7th Semester (Honors)		Total Course Credit: 3		
			L	T	P
			3	0	0
Evaluation Policy	Mid-Term (26 Marks)	Continuous Assessment (24 Marks)	End-Term (50 Marks)		

COURSE OUTCOMES:
After completing this course, the student must demonstrate the knowledge and ability to:

CO1	Demonstrate knowledge of the types and models of Innovation.	BTL 3
CO2	Analyze management tools for innovation.	BTL 4
CO3	Evaluate innovation radar and triggers of innovation.	BTL 4
CO4	Design patents using R&D and innovation tools.	BTL 6

Detailed Syllabus:

Module No.	Contents	Hours
Module I	Introduction to Innovation, Types of Innovation, Models of Innovation, Innovation Process, Managed Innovation, Innovation Diffusion Theory, Managing Innovation within Firms-Managing Uncertainty, Managing Project Portfolio.	12
Module II	Innovative Organizations- Management Tools for Innovation, Innovation and Operations, Management Design principles, Manufacturing Principles of Innovation.	10
Module III	Innovation radar- 360 Innovation, Supply Chain Innovation, Triggers of Innovation-Innovation Tools, Managing IP- Development of IP Strategy.	10
Module IV	Introduction to Patents, How to Evaluate and use Patents- "Freedom to Use" concept, how to handle Confidential Information, New approach to R&D Organizations and Innovation, Managing, R&D Project Portfolio.	10

Books Recommended:

Text books	1.	Maital, S., & Seshadri, D. V. R. (2012). Innovation management: Strategies, Concepts and Tools for Growth and Profit. SAGE Publications India.
	2.	Dodgson, M., Gann, D. M., & Phillips, N. (Eds.). (2013). The Oxford handbook of innovation management. OUP Oxford.
	3.	Goffin, K., & Mitchell, R. (2016). Innovation Management: Effective Strategy and Implementation. Macmillan International Higher Education.
	4.	O'Sullivan, D., & Dooley, L. (2008). Applying Innovation. SAGE publications.
Reference books	5.	McDonald, G. (2014). Business Ethics: A Contemporary Approach. Cambridge University Press.
	6.	Tushman, M. L., & Moore, W. L. (2008). Readings in the Management of Innovation. Ballinger Publishing Co/Harper & Row Publishers.

8th Semester

Project Work (CEP-450)

<table>
<tr><td rowspan="3">Subject: Project Work (CEP-450)</td><td colspan="2" rowspan="3">Year & Semester: B. Tech Chemical Engineering
4th Year & 8th Semester</td><td colspan="3">Total Course Credit: 6</td></tr>
<tr><td>L</td><td>T</td><td>P</td></tr>
<tr><td>0</td><td>0</td><td>12</td></tr>
<tr><td>Evaluation Policy</td><td>Mid-Term
(20 Marks)</td><td>Supervisor
(40 Marks)</td><td colspan="3">End-Term
(40 Marks)</td></tr>
</table>

*Based on presentations by each/group of the student(s) before a panel of examiners nominated by H.O.D as per UG manual and the rubrics.

Course outcomes (COs): Upon successful completion of the course, students will be able to:

CO1	Survey, appraise, and categorize the existing literature to find the research gaps and define the objectives	BTL 4
CO2	Apply the theoretical knowledge in conducting the research	BTL 3
CO3	Discuss and develop the models/set-ups/materials to enhance productivity to contribute to the sustainable development	BTL 6
CO4	Conclude the research findings in the form of a comprehensive report and defend the outcomes of the project	BTL 5

Note: No course content has been fixed. Based on a collection of information, survey, and appraisal of the existing literature on the specified research topic, finding the research gaps, defining the objectives the procurement of materials including chemicals/software during the pre-project work, the project work is carried out in the eighth semester by focusing mainly on the experimental/simulation/modeling part. The final evaluation is based on the quality of the report, presentations, and viva-voice examination by the examiners as per UG manual.

B. Tech Honours

Multi Component Distillation (CET-025)

Subject: MULTI COMPONENT DISTILLATION (CET-459)	Year & Semester: B. Tech Chemical Engineering 4th Year & 8th Semester (Honors)		Total Course Credit: 3		
			L	T	P
			2	1	0
Evaluation Policy	Mid-Term (26 Marks)	Continuous Assessment (24 Marks)	End-Term (50 Marks)		

Pre-requisites: Mass Transfer

Course Outcomes: At the end of the course, the student will be able to:

CO1	Solve the bubble point and dew point for multi-component mixture using K-values and relative volatility.	BTL 6
CO2	Examine the minimum reflux ratio, minimum no. of stages, feed tray location and distribution of key components.	BTL 4
CO3	Estimate the various design options for energy conservation in distillation column.	BTL 5
CO4	Design the multi-component distillation column.	BTL 6

Detailed Syllabus:

Module No.	Contents	Hours
Module I	Multi-component Distillation: Degrees of freedom in multi-component distillation, Key components, Column operating conditions, Approximate methods of distillation, The FUG technique, Fenske equation, The Underwood equation for minimum reflux. Gilliland correlation for the number of Trays. Separation of Azeotropic mixtures, Extractive distillation, Azeotropic distillation, Reactive distillation.	12
Module II	Separation processes: Separating agent, Categorizations of separation processes, Separation factor, Inherent separation factor. Equilibrium Processes: Vapor-Liquid system, Liquid-Liquid system, Liquid –Solid system, Multi-component systems, Equilibrium calculation, Phase conditions for a mixture. Analysis of simple equilibrium separation processes: Algebraic approaches and Graphical approaches.	10
Module III	Factors Influencing Product Purities: Entrainment, Washing, Leakage, Flow configuration and mixing effects, Co-current, Crosscurrent and Counter-current Flow. Multistage Separation Processes: Increasing product purity, Reducing consumption of separating agent.	10
Module IV	Design calculations: Design procedures for Multi-component mixtures, Azeotropic and extractive distillation, Distillation equipment, Plate and packed towers.	10

Books Recommended:

Text books	1.	Fundamentals of Multi-component Distillation, Holland, C. D., Mc-Graw-Hill, 1981.
	2.	Mass-Transfer Operations, Treybal, R. E., Mc-Graw-Hill, 1981, 3rd Edition.
	3.	Distillation design, H.Z. Kister, McGraw-Hill, 1992.
Reference books	1.	Perry's chemical engineer's handbook, Mc-Graw-Hill, USA, 2000, 7th Edition.
	2.	Introduction to Process Engineering & Design by S.B.Thakore & B.I. Bhatt. Tata Mc-Graw-Hill, 2007.
	3.	Separation Process Principles, Ernest J. Henley, J. D. Seader, D. Keith Roper, Wiley, 2011, 3rd Edition.

Heterogeneous Catalysis and Catalytic Processes (CET-026)

<table>
<tr><td rowspan="3">Subject: Heterogeneous Catalysis and Catalytic Processes (CET-460)</td><td colspan="2" rowspan="3">Year & Semester: B.Tech. Chemical Engineering
4th Year & 8th Semester (Honors)</td><td colspan="3">Total Course Credit: 3</td></tr>
<tr><td>L</td><td>T</td><td>P</td></tr>
<tr><td>3</td><td>0</td><td>0</td></tr>
<tr><td>Evaluation Policy</td><td>Mid-Term
(26 Marks)</td><td>Continuous Assessment
(24 Marks)</td><td colspan="3">Final-Term
(50 Marks)</td></tr>
</table>

Course Objectives

The focus of the course is to impart fundamental knowledge of heterogeneous catalysis, understanding of the deactivation kinetics, evaluation of transport processes involved in order to model and design catalysts and catalytic reactors for industrially important processes.

