NATIONAL INSTITUTE OF TECHNOLOGY WARANGAL

B.Tech. in
CHEMICAL ENGINEERING

SCHEME OF INSTRUCTION AND SYLLABI

(Effective from 2021-22)

DEPARTMENT OF CHEMICAL ENGINEERING

Vision and Mission of the Institute

National Institute of Technology Warangal

VISION

Towards a Global Knowledge Hub, striving continuously in pursuit of excellence in Education, Research, Entrepreneurship and Technological services to the society

MISSION

- Imparting total quality education to develop innovative, entrepreneurial and ethical future professionals fit for globally competitive environment.
- Allowing stake holders to share our reservoir of experience in education and knowledge for mutual enrichment in the field of technical education.
- Fostering product-oriented research for establishing a self-sustaining and wealth creating centre to serve the societal needs.

Vision and Mission of the Department

Department of Chemical Engineering

VISION

To attain global recognition in research and training students for meeting the challenging needs of chemical & allied industries and society.

MISSION

- Providing high quality undergraduate and graduate education in tune with changing needs of industry.
- Generating knowledge and developing technology through quality research in frontier areas of chemical and interdisciplinary fields.
- Fostering industry-academia relationship for mutual benefit and growth.

Department of Chemical Engineering:

Brief about the Department:

The department was started in the year 1964 and since then it has come a long way in educating budding chemical engineers and scholars. The department celebrated its Golden Jubilee in 2014-15. The department is operating in a new building spanning around 8000 sq. m with ample space in class rooms and laboratories since 2018. The building of the department with green ambience having aesthetic landscaping and gardening has secured first place based on its architectural elegance.

The department of Chemical Engineering offers B.Tech., M.Tech. andPh.D programs. The department has well qualified faculty dedicated to teaching and doing research in fundamental and advanced areas. The department houses various laboratories catering to the needs of the curriculum. The Department has good experimental as well as simulation based research facilities. The faculty are actively engaged in industrial consultancy and sponsored research projects. The department has inked MoUs with some of the leading industries and Universities in India and abroad. The graduating students are absorbed into reputed firms through campus placements and good number of students are going for higher studies. The department aims at inculcating lifelong learning skills in the students. The alumni of the department are shouldering high positions in multifarious organizations.

Both B.Tech. and M.Tech. programs in Chemical Engineering have been fully accredited for 5 years by National Board of Accreditation (NBA) in June 2015.

List of Programs offered by the Department:

Program	Title of the Program
B.Tech.	Chemical Engineering
M.Tech.	Chemical Engineering
M.Tech.	Systems and Control Engineering
PG Diploma	Systems and Control Engineering
Ph.D.	Chemical Engineering

Note: Refer to the following weblink for Rules and Regulations of B.Tech. program:
https://www.nitw.ac.in/media/uploads/2021/08/27/btech_rules-and-regulations-2021-22.pdf

B.Tech. – Chemical Engineering

Program Educational Objectives

PEO-1	Apply theoretical knowledge and experimental skills of basic sciences, mathematics and program core to address challenges faced in chemical engineering and allied areas.
PEO-2	Execute chemical engineering projects to improve quality of life.
PEO-3	Analyze issues related to energy, environment and safety.
PEO-4	Demonstrate effective communication, management and leadership skills.
PEO-5	Carry out cradle to grave analysis of chemical processes

Program Articulation Matrix

PEO / Mission Statements	PEO1	PEO2	PEO3	PEO4	PEO-5
Providing high quality education in tune with changing needs of industry.	3	3	3	3	3
Generating knowledge and developing technology through quality research in frontier areas of chemical and interdisciplinary fields.	3	2	2	-	-
Fostering industry-academia relationship for mutual benefit and growth.	-	2	-	3	2

1-Slightly; **2-Moderately;** **3-Substantially**

B.Tech. – Chemical Engineering

Program Outcomes

PO-1	Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and chemical engineering to the solution of complex engineering problems.
PO-2	Problem analysis: Identify, formulate, research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
PO-3	Design/Development of solutions: Design solutions for complex chemical 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.
PO-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.
PO-5	Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modelling to complex chemical engineering activities with an understanding of the limitations.
PO-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 chemical engineering practice.
PO-7	Environment and sustainability: Understand the impact of the chemical engineering solutions in societal and environmental contexts, and demonstrate the knowledge of and need for sustainable development.
PO-8	Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
PO-9	Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
PO-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.
PO-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.
PO-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

PSO-1	Apply the knowledge of unit operations and unit processes for designing a chemical plant.
PSO-2	Analyze the processes & equipment using conservation and phenomenological laws, reaction kinetics, thermodynamics, process control, economics for sustainable environment
PSO-3	Develop mathematical models& simulation tools to design and/or optimize Chemical Processes

SCHEME OF INSTRUCTION

B.Tech. Chemical Engineering – Course Structure

I - Year, I – Semester

S. No.	Course Code	Course Title	L	T	P	Credits	Cat. Code
1	HS132	English for Technical Communication	2	0	2	3	HSC
2	MA134	Matrix Theory, Calculus And Ordinary Differential Equations	3	0	0	3	BSC
3	BT131	Biology for Chemical Engineering	2	0	0	2	ESC
4	CE101	Engineering Mechanics	3	0	0	3	ESC
5	CY132	Chemistry	3	0	0	3	BSC
6	EE132	Basic Electrical &Electronics Engineering	3	0	0	3	ESC
7	ME135	Workshop Practice for Chemical Engineering	0	0	3	1.5	ESC
8	IC001	MNC-1 (Induction Program) *	-	-	-	0	MNC
9	IC101	MNC-2 (EAA) *	0	0	2	0	MNC
		Total	**16**	**0**	**7**	**18.5**	

* MNC weblink: https://www.nitw.ac.in/media/uploads/2021/10/22/mnc_1st-year.pdf

I - Year, II – Semester

S. No.	Course Code	Course Title	L	T	P	Credits	Cat. Code
1	MA184	Integral Calculus and Laplace Transforms	3	0	0	3	BSC
2	PH185	Physics for Chemical Engineering	2	0	2	3	BSC
3	CY181	Industrial Organic Chemistry	3	0	0	3	BSC
4	CS181	Problem Solving & Comp Programming	3	0	2	4	ESC
5	ME133	Engineering Drawing	0	1	2	2	ESC
6	MM186	Materials Science & Engineering	3	0	0	3	ESC
7	CY182	Chemistry Laboratory	0	0	3	1.5	BSC
8	IC151	MNC-3 (EAA) *	0	0	2	0	MNC
		Total	**14**	**1**	**11**	**19.5**	

* MNC weblink: https://www.nitw.ac.in/media/uploads/2021/10/22/mnc_1st-year.pdf

Note: BSC – Basic Science Courses
ESC – Engineering Science Courses
HSC – Humanities and Social Science Courses
MNC – Mandatory Non-credit Courses

SCHEME OF INSTRUCTION

B.Tech. Chemical Engineering – Course Structure

II - Year, I – Semester

S. No.	Course Code	Course Title	L	T	P	Credits	Cat. Code
1	MA236	Partial Differential Equations, Statistics and Numerical Methods	3	0	0	3	BSC
2	CH201	Chemical Process Calculations	3	0	0	3	PCC
3	CH202	Fluid and Particle Mechanics	3	0	0	3	PCC
4	CH203	Mechanical Operations	3	0	0	3	PCC
5	CH204	Chemical Engineering Thermodynamics – I	3	0	0	3	PCC
6	CH205	Chemical Reaction Engineering – I	3	0	0	3	PCC
7	CH206	Chemical Processing Laboratory	0	1	2	2	PCC
8	CH207	Fluid and Particle Mechanics Laboratory	0	0	3	1.5	PCC
9	ICXXX	MNC-4 *	1	0	0	0	MNC
		Total	**19**	**1**	**5**	**21.5**	

II - Year, II – Semester

S. No.	Course Code	Course Title	L	T	P	Credits	Cat. Code
1	CH251	Chemical Engineering Thermodynamics-II	3	0	0	3	PCC
2	CH252	Heat Transfer	3	0	0	3	PCC
3	CH253	Mass Transfer-I	3	0	0	3	PCC
4	CH254	Chemical Reaction Engineering – II	3	0	0	3	PCC
5	CH255	Process Instrumentation	3	0	0	3	PCC
6	CH256	Chemical Technology	3	0	0	3	PCC
7	CH257	Industrial Safety and Hazard Mitigation	3	0	0	3	PCC
8	CH258	Heat Transfer Laboratory	0	0	3	1.5	PCC
9	CH259	Chemical Reaction Engineering Laboratory	0	1	2	2	PCC
		Total	**21**	**1**	**5**	**24.5**	

* MNC weblink: https://www.nitw.ac.in/media/uploads/2021/10/22/mnc_2nd-year.pdf

Note: BSC – Basic Science Courses
PCC – Professional Core Courses
MNC – Mandatory Non-credit Courses

SCHEME OF INSTRUCTION

B.Tech. Chemical Engineering – Course Structure

III - Year, I – Semester

S. No.	Course Code	Course Title	L	T	P	Credits	Cat. Code
1	CH301	Mass Transfer – II	3	0	0	3	PCC
2	CH302	Elements of Transport Phenomena	3	0	0	3	PCC
3	CH303	Process Equipment Design (Open Book)	3	0	0	3	PCC
4	CH304	Pollution Control in Process Industries	3	0	0	3	PCC
5	CH3XX	Elective-1	3	0	0	3	PEC
6	CH3XX	Elective-2	3	0	0	3	PEC
7	MA336	Scientific Computing With Python & R	2	0	2	3	ESC
8	CH305	Mass Transfer Laboratory	0	0	3	1.5	PCC
9	CH306	Computational Methods in Chemical Engineering Lab	0	1	2	2	PCC
		Total	**20**	**1**	**7**	**24.5**	

III - Year, II – Semester

S. No.	Course Code	Course Title	L	T	P	Credits	Cat. Code
1	CH351	Process Dynamics and Control	3	0	0	3	PCC
2	CH352	Chemical Process Optimization	3	0	0	3	PCC
3	CH353	Petroleum Refining Processes	3	0	0	3	PCC
4	CH3XX	Elective-3	3	0	0	3	PEC
5	CH3XX	Elective-4	3	0	0	3	PEC
6		Open Elective-1 #	3	0	0	3	OEC
7	CH354	Design and Simulation Laboratory	0	1	3	2.5	PCC
8	CH355	Minor Research Project	0	0	2	1	PCC
9	ICXXX	MNC-5 *	1	0	0	0	MNC
		Total	**19**	**1**	**5**	**21.5**	

* MNC weblink: https://www.nitw.ac.in/media/uploads/2021/10/22/mnc_3rd-year.pdf

OEC weblink: https://www.nitw.ac.in/media/uploads/2021/10/22/open-elective-1_vi-sem.pdf

Note: ESC – Engineering Science Courses
PCC – Professional Core Courses
PEC – Professional Elective Courses
OEC – Open Elective Courses

SCHEME OF INSTRUCTION

B.Tech. Chemical Engineering – Course Structure

IV - Year, I – Semester

S. No.	Course Code	Course Title	L	T	P	Credits	Cat. Code
1	SM436	Industrial Engineering & Management	3	0	0	3	HSC
2	CH401	Process Engineering Economics	3	0	0	3	PCC
3	CH402	Process Integration	3	0	0	3	PCC
4	CH4XX	Elective-5	3	0	0	3	PEC
5		Open Elective-2 *	3	0	0	3	OEC
6	CH403	Process Instrumentation and Control Laboratory	0	1	2	2	PCC
7	CH449	Summer/Research Internship/EPICS Project	-	-	-	2	PCC
		Total	**15**	**1**	**2**	**19.0**	

OEC weblink: https://www.nitw.ac.in/media/uploads/2021/10/22/open-elective-2_vii-sem.pdf

IV - Year, II – Semester

S. No.	Course Code	Course Title	L	T	P	Credits	Cat. Code
1	CH4XX	Elective-6	3	0	0	3	PEC
2	CH4XX	Elective-7	3	0	0	3	PEC
3	CH498	Seminar	0	0	2	1	SEM
4	CH499	Project Work @	0	0	8	4	PW
		Total	**6**	**0**	**10**	**11.0**	

@ **NOTE: Refer to the following link for the guidelines to prepare dissertation report:**
https://www.nitw.ac.in/media/uploads/2021/08/27/ug_project-report-format_55vW5pL.pdf

Note: PCC – Professional Core Courses
PEC – Professional Elective Courses
OEC – Open Elective Courses
HSC – Humanities and Social Science Courses
SEM – Seminar
PW – Project Work

Credits in Each Semester									
Cat. Code	**Sem-I**	**Sem-II**	**Sem-III**	**Sem-IV**	**Sem-V**	**Sem-VI**	**Sem-VII**	**Sem-VIII**	**Total**
BSC	6	10.5	3	-	-	-	-	-	19.5
ESC	9.5	9	-	-	3	-	-	-	21.5
PCC	-	-	18.5	24.5	15.5	12.5	10	-	81
PEC	-	-	-	-	6	6	3	6	21
OEC	-	--	-	-	-	3	3	-	6
HSC	3	-	-	-	-	-	3	-	6
MNC									
SEM	-	-	-	-	-	-	-	1	1
PW	-	-	-	-	-	-	-	4	4
Total	**18.5**	**19.5**	**21.5**	**24.5**	**24.5**	**21.5**	**19.0**	**11.0**	**160**

Mandatory Non-Credit Courses	
Course Code	**Course**
MNC-1	Induction Program
MNC-2	Sports and Games
MNC-3	Each audit course content is expected to be worth of 2 credits. Courses like Indian Constitution,Design Thinking,Programming Languages, Indian Culture and Art, History of Science and Technology,Environmental Science, IPR, Professional Ethics, Human Values, CommunicationSkills, Foreign/Indian Languages, Entrepreneurship, etc.
MNC-4	
MNC-5	

Cat Code	**Description**
BSC	Basic Science Courses
ESC	Engineering Science Courses
PCC	Professional Core Courses
PEC	Professional Elective Courses
OEC	Open Elective Courses
HSC	Humanities and Social Science Courses
MNC	Mandatory Non-credit Courses
SEM	Seminar
PW	Project Work

Professional Elective Courses

Electives-1 & 2 (III Year, I Semester)		
S. No.	**Course Code**	**Course**
1	CH311	Pharmaceuticals and Fine Chemicals
2	CH312	Renewable Energy Sources
3	CH313	Fuel Cells and Flow Batteries
4	CH314	Energy Management
5	CH315	Corrosion Engineering
6	CH316	Nanotechnology
7	CH317	Polymer Technology
8	CH318	Mechanical design and drawing
9	CH319	Fuel and combustion
Electives - 3 & 4 (III Year, II Semester)		
S. No.	**Course Code**	**Course**
1	CH361	Energy Technologies
2	CH362	Fertilizer Technology
3	CH363	Food Technology
4	CH364	Green Technology
5	CH365	Pulp and Paper Technology
6	CH366	Heterogeneous Catalysis
7	CH367	Analytical Techniques for Chemical Engineers
8	CH368	Complex Fluids
9	CH369	Natural Gas Engineering
10	CH370	Biomass and Biofuels Technology
Electives-5 (IV Year, I Semester)		
S. No.	**Course Code**	**Course**
1	CH411	Biochemical Engineering Fundamentals
2	CH412	Interfacial Science
3	CH413	Process Modelling and Simulation
4	CH414	CO2 Capture & Utilization
5	CH415	Advanced Control Systems
6	CH5114	Wastewater Treatment
Elective-6 & 7 (IV Year, II Semester)		
S. No.	**Course Code**	**Course**
1	CH461	Microscale Unit Operations
2	CH462	Process and Product Design
3	CH463	Mathematical Methods in Chemical Engineering
4	CH464	Molecular Simulations in Chemical Engineering
5	CH465	Statistical Thermodynamics
6	CH466	Plant Utilities
7	CH467	Bioseparation Techniques
5	CH468	Scale up Methods
8	CH5162	Heat Integration and Process Scheduling
9	CH5163	Novel Separation Techniques

SCHEME OF INSTRUCTION

Service Courses offered to Other Department Programs

S. No.	Course Code	Course Title	L	T	P	Credits	Sem.
1	CH281	Polymer Technology	3	0	0	3	IV
2	CH431	Bioprocess Engineering Economics	3	0	0	3	VII

Open Elective Course offered to Other Department Programs

Open Elective Course-1 (III Year, II Semester)		
S. No.	**Course Code**	**Course**
1	CH395	Nanotechnology and Applications
2	CH396	Industrial Pollution Control
3	CH397	Soft Computing Methods for Engineers
4	CH398	Industrial Safety and Management
Open Elective Course-2 (IV Year, I Semester)		
S. No.	**Course Code**	**Course**
1	CH445	Data Driven Modelling
2	CH446	Fuel Cell Technology
3	CH447	CO_2Capture, Sequestration and Utilization
4	CH448	Design of Experiments

SCHEME OF INSTRUCTION

Minor Program* – Chemical Engineering

S. No.	Course Code	Course Title	L	T	P	Credits	Sem.
1	CHM01$	Introduction to Unit Operations and Process Calculations	3	0	0	3	III
2	CHM02$	Fluid Mechanics and Heat Transfer	3	0	0	3	III
3	CHM03	Chemical Engineering Thermodynamics	3	0	0	3	IV
4	CHM04$	Chemical Reaction Engineering	3	0	0	3	IV
5	CH203	Mechanical Operations	3	0	0	3	V
6	CHM05	Mass Transfer	3	0	0	3	VI
7	CH302	Elements of Transport Phenomena	3	0	0	3	VII
8	CH351	Process Dynamics and Control	3	0	0	3	VIII

* Out of the above, six courses (18 credits) should be completed by students for the award of Minor.

$ Mandatory courses: CHM01, CHM02, CHM04

SCHEME OF INSTRUCTION

Honors Program* – Chemical Engineering

S. No.	Course Code	Course Title	L	T	P	Credits	Sem.
1	CH5102$	Advanced Reaction Engineering	3	0	0	3	V
2	CH5161	Molecular Thermodynamics	3	0	0	3	VI
3	CH5101$	Advanced Transport Phenomena	3	0	0	3	VII
4	CH5202$	Advanced Process Control	3	0	0	3	VII
5	CH5152	Steady State Process Simulation	3	0	0	3	VIII
6	CH5153	Computational Fluid Dynamics	3	0	0	3	VIII
7	CH5251	Intelligent Control	3	0	0	3	VIII
8	CH5167	Electrochemical Engineering	3	0	0	3	VIII
9	CHH01$	Project	0	0	6	3	VIII

* Out of the above, six courses (18 credits) should be completed by students for the award of Honor.

$ Mandatory courses: CH5102, CH5101, CH5202, CHH01

DETAILED SYLLABUS

B.Tech. – Chemical Engineering

I-Year I Semester

HS132	ENGLISH FOR TECHNICALCOMMUNICATION	2-0-2	3 Credits	HSC

Pre-Requisites:

Course Outcomes:

At the end of the course, the student will be able to

CO1	Understand basic grammar principles
CO2	Write clear and coherent passages
CO3	Write effective letters for job application and complaints
CO4	Prepare technical reports and interpret graphs
CO5	Enhance reading comprehension
CO6	Comprehend English speech sounds, stress and intonation

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	-	-	-	-	-	2	-	-	3	3	-	3	-	-	-
CO2	-	-	-	-	-	-	-	-	3	3	-	3	-	-	-
CO3	-	-	-	-	-	-	-	-	3	3	-	3	-	-	-
CO4	-	-	-	2	-	-	-	-	3	3	-	3	-	-	-
CO5	-	-	-	-	-	-	-	-	3	3	-	3	-	-	-
CO6	-	-	-	-	-	-	-	-	3	3	-	3	-	-	-

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Grammar Principles (Correction of sentences, Concord) and Vocabulary Building (synonyms and antonyms): Idioms and Phrasal verbs--patterns of use and suggestions for effective employment in varied contexts.

Effective Sentence Construction - strategies for bringing variety and clarity in sentences- removing ambiguity - editing long sentences for brevity and clarity

Reported speech- contexts for use of reported speech - its impact on audiences and readers- active and passive voice- reasons for preference for passive voice in scientific English.

Paragraph-writing: Definition of paragraph and types- features of a good paragraph - unity of theme- coherence- linking devices- direction- patterns of development.

Note-making - definition- the need for note-making - its benefits - various note formats- like tree diagram, block or list notes, tables, etc.
Letter-Writing: Its importance in the context of other channels of communication- qualities of effective letters-types -personal, official, letters for various purposes- emphasis on letter of application for jobs - cover letter and resume types -examples and exercises.

Reading techniques: Definition- Skills and sub-skills of reading- Skimming and Scanning - their uses and purposes- examples and exercises.

Reading Comprehension - reading silently and with understanding- process of comprehension- types of comprehension questions.

Features of Technical English - description of technical objects and process- Report-Writing- definition- purpose -types- structure- formal and informal reports- stages in developing report- proposal, progress and final reports-examples and exercises.

Book Reviews- Oral and written review of a chosen novel/play/movie- focus on appropriate vocabulary and structure - language items like special vocabulary and idioms used

Language laboratory

English Sound System -vowels, consonants, Diphthongs, phonetic symbols- using dictionary to decode phonetic transcription-- Received Pronunciation, its value and relevance-transcription of exercises-

Stress and Intonation –word and sentence stress - their role and importance in spoken English-Intonation in spoken English -definition, patterns of intonation- –falling, rising, etc.-use of intonation in daily life-exercises

Introducing oneself in formal and social contexts- Role plays. - their uses in developing fluency and communication in general.

Oral presentation - definition- occasions- structure- qualities of a good presentation with emphasis on body language and use of visual aids.

Listening Comprehension -Challenges in listening, good listening traits, some standard listening tests- practice and exercises.

Debate/ Group Discussions-concepts, types , Do's and don'ts- intensive practice.

Learning Resources:

Text Books:

1. English for Engineers and Technologists (Combined edition , Vol. 1 and 2) Orient Blackswan 2010.
2. Ashraf, M Rizvi. Effective Technical Communication. Tata McGraw-Hill, 2006
3. Meenakshi Raman and Sangeetha Sharma. Technical Communication: Principles and Practice 2nd Edition, Oxford University Press, 2011

Software:

1.Clear Pronunciation – Part-1 *Learn to Speak English.*
2. Clear Pronunciation – Part-2 *Speak Clearly with Confidence*
3. Study Skills
4.English Pronunciation

MA134	MATRIX THEORY, CALCULUS AND ORDINARY DIFFERENTIAL EQUATIONS	3-0-0	3 Credits	BSC

Pre-Requisites:

Course Outcomes:

At the end of the course, the student will be able to

CO1	Solve the consistent system of linear equations
CO2	Apply orthogonal and congruent transformations to a quadratic form
CO3	Find the maxima and minima of multivariable functions
CO4	Solve arbitrary order linear differential equations with constant coefficients
CO5	Apply the concepts in solving physical problems arising in engineering

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	1	2	1	-	-	-	-	-	-	-	-	1	2
CO2	3	3	1	2	1	-	-	-	-	-	-	-	-	1	2
CO3	3	3	1	2	1	-	-	-	-	-	-	-	-	1	2
CO4	3	3	1	2	1	-	-	-	-	-	-	-	-	1	2
CO5	3	3	1	3	1	-	-	-	-	-	-	-	-	1	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Matrix Theory: Linear dependence and independence of vectors; Rank of a matrix; Consistency of the system of linear equations; Eigenvalues and eigenvectors of a matrix; Caley-Hamilton theorem and its applications; Reduction to diagonal form; Reduction of a quadratic form to canonical form - orthogonal transformation and congruent transformation; Properties of complex matrices - Hermitian, skew-Hermitian and Unitary matrices

Differential Calculus: Taylor's theorem with remainders; Taylor's and Maclaurin's expansions;
Asymptotes; Curvature; Curve tracing; Functions of several variables - partial differentiation; total differentiation; Euler's theorem and generalization; Change of variables - Jacobians; maxima and minima of functions of several variables (2 and 3 variables) - Lagrange's method of multipliers

Ordinary Differential Equations: Geometric interpretation of solutions of first order ODE $y' = f(x,y)$; Exact differential equations; integrating factors; orthogonal trajectories; Higher order linear differential equations with constant coefficients - homogeneous and non-homogeneous; Euler and Cauchy's differential equations; Method of variation of parameters; System of linear differential equations; applications in physical problems - forced oscillations, electric circuits, etc

Learning Resources:

Text Books:

1. Advanced Engineering Mathematics, R. K. Jain and S. R. K. Iyengar, Narosa Publishing House, 2016, 5thEdition
2. Advanced Engineering Mathematics, Erwin Kreyszig, John Wiley and Sons, 2015, 10thEdition
3. Calculus and Analytic Geometry, George B. Thomas and Ross L. Finney, Pearson, 2020, 9thEdition.