Course Outcomes (COs)

CO1.	Develop the understanding of basics of heterogenous catalysis, **i**ndustrially important catalysts and catalytic processes.	BTL 3
CO2.	Identification of the external transport processes governing the heterogenous catalytic reactions.	BTL 4
CO3.	Model and design of catalytic reactors.	BTL 6
CO4.	Utilize the chemistry governing catalytic processes to problems faced industrially, and solve them.	BTL 3

Details of the Syllabus

Module No.	Contents	Hours
Module I	Basic concepts in heterogeneous catalysis, catalyst preparation and characterization, poisoning and regeneration.	12
Module II	Industrially important catalysts and processes such as oxidation, processing of petroleum and hydrocarbons, synthesis gas and related processes.	10
Module III	Heat and mass transfer and its role in heterogeneous catalysis. Calculations of effective diffusivity and thermal conductivity of porous catalysts.	10
Module IV	Commercial reactors and reactor modeling. Chemistry and engineering aspects of catalytic processes along with problems arising in industry. Catalyst deactivation kinetics and modelling.	10

Books Recommended:

<table>
<tr><td rowspan="3">Text books</td><td>1.</td><td>Fundamental Concepts in Heterogenous Catalysis, J.K. Norskov, Felix Studt, Frank Abild-Pedersen and Thomas Bligaard, 1st edition, Wiley, 2014.</td></tr>
<tr><td>2.</td><td>Concepts of Modern Catalysis and Kinetics, I. Chorkendorff and J.W. Niemantsverdriet, 1st edition, Wiley, 2003</td></tr>
<tr><td>3.</td><td>Elements of Chemical Reaction Engineering, H. Fogler, 5th edition, Pearson Education, 2016</td></tr>
<tr><td rowspan="2">Reference books</td><td>1.</td><td>Chemical Reaction Engineering, Octave Levenspiel, 3rd edition, Wiley, 2016</td></tr>
<tr><td>2.</td><td>Catalytic Chemistry, Bruce C. Gates, 1st edition, Wiley, 1992</td></tr>
</table>

Advanced Computational Laboratory (CEL-027)

<table>
<tr><td rowspan="3">Subject: Advanced Computational Laboratory (Code: CEL-454)</td><td rowspan="3">Year & Semester: B. Tech Chemical Engineering 4th Year & 8th Semester</td><td colspan="3">Total Course Credit: 1</td></tr>
<tr><td>L</td><td>T</td><td>P</td></tr>
<tr><td>0</td><td>0</td><td>2</td></tr>
<tr><td>Evaluation Policy</td><td>Mid-Term/Class Assessment
(60 Marks)</td><td colspan="3">End-Term
(40 Marks)</td></tr>
</table>

Course Objective: Equip students with the advanced skills necessary to proficiently apply numerical methods, software tools, and simulation techniques in the analysis and optimization of chemical engineering processes, encompassing individual equipment simulations, flow sheet integration, and real-world case studies.

Course outcomes (COs): At the end of the course, students will be able to:

CO1.	Proficiently use the software for solving chemical engineering problems	BTL 3
CO2.	Apply computational methods to model and simulate complex chemical engineering processes	BTL 3
CO3.	Improve their skills in analyzing and visualizing data using computational tools	BTL 6
CO4.	Develop creative and critical thinking skills in approaching engineering challenges through computational methods	BTL 6

Details of the Syllabus (Total Contact hours:28)

Introduction to relevant software tools, Hands-on exercises for software proficiency, In-depth exploration of key computational techniques, Application of techniques to solve chemical engineering problems, Hands-on experience in simulating and analyzing individual chemical engineering equipment, Understanding the impact of different parameters on equipment performance, Integration of equipment simulations into comprehensive flow sheets, Analysis of system behavior and optimization strategies, Investigation of real-world case studies in chemical engineering, Application of simulation tools to solve complex engineering problems.

Books Recommended

1.	Nayef Ghasem, “Modeling and Simulation of Chemical Process Systems”, CRC Press, Taylor & Francis Group (2019).
2.	Amiya K Jana, “Chemical Process Modelling and Computer Simulation”, 2nd Edition, PHI Learning Private Limited, (2011).
3.	Mark E. Davis, “Numerical methods and modeling for Chemical Engineers”, Dover Publications, 1984
4.	William L Luyben, “Process Modeling, Simulation, and Control for Chemical Engineers, McGraw-Hill Publishing Company, International edition 1996
5.	http://courses.washington.edu/overney/ChemE435.html.

Instrumentation Laboratory (CEL-028)

Subject: Instrumentation Laboratory (CEL-455)	**Year & Semester: B.Tech. Chemical Engineering 4th Year & 8th Semester**	**Total Course Credit: 3**		
		L	T	P
		0	0	2
Evaluation Policy	Total Marks (100) *Based on written examination and viva-voce. External examiner from the department to be nominated by H.O.D.			

Course Outcomes: At the end of the course, the student will be able to:

CO1	Students will develop practical skills in using a wide range of instruments and equipment commonly found in industrial, scientific, and engineering settings.	BTL 3
CO2	Students will learn how to calibrate various instruments, ensuring accurate measurements and data collection.	BTL 3
CO3	Students will be proficient in collecting and analyzing data using instrumentation, including sensors and data acquisition systems.	BTL 3
CO4	Students will be able to process and interpret data obtained from instruments and use statistical methods for analysis. Understanding and practicing safety protocols in the laboratory to ensure the well-being of themselves and others.	BTL 4

Detailed Syllabus: (Total Contact hours:28)

Module No.	**Contents**	**Hours**
Module I	Introduction to Laboratory Safety and Protocols: Safety guidelines, emergency procedures, Laboratory equipment and their safe operation, Personal protective equipment (PPE)	12
Module II	Introduction to Common Measurement Instruments: Thermometers, Conductivity Measurement, pH meters, Pressure measurement, Heating tools, Oven, Furnace,	10
Module III	Introduction to Common Analytical Instruments: Spectroscopy: FTIR, UV Spectrophotometer, HPLC, Gas Chromatograph, etc.	10
Module IV	Calibration and Data acquisition Importance of calibration. Hands-on calibration exercises, Setup and configuration, Data acquisition and processing, Statistical analysis of data	10

Books Recommended:

Text books	1.	Skoog, Holler and Crouch, Principles of Instrumental Analysis, Brooks Cole, 6th edition, 2006.
	2.	Rouessac and Rouessac, Chemical Analysis: Modern Instrumentation Methods and Techniques, Wiley, 2nd edition, 2007.
	3.	Willard H.H., Merritt J.L., Dean, J.A., Settle, F.A., “Instrumental methods of analysis” CBS Publishers & Distributors Pvt. Ltd. 7th Edition, 2009.

Professional Electives

5th Semester

Operations Research (MAT-001)

Subject: Operations Research (MAT-001)	Year & Semester: B.Tech. Chemical Engineering 3rd year & 5th Semester		Total Course Credit: 3		
			L	T	P
			2	1	0
Evaluation Policy	Mid-Term (26 Marks)	Internal Assessment (24 Marks)	Final-Term (50 Marks)		

Pre-requisites: None.

Course Outcomes (COs): At the end of the course, the student will be able to:

CO1	Analyze the problem and provide its solution by using graphical method.	BTL 4
CO2	Determine the optimal solution of LPP by using simplex and dual simplex method.	BTL 4
CO3	Determine the solution of a transportation problem by various methods.	BTL 4
CO4	Solve the Assignment model by using Hungarian method.	BTL 6

Detailed Syllabus:

Module No.	Contents	Hours
Module I	Formulation of Linear Programming Problems, General Statement of LPP, Assumptions Underlying LP, Solution of Linear Programming Problems: Graphic Method. Some Special Cases of Graphic Method, Convex Set: Extreme points of Convex Set, Convex hull.	12
Module II	LP Model in Equation Form, Transition from Graphical to Algebraic Solution, Simplex Algorithm, Artificial starting solution: Big M-Method, Two-phase Method, Special cases in Simplex Method: Degeneracy, Alternative Optima, Unbounded solution, infeasible solution. Duality in LP, Primal-Dual Relationships, General Rules for Converting any Primal into its Dual, Optimal Dual Solution, Dual Simplex Method, Comparison of solutions to the primal and its Dual.	10
Module III	Mathematical Model of Transportation Problem, Methods of finding Initial basic feasible solution by NWC Rule, LCM, VAM, Test for optimality by Stepping Stone and MODI method, Balanced and Unbalanced Transportation Problems, Degeneracy.	10
Module IV	Assignment Model: Mathematical Model of Assignment Problem, The Hungarian Method, Simplex Explanation of the Hungarian Method.	10

Books Recommended:

Text Books	**1.**	Operations Research: An Introduction by Taha, H.A, Prentice Hall of India Private Limited, New Delhi.
	2.	Operations Research, An Introduction 10th Edition by Hamdy A Taha, PEARSON INDIA.
	3.	Operations Research: An Introduction 1st Edition by P Mariappan, Pearson India.
	4.	Operations Research 2nd Edition by A Tamilarasi and A M Natarajan, Pearson India.