ReferenceBooks:

1. Advanced Engineering Mathematics, Dennis G. Zill, Jones & Bartlett Learning, 2018, 6thEdition.
2. Higher Engineering Mathematics, B. S. Grewal, Khanna Publishers, 2012, 42ndEdition.

BT131	BIOLOGY FOR CHEMICAL ENGINEERING	2-0-0	2 Credits	ESC

Pre-Requisites: None

Course Outcomes:

At the end of the course, the student will be able to

CO1	Realize the significance of biomolecules for sustaining life
CO2	Identify the difference between unicellular to multi-cellular organisms
CO3	Understand the central dogma of life
CO4	Apply the concepts of biology for engineering the cell

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	2	2	1	1	-	2	2	-	-	1	-	1	1	1	-
CO2	2	2	1	1	-	2	2	-	-	1	-	1	1	1	-
CO3	2	2	1	1	-	2	2	-	-	1	-	1	1	1	-
CO4	2	2	1	1	-	2	2	-	-	1	-	1	1	1	-

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Biomolecular Design - Structure and Functions: Chemical basis of life, water, carbon, proteins, nucleic acids, carbohydrates, lipids and membranes and first cells. design principles of cell and organelles.

Information Processing: Intra and Inter Cellular Communication: Central dogma, genetic code, gene and control of gene expression, cell cycle, cell–cell interactions, biological signal transduction, concept of networks in the cell, interaction between cell and environment, quorum sensing and biofilm formation.

Biomolecular Machines and Motors: Linear and rotary molecular motors: cytoskeletal motor proteins, DNA polymerase - replication and proofreading, helicases, ribosome, ATP synthase, cell motility: bacterial flagellum, mechanism of sperm motility, DNA nanomotors.

Bioengineering: Biological data types; biocomputing; DNA based data storage, synthetic biology, synthetic gene regulatory circuit and application; biomolecules for sensor design, biomedical instrumentation in disease diagnosis, bioimaging techniques and analysis in clinical diagnosis.

Applied Biotechnology: Biomimicry, biomechanics, biomaterials, nanobiotechnology, industrial microbiology. biomass, biofuels and bioenergy, microbial fuel cells, environmental microbiology, biological waste treatment.

Learning Resources:

Text Books:

1. Biological Science, Quillin, Allison Scott Freeman, Kim Quillin and Lizabeth Allison,

Pearson Education, 2016, 1st Edition.
2. Lehninger Principles of Biochemistry, David L. Nelson,Michael M. Cox, Macmillan Higher Education, 2017, 7thEdition.

Reference Books:

1. Biotechnology for Beginners, Reinhard Renneberg, Viola Berkling and Vanya Loroch, Academic Press, 2017, 1st Edition.
2. Molecular Diagnostics, Harald Seitz, Sarah Schumacher, Springer, 2013, 1st Edition.

Online Resources:

1. DNA storage: research landscape and future prospects, National Science Review, Oxford academic, 2020, (https://academic.oup.com/nsr/article/7/6/1092/5711038)
2. DNA data storage: https://wyss.harvard.edu/technology/dna-data-storage.
3. Synthetic Biology: Integrated Gene Circuits, Science, 2011,(https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4117316)
4. Synthetic biology: applications come of age, Nature Reviews Genetics, 2010, (https://www.nature.com/articles/nrg2775), (https://nptel.ac.in/courses/121/106/121106008/)

CE101	ENGINEERING MECHANICS	3-0-0	3 Credits	ESC

Pre-Requisites:Nil

Course Outcomes:

At the end of the course, the student will be able to

CO1	Determine the resultant force and moment for a given system of forces
CO2	Analyze planar and spatial systems to determine the forces in members of trusses,frames and problems related to friction
CO3	Calculate the motion characteristics of a body subjected to a given force system
CO4	Determine the deformation of a shaft and understand the relationship betweendifferent material constants
CO5	Determine the centroid and second moment of area

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	2	-	-	1	-	-	-	-	-	-	-	1	-
CO2	3	3	2	-	-	1	-	-	-	-	-	-	-	1	-
CO3	3	3	2	-	-	1	-	-	-	-	-	-	-	1	-
CO4	3	3	2	-	-	1	-	-	-	-	-	-	-	1	-
CO5	3	3	2	-	-	1	-	-	-	-	-	-	-	1	-

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction - Specification of force vector, Formation of Force Vectors, Moment of Force – Cross product – Problems, Resultant of a general force system in space, Degrees of freedom-Equilibrium Equations, Kinematics – Kinetics – De' Alemberts principle, Degree of Constraints –Freebody diagrams.

Spatial Force systems - Concurrent force systems - Equilibrium equations – Problems, Problems (Vector approach) – Tension Coefficient method, Problems (Tension Coefficient method), Parallel force systems - problems, Center of Parallel force system – Problems.

Coplanar Force Systems - Introduction – Equilibrium equations – All systems, Problems on Coplanar Concurrent force system, Coplanar Parallel force system, Coplanar General force system – Point of action, Method of joints, Method of sections, Method of sections, Method of members, Friction – Coulombs laws of dry friction – Limiting friction, Problems on Wedge friction, Belt Friction-problems.

Mechanics of Deformable Bodies - Stress & Strain at a point- Normal and shear stresses, Axial deformations – Problems on prismatic shaft, tapered shaft and deformation due to self-weight, Deformation of Stepped shaft due to axial loading, Poisson's Ratio – Bulk Modulus - Problems, change in dimensions and volume.

Centroid & Moment of Inertia - Centroid and M.I – Arial – Radius of Gyration, Parallel axis–Perpendicular axis theorem – Simple Problems.

Dynamics of Particles - Rectilinear Motion – Kinematics Problems, Kinetics – Problems, Work &Energy – Impulse Moment, Curvilinear Motion – Normal and tangential components.

Learning Resources:

Text Books:

1. J.L. Meriam, L.G. Kraige, Engineering Mechanics, John Wiley &Sons, 2012, 7^{th}Edition.
2. Timoshenko, Young, Engineering Mechanics, McGraw Hill Publishers, 2006, 3^{rd}Edition.
3. Gere, Timoshenko, Mechanics of Materials, CBS Publishers, 2011, 2^{nd}Edition.

CY132	CHEMISTRY	3-0-0	3 Credits	BSC

Pre-Requisites:

Course Outcomes:

At the end of the course, the student will be able to

CO1	Understand the basicconceptsofQuantum Chemistry and Chemical Bonding, Chemical Thermodynamics, Equilibrium and Kinetics
CO2	Illustrate the basic principles of Organic reaction mechanism and Characterization of organic compounds.
CO3	Utilize the spectroscopic methods in characterizing the material.
CO4	Develop electro chemical methods to protect different metals from corrosion
CO5	Design green energy harvesting and storage materials, industrial production materials to reduce the environmental pollution using greener methods to replace the existing non-eco-friendly process.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	3	-	2	-	2	-	2	-	-	-	-	1	-
CO2	3	3	3	-	2	-	2	-	2	-	-	-	-	1	-
CO3	3	3	3	-	2	-	2	-	2	-	-	-	-	1	-
CO4	3	3	3	-	2	-	2	-	2	-	-	-	-	1	-
CO5	3	3	3	-	2	-	2	-	2	-	-	-	-	1	-

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Quantum Chemistry and Chemical Bonding: Emergence of Quantum Theory; Postulates of Quantum Mechanics, Operators and Observables, Schrodinger Equation, Particle in a One- Dimensional Box and Colour of Conjugate Molecules, Hetero-diatomic Molecule as Harmonic Oscillator and Rigid Rotor, Hydrogen Atom, LCAO-MO Theory (MO Diagram of CO and NO Molecules)

Coordination Chemistry: Crystal Field Theory, Colour and Magnetic properties, Molecular Orbital Theory, MO-Diagram for an Octahedral Complex.

Chemical Thermodynamics, Equilibrium and Kinetics: Enthalpy and Free Energy Changes in Chemical Reactions; Relevance of Cp and Cv in Gas Phase Reactions, Chemical Potential; Heat Capacity of Solids, Absolute Entropy and Third Law of Thermodynamics, Rates of Enzyme Catalysed Homogeneous and Heterogeneous Surface-Catalysed Chemical Reactions.

Electrochemistry, Corrosion and Energy Systems: Electrodes and Electrochemical Cells;Potentiometric and Amperometric Sensors; Li-Ion and Ni-Cd Rechargeable Batteries; Capacitance and fundamentals of super capacitors.; Fuel Cells (Methanol-Oxygen); Corrosion: Introduction, causes and effects of corrosion; Theories of corrosion: Chemical and electrochemical corrosion with mechanism; Factors affecting the rate of corrosion: Nature of the metal and nature of the environment; Types of corrosion: Waterline and crevice corrosion; Corrosion control methods: Cathodic protection- sacrificial anodic protection and impressed current cathodic protection; Surface coatings: Metallic coatings, hot dipping(galvanizing, tinning), electroplating(copper plating); Organic coatings: Paints, its constituents and their functions.

Basics of Organic Chemistry: Classification of Organic reaction and their mechanisms (Substitution, Elimination, Addition and Rearrangement Reactions). Reaction intermediates: (Carbocation, Carbanion, Free Radials, Carbenes, Nitrenes, Benzyne) formation, structure and properties. Named Reactions: Skraup's synthesis, DielsAlder reaction, Click Reactions.

Structural Characterization Techniques; The principles and instrumentation of UV-Visible, FTIR and NMR Spectroscopy Methods. Applications of Spectral methods in the Analysis of Structures of Organic Compounds.

Learning Resources:

Text Books:

1. Shashi Chawla, Engineering Chemistry, Dhanpat Rai & Co. 2017.
2. Organic Spectroscopy, William Kemp, Macmillan Education, Limited, 2017

Reference Books:

1. Physical Chemistry, P. Atkins., Julio de Paula, Freeman & Co. 2017, 8th Edition.
2. Inorganic Chemistry, Atkins and Shriver, Oxford University Press, 2008, 4th Edition.
3. Organic Chemistry, Clayden, Greaves, Warren and Wothers, Oxford University Press, 2014.
4. Engineering Materials, Michael F. Ashby/David R.H. Jones, Elsevier Science, 2012
5. Material Science and Engineering, V. Raghava, PHI Learning, 2015
6. Materials for Engineering, J.M.. Martin, Elsevier Science, 20006
7. Physical Chemistry, Peter Atkins, Julio de Paula, James Keeler, Oxford University Press, 2018.
8. Organic Chemistry, Paula Bruce, Pearson, 2013, 8th Edition.

EE132	BASIC ELECTRICAL & ELECTRONICS ENGINEERING	3-0-0	3 Credits	ESC

Pre-Requisites:

Course Outcomes:

At the end of the course, the student will be able to

CO1	Analyze DC & AC circuits and determine power & power factor.
CO2	Understand the specifications of electrical machines.
CO3	Identifythetypeofelectricalmachinesforagivenapplication
CO4	Analyze basic electronic circuits and estimate theillumination requirements.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	2	2	2	2	1	-	-	-	-	-	-	-	-
CO2	3	3	2	2	2	2	1	-	-	-	-	-	-	-	-
CO3	3	3	2	2	2	2	1	-	-	-	-	-	-	-	-
CO4	3	3	2	2	2	2	1	-	-	-	-	-	-	-	-

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

DCCircuits: Kirchoff'sVoltageandCurrentLaws,SuperpositionTheorem,Star-DeltaTransformations.