Material Science and Technology (CET-002)

<table>
<tr><td rowspan="3">Subject: Material Science and Technology (CET-002)</td><td colspan="2" rowspan="3">Year & Semester: B.Tech. Chemical Engineering 3rd year & 5th Semester</td><td colspan="3">Total Course Credit: 3</td></tr>
<tr><td>L</td><td>T</td><td>P</td></tr>
<tr><td>2</td><td>1</td><td>0</td></tr>
<tr><td>Evaluation Policy</td><td>Mid-Term
(26 Marks)</td><td>Internal Assessment
(24 Marks)</td><td colspan="3">Final-Term
(50 Marks)</td></tr>
</table>

Pre-requisites: None.

Course Outcomes (COs): At the end of the course, the student will be able to:

CO1	Analyze the micro structure of crystalline materials like lattice systems, unit cells and theoretical density	BTL 4
CO2	Explain the concept of mechanical behavior of materials through calculations and appropriate equations along with their failure mechanics including corrosion.	BTL 5
CO3	Examine the concept of phase diagrams and their construction, usage and applications.	BTL 4
CO4	Build and analyze the heat treatment processes and their types involving solid state diffusion processes	BTL 3

Detailed Syllabus:

Module No.	Contents	Hours
Module I	**Introduction :** Properties of materials of importance to chemical equipment. Materials of construction for chemical industries (metallic and non-metallic). Principles of usage of materials. FCC, BCC, HCP crystal planes. Microscopic and macroscopic structure of metallic crystals. **Imperfection in crystals:** Point imperfection, line imperfection and surface imperfection.	12
Module II	**Failure of Materials:** Single phase metals, properties of single phase metals. Plastic deformation, re-crystallization. Plastic deformation of metal crystals, properties of plastically deformed metals, mechanism of slip. Creep, mechanized creep, ductile fracture, cleavage fracture, fracture in glass and theory of fracture, fatigue and mechanism of fatigue.	10
Module III	**Iron-Carbon Alloys:** Definition of alloys, Substitution and interstitial solid solutions, eutectic and eutectoid reactions, peritectic transformation, peritectic and pertectoid reaction, constituent diagram for iron-carbon system, time-temperature-transformation curves.	10
Module IV	**Inorganic Materials:** Ceramic, example of ceramic phases. Structure of silicates. Dielectric ceramic semiconductors. Mechanical behavior of ceramic materials. Introduction to Composite Materials **Corrosion:** Corrosion by solution, electrochemical oxidation. Electrode potential, galvanic couples. Types of galvanic cells. Corrosion prevention. Protective surfaces, avoidance of galvanic couples, use of galvanic protection. Use of organic, inorganic and metallic linings. **Polymers:** Structure, deformation, plastic deformation.	10

Books Recommended:

Text books	**1.**	William D. Callister, Jr. *" Material Science and Engineering, An introduction"* 8th Edn., (2010), John Wiley and Sons Inc
	2.	Raghavan, V., *" Materials Science and Engineering- A First Course",* 5th Edn., Prentice-Hall India (2009).
Reference Books	**3.**	Van Vlack, L.H., "*Elements of Material Science and Engineering*", 6th Edn., Pearson Education (1989).
	4.	D. R. Askaland, P.P Fulay, "*Essentials of Material Science & Engineering*" 2nd Edn., Cengage Learning (2009).

Cement Technology (CET-003)

Subject: Cement Technology (CET-003)	**Year & Semester: B.Tech. Chemical Engineering 3rd year & 5th Semester**		**Total Course Credit: 3**		
			L	T	P
			2	1	0
Evaluation Policy	Mid-Term (26 Marks)	Internal Assessment (24 Marks)	Final-Term (50 Marks)		

Course Outcomes: At the end of the course, the student will be able to:

CO1	Identify and analyze the various raw materials used in cement production, such as limestone, clay, shale, and iron ore. They should understand the chemical composition and properties of these materials.	BTL 4
CO2	Analyze and differentiate between various types of cement (e.g., Portland cement, blended cement), and understand their specific properties and applications.	BTL 4
CO3	Gain knowledge of the machinery and equipment used in cement manufacturing, including crushers, kilns, mills, and quality control instruments.	BTL 3
CO4	Have awareness of the environmental impact of cement production and be familiar with sustainable practices and technologies in the cement industry.	BTL 3

Detailed Syllabus:

Module No.	**Contents**	**Hours**
Module I	Introduction to Cement and cement manufacturing process: Cement and its importance in construction, History of cement and Cement manufacturing process, flow sheet & material composition of cement, various Module operation of cement manufacture, the present status and future of cement industry in India.	12
Module II	Types of Cement and their brief description and application. Calcareous Raw Materials: Source of Lime, Limestone, Chalk, Marl, Industrial waste, geological distribution of limestone deposits in India, Argillaceous Raw Materials: Source of Silica, Alumina, Iron Oxide, Shale and effect of coal ash and additives use as corrective materials, Fly ash, Slag, lime sludge as cement raw materials. Reactivity of Raw materials, Proportioning of Raw materials and preparation of kiln feed.	10
Module III	Pyroprocessing and clinker formation. Characterization of Portland Cement Clinker., Mineralizer, Role of additive in clinker formation, various mineralizer and fluxes, their role in manufacture of clinker. Properties of Cement Paste.	10
Module IV	Cement milling, Finess of cement, Setting times, workability, Compressive strength, Heat of hydration. Environmental impact of Cement manufacture. Air and Water emissions,	10

Books Recommended:

Textbooks	**1.**	Properties of concrete / A.M.Neville / Pearson 5th edition
	2.	Concrete Technology, (4th edition) by Gambhir, M.L., Tata McGraw-Hill, New Delhi, 2009.
	3.	Rao, M.G., Sittig, M., "*Dryden's Outlines of Chemical Technology- for the 21st Century.*East-West Press (1997).

Energy Technology (CET-004)

<table>
<tr><td rowspan="3">Subject: Energy Technology (CET-004)</td><td colspan="2" rowspan="3">Year & Semester: B.Tech. Chemical Engineering 3rd year & 5th Semester</td><td colspan="3">Total Course Credit: 3</td></tr>
<tr><td>L</td><td>T</td><td>P</td></tr>
<tr><td>2</td><td>1</td><td>0</td></tr>
<tr><td>Evaluation Policy</td><td>Mid-Term (26 Marks)</td><td>Internal Assessment (24 Marks)</td><td colspan="3">Final-Term (50 Marks)</td></tr>
</table>

Course Objectives

The aim of this course is to provide the fundamental knowledge regarding the utilization and characteristics of various energy resources available (natural or transformed) which usually pertain to Chemical Engineering field.