AC Circuits: Complex representation of Impedance, Phasor diagrams, Power & Power Factor,Solution of 1-Phase Series & Parallel Circuits.

SinglePhaseTransformers: PrincipleofOperationofaSingle-Phase Transformer,EMFEquation, Phasor Diagram, Equivalent Circuit of a 1-Phase Transformer, Determination of Equivalentcircuitparameters,calculationofRegulation& Efficiencyofa Transformer.

DCMachines: PrincipleofOperation,Classification,EMFandTorqueEquations,Characteristicsof GeneratorsandMotors.SpeedControlMethods.

AC Machines: 3-Phase Induction Motor- Principle of Operation, Torque – Speed Characteristics of 3-Phase Induction Motor & Applications.

Electronic Devices & Circuits: P-type and N-Type semiconductors, P-N junction diode and its I-V characteristics, Single-phase Half-wave and Full wave rectifiers, Voltage Regulator. Bipolar Junction Transistor-operation and CE, CC & CB amplifiers.

Illumination: Laws of illumination and luminance (qualitative).

Learning Resources:

Text Books:

1. EdwardHughes,Electrical&ElectronicTechnology,Pearson,2016,12thEdition.
2. VincentDelToro,ElectricalEngineeringFundamentals,Pearson,2015,2ndEdition.
3. V. K Mehtha, “Principals of Electrical & Electronics Engineering, S. Chand Publications, New Delhi, 2010, 3rd Edition.

Reference Books:

1. U Bakshi& A. Bakshi, Basic Electrical Engineering, Technical Publications, 2005.
2. VNMittleandArvindMittal,BasicElectricalEngineering,TataMcGrawHill,2005,2ndEdition.
3. Millman&Halkias, Integrated Electronics, Tata McGraw-Hill Education, 2001.

ME135	WORKSHOP PRACTICE FOR CHEMICAL ENGINEERING	0-0-3	1.5 Credits	ESC

Pre-Requisites:

Course Outcomes:

At the end of the course, the student will be able to

CO1	Study and practice on tools and their operations
CO2	Practice on manufacturing of components using workshop trades including fitting, Sheet metal, carpentry, foundry and welding
CO3	Identify and apply suitable tools for machining processes including Facing, Turning, Taper Turning, Grooving, Chamfering, Thread cutting, Knurling and tapping.
CO4	Apply basic electrical engineering knowledge for House Wiring Practice

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	1	-	-	1	-	-	2	2	-	-	2	-	-
CO2	3	3	1	-	-	1	-	-	2	2	-	-	2	-	-
CO3	3	3	1	-	-	1	-	-	2	2	-	-	2	-	-
CO4	3	3	1	-	-	1	-	-	2	2	-	-	2	-	-

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Demonstration of safety practices and precautions to be observed in workshop.

Fitting Trade: Demonstration and practice of fitting tools, Preparation of T-Shape, Dovetail Joint.

Carpentry:. Demonstration and practice of carpentry tools, Preparation of Cross Half lap joint and Mortise Tenon Joint.

Plumbing: Demonstration and practice of Plumbing tools, Preparation of Pipe joints with coupling for same diameter and with reducer for different diameters.

Machine shop: Demonstration and practice on Lathe Machine, Preparation of work pieces involving Facing, Plane Turning, step turning, knurling and parting operations.

House Wiring: Demonstration and practice on Electrical tools, wiring and earthing, Exercises on Staircase Wiring &Godown wiring.

Power Tools: Demonstration and practice on Power tools (Bosch Power Tools) and Safety Practices.

Foundry Trade: Demonstration and practice on Moulding tools and processes, Preparation of Green Sand Moulds for given Patterns (Solid / Split Patterns).

Welding Shop: Demonstration and practice on Arc Welding and Gas welding. Preparation of Lap joint and Butt joint.

Sheet metal: Demonstration of & Practice on sheet metal tools. Practice on preparing required shapes from a sheet using appropriate tools.

Learning Resources:

Text Books:

1. Basic Workshop Technology: Manufacturing Process,Felix W.
2. Bruce J. Black, “Workshop Processes, Practices and Materials”, Routledge publishers, 5th Edition.
3. A Course in Workshop Technology Vol I. & II,B.S. Raghuwanshi, Dhanpath Rai & Co.
4. Technology of Machine Tools.,Steve F Krar et.al, TMH publishers.
5. Engineering Practices Laboratory Manual,Ramesh Babu.V., VRB Publishers Private Limited, Chennai, 2013 – 2014.
6. Engineering Practices Lab Manual, T.Jeyapoovan,Vikas Publishers, 4th Edition.
7. Mechanical Workshop Practice,John K.C, PHI.

Reference Books:

1. Elements of Workshop Technology, Vol. I byS. K. Hajrachoudhury&Others, Media Promoters and Publishers, Mumbai. 2007, 14th Edition
2. Elements of Workshop Technology, Vol. II by S. K. Hajrachoudhury&Others, Media Promoters and Publishers, Mumbai. 2007, 12th Edition
3. Workshop Practice by H. S. Bawa, Tata-McGraw Hill, 2004.

Online Resources:

Different Trade E-Books (Fitting, Plumbing, Welding, Carpentry, Foundryman, Turner and House Wiring etc.) developed by National Instructional Media Institute, Chennai.
Directorate General of Training, Ministry of Skill Development & Entrepreneurship, Govt. of India. (https://bharatskills.gov.in).

I –Year II Semester

MA184	INTEGRAL CALCULUS AND LAPLACE TRANSFORMS	3-0-0	3 Credits	BSC

Pre-Requisites:MA134:Matrix Theory, Calculus and Ordinary Differential Equations

Course Outcomes:

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

CO1	Analyse improper integrals
CO2	Evaluate multiple integrals in various coordinate systems
CO3	Apply the concepts of gradient, divergence and curl to formulate engineering problems
CO4	Convert line integrals into surface integrals and surface integrals into volume
CO5	Apply Laplace transforms to solve physical problems arising in engineering

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	1	2	1	-	-	-	-	-	-	-	-	1	2
CO2	3	3	1	2	1	-	-	-	-	-	-	-	-	1	2
CO3	3	3	1	2	1	-	-	-	-	-	-	-	-	1	2
CO4	3	3	1	2	1	-	-	-	-	-	-	-	-	1	2
CO5	3	3	1	3	1	-	-	-	-	-	-	-	-	1	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Integral Calculus:Convergence of improper integrals; Beta and Gamma integrals; Differentiation under integral sign; Double and Triple integrals - computation of surface areas and volumes; change of variables in double and triple integrals

Vector Calculus:Scalar and vector fields; vector differentiation; level surfaces; directional derivative; gradient of a scalar field; divergence and curl of a vector field; Laplacian; Line and Surface integrals; Green's theorem in a plane; Stoke's theorem; Gauss Divergence theorem

Laplace Transforms:Laplace transforms; inverse Laplace transforms; Properties of Laplace transforms; Laplace transforms of unit step function, impulse function, periodic function; Convolution theorem; Applications of Laplace transforms - solving certain initial value problems, solving system of linear differential equations, finding responses of systems to various inputs viz. sinusoidal inputs acting over a time interval, rectangular waves, impulses etc.

Learning Resources:

Text Books:

1. Advanced Engineering Mathematics, R. K. Jain and S. R. K. Iyengar, Narosa Publishing House, 2016, 5th Edition
2. Advanced Engineering Mathematics, Erwin Kreyszig, John Wiley and Sons, 2015,

10thEdition

3. Calculus and Analytic Geometry, George B. Thomas and Ross L. Finney, Pearson, 2020, 9thEdition

ReferenceBooks:

1. Advanced Engineering Mathematics, Dennis G. Zill, Jones & Bartlett Learning, 2018, 6thEdition
2. Higher Engineering Mathematics, B. S. Grewal, Khanna Publishers, 2012, 42ndEdition

PH185	PHYSICS FOR CHEMICAL ENHINEERING	2-0-2	3 Credits	BSC

Pre-Requisites: None

Course Outcomes:

At the end of the course, the student will be able to

CO1	Apply the concepts of wave and particle nature of energy for solving problems radiant energy
CO2	Understand the applications of Interference, diffraction, optical fibers, holography and lasers in Industry
CO3	Understand the basics of crystallography and semiconductors
CO4	Apply the concepts of interference, diffraction, and polarization in engineering Measurements.
CO5	Make use of lasers and optical instruments for experimentation.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	3	3	1	-	-	-	-	-	-	-	3	3	1
CO2	3	3	3	3	-	-	-	-	-	-	-	-	3	3	2
CO3	3	3	3	3	-	-	-	-	-	-	-	-	3	3	3
CO4	3	3	3	3	-	-	-	-	-	-	-	-	3	3	3
CO5	3	3	3	3	1	-	3	-	-	-	-	-	3	3	3

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Wave optics and Modern Optics

Interference and Diffraction: Concept of interference, working of Michelson Interferometer, Fabry-perot Interferometer and its application as wavelength filter-concept of diffraction, Fraunhofer and Fresnel diffraction, Fraunhofer diffraction at single slit, double slit, and multiple slits; diffraction grating, characteristics of diffraction grating and its applications.

Polarization: Introduction, polarization by reflection, polarization by double refraction, scattering of light, circular and elliptical polarization, optical activity.

Laser: *Introduction to interaction of radiation with matter, principles and working oflaser* population inversion, pumping, various modes, threshold population inversion, types of laser: solid state, semiconductor, gas; application of lasers.

Quantum Mechanics: Concepts and Experiments that led to the discovery of Quantum Nature. Heisenberg uncertainty principle; Schrodinger time independent and time dependent wave equations, The free particle problem - Particle in an infinite and finite potential well, Quantum mechanical tunneling. MB, BE and FD distributions (qualitative treatment).

Crystal structure of solids

Crystal structure of solids: unit cell, space lattices and Bravais lattice, Miller indices, directions and crystallographic planes, Cubic crystals: SC, BCC, FCC, Hexagonal crystals: HCP, atomic radius, packing fraction, Bragg's law of x-ray diffraction, determination of crystal structure using Bragg spectrometer.

Semiconductor physics

Semiconductor Physics: Formation of energy bands in solids, concept of Fermi level, classification of solids: conductor, semiconductor and insulator, intrinsic and extrinsic semiconductors, effect of doping, mobility of charge carriers, conductivity, Hall Effect.

Ultrasounds

Mechanical, electromechanical transducers; propagation of ultrasound, attenuation, velocity of ultrasound and parameters affecting it, measurement of velocity, cavitation, applications of ultrasound.

Experiments include:

1. Determination of Wavelength of Sodium light using Newton's Rings.
2. Determination of Wavelength of He-Ne laser – Metal Scale.
3. Measurement of Width of a narrow slit using He- Ne Laser.
4. Determination of Specific rotation of Cane sugar by Laurent Half-shade Polarimeter.
5. Determination of capacitance by using R-C circuit.

Learning Resources:

Text Books:

1.Optics by Ajoy K. Ghatak, Tata McGraw Hill, 2017, 6th Edition.
2. Concepts of Modern Physics by Arthur Beiser, Shobhit Mahajan, S. Rai Choudhury, McGraw Hill Publications,2009, 6th edition.
3.A Text book of Engineering Physics by M.N. Avadhanulu, P.G. Khirsagar,2011,9th edition.
4. Physics Laboratory Manual by Physics Department, NIT Warangal, 2021.

Reference Books:

1.Understanding Lasers An Entry-Level Guide, by Jeff Hecht, Wiley Publications, 2018, 4th edition.
2.University Physics with modern physics by Hugh D. Young, Roger A. FreedmanPearson Education,2014.
3.Engineering Physics by Shatendra Sharma, Jyotnsa Sharma, Pearson Education,2018.