Course Outcomes (COs)

CO1.	Develop the fundamental understanding of solid, liquid and gaseous fuels and their properties.	BTL 3
CO2.	Inspect the various conventional energy sources.	BTL 4
CO3.	Analyze the governing stoichiometry, chemistry as well as thermodynamics of the combustion of fuels.	BTL 4
CO4.	Inspect the various non-conventional energy sources.	BTL 4

Details of the Syllabus

Module No.	Contents	Hours
Module I	Concept of solid, liquid and gaseous fuels, basic understanding of various properties: heating value, ultimate analysis, proximate analysis, heating value, density, specific gravity, viscosity, flash point, ignition temp, pour point, ash composition	12
Module II	Conventional energy sources and their utilization: Coal, petroleum, natural gas, syngas, LPG, refinery gas, producer gas, water gas. Combustion calculations of coal and petroleum fractions.	10
Module III	Non-conventional energy sources and their utilization: Geothermal energy, solar energy, wind energy, hydrogen energy, nuclear energy	10
Module IV	Generation of energy from biomass-based feedstock and wastes: biogas, landfill gas, biodiesel	10

Books Recommended:

Text books	1	Sarkar, S. “Fuel and Combustion” (2000).
	2	Griswold, J. , “Fuels, Combustion and Furnaces”
	3	Larry C White, “Industrial Energy Management & Utilization”
	4	Himus, G.W., “The Elements of Fuel Technology”

Polymer Science and Engineering (CET-005)

<table>
<tr><td rowspan="3">Subject: Polymer Science and Engineering (CET-005)</td><td colspan="2" rowspan="3">Year & Semester: B.Tech. Chemical Engineering 3rd year & 5th Semester</td><td colspan="3">Total Course Credit: 3</td></tr>
<tr><td>L</td><td>T</td><td>P</td></tr>
<tr><td>2</td><td>1</td><td>0</td></tr>
<tr><td>Evaluation Policy</td><td>Mid-Term
(26 Marks)</td><td>Internal Assessment
(24 Marks)</td><td colspan="3">Final-Term
(50 Marks)</td></tr>
</table>

Course Objective

To impart knowledge about polymers, polymerization reactions and their kinetics, polymerization processes, and the mathematical understanding with respect to the rheological behaviour of polymers

Course outcomes (COs): At the end of the course, student will be able to:

CO1	Analyze polymerization reactions and their kinetics	BTL 4
CO2	Critically evaluate various methods used for estimating molecular weight.	BTL 5
CO3	Identify key processes and principles involved in polymerization reactions.	BTL 3
CO4	Conceive understanding of mathematical expressions reflecting rheological behaviour of	BTL 3

Details of the Syllabus

Module No.	Contents	Hours
Module I	**Chemistry of Polymerisation Reaction:** Functionality, polymerization reactions, polycondensation, addition free radical and chain polymerization, copolymerization, block and graft polymerizations, stereo specific polymerization	12
Module II	**Polymerisation Kinetics:** Kinetics of radial, chain and ionic polymerization and copolymerisation systems.	10
Module III	**Molecular Weight Estimation:** Average molecular weight, number average and weight average, theoretical distributions, methods for the estimation of molecular weight.	10
Module IV	**Polymerisation Processes:** Bulk, solution, emulsion and suspension polymerization. Thermoplastic composites, fibre reinforcement fillers, surface treatment, reinforced thermoset composites-resins, fibers additives, fabrication methods. **Rheology:** Simple rheological equations, simple linear viscoelastic models-Maxwell, Voigt, materials response time, temperature dependence of viscosity.	10

Books Recommended:

Text books	1	Kumar, A., Gupta, R., “Fundamentals of Polymer Engineering”, CRC (2003).
	2	Fried, J., “Fundamentals of Polymer Science”, Prentice Hall (2004).
	3	Williams, D.J., “Polymer Science & Engg.” Prentice Hall (1971).
	4	Billmayer, Jr., W., “Textbook of Polymer Science” Wiley Tappers (1984).
	5	Rodriguez, F., “Principles of Polymer Systems”, 5thEdn., CRC Press (2003).

6th Semester

Industrial Pollution Abatement (CET-006)

Subject: Industrial Pollution Abatement (CET-006)	Year & Semester: B. Tech Chemical Engineering 3rd Year & 6th Semester		Total Course Credit: 3		
			L	T	P
			2	1	0
Evaluation Policy	Mid-Term (26 Marks)	Class Assessment (24 Marks)	End-Term (50 Marks)		

Course outcomes (COs): Upon successful completion of the course, students will be able to:

CO1.	Analyze the sources, effects and prevention of pollution and recycling of water and waste.	BTL 4
CO2.	Measure the industrial pollution.	BTL 5
CO3.	Design air pollution control systems from the principles of industrial pollution control.	BTL 6
CO4.	Apply the basic chemical engineering concepts in design of industrial wastewater treatment systems.	BTL 3

Details of the Syllabus:

Module No.	Contents	Hours
Module I	**Introduction:** Environment and environmental pollution from chemical process industries, characterization of emission and effluents, environmental Laws and rules, standards for ambient air, noise emission and effluents.	12
Module II	**Pollution Prevention:** Process modification, alternative raw material, recovery of by/co-products from industrial emissions/effluents, recycle and reuse of waste, energy recovery and waste utilization. Material and energy balance for pollution minimization. Water use minimization, Fugitive emission/effluents and leakages and their control-housekeeping and maintenance.	10
Module III	**Air Pollution Control:** Particulate emission control by mechanical separation and electrostatic precipitation, wet gas scrubbing, gaseous emission control by absorption and adsorption; Design of cyclones, ESP, fabric filters and absorbers.	10
Module IV	**Water Pollution Control:** Physical treatment, pre-treatment, solids removal by setting and sedimentation, filtration centrifugation, coagulation and flocculation. **Biological Treatment:** Anaerobic and aerobic treatment biochemical kinetics, trickling filter, activated sludge and lagoons, aeration systems, sludge separation and drying. **Solids Disposal:** Solids waste disposal – composting, landfill, briquetting / gasification and incineration.	10

Books Recommended:

Text books	**1.**	Tchobanoglous, G., Burton, F. L., Stensel, H.D., “Waste Water Engineering: Treatment and Reuse”, Tata McGraw Hill, (2003)
	2.	Vallero, D., “Fundamentals of Air Pollution”, Academic Press, (2007)
	3.	Eckenfelder W. W., “Industrial Water Pollution Control”, McGraw Hill, (1999)
Reference Books	**4.**	Kreith F. and Tchobanoglous G., “Handbook of Solid Waste Management”, Mc Graw Hill, (2002)
	5.	Pichtel, J., “Waste Management Practices: Municipal, Hazardous and Industrial”, CRC (2005)

Petroleum Refining (CET-007)

<table>
<tr><td rowspan="3">Subject: Petroleum Refining (CET-007)</td><td colspan="2" rowspan="3">Year & Semester: B.Tech. Chemical Engineering 3rd year & 6th Semester</td><td colspan="3">Total Course Credit: 3</td></tr>
<tr><td>L</td><td>T</td><td>P</td></tr>
<tr><td>2</td><td>1</td><td>0</td></tr>
<tr><td>Evaluation Policy</td><td>Mid-Term (26 Marks)</td><td>Internal Assessment (24 Marks)</td><td colspan="3">Final-Term (50 Marks)</td></tr>
</table>

Pre-requisites: None.

Course Outcomes (COs): At the end of the course, the student will be able to:

CO1	Develop a comprehensive understanding of crude oil production, properties, and characterization methods.	BTL 3
CO2	Identify various treatments processes associated with good quality petroleum.	BTL 4
CO3	Classify different fractionation processes and their best utilization.	BTL 4
CO4	Make use of refining processes pertaining to crude oil refinery engineering.	BTL 3

Detailed Syllabus:

Module No.	Contents	Hours
Module I	**Introduction:** Petroleum Industries: An overview, Crude oil, Properties and composition of Crude oil, Origin and occurrence of petroleum crude, Physical properties of petroleum.	12
Module II	**Crude Oil Distillation Processes:** Pretreatment of crude, atmospheric and vacuum distillation process, effects of crude characteristics and operating variables on Crude oil distillation. Processing of high TAN crude oil.	10
Module III	**Thermal Conversion Process:** Thermal Cracking Reactions, Thermal Cracking, Visbreaking, Coking Process, Delayed coking.	10
Module IV	**Catalytic Conversion Process**: Catalytic Conversion Process: Fluid Catalytic Cracking (FCC), Hydrocracking, Catalytic Reforming, Alkylation, Isomerization and Polymerization.	10

Books Recommended:

Text Books	**1.**	O.P. Gupta, "Elements of Petroleum Refinery Engineering", 2nd Edition, Khanna Publication, (2021).
	2.	Nelson W. L., "Petroleum Refinery Engineering" McGraw Hill. (1987).
	3.	Wauquier J. P., "Petroleum Refining 2 Separation Processes", Vol:1-5, (1998).
Reference Books	**4.**	Bhaskar Rao, B.K. "Modern Petroleum refining processes" Oxford &IBH Publishing Co Pvt. Ltd., (2005).
	5.	Meyers R. A., "Hand book of Petroleum Refining Processes", 3rd Ed., The McGraw-Hill Publication. (2004)

Instrumental Methods of Analysis (CET-008)

Subject: Instrument Method of Analysis (CET-008)	**Year & Semester: B.Tech. Chemical Engineering 3rd year & 6th Semester**		**Total Course Credit: 3**		
			L	T	P
			2	1	0
Evaluation Policy	Mid-Term (26 Marks)	Continuous Assessment (24 Marks)	Final-Term (50 Marks)		

Course Objective:
The aim of this course is to study the application of instrumental methods in qualitative and quantitative analysis.

Course Outcomes (COs): At the end of the course, student will be able to:

CO1	Selection of suitable instrumentation method for analysis.	BTL 5
CO2	Analyzing Spectrophotometry methods for evaluation of required results.	BTL 4
CO3	Analyze electrometric methods to achieve specific electrical outcomes.	BTL 4
CO4	Discuss qualitative analysis of radiometry methods with chromatography methods.	BTL 6

Details of the Syllabus:

Module No.	Contents	Hours
Module I	**Instrumentation:** Selection of suitable method, Sources of radiation, wavelength selectors, sample cells, Detectors-Photo tube, Photomultiplier tube, Photo voltaic cell, Silicon Photodiode.	12
Module II	**Spectrometric methods:** Spectrophotometry, Flourometry, emission spectroscopy, flame photometry and atomic absorption spectrometry.	10
Module III	**Electrometric methods:** Conductometry, Potentiometry, Polarography, Amperometry and Coulometry.	10
Module IV	**Radiometric methods:** Activation analysis and isotopic dilution. Gas chromatography (GC), High performance liquid chromatography (HPLC).	10

Books Recommended:

Text Books	**1.**	Lyalikov, Y., "*Problems in Physico Chemical Methods of Analysis*", Mir Publishers, (1974).
	2.	Howard, A., Strobel, William, R., Heineman, "*Chemical Instrumentation: A Systematic Approach.*", John Wiley & Sons, New York, (1989)
	3.	Robinson, J.W., "*Undergraduate Instrumental Analysis*,", Marcel Decker, New York, (1982)
Reference Books	**4.**	Ewing, G.W., "*Instrumental Methods of Chemical Analysis*", McGraw-Hill. New York, (1985).
	5.	Willard, H.H., Merritt, L.L., Dean, J.A., "*Instrumental Methods of Analysis*,Van Nostrand, (1981).

Clean Technology in Process Industries (CET-009)

<table>
<tr><td rowspan="3">Subject: Clean Technology in Process Industries (CET-009)</td><td colspan="2" rowspan="3">Year & Semester: B.Tech. Chemical Engineering 3rd year & 6th Semester</td><td colspan="3">Total Course Credit: 3</td></tr>
<tr><td>L</td><td>T</td><td>P</td></tr>
<tr><td>2</td><td>1</td><td>0</td></tr>
<tr><td>Evaluation Policy</td><td>Mid-Term (26 Marks)</td><td>Continuous Assessment (24 Marks)</td><td colspan="3">Final-Term (50 Marks)</td></tr>
</table>

Course Objectives This course aims to equip students with a comprehensive understanding of clean technology principles and their application in industrial processes.

Course Outcomes (COs): At the end of the course, the student will be able to:

CO1	Build an understanding of the importance of clean technology and critically evaluate conventional technologies in this context.	BTL 6
CO2	Select and apply alternate technologies to facilitate clean technology practices.	BTL 5
CO3	Develop strategies for process modification and waste minimization.	BTL 3
CO4	Utilize advanced technologies in the pursuit of clean industrial processes.	BTL 3

Details of the Syllabus

Module No.	Contents	Hours
Module I	**Introduction:** Environmental impact of chemicals and chemical production, life cycle assessment, waste minimization techniques, sustainable development.	12
Module II	**Evaluation of Conventional Technologies:** Evaluation of present process technologies for ammonia, sulphuric acid, caustic soda, pulp and paper, plastics and polymers synthesis. Analysis of raw materials, intermediates, final products, by-products and wastes.	10
Module III	**Minimization of water and heat consumption:** Process Integration and water pinch technology for minimizing water and heat consumption; data extraction, minimum fresh water target with and without reuse: limiting water profile, concentration-composite curve, concentration-interval diagram, block diagram, grid diagram, mass-content diagram, network design, network evolution: lop identification and loop breaking.	10
Module IV	**Process Modification and energy production from waste:** Process modification waste utilization and energy production from solid waste, recycling and reuse of solid waste management. **Advanced Technologies:** Development of biodegradable and end-products of polymers and plastics, CO_2 capture, sequestration and utilization.	10

Books Recommended:

<table>
<tr><td rowspan="3">Text Books</td><td>1</td><td>Jacob A. Moulijn, Michiel Makkee, Annelies E. van Diepen, “Chemical Process Technology”, John Wiley and Sons Ltd. (2013)</td></tr>
<tr><td>2</td><td>George T. Austin, “Shreve‟s Chemical Process Industries”, Tata McGraw Hill, (2012)</td></tr>
<tr><td>3</td><td>Gerard Kiely, “Environmental Engineering‟‟‟, Tata McGraw-Hill Education, 2007.</td></tr>
<tr><td rowspan="3">Reference Books</td><td>4</td><td>J. Mann, Y.A. Liu, “Industrial Water Reuse and Wastewater Minimization”, McGraw-Hill Professional”, (1999)</td></tr>
<tr><td>5</td><td>Mahmoud, M., Halwai,” Sustainable Design Through Process Integration: Fundamentals and Application to Industrial Pollution Prevention, Resource Conservation, and Profitability Enhancement”, Elsevier Science & Technology, (2011)</td></tr>
<tr><td>6</td><td>Roberto Solaro, Emo Chiellini, “Biodegradable Polymers and Plastics”, Springer, (2003)</td></tr>
</table>

7th Semester

Nano-Science and Technology (CET-011)

<table>
<tr><td rowspan="2">Subject: Nano-Science and Technology (CET-011)</td><td colspan="2" rowspan="2">Year & Semester: B.Tech. Chemical Engineering 3rd year & 7th Semester</td><td colspan="3">Total Course Credit: 3</td></tr>
<tr><td>L
2</td><td>T
1</td><td>P
0</td></tr>
<tr><td>Evaluation Policy</td><td>Mid-Term (26 Marks)</td><td>Continuous Assessment (24 Marks)</td><td colspan="3">Final-Term (50 Marks)</td></tr>
</table>

Course Outcomes: At the end of the course, the student will be able to:

CO1	Develop a comprehensive understanding of nanomaterial properties and applications.	BTL 3
CO2	Apply chemical engineering principles to nanoparticles production and scale-up.	BTL 3
CO3	Solve the quantum confinement equations and analyze the nanomaterials characterization.	BTL 4
CO4	State the applications of nanotechnology in electronics and chemical industries	BTL 3

Detailed Syllabus:

Module No.	Contents	Hours
Module I	**Introduction:** Nanotechnology and its historic perspective; Foundation of Nanotechnology in Chemistry, Physics and Biology; Nanostructures in Nature. Nano-scale Characterization Techniques: X-Ray Diffraction; Brunauer-Emmett-Teller (BET), Scanning Tunneling Microscopy (STM), Atomic Force Microscopy (AFM), Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM), Auger Electron Spectroscopy (AES), X-Ray Photo-electron Spectroscopy (XPS), Electron Energy Loss Spectroscopy (EELS).	12
Module II	**Nano-scale Manufacturing Techniques:** Bottom-up Approach: Sol-Gel Synthesis, Hydrothermal Growth, Thin-Film Growth, Physical Vapour Deposition, Chemical Vapour Deposition; Top-Down-Approach: Ball Milling, Micro-fabrication, Lithography, Ion-Beam Lithography.	10
Module III	**Properties of Nano-structures:** Crystal defects, surfaces and interfaces in nanostructures, ceramic interfaces, Super-hydrophobic surfaces; Thermodynamics of Nanostructures; Diffusion Kinetics; Properties: Optical, Emission, Electronic transport, Photonic, Refractive Index, Dielectric, Mechanical, Magnetic, Non-linear optical, Catalytic and Photo-catalytic.	10
Module IV	**Chemical Engineering Aspects:** Flow of Nano-fluids in Micro-channel; Heat Transfer from Nano-fluids: Convective and Radiative; Surface energy, Colloidal and Catalytic Behaviour of Nano-particles: Gold Nano-particles; Nano-particulate Suspensions; Membrane Nanotechnology; Nano-engineered Catalysts and Polymers; Nano-material Filters.	10