Online Resources:

https://nptel.ac.in/courses/122/107/122107035/

CY181	INDUSTRIAL ORGANIC CHEMISTRY	3-0-0	3 Credits	BSC

Pre-Requisites:None

Course Outcomes:

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

CO1	Understand the concepts of organic chemistry to synthesize small organic molecules
CO2	Apply the knowledge to purify organic compounds
CO3	Analyse approaches of drug discovery process
CO4	Design the synthetic process using sustainable approach
CO5	Predict the structure of organic molecule using spectroscopic methods
CO6	Develop a synthetic process for an organic compound at larger scale

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	-	3	-	-	2	3	-	-	-	-	3	-	3	-
CO2	3	-	3	-	-	2	3	-	-	-	-	3	-	3	-
CO3	3	-	3	-	-	2	3	-	-	-	-	3	-	3	-
CO4	3	-	3	-	-	2	3	-	-	-	-	3	-	3	-
CO5	3	-	3	-	-	2	3	-	-	-	-	3	-	3	-
CO6	3	-	3	-	-	2	3	-	-	-	-	3	-	3	-

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Current approaches to organic synthesis:Functional group interconversions, synthesis of value added chemicals based on functional group inter conversions (synthon approach), alternative reaction media (water, ionic liquids, and deep eutectic solvents), and alternative energy sources (microwave, sonication) for organic reactions**.** Homogeneous and heterogeneous catalysis.**Purification of organic compounds:**Chromatography (Thin-layer, Column, Gas and high performance liquid chromatography), Bulk separation

Heterocyclic Compounds and Pharmaceutical chemistry: Structure and reactivity of pyrrole, furan, thiophene and pyridine. Importance of heterocyclic molecules in pharmaceutical chemistry, Modern approaches of drug discovery, strategies for bulk drug preparation.

Stereochemistry: Introduction to stereochemistry, isomerism, enantiomers, diastereomers, CIP rules,relative and absolute configuration (D, L and R, S-nomenclature)**,** racemization**,** resolution techniques.Conformational analysis of ethane, butane and cyclohexane.

Chemistry of biomolecules: Structure and biological importance of carbohydrates, amino acids, peptide synthesis, proteins structure, purification of proteins, structure and biological importance of nucleic acids (DNA and RNA).

Polymer chemistry: Polymerization methods, conducting polymers, liquid crystalline materials, paints and colouring agents.

Advanced Spectroscopy Methods of Analysis: ^{13}C NMR spectroscopic methods, Coupling Constant, Lanthanide Shift reagents, Mass spectrometry: EI, ESI, and structural elucidation small molecules (combined problems).

Learning Resources:

Text Books:

1. Organic Chemistry, John E. McMurry, Brooks Cole, 2011, 8th Edition.
2. Organic Chemistry, T. W. Graham Solomons, Craig B. Fryhle, Scott A. Snyder –Wiley, 2013, 12th Edition.

ReferenceBooks:

1. Organic Chemistry by Francis A. Carey, Tata Mc Graw Hill Publishing Company Limited, 2011, 7th Edition.
2. Organic Chemistry by Francis A. Carey, Tata Mc Graw Hill Publishing Company Limited, 2011, 7th Edition.
3. Principles and Applications of Stereochemistry, Micheal North, Taylor&Francis, 2017, 2nd Edition.
4. Heterocyclic Chemistry, John A. Joule, Keith Mills, XX publishers, 2010, John Wiley & Sons, Ltd., 5th Edition
5. Introduction to Spectroscopy, Donald L. Pavia, Gary M Lanyman, Cengage Learning, 2015, 5th Edition.
6. The Organic Chemistry of Drug Design and Drug Action, Richard B. Silverman, Elsevier, 2013, 3rd Edition.
7. Introduction to Polymer Chemistry, Charles E Carraher Jr, CRC Press, 2017, 4th Edition

OnlineResources:

1. https://www2.chemistry.msu.edu/faculty/reusch/VirtTxtJml/intro1.htm
2. https://chem.libretexts.org/Bookshelves/Organic_Chemistry

CS181	PROBLEM SOLVING AND COMPUTER PROGRAMMING	3-0-2	4 Credits	ESC

Pre-requisites:None

Course Outcomes:

At the end of the course, the student will be able to

CO1	Design and test programs to solve mathematical and scientific problems
CO2	Develop and test programs using control structures
CO3	Implement modular programs using functions
CO4	Develop programs using classes

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	2	3	3	-	-	-	-	1	-	3	-	-	3
CO2	3	3	2	3	3	-	-	-	-	1	-	3	-	-	3
CO3	3	3	2	3	3	-	-	-	-	1	-	3	-	-	3
CO4	3	3	2	3	3	-	-	-	-	1	-	3	-	-	3

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Fundamentals of Computers, Historical perspective, Early computers, Components of a computers, Problems, Flowcharts, Memory, Variables, Values, Instructions, Programs.

Problem solving techniques – Algorithmic approach, characteristics of algorithm, Problem solving strategies: Top-down approach, Bottom-up approach, Time and space complexities of algorithms.

Number systems and data representation, Basics of C++, Basic data types.

Numbers, Digit separation, Reverse order, Writing in words, Development of Elementary School Arithmetic Testing System, Problems on Date and factorials, Solutions using flow of control constructs, Conditional statements - If-else, Switch-case constructs, Loops - while, do-while, for.

Functions – Modular approach for solving real time problems, user defined functions, library functions, parameter passing - call by value, call by reference, return values, Recursion, Introduction to pointers.

Sorting and searching algorithms, Large integer arithmetic, Single and Multi-Dimensional Arrays, passing arrays as parameters to functions

Magic square and matrix operations using Pointers and Dynamic Arrays, Multidimensional Dynamic Arrays

String processing, File operations.
Structures and Classes - Declaration, member variables, member functions, access modifiers, function overloading, Problems on Complex numbers, Date, Time, Large Numbers.

Lab Part-Syllabus:

1. Programs on conditional control constructs.
2. Programs on loops (while, do-while, for).
3. Programs using user defined functions and library functions.
4. Programs on arrays, matrices (single and multi-dimensional arrays).
5. Programs using pointers (int pointers, char pointers).
6. Programs on structures.
7. Programs on classes and objects.

Text Books / Reference Books / Online Resources:

1. Problem Solving with C++, Walter Savitch, Pearson, 2014, 9th Edition.
2. Big C++, Cay Horstmann, Timothy Budd, Wiley, 2009, 2nd Edition.
3. How to solve it by Computer, R.G. Dromey, Pearson, 2008.

ME133	ENGINEERING DRAWING	0-1-2	2 Credits	ESC

Pre-requisites: None

Course Outcomes:

At the end of the course, the student will be able to

CO1	Apply BIS standards and conventions while drawing Lines, printing Letters and showing Dimensions.
CO2	Classify the systems of projection with respect to the observer, object and the reference planes.
CO3	Construct orthographic views of an object when its position with respect to the reference planes is defined in CAD environment
CO4	Analyse the internal details of an object through sectional views in CAD environment.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	1	1	1	-	-	-	1	1	3	3	-	-	-	-	-
CO2	1	1	1	-	-	-	1	1	3	3	-	-	-	-	-
CO3	1	1	1	-	-	-	1	1	3	3	-	-	-	-	-
CO4	1	1	1	-	-	-	1	1	3	3	-	-	-	-	-

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction:

Drawing instruments and their uses, Types of lines, Lettering, General rules for dimensioning, Geometrical constructions using instruments. (**Conventional**)

Orthographic Projection:

Methods of projection, Principles of Orthographic projection, First angle versus third angle of projection, Six views of an object, Conventions. (**Conventional**)

Projection of Points:

Projections of points when they are situated in different quadrants. (**Conventional**)

Fundamentals of AutoCAD:

Introduction to Auto-CAD, DRAW tools, MODIFY tools, TEXT, DIMENSION, PROPERTIES (**AutoCAD**)

Projections of Lines:

Projections of a line parallel to one of the reference planes and inclined to the other, line inclined to both the reference planes, Traces. (**AutoCAD**)

Projections of Planes:

Projections of a plane perpendicular to one of the reference planes and inclined to the other, Oblique planes. (**AutoCAD**)

Projections of Solids:
Projections of solids whose axis is parallel to one of the reference planes and inclined to the other, axis inclined to both the planes. (**AutoCAD**)

Section of Solids:
Sectional planes, Sectional views - Prism, pyramid, cylinder and cone, true shape of the section. (**AutoCAD**)

Learning Resources:

Text Books:

1. N.D. Bhatt and V.M. Panchal, Engineering Graphics, Charotar Publishers, 2016, 53rd Edition.

ReferenceBooks:

1. Agarwal, B, Engineering Drawing, Second edition, McGraw Hill Education, 2015
2. Prof. Sham Tickoo, AutoCAD 2017 for Engineers & Designers, 23ed, Dreamtech Press

MM186	MATERIALS SCIENCE AND ENGINEERING	3-0-0	3 Credits	ESC

Pre-Requisites: General Physics and General Chemistry

Course Outcomes:

At the end of the course, the student will be able to

CO1	Classify the materials and discuss their applications.
CO2	Describe the crystal structure, constitution and microstructure of materials.
CO3	Suggest ferrous and non-ferrous alloys for different applications based on their properties.
CO4	Differentiate the properties and applications of ceramics, polymers and composites.
CO5	Select suitable advanced materials for electronic and thermochemical applications

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	-	1	-	1	-	2	-	-	-	-	-	1	-	-	-
CO2	-	1	3	3	-	-	-	2	-	-	-	1	-	-	-
CO3	-	1	3	3	-	2	-	-	-	-	-	1	-	-	-
CO4	-	1	3	3	-	2	-	-	-	-	-	1	-	-	-
CO5	-	1	2	2	-	2	-	-	-	-	-	1	-	-	-

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction: Historical materials, Introduction and classification of materials.

Crystal Geometry and Constitution of Alloys: Space lattices, Unit cells, Crystal structure, Crystal directions and planes, Crystal imperfections- Point defects, Line defects, Surface defects, Volume defects; Types of solid solutions- substitutional and interstitial; Hume-Rothery rules for solid solutions, Construction and interpretation of binary equilibrium diagrams-isomorphous, eutectic and peritectic-type diagrams, Intermediate phases and phase rule.

Plain Carbon Steels, Cast Irons and Alloy Steels: Iron-carbon phase diagram, Types of steels- low, medium and high carbon steels, Cast irons: white, grey, nodular, and malleable cast irons, Alloy steels: Stainless steels and their applications in chemical industries; Heat treatment-annealing, normalizing, hardening, tempering.

Non-ferrous Metals and Alloys: Properties and applications of - Cu and its alloys, Al and its alloys, Age hardening, Ti and its alloys, Ni-based alloys.

Ceramics, Polymers and Composites: Ceramics - Crystalline ceramics, Glasses, Properties and applications of ceramics; Polymers – Polymerization, Thermoplastics and thermosetting plastics, Properties and applications of polymers; Composites – Concept of composites, Matrix and reinforcement, Rule of mixtures, Classification of composites, Applications of composites.

Advanced Materials: Materials for electronics: Materials for solar cells, photovoltaics, fuel cells; Shape memory alloys, Phase change materials, High temperature materials for subcritical, super critical and ultra-super critical boilers, Hydrogen energy storage materials, nuclear materials.

Learning Resources:

Text Books:

1. W.D. Callister (Adapted by R. Balasubramaniam), Materials Science and Engineering,Wiley India,NewDelhi, 2014, 2nd edition.
2. V.Raghavan,MaterialsScienceandEngineering:AFirstCourse,PrenticeHallofIndiaLearning Pvt.Ltd.,Delhi, 2015, 6thedition.
3. S.H.Avner,IntroductiontoPhysicalMetallurgy,McGraw-HillEducationPublishers,NewYork,USA, 1997, 2nd Edition.

Reference Books:

1. D.S.ClarkandW.Varney,PhysicalMetallurgyforEngineers,CBSPublishersand DistributorsNewDelhi, 2004, 2nd Edition.
2. V.Raghavan,PhysicalMetallurgy:PrinciplesandPractice,PrenticeHallofIndiaLearningPvt.Ltd., Delhi, 2012, 2nd Edition.