Books Recommended:

Text Books	**1.**	Rao, M. S. R., Singh, S., "Nanoscience and Nanotechnology: Fundamentals to Frontiers", Wiley India Pvt. Ltd. (2013)
	2.	Ashby, D. M., Ferreira, P., Schodek, D. L., "Nanomaterials, Nanotechnologies and Design: an Introduction to Engineers and Architects", Butterworth-Heinemann. (2009)
	3.	Bhushan, B., "Handbook of Nanotechnology", Springer,(2010)
Reference Books	**4.**	Minkowwycz, W. J., Sparrow, E. M., Abraham, J. P., "Advances in Numerical Heat Transfer: Nanoparticle Heat Transfer and Fluid Flow", Vol.4, Eds: CRC Press. (2013)
	5.	Ferry, D. K., Goodnick, S. M. and Bird, J., "Transport in Nanostructure", Cambridge University Press, 2nd Edition. (2009)

Microfluidics (CET-012)

Subject: Microfluidics (Code: CET-012)	Year & Semester: B. Tech Chemical Engineering 4th Year & 7th Semester		Total Course Credit: 3		
			L	T	P
			2	1	0
Evaluation Policy	Mid-Term (26 Marks)	Continuous Assessment (24 Marks)	Final-Term (50 Marks)		

Course Objective: Comprehensive understanding of microfluidics and its relevance to chemical engineering applications.

Course Outcomes (COs): At the end of the course, students will be able to:

CO1	Identify and discuss the fundamentals of microfluidics	BTL 4
CO2	Discuss fluid flow behavior in microchannels and microscale channels	BTL 6
CO3	Elaborate the fabrication techniques	BTL 6
CO4	Apply microfluidics in chemical engineering systems	BTL 3

Details of the Syllabus:

Module No.	Contents	Hours
Module I	Introduction to Microfluidics, Definition, and scope of microfluidics, Historical development, and applications, Importance in chemical engineering and broader scientific contexts	12
Module II	Microscale fluid behavior, Fluid flow in microchannels, Pressure, flow rate, and flow characteristics in microfluidic systems	10
Module III	Microfabrication techniques, photolithography, soft lithography, micro-machining techniques, polymer and glass microfabrication methods, etc.	10
Module IV	Applications of Microfluidics, Lab-on-a-chip technologies, Microreactors for chemical synthesis, Recent advancements in microfluidic technologies, Challenges and opportunities in the field of microfluidics, Potential impact on chemical engineering and related industries	10

Books Recommended

Text Books	**1.**	Microfluidics and Microscale Transport Processes by S. M. A. Salehizadeh and S. Whitaker, 1st edition, Springer, 2007
	2.	Microfluidics: Theory and Applications by Suman Chakraborty, 1st edition, CRC Press, 2019
	3.	Introduction to Microfluidics by Patrick Tabeling, 1st edition, Oxford University Press, 2005
Reference Books	**1.**	Microfluidics for Biological Applications by Stephen R. Quake and Todd Thorsen, 1st edition, Springer, 2016
	2.	Microfluidics: Fundamentals and Selected Applications by A. van den Berg, W. Olthuis, and P. Bergveld, 1st edition, CRC Press, 2005
	3.	Lab-on-a-Chip Technology: Fabrication and Microfluidics" by Soo-Ik Chang, 1st edition, Caister Academic Press, 2015

Advanced Separation Processes (CET-013)

Subject: Advanced separation Processes (CET-013)	Year & Semester: B.Tech. Chemical Engineering 3rd year & 7th Semester		Total Course Credit: 3		
			L	T	P
			2	1	0
Evaluation Policy	Mid-Term (26 Marks)	Continuous Assessment (24 Marks)	Final-Term (50 Marks)		

Course Objective:
The aim of this course is to study the basic concepts of some separation processes usually not covered in other core subjects

Course Outcomes (COs): At the end of the course, student will be able to:

CO1	Analysis and classification of novel separation techniques with selection criteria.	BTL 4
CO2	Analyze adsorption techniques for chemical process separation.	BTL 4
CO3	Utilization of various membrane separation processes with their suitable applications.	BTL 3
CO4	Discussion on some special novel separation processes to provide glance on advance level.	BTL 6

Details of the Syllabus:

Module No.	Contents	Hours
Module I	**Fundamentals:** Fundamentals of transport processes, Mechanism of separation, Selection of feasible separation processes, RIPP scheme, Separation factor, Equilibrium and rate governed separation processes.	12
Module II	**Separations by adsorption techniques:** Separation by adsorbents and foam separation. Foam fractionation techniques: Batch and continuous, Hydro-cyclones, Plate columns, Electro-static precipitators.	10
Module III	**Membrane separations:** Basics and Types of membranes, Applications, Membrane, Fundamentals of Dialysis, Microfiltration, Ultrafiltration, Nanofiltration & Reverse Osmosis, Liquid membrane separation.	10
Module IV	**Special Novel Separation Processes:** Gas Separation, Supercritical Extraction, Pressure Swing Adsorption, Crystallization, Flash Vaporization, Pervaporation and Permeation.	10

Recommended Books:

Text Books	**1.**	R. E. Treybal, Mass Transfer Operations, 3rd Ed., McGraw Hill, 1983
	2.	Ernest J. Henley, J. D. Seader Separation Process Principles, 2nd Edition" (2010)
	3.	Baker, R.W., *Membrane Technology and Applications*, 2nd ed., John Wiley 2004

Process Heat Integration (CET-014)

Subject: Process Heat Integration (CET-014)	Year & Semester: B.Tech. Chemical Engineering 3rd year & 7th Semester		Total Course Credit: 3		
			L	T	P
			2	1	0
Evaluation Policy	Mid-Term (26 Marks)	Internal Assessment (24 Marks)	Final-Term (50 Marks)		

Course Outcomes: Upon the successful completion of this course, the student will be able to:

CO1	Construct composite and grand composite grand curves	BTL 3
CO2	Evaluate the pinch point & determine the minimum heating and cooling requirements.	BTL 4
CO3	Explain the concept of the appropriate placement of distillation column, evaporator, heat engine and heat pump in a heat integration.	BTL 5
CO4	Design a heat exchanger network for the maximum energy recovery	BTL 6

Detailed Syllabus:

Module no.	Contents	Hours
Module I	**Process Integration and its Building Blocks:** Definition of Process Integration (PI), School of thoughts, Areas of application and Techniques available for PI, Onion diagram.	10
Module II	**Pinch Technology – An Overview:** Introduction, Basic concept, how it is different than energy auditing, Role of thermodynamic laws, Problem addressed by Pinch technology **Pinch Technology:** Data extraction, Targeting, Designing, Optimization-Super targeting. Grid diagram, Composite curve, Problem table algorithm, Grand composite curve. **Targeting of Heat Exchanger Network (HEN):** Energy targeting, Area targeting, Number of Modules targeting, Shell targeting, cost targeting.	12
Module III	**Designing of HEN:** Pinch design methods, Heuristic rules, Stream splitting, Design of maximum energy recovery (MER), Design of multiple utilities and pinches, Design for threshold problem, Loops and Paths.	10
Module IV	**Heat Integration of Equipments:** Heat engine, Heat pump, Distillation column, Reactor, Evaporator, Drier, Refrigeration systems. **Heat and Power Integration:** Co-generation, Steam turbine, Gas turbine.	10

Books Recommended:

Text Books	**1.**	Kemp I. C., “Pinch Analysis and Process Integration: A user Guide on Process Integration for the Efficient Use of Energy”, Butterworth-Heinemann. (2007).
	2.	Smith R.., “Chemical Process Design and Integration”, 2nd Ed., Wiley. (2005).
	3.	Shenoy U. V., “Heat Exchanger Network Synthesis”, Gulf Publishing Company (1995).
	4.	Halwagi, M. M., “Process Integration”, 7th Ed., Academic Press. (2006).