Online Resources:

https://nptel.ac.in/courses/112/106/112106293/

CY182	CHEMISTRY LABORATORY	0-0-3	1.5 Credits	BSC

Pre-Requisites:

Course Outcomes:

At the end of the course, the student will be able to

CO1	Select a suitable methodology for the estimation of metal content, iodine content, active chlorine or hardness of water
CO2	Analyse acids, bases, redox compounds, etc. using instrumental methods
CO3	Determine the corrosion inhibitor efficiency of selective compounds and process

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	3	-	2	-	2	-	2	-	-	-	-	1	-
CO2	3	3	3	-	2	-	2	-	2	-	-	-	-	1	-
CO3	3	3	3	-	2	-	2	-	2	-	-	-	-	1	-

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Any of the twelve Experiments will be performed from the given list:

1. Introduction: Standardization procedure. Understanding the redox process, electron transfer, importance of qualitative and quantitative analysis.

2. Estimation of Hematite: Understanding the importance on purity of a ore, % of metal content (for Fe).

3. Hardness of Water: Understanding the of metal complexes, multi dentate ligands, importance of purity of ground water, (EDTA method; complexometry).

4. Preparation of nanomaterials: Understanding the importance of nanomaterials, their preparation and characterization using FT-IR

5. pHmetry: Concept of pH, Instrumentation, calibration, determination of the concentrations by instrumental methods

6. Conductometry: Concept of conductivity, importance of conductivity

7..Potentiometry: Determination of the redox potential of the reaction

8. Colorimetry: Analysis of Phosphate from soft drinks using Volumetry/Colorimetry Importance of Beers and Lamberts law,

9. Photochemical experiment: Chemistry of Blue Print. Importance of visible light and its application for a redox process, importance of coloring agent

10. Preparation of bakelite / polypyrrole: Concepts of organic reactions and application for the organic material preparation.

11. Corrosion experiment: Concept of corrosion, importance of corrosion agents

12.Adsorption experiment: Understanding phenomena of adsorption and absorption

13. Analysis of a drug: Importance of the purity, concentrations of a drug molecule.

14. Preparation of red azo dye / Aspirin / Fe(acac). Concepts of organic reactions and application for the org

Learning Resources:

Text Books:

1. Introductory Chemistry laboratory manual: Concepts and Critical Thinking, Charles Corwin,Pearson Education, 2012.
2. Investigating Chemistry: Laboratory Manual, David Collins, Freeman & Co., 2006.

II-Year I-Sem

MA236	PARTIAL DIFFERENTIAL EQUATIONS, STATISTICS AND NUMERICAL METHODS	3-0-0	3 Credits	BSC

Pre-Requisites: Integral Calculus and Laplace Transforms

Course Outcomes:

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

CO1	Determine the solution of a PDE by variable separable method
CO2	Interpret an experimental data using interpolation / curve fitting
CO3	Solvealgebraic/transcendental equations and ordinary differential equations
CO4	Understand the concepts of probability and statistics
CO5	Perform testing of hypothesis

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	1	2	1	-	-	-	-	-	-	-	-	1	2
CO2	3	3	1	2	1	-	-	-	-	-	-	-	-	1	2
CO3	3	3	1	2	1	-	-	-	-	-	-	-	-	1	2
CO4	3	3	1	2	1	-	-	-	-	-	-	-	-	1	2
CO5	3	3	1	2	1	-	-	-	-	-	-	-	-	1	2

Syllabus:

Partial Differential Equations:Introduction to Fourier series **(**including half range)**,** Method of separation of variables - Solution of one-dimensional wave equation, one dimensional heat conduction equation and two dimensional steady state heat conduction equation with illustrations

Numerical Methods:Curve fitting by the method of least squares. Fitting of (i) Straight line (ii) Second degree parabola (iii) Exponential curves - Gauss-Seidal iteration method to solve a system of equations - Numerical solution of algebraic and transcendental equations by Regula-Falsi method and Newton-Raphson’s method - Lagrange interpolation, Forward and backward differences, Newton’s forward and backward interpolation formulae - Numerical differentiation with forward and backward differences - Numerical Integration with Trapezoidal rule, Simpson’s 1/3 rule and Simpson’s 3/8 rule - Taylor series method, Euler’s method, 4th order Runge-Kutta method for solving first order ordinary differential equations

Probability and Statistics:Random variables, discrete and continuous random variables, Mean and variance of Binomial, Poisson and Normal distributions and applications. Testing of Hypothesis – Null and alternate hypothesis, level of significance and critical region - Z-test for single mean and difference of means, t-test for single mean and difference of means - F-test for comparison of variances, Chi-square test for goodness of fit - Karl Pearson coefficient of correlation, lines of regression and examples

Learning Resources:

Text Books:

1. Advanced Engineering Mathematics, R. K. Jain and S. R. K. Iyengar, Narosa Publishing House, 2016, FifthEdition
2. Advanced Engineering Mathematics, Erwin Kreyszig, John Wiley and Sons, 2015, TenthEdition

ReferenceBooks:

1. Miller & Freund's Probability and Statistics for Engineers, Richard A. Johnson, Pearson, 2018, NinthEdition
2. Advanced Engineering Mathematics, Dennis G. Zill, Jones & Bartlett Learning, 2018, SixthEdition
3. Higher Engineering Mathematics, B. S. Grewal, Khanna Publishers, 2012, Forty-secondEdition

CH201	CHEMICAL PROCESS CALCULATIONS	3-0-0	3 Credits	PCC

Pre-Requisites:None

Course Outcomes:

At the end of the course, the student will be able to

CO1	Convert physico-chemical quantities from one system of units to another
CO2	Calculate mass balances on non-reactive systems
CO3	Carry out mass balances on reactive systems
CO4	Perform mass and energy balances in processes involving phase changes
CO5	Analyse the mass and energy balances for combustion and reactive processes

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	3	3	2	-	-	-	2	2	1	1	3	3	2
CO2	3	2	3	3	2	-	-	-	2	2	1	1	3	3	2
CO3	3	2	3	3	3	-	-	-	2	2	1	1	3	3	2
CO4	3	2	3	3	3	-	-	-	2	2	1	1	3	3	2
CO5	3	2	3	3	3	-	-	-	2	2	1	1	3	3	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction to process calculations: Units and Dimensions - Conversion of Units, Systems of units; Process and process variables – mass and volume, density, specific gravity, specific gravity scales, mass and volumetric flow rates; Chemical composition - mole concept, molecular and equivalent weights; Composition of streams; other expressions for concentration;

Fundamentals of material balances: Process classification; Balances; Material balance calculations – flow charts, basis of calculation, balancing a process, degrees of freedom analysis, general procedure for single unit process material balance calculations, examples including – Evaporation, Crystallization, Absorption, Distillation, Drying, Extraction,etc.; Balances on multiple unit processes – Recycle and bypass

Chemical Reaction stoichiometry: Stoichiometry, limiting and excess reactants, fractional conversion, extent of reaction, multiple reactions - yield and selectivity; Balances on reactive processes – molecular species balances, atomic species balances, product separation and recycle, Purging; Combustion reactions – Orsat analysis, theoretical and excess air, material balances on combustion reactions.

Energy balances: Elements of energy balance calculations – reference states, process paths, procedure for energy balance; Sensible heat and heat capacities, estimation of heat capacities as function of temperature, Energy balances on single phase systems; Phase change operations – latent heats and their estimation, energy balances on process involving phase changes, Humidity, Partial saturation, Psychrometric charts; Enthalpy-concentration charts

Energy balances on reactive processes: Heats of reaction; Hess law; Heats of formation; Heats of combustion; Energy balances with reactions – general procedure, processes with known heat inputs: adiabatic reactors, Fuels and combustion – adiabatic flame temperature

Learning Resources:

Text Books:

1. Elementary Principles of Chemical Processes, R.M. Felder, R.W. Rousseau, L.G. Bullard, Wiley, 2016, 4th Edition.
2. Basic Principles and Calculations in Chemical Engineering, D.H. Himmelblau, J. B. Riggs, Prentice Hall,2012, 8th Edition.

Reference Books:

1. PrinciplesofChemicalEngineeringProcesses:Material and Energy Balances, NayefGhasem,R.Henda,CRC Press,2015, 2ndEdition.
2. StoichiometryandProcessCalculations, K.V. Narayanan, B.Lakshmikutty,PHILearningPvt. Ltd.,2015, 7th Edition.
3. Chemical Process Principles (Part-I): Materialand Energy Balances, O.A. Hougen, K.M. Watson, R.A. Ragatz, CBS Publishers,2004, 2ndEdition.
4. Stoichiometry, B.I. Bhatt, S.M. Thakore, Tata McGraw-Hill Publishing Company Ltd., 2010, 5th Edition.

Online Resources:

1. https://nptel.ac.in/courses/103/103/103103165/
2. https://www.youtube.com/watch?v=4EWmB9JVcBo&list=PL23LJMmRTn8fwtijrPEgIbqZAaKCc3oEg

CH202	FLUID AND PARTICLE MECHANICS	3-0-0	3 Credits	PCC

Pre-Requisites: None.

Course Outcomes:

At the end of the course, the student will be able to

CO1	Derive dimensionless groups using dimensional analysis.
CO2	Evaluate pressure measuring devices and decanters using the principles of fluid statics.
CO3	Determine the pipe size / flow rate / power requirements under laminar and turbulent flow conditions.
CO4	Solve problems involving motion of particles in fluid, fluid–solid operations in packed beds and fluidized beds.
CO5	Select machinery and measuring devices for fluid flow.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	1	1	1	-	-	-	-	-	-	-	-	3	0	3
CO2	3	2	2	2	-	-	-	-	-	-	-	-	3	1	0
CO3	3	1	3	3	1	2	-	-	-	-	-	-	3	1	2
CO4	3	3	3	3	1	2	-	-	-	-	-	-	3	1	2
CO5	3	3	2	3	1	-	-	-	-	-	-	-	3	1	0

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Unit Systems: Unit systems, Dimensional analysis: Rayleigh's method, Buckingham π-method.

Fluid Statics and Its Applications: Nature of Fluids, Hydrostatic Equilibrium, Applications of Fluid Statics.

Fluid Flow Phenomena: Laminar flow, Shear rate, Shear stress, Rheological properties of fluids, Turbulence, Boundary layers.

Basic Equations of Fluid Flow: Mass balance in a flowing fluid; Continuity, Differential momentum balance; Equations of motion, Macroscopic momentum balances, Mechanical energy equations.

Incompressible Flow in Pipes and Channels: Shear stress and skin friction in pipes, Laminar flow in pipes and channels, Turbulent flow in pipes and channels, Friction from changes in velocity or direction.

Flow of Compressible Fluids: Definitions and basic equations.
Flow past immersed objects: Friction in flow through beds of solids, Motion of particles through fluids, Fluidization.

Transportation and Metering of Fluids: Pipes, Fittings and valves. Pumps - positive displacement pumps and centrifugal pumps, Fans, blowers, and compressors, Flow measuring devices.

Learning Resources:

Text Books:

1. Unit operations of Chemical Engineering, McCabe W. L., Jullian, Smith C. and Peter Harriott, McGraw-Hill international edition, 2005, 7^{th} Edition.

Reference Books:

1. Chemical Engineering Volume I and II, Coulson J.M, Richardson. J.F, Elsevier India, 2006, 5^{th} Edition.
2. Fluid Mechanics for Chemical Engineers, De Nevers N H, McGraw Hill, NY, 2004, 3^{rd} Edition.
3. Fluid Mechanics for Chemical Engineers, Wilkes James O., Prentice Hall, 2017, 3^{rd} Edition.

CH203	MECHANICAL OPERATIONS	3-0-0	3 Credits	PCC

Pre-Requisites:None

Course Outcomes:

At the end of the course, the student will be able to

CO1	Identify the role of mechanical unit operations in chemical industries
CO2	Select suitable size reduction equipment based on performance and power requirement.
CO3	Analyse particle size distribution of solids
CO4	Evaluate solid-solid and solid-fluid separation equipment
CO5	Demonstrate agitation and mixing processes

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	1	2	1	1	1	2	1	1	1	2	3	0	3
CO2	3	2	2	3	1	1	1	2	1	1	1	2	3	1	0
CO3	3	2	2	3	1	1	1	2	1	1	1	2	3	1	2
CO4	3	2	3	3	1	1	1	2	1	1	1	2	3	1	2
CO5	3	2	2	2	1	1	1	2	1	1	1	2	3	1	0

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction: Unit operations and their role in chemical industries; Types of mechanical operations.