8th Semester
Environmental Engineering (CET-016)

<table>
<tr><td rowspan="3">Subject: Environmental Engineering (CET-016)</td><td colspan="2" rowspan="3">Year & Semester: B.Tech. Chemical Engineering 4th year & 8th Semester</td><td colspan="3">Total Course Credit: 3</td></tr>
<tr><td>L</td><td>T</td><td>P</td></tr>
<tr><td>2</td><td>1</td><td>0</td></tr>
<tr><td>Evaluation Policy</td><td>Mid-Term
(26 Marks)</td><td>Internal Assessment
(24 Marks)</td><td colspan="3">End-Term
(50 Marks)</td></tr>
</table>

Course Outcomes: At the end of the course, the student will be able to:

CO1	Realize the importance of ecological engineering in addressing the issues and challenges in environmental management	BTL 3
CO2	Apply technology to manage ecosystems efficiently by understanding the essential workings of natural ecological systems	BTL 3
CO3	Understand and develop the mathematical concepts and models to use for the environmental systems such as wetlands, lakes, reservoirs etc.	BTL 6
CO4	Ability to introduce environmental friendly materials in the built environment.	BTL 5

Detailed Syllabus:

Module No.	**Contents**	**Hours**
Module I	Environmental disturbances, interaction of systems, public awareness and action, Microbiology & Epidemiology (Fundamentals, Water borne diseases and water quality, Airborne diseases, inorganic and organioc concentrations, safe limits). Changing role of Technology (Sustainable Development, Preventive Technology).	12
Module II	Particle dispersion (Particle shape & size, Colloidal dispersion, methods of expressing particle concentrations) Solutions: Solubility, Methods of expressing the concentration of solutions, Acid-base reactions. Gases and gaseous mixtures: Concept & calculations of material balance in environmental problems,	12
Module III	Quantification of Environmental Issues: Environmental impact, Environmental effect of energy development, Extreme events and Environmental change, Greenhouse effect & Ozone depletion, Acid rain. Environmental Chemistry	10
Module IV	Solid Waste and its characteristics, Considerations in solid waste management, Conversion of MSW, Hazardous waste and its disposal, Treatment & disposal of leachate.	8

Books Recommended:

<table>
<tr><td rowspan="2">Text Books</td><td>1.</td><td>Environmental Science and Engineering, Second Edition, J. Glynn Henry, Gary W. Heinke. Pearson Education, Inc.</td></tr>
<tr><td>2.</td><td>Introduction to Environmental Engineering and Science, Gilbert M. Masters. Pearson Education, Inc.</td></tr>
</table>

Computational Fluid Dynamics (CET-017)

<table>
<tr><td rowspan="3">Subject: Computational Fluid Dynamics (CET-017)</td><td colspan="2" rowspan="3">Year & Semester: B. Tech Chemical Engineering 4th Year & 8th Semester</td><td colspan="3">Total Course Credit: 3</td></tr>
<tr><td>L</td><td>T</td><td>P</td></tr>
<tr><td>2</td><td>1</td><td>0</td></tr>
<tr><td>Evaluation Policy</td><td>Mid-Term
(26 Marks)</td><td>Class Assessment
(24 Marks)</td><td colspan="3">Final-Term
(50 Marks)</td></tr>
</table>

Course Objective: To learn the fundamental concepts of computational fluid dynamics along with basic numerical techniques and discretization techniques using Finite difference method.

Course outcomes (COs):

CO1.	Fundamental understanding and interpretation of governing equations involved in heat and fluid flow problems.	BTL 5
CO2.	Develop a thorough understanding of fundamental numerical techniques.	BTL 3
CO3.	Developing an understanding of grid formation.	BTL 3
CO4.	Developing an understanding of discretization technique's using FDM.	BTL 3

Details of the Syllabus

Module No.	**Contents**	**Hours**
Module I	**Basic Concepts of Fluid Flow**: Philosophy of computational fluid dynamics (CFD), review of equations governing fluid flow and heat transfer, simplified flow models such as incompressible, inviscid, potential and creeping flow.	12
Module II	**Overview of numerical methods:** understanding of numerical methods involved like Gauss-Seidel, Rungekutta and Crank Nicolson method**.**	10
Module III	**Grid Generation**: Structured and unstructured grids, choice of suitable grid, Grid transformation of equations, Grid Independence test.	10
Module IV	**Finite Difference Method (FDM):** Discretization of ODE and PDE, approximation for first, second and mixed derivatives, implementation of boundary conditions, discretization errors, applications to the engineering problems.	10

Books Recommended:

Text Books	**1.**	Ghosh, P.S., "Computer Simulation of Flow and Heat Transfer", Tata McGraw-Hill (1998).
	2.	Patankar, S.V., "Numerical Heat Transfer and Fluid Flow", Taylor and Francis (2004).
	3.	Fletcher, C.A.J., "Computational Techniques for Fluid Dynamics, Vol. 1: Fundamental and General Techniques", Springer-Verlag (1998).
Reference Books	**4.**	Fletcher, C.A.J., "Computational Techniques for Fluid Dynamics, Vol. 2: Specific Techniques for Different Flow Categories", Springer-Verlag (1998).
	5.	Anderson, J.D., "Computational Fluid Dynamics", McGraw Hill (1995).

Modeling & Simulation of Chemical Process Systems (CET-018)

<table>
<tr><td rowspan="3">Subject: Modeling & Simulation of Chemical Process Systems (Code: CET-018)</td><td colspan="2" rowspan="3">Year & Semester: B. Tech Chemical Engineering 4th Year & 8th Semester</td><td colspan="3">Total Course Credit: 3</td></tr>
<tr><td>L</td><td>T</td><td>P</td></tr>
<tr><td>2</td><td>1</td><td>0</td></tr>
<tr><td>Evaluation Policy</td><td>Mid-Term (26 Marks)</td><td>Class Assessment (24 Marks)</td><td colspan="3">Final-Term (50 Marks)</td></tr>
</table>

Course Objective: To provide adequate information to the modeling of chemical engineering process systems and familiarize the numerical simulation of model equations.

Course Outcomes (COs): At the end of the course, students will be able to:

CO1	Identify and discuss the basic concepts involved in modeling and simulation	BTL 4
CO2	Analyse conservation of mass, momentum, and energy equations to engineering problems	BTL 4
CO3	Develop model equations for chemical engineering systems	BTL 6
CO4	Solve the model equations and chemical engineering problems using numerical techniques	BTL 3

Details of the Syllabus:

Module No.	**Contents**	**Hours**
Module I	**Introduction**: Introduction to process modeling and simulation, terminology of Process modeling and simulation, Steps for building a mathematical model, Inventory rate equation of the conserved quantities, Mathematical formulation of the conserved quantities (Mass, Momentum and Energy equations), Molecular and Convective Transport.	12
Module II	**Rate of generation term and steady state macroscopic balance:** Rate of Generation in Momentum, Energy and Mass Transfer, Steady-State Macroscopic Balances, comparison of microscopic and macroscopic balances, steady state macroscopic balance problem solving using least square method.	10
Module II	**Unsteady state macroscopic balance:** Building blocks of unsteady state macroscopic balance, Pseudo-Steady-State-Approximation, Conservation of Chemical Species, Momentum, Energy and total Mass, Unsteady state Energy balance around a Continuous Stirred Tank, unsteady state macroscopic balance problem solving using Euler's method.	10
Module IV	**Modeling of chemical process systems:** Models, need of models and their classification, models based on transport phenomena principles, alternate classification of models, Continuous Stirred Tank Reactor (CSTR) with constant holdup, Continuous Stirred Tank Reactor (CSTR) with Variable holdup, Two Heated Tank, Gas phase Pressurized CSTR, Multi-Component Flash Drum, Gravity Flow Tank, Non-isothermal CSTR, Ideal Binary Distillation Column, Batch reactor.	10

Books Recommended

Text Books	**1.**	Luyben, W. L., "Process Modeling, Simulation and Control for Chemical Engineers". McGraw Hill (1990).
	2.	Nayef Ghasem, "Modeling and Simulation of Chemical Process Systems", CRC Press, Taylor & Francis Group (2019).
	3.	Ismail Tosun, Modeling in Transport Phenomena – A Conceptual Approach, 2nd Edn, Elsevier Publications 2007.
Reference Books	**1.**	Davis M.E., Numerical Methods and Modeling for Chemical Engineers, Wiley, New York, 1984
	2.	Ashok Kumar Verma, Process Modelling and Simulation in Chemical, Biochemical and Environmental Engineering, CRC Press, Taylor & Francis Group (2015).
	3.	Amiya K Jana, "Chemical Process Modelling and Computer Simulation", 2nd Edition, PHI Learning Private Limited, (2011).