Properties and handling of particulate solids: Characterization of solid particles, Properties of masses of particles, mixing of solids, Size reduction, ultrafine grinders.

Screening: Screening equipment, Screen capacity.

Cake filters: Centrifugal filters, Filter media, Principles of cake filtration, Washing filter cakes.

Clarifying filters: Liquid clarification, Gas cleaning, Principles of clarification.

Cross flow filtration: Types of membranes, Introduction to ultrafiltration, diafiltration and microfiltration.

Sedimentation: Gravity sedimentation processes, Centrifugal sedimentation processes.

Agitation and mixing: Introduction to agitation and mixing process

Learning Resources:

Text Books:

1. Unit Operations of Chemical Engineering, McCabe W. L., Jullian Smith C and Peter Harriott, McGraw-Hill international Edition, 2005,7thEdition.

Reference Books:

1. Chemical Engineering, Coulson J.M., Richardson J.F, Vol. II,Elsevier India, 2006,4th Edition
2. Principles of Unit Operations, Alan S. Foust, Leonard A. Wenzel, Curtis W. Clump, Louis Maus and L. Bryce Andersen,, Wiley, 2008, 2nd Edition.
3. Introduction to Chemical Engineering, Walter L. Badger and Julius T. Banchero,Tata McGraw Hill Edition, 2001.
4. Transport Processes and Separation Process Principles (Includes Unit Operations), Christie John Geankoplis, Prentice Hall India Learning Private Limited, 2004,4th Edition.

Online Resources:

https://nptel.ac.in/courses/103/107/103107123/

CH204	CHEMICAL ENGINEERING THERMODYNAMICS-I	3-0-0	3 Credits	PCC

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.
CO2	Compute the properties of ideal and real gas mixtures.
CO3	Evaluate the efficiency of flow processes.
CO4	Estimate heat and work requirements for industrial processes.
CO5	Analyze refrigeration and liquefaction processes.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	2	2	1	-	-	-	-	-	-	-	-	-	1	3	3
CO2	2	3	2	2	1	-	-	-	-	-	-	-	2	2	3
CO3	2	2	3	3	2	-	-	-	-	-	-	-	2	1	1
CO4	2	2	2	3	2	-	-	-	-	-	-	-	3	1	2
CO5	2	2	3	3	1	-	-	-	-	-	-	-	3	2	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

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.

Volumetric Properties of Pure Fluids: General P-V-T Behavior 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.

The Second Law of Thermodynamics: Statements of the Second Law, Heat Engines, Entropy, Entropy Changes of an Ideal Gas, Mathematical Statement of the Second Law, Entropy Balance for Open Systems, Calculation of Ideal Work, Lost Work, The Third Law of Thermodynamics.

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.

Applications of Thermodynamics to Flow Processes: Duct Flow of Compressible Fluids, Turbines (Expanders), Compression Processes.

Refrigeration and Liquefaction: Carnot Refrigerator, Vapor-Compression Cycle, Choice of Refrigerant, Absorption Refrigeration, Heat Pump, Liquefaction Processes.

Learning Resources:

Text Books:

1. Introduction to Chemical Engineering Thermodynamics, Smith J. M, H. C. Van Ness and M. M. Abbott, McGraw-Hill, 2018, 8th Edition.
2. Chemical Engineering Thermodynamics, K. V. Narayanan, Prentice Hall of India Pvt. Ltd., 2013, 2nd Edition.

Reference Books:

1. Thermodynamics and its Applications, J.W. Tester and M. Modell, Prentice Hall, 1999, 3rd Edition.
2. Chemical, Biochemical, and Engineering Thermodynamics, Stanley I. Sandler, Wiley, 2020, 5th edition 2020.

Online Resources:

https://nptel.ac.in/courses/103/104/103104151/
https://nptel.ac.in/courses/103/103/103103144/
https://nptel.ac.in/courses/103/101/103101004/

CH205	CHEMICAL REACTION ENGINEERING - I	3-0-0	3 Credits	PCC

Pre-Requisites:None

Course Outcomes:

At the end of the course, the student will be able to

CO1	Derive the rate law for non-elementary chemical reactions.
CO2	Determine the kinetics of chemical reaction using integral, differential, fractional-life methods and method of initial rates.
CO3	Design reactors for homogenous reactions under isothermal conditions.
CO4	Select optimal sequence in multiple reactor systems
CO5	Analyze the performance of non-ideal reactors using segregation model, tanks-in series model and dispersion model.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	3	3	1	-	-	-	-	-	-	-	3	3	1
CO2	3	3	3	3	-	-	-	-	-	-	-	-	3	3	2
CO3	3	3	3	3	-	-	-	-	-	-	-	-	3	3	3
CO4	3	3	3	3	-	-	-	-	-	-	-	-	3	3	3
CO5	3	3	3	3	1	-	3	-	-	-	-	-	3	3	3

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Kinetics of Homogeneous Reactions: Concentration-Dependent Term of a Rate Equation, Temperature-Dependent Term of a Rate Equation, Searching for a Mechanism, Predictability of Reaction Rate from Theory.

Conversion and Reactor Sizing: Definition of Conversion, Batch Reactor Design Equations, Design Equations for Flow Reactors, Applications of the Design Equations for Continuous-Flow Reactors, Reactors in Series.

Analysis of Rate Data: The Algorithm for Data Analysis, Batch Reactor Data, Method of Initial Rates, Method of Half-Lives, Differential Reactors, Experimental Planning, Evaluation of Laboratory Reactors.

Isothermal Reactor Design: Mole Balances in Terms of Conversion- Design Structure for Isothermal Reactors, Scale-Up of Liquid-Phase Batch Reactor Data to the Design of a CSTR, Design of Continuous Stirred Tank Reactors (CSTRs), Tubular Reactors. Mole Balances

Written in Terms of Concentration and Molar Flow Rate- Mole Balances on CSTRs, PFRs, and Batch Reactors, recycle reactor.

RTD for Chemical Reactors: General Characteristics, Measurement of the RTD, Characteristics of the RTD, RTD in Ideal Reactors, Diagnostics and Troubleshooting, Reactor Modelling Using the RTD, Zero-Parameter Models, RTD and Multiple Reactions.

Analysis of non-ideal reactors: One- parameter models, two-parameter models, Tanks-in-Series (T-I-S) Model, Dispersion Model.

Learning Resources:

Text Books:

1. Chemical Reaction Engineering, O. Levenspiel, Wiley India, 2006, 3rd Edition.
2. Elements of Chemical Reaction Engineering, H. Scott Fogler, Prentice Hall India Learning Private Limited, 2016., 5th Edition.

Reference Books:

1. Introduction to Chemical Reaction Engineering & Kinetics, Ronald W. Missen, Charles A. Mims, Bradley A. Saville, Wiley, 1998, 2nd Edition.
2. Chemical Reactor Design, E. Bruce Nauman, Optimization and Scaleup, Wiley, 2008.
3. Fundamentals of Chemical Reaction Engineering, Mark E. Davis & Robert J. Davis, McGraw Hill, 2002.
4. Chemical Reaction Engineering: Essentials, Exercises and Examples, Martin Schmal, CRC Press, 2014, 1st edition.
5. Chemical Engineering Kinetics, Smith J. M., McGraw Hill India, 1981, 3rd Edition.

Online resources:

http://umich.edu/~elements/5e/

CH 206	CHEMICAL PROCESSING LABORATORY	0-1-2	2 Credits	PCC

Pre-Requisites:CH203–Mechanical Operations, CH205– Chemical Engineering Thermodynamics – I

Course Outcomes:

At the end of the course, the student will be able to

CO1	Analyse samples such as water, soap, urea and petroleum products
CO2	Synthesize products such as soap, formaldehyde and silica colloids
CO3	Achieve the desired size reduction using appropriate equipment
CO4	Separate solid-solid, solid-liquid and solid-gas mixtures using mechanical operations
CO5	Estimate VLE data for a given binary system
CO6	Evaluate thermodynamic properties such as specific heat capacity, volume of mixing and heat of mixing of binary liquids

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	2	2	2	2	1	1	1	2	3	3	1	1	-	1	-
CO2	3	2	2	2	1	1	1	2	3	3	1	1	2	1	1
CO3	3	2	1	2	1	1	1	2	3	3	1	1	3	3	2
CO4	3	2	1	2	1	1	1	2	3	3	1	1	3	3	2
CO5	3	2	1	2	1	1	1	2	3	3	1	1	3	3	2
CO6	3	2	1	2	1	1	1	2	3	3	1	1	2	3	1

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

I. Analysis

Water:

Experiment 1a: Determine total alkalinity of a given water sample using methyl orange indicator

Experiment 1b: Determine total alkalinity of a given water sample using methyl orange &phenolphthalein indicator

Soap:

Experiment 2a: Determine the alkali content present in the given sample of soap

Experiment 2b: Determine the Fatty acid content present in the given sample of soap

Urea:

Experiment 3: Determine the percentage of nitrogen content present in the given sample of urea fertilizer

II. Product Synthesis

Experiment 4: Preparation of soap

Experiment 5: Preparation of formaldehyde resin

Experiment 6: Synthesis of silica colloids

III. Testing Methods of fuels

Experiment 7: Determine the Flash and Fire point of petroleum products
Experiment 8: Determine Smoke point and Aniline point of petroleum products

IV. Mechanical Operations
Jaw crusher:
Experiment 9: Determine the efficiency of given crushing material
Vibrating screen:
Experiment 10: Determine the overall effectiveness for a given solid mixture
Ball mill:
Experiment 11: Determine the energy required for crushing the given feed and thus obtain the work index for the same
Batch sedimentation:
Experiment 12: Obtain the batch settling data and demarcate the different settling regimes for the given slurry
Cyclone separator:
Experiment 13: Study the performance of a given solid-air mixture

V. Thermodynamics
Experiment 14: Determine thermodynamic properties of a given binary mixture.
Experiment 15: Obtain the VLE data for a given binary mixture.

Learning Resources:

Text Books:
1. Lab manuals

Reference Books:
1. Unit Operations of Chemical Engineering, McCabe W. L., Jullian Smith C and Peter Harriott, McGraw-Hill international Edition, 2005,7th Edition.
2. Introduction to Chemical Engineering Thermodynamics, Smith J. M, H. C. Van Ness and M. M. Abbott, McGraw-Hill, 2018, 8th Edition.

CH207	FLUID AND PARTICLE MECHANICS LABORATORY	0-0-3	1.5 Credits	PCC

Pre-Requisites: None.

Course Outcomes:

At the end of the course, the student will be able to

CO1	Determine viscosity of liquids using Cannon Fenske viscometer and terminal settling velocity.
CO2	Distinguish laminar and turbulent flows.
CO3	Determine the characteristics of flow meters, packed & fluidized beds and centrifugal pumps.
CO4	Verify Bernoulli's theorem
CO5	Calculate pressure drop across pipe, valves and fittings.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	2	1	2	3	-	-	-	2	3	3	2	1	1	3	1
CO2	2	1	2	3	-	-	-	2	3	3	2	1	2	3	1
CO3	2	1	2	3	-	-	-	2	3	3	2	1	2	3	1
CO4	2	1	2	3	-	-	-	2	3	3	2	1	2	3	1
CO5	2	1	2	3	-	-	-	2	3	3	2	1	2	3	1

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

1. Determination of viscosity using Cannon Fenske Viscometer.
2. Distinguish between laminar and turbulent flow using Reynolds Experiment.
3. Verification of Bernoulli's theorem experimentally.
4. Determination of frictional losses in flow through pipes
5. Determination of frictional losses in pipe fittings and valves.
6. Determination of the viscosity of given solution using Terminal settling velocity data.
7. Study the characteristics of a packed bed with air flow.
8. Study the characteristics of a packed bed with water flow.
9. Study the characteristics of fluidized bed.
10. Determination of Orifice coefficient and Venturi coefficient.
11. Measurement of point velocity and determination of velocity profile using Pitot tube.
12. Determination of pressure drop in flow through non-circular pipes.
13. Study the characteristics of a centrifugal pump.
14. Determination of Efflux time.