Bioresource Technology (CET-019)

<table>
<tr><td rowspan="3">Subject: Bioresource Technology (CET-019)</td><td colspan="2" rowspan="3">Year & Semester: B.Tech. Chemical Engineering 3^{rd} year & 8^{th} Semester</td><td colspan="3">Total Course Credit: 3</td></tr>
<tr><td>L</td><td>T</td><td>P</td></tr>
<tr><td>2</td><td>1</td><td>0</td></tr>
<tr><td>Evaluation Policy</td><td>Mid-Term
(26 Marks)</td><td>Internal Assessment
(24 Marks)</td><td colspan="3">Final-Term
(50 Marks)</td></tr>
</table>

Course Objective:
The aim of this course is to provide fundamental knowledge for bioenergy generation and product formation with the help of various conversion processes adequate to diverse bioresource characteristics.

Course Outcomes (COs):

CO1	Fundamental understanding of the bioresources and its applications for attainment of social objectives (energy, environment, product, sustainability).	BTL 3
CO2	Develop knowledge with respect to the properties of the bioresources and the conversion technologies.	BTL 3
CO3	Exhibit knowledge of the systems used for bioresource technology.	BTL 3
CO4	Analysis of data and their applications in design of the systems and development of the bioprocess.	BTL 4

Details of the Syllabus:

Module No.	**Contents**	**Hours**
Module I	Bioresources- natural and anthropogenic; importance of bio-resources and their utilization. Natural bio-resources: agricultural, forestry and aquatic biomass. Biomass availability, production and food security, non- edible biomass characteristics. Anthropogenic bio-resources: Organic wastes-domestic and industrial; characteristics of municipal sewage / sludge and industrial sludges.	12
Module II	Conversion processes: biochemical, thermo-chemical and physico-chemical conversion processes. Biochemical processes: Microbial anaerobic and aerobic processes, enzymatic processes; fermentation for alcohols and acids; penicillin and other therapeutic products. Production of single cell protein (SCP); bio-pulping, biogasification. Thermo-chemical processes: pyrolysis (coke and pyro-oils), oxidation-combustion, gasification (downdraft, updraft and fixed bed gasification, fluidized bed and entrained bed gasification). Various methods of manufacture of activated carbons	10
Module III	Physico-chemical processes: Pretreatment, steam/acid/alkali hydrolysis, effect of temperature on hydrolysis.	10
Module IV	Special topics: biofuels, biomaterials, specialty chemicals (gylcol, acetic acid and downstream chemicals), anhydrous alcohols-ethanol and butanol; biodiesel, bio-aviation turbine fuel (BATF).	10

Books Recommended:

Text Books	**1.**	Shuler, M., Kargi, F., "*Bioprocess Engineering, Basic Concep*", 2^{nd} Edn., Prentice Hall of India Pvt. Ltd. (2004).
	2.	Chakraverty, A., "*Biotechnology and other Alternative Technologies*", Oxford and IBH Publishing Co. Pvt. Ltd. (1995).
	3.	Rao, M.G., Sittig, M., "*Dryden's Outlines of Chemical Technology- for the 21stCentury.*East-West Press (1997).
	4.	Austin, G.T., "*Shreve's Chemical Process Industries*", McGraw-Hill Book Company (1984).
Reference Books	**1.**	Pandey, A., "*Concise Encyclopaedia of Bioresource Technology*", CRC Press (2004).
	2.	Glaucia, M.S. et al. (eds), "Bioenergy & Sustainability: Bridging the Gaps", SCOPE 72, Universidade de São Paulo, Brazil (2015).
	3.	Eckert & Trihn (eds), " Biotechnology for Biofuel Production and Optimization", Elsevier (2016).
	4.	Cock, "Encyclopedia of Life Support Systems (EOLSS)", UNESCO, (2011)
	5.	S. Van Loo, "Handbook of Biomass Combustion and Co-Firing", Twente University Press, 2002.
	6.	Wang, W.C. et al., " Review of Biojet Fuel Conversion Technologies", National Renewable Energy Laboratory (USDE), Technical Report, 2016.

Fuel Cell Technology (CET-020)

<table>
<tr><td rowspan="3">Subject: Fuel Cell Technology (CET-020)</td><td colspan="2" rowspan="3">Year & Semester: B. Tech Chemical Engineering
4th Year & 8th Semester</td><td colspan="3">Total Course Credit: 3</td></tr>
<tr><td>L</td><td>T</td><td>P</td></tr>
<tr><td>1</td><td>1</td><td>0</td></tr>
<tr><td>Evaluation Policy</td><td>Mid-Term
(26 Marks)</td><td>Continuous Assessment
(24 Marks)</td><td colspan="3">End-Term
(50 Marks)</td></tr>
</table>

Course Outcomes

CO1	Develop a comprehensive understanding of fuel cell technology in modern energy applications.	BTL 3
CO2	Analyzing the working and applications of various fuel cells.	BTL 4
CO3	Developing an understanding of the thermodynamic and kinetic aspects of fuel cell systems.	BTL 3
CO4	Assessment of various fuel cells by several characterization techniques.	BTL 5

Details of Syllabus

Module No.	Content	Hours
Module I	Introduction: Fuel cell definition, Fuel cells versus batteries, type of fuel cell, basic fuel cell operation, fuel cell performance, advantages and disadvantages of fuel cell, overview of fuel cell system, fuel cell stack, thermal management subsystem, fuel delivery and processing subsystem, hydrogen storage, generation and delivery	12
Module II	Working principle and application: Phosphoric acid fuel cell (PAFC), polymer electrolyte membrane fuel cell (PEMFC), alkaline fuel cell (AFC), molten carbon fuel cell (MCFC), solid- oxide fuel cell (SOFC), performance characterization of fuel cell system.	10
Module III	Fuel cell thermodynamics: Thermodynamic potential, heat potential of a fuel, enthalpy of reaction, temperature dependency of enthalpy, working potential of fuel, relationship between Gibbs free energy and electrical work, relationship between Gibbs free energy and voltage, standard electrode potential, reversible voltage variation of reversible voltage with temperature, pressure and concentration, real and ideal fuel cell efficiency.	10
Module IV	Reaction kinetics in fuel cell: Electrode kinetics, electrochemical reaction, heterogeneous electrochemical process, current rate, current amount and current density, activation energy in current transfer reaction, net rate of reaction calculation, potential and rate: Butler-Volmer equation, how to improve kinetic performance, catalyst electrode design. Transport in fuel cell system: Ion transport in an electrolyte, electron transport, gas-phase mass transport, diffusive transport in electrode, convective transport in flow structures.	10

Books Recommended:

Text Books	**1.**	Ohayre, R.P., Cha Suk-Won, Colella, W. G., Prinz, F. B., "*Fuel Cell*
	2.	*Fundamentals*", John Wiley & Sons Inc. (2009).
	3.	Larminie J., Dicks A., *Fuel Cell System Explained*", John Wiley & Sons (2003).
Reference Books	**4.**	Mench M. M., "*Fuel Cell Engines*", John Wiley & Sons Inc. (2008).
	5.	Zhao, T.S.; Kreuer, K.D., "*Advances in Fuel cells*", Elsevier (2007).
	6.	Linden, D., "*Handbook of Batteries and Fuel Cells*", McGraw-Hill (1984).