Learning Resources:

Text Books

1. Laboratory Manuals.
2. Unit operations of Chemical Engineering, McCabe W. L., Jullian Smith C. and Peter Harriott, McGraw-Hill International Edition, 2005, 7th Edition.
3. Chemical Engineering Volume I and II, Coulson J.M and Richardson. J.F, Elsevier India, 2006, 5th Edition.
4. Fluid Mechanics for Chemical Engineers, De Nevers N H, McGraw Hill, NY, 2004, 3rd Edition.

II-Year II-Sem

CH251	CHEMICAL ENGINEERING THERMODYNAMICS-II	3-0-0	3 Credits	PCC

Pre-Requisites: Chemical Engineering Thermodynamics – I

Course Outcomes:

At the end of the course, the student will be able to

CO1	Evaluate heat effects involved in industrial chemical processes
CO2	Determine thermodynamic properties of gaseous mixtures and solutions
CO3	Estimate Bubble-P & T, Dew-P & T for binary and multi-component systems
CO4	Calculate vapor-liquid equilibrium (VLE) composition for ideal and non-ideal systems
CO5	Determine equilibrium constant and composition of product mixture for single and multiple reactions

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	2	1	1	2	2	-	-	-	-	-	-	-	2	2	3
CO2	1	2	1	2	2	-	-	-	-	-	-	-	1	1	2
CO3	2	2	1	1	2	-	-	-	-	-	-	-	1	1	2
CO4	2	1	1	2	2	-	-	-	-	-	-	-	2	2	2
CO5	1	1	1	1	2	-	-	-	-	-	-	-	1	1	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

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.

VLE at low to moderate pressures: The nature of equilibrium, Criteria of equilibrium, The phase rule, Duhem's theorem, Raoult's law, Henry's law, Modified Raoults's law, Dew point and bubble point calculations, Relative volatility, Flash calculations.

Solution Thermodynamics: Fundamental property relation, Chemical potential, Partial properties, The ideal gas mixture model, Fugacity and fugacity coefficient, The ideal solution model, Excess properties.

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.

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, Multireactionequilibria.

Learning Resources:

Text Books:

1. Introduction to Chemical Engineering Thermodynamics, Smith J. M, H. C. Van Ness and M. M. Abbott, McGraw-Hill, 2018, 8th Edition.
2. Chemical Engineering Thermodynamics, K. V. Narayanan, Prentice Hall of India Pvt. Ltd., 2013, 2nd Edition.

Reference Books:

1. Thermodynamics and its Applications, J.W. Tester and M. Modell, Prentice Hall, 1999, 3rd Edition.
2. Chemical, Biochemical, and Engineering Thermodynamics, Stanley I. Sandler, Wiley, 2020, 5th edition 2020.

Online Resources:

https://nptel.ac.in/courses/103/104/103104151/
https://nptel.ac.in/courses/103/103/103103144/
https://nptel.ac.in/courses/103/101/103101004/

CH252	HEAT TRANSFER	3-0-0	3 Credits	PCC

Pre-Requisites:Chemical Process Calculations, Fluid and Particle Mechanics

Course Outcomes:

At the end of the course, the student will be able to

CO1	Identify the modes of heat transfer.
CO2	Calculate heat transfer coefficients for forced and natural convection.
CO3	Perform heat transfer calculations involving phase changes.
CO4	Calculate net radiant heat loss from a surface.
CO5	Carryout preliminary design calculations for double pipe and shell & tube heat exchangers.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	3	1	1	2	3	-	2	3	1	1	3	3	2
CO2	3	2	3	1	1	2	3	-	2	3	1	1	3	3	2
CO3	3	2	3	1	1	2	3	-	2	3	1	1	3	3	2
CO4	3	2	3	`1	1	2	3	-	2	3	1	1	3	3	2
CO5	3	2	3	1	1	2	3	-	2	3	1	1	3	3	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction: Modes of heat transfer, material properties of importance in heat transfer.
Heat Transfer by Conduction in Solids: Governing partial differential equations - Steady state heat conduction, Conduction through bodies in series; Unsteady state heat conduction - lumped capacity method, Heisler's charts.

Principles of heat flow in fluids - Concept of heat transfer coefficient; Individual and overall heat transfer coefficient; Critical insulation thickness.

Heat Transfer to fluids without phase change: Principle of convection; Concept of Boundary layers; Heat transfer by forced convection in laminar flow; Turbulent flow and transition region; Heat transfer to liquid metals; Forced convection on outside tubes; Natural convection; Momentum and heat transfer analogies.
Heat Transfer to fluids with phase change: Heat transfer from condensing vapors; Heat transfer to boiling liquids.

Radiation Heat Transfer: Concepts of radiation; Laws of radiation; Radiation between black surfaces; Interchange factor; Exchange of energy between parallel planes and concentric cylinders/spheres.

Heat Exchange equipment: Heat Exchangers; Condensers and Boilers; Shell and Tube Heat Exchangers; Other types of Heat Exchangers; Concept of fins, Preliminary Design of Heat Exchangers; Effectiveness-NTU Method.Evaporation: Basics of evaporation; Types of evaporators, Performance of tubular evaporators; Capacity & Economy; Multiple effect evaporator; Principles of Crystallization; Crystallization equipment.

Learning Resources:

Text Books:

1.Unit Operations of Chemical Engineering, McCabe W. L., Smith J. C., Harriott P., McGraw Hill, 2005, 7th Edition.
2. Heat Transfer, Holman J. P, McGraw Hill, 2010, 10th Edition.

Reference Books:

1. Heat Transfer: A Practical Approach, Cengel Y. A, McGraw Hill, 2003, 2nd Edition.
2. Process Heat Transfer, Kern D. Q., Tata McGraw Hill Education Pvt. Ltd., 2001.
3. Introduction to heat transfer, Incropera F. and David DeWitt., John Wiley and Sons Inc, 1985.

Online Resources:

https://onlinecourses.nptel.ac.in/noc20_ch21/preview

CH253	MASS TRANSFER - I	3-0-0	3 Credits	PCC

Pre-Requisites: CH201-Chemical Process Calculations, CH204-Chemical Engineering Thermodynamics - I

Course Outcomes:

At the end of the course, the student will be able to

CO1	Identify diffusion phenomena in various chemical processes.
CO2	Determine diffusivity coefficient in gases, liquids and solids.
CO3	Calculate mass transfer coefficients at interfaces of multiphase mass transfer systems
CO4	Design equipment for gas-liquid mass transfer operations.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	2	2	2	2	2							2	2	2	1
CO2	3	3	2	2	2							2	2	2	2
CO3	3	3	2	2	2							2	2	2	2
CO4	3	3	3	2	2							2	3	2	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction: Unit operations with mass transfer phenomena, Introduction to solute transport.

Molecular Diffusion: Stefan tube experiment to determine diffusion coefficient in gases, Fick's law of diffusion, Determination of diffusion coefficient in liquids, Diffusion of naphthalene into air – example, Two bulb method to determine diffusion coefficient in gases, Correlations for diffusion coefficient in gases and liquids, Dependence on temperature and pressure, Unsteady state diffusion: semi-infinite slab example, Correlation for diffusion coefficient in multi-component gaseous mixture, Formulation of flux with a reaction occurring on surface, Diffusion in solids.

Inter-Phase Mass Transfer: Pure liquid (stationary) to gas mixture (gently mixed), Concept of mass transfer coefficient and driving force, Pure gas (stationary) to liquid mixture (gently mixed), Pure gas to liquid (laminar falling film), Concept of Sherwood number, Sherwood number correlations for various geometries and flow regimes: The Route to Correlations, Theories of mass transfer coefficient for gas to turbulent liquid flow, Two film resistance theory; Analogies between heat, mass and momentum transfer.

Equipment for Gas-Liquid Operations: Components of equipment in packed towers, Bubble column, Tray towers, etc. Material balance for packed tower absorption process – Distributed parameter model, Equilibrium curve & Operating line, height of transfer unit and number of transfer units, Stage efficiency.

Humidification Operations: Terminology and definitions, Psychrometric charts, Adiabatic operation, Equipment & components, Non-adiabatic operation, Introduction to cooling tower and domestic air cooler.

Learning Resources:

Text Books:

1. Mass Transfer Operations, Treybal R.E., McGrawHill, 1981, 3rd Edition.
2. Principles of Mass Transfer and Separation Processes, Binay K. Dutta, Prentice-Hall India, 2007, 2nd Edition.
3. Mass Transfer – Theory and Applications, K V Narayanan and B Lakshmikutty, CBS Publishers & Distributors pvt. ltd., 2014.

Reference Books:

1. Transport processes and Separation Process Principles, Geankoplis C.J., Prentice-Hall India, 2003, 4th Edition.
2. Diffusion – Mass transfer in fluid systems, E. L. Cussler, Cambridge University Press, 2009, 3rd Edition.
3. Separation Process Principles, Ernest J. Henley, J. D. Seader, D. Keith Roper, Wiley, 2011, 3rd Edition.

Online Resources:

1. https://nptel.ac.in/courses/103/103/103103035/
2. https://www.youtube.com/playlist?list=PL23LJMmRTn8ds1rekMjTxHARlnKrPcPch

CH254	CHEMICAL REACTION ENGINEERING – II	3-0-0	3 Credits	PCC

Pre-Requisites: CH205-Chemical Reaction Engineering-I, CH204-Chemical Engineering Thermodynamics – I

Course Outcomes:

At the end of the course, the student will be able to

CO1	Select reactor type and operating conditions for conducting multiple reactions
CO2	Design reactors under non-isothermal conditions
CO3	Derive the rate law for heterogeneous catalytic reactions
CO4	Design packed bed reactor in the absence and presence of mass transfer effects
CO5	Analyze the effect of velocity, particle size and fluid properties on rate of reactions controlled by mass transfer
CO6	Design fluidized bed reactors

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	2	1	-	-	-	-	-	-	-	-	3	2	1
CO2	3	2	3	-	-	-	-	-	-	-	-	-	3	3	1
CO3	3	2	2	-	1	-	-	-	-	-	-	-	3	2	1
CO4	3	2	3	-	-	-	-	-	-	-	-	-	3	2	2
CO5	3	2	2	-	-	-	-	-	-	-	-	-	3	2	1
CO6	2	2	3	1	1	-	-	-	-	-	-	-	3	2	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Design of multiple reactions: Design of parallel reactions, Irreversible reactions in series, Successive irreversible reactions of different orders. Reversible reactions, Complex reactions.

Non-isothermal reactor design: Energy balances, Adiabatic tubular reactor design. Equilibrium conversion, multiple steady state in CSTR.

Catalysis and Catalytic Reactors: Catalysts, Steps in a Catalytic Reaction, Synthesizing a Rate Law, Mechanism, and Rate-Limiting Step, Heterogeneous Data Analysis for Reactor Design.

External Diffusion Effects on Heterogeneous Reactions: Diffusion Fundamentals, Binary Diffusion, External Resistance to Mass Transfer, Shrinking Core Model. Rate equation for fluid solid reactions. Design of heterogeneous catalytic reactors.

Diffusion and Reaction: Internal Effectiveness Factor, Falsified Kinetics, Overall Effectiveness Factor, Estimation of Diffusion and Reaction-Limited Regimes, Mass Transfer and Reaction in a Packed Bed, Determination of Limiting Situations from Reaction Data, Multiphase Reactors, Fluidized Bed Reactors.

Learning Resources:

Text Books:

1. H. Scott Fogler, Elements of Chemical Reaction Engineering, Prentice Hall India Learning Private Limited, 5^{th} Edition, 2016.
2. O. Levenspiel, Chemical Reaction Engineering, Wiley India, 3rd Edition, 2006.

Reference Books:

1. Problem Solving in Chemical Engineering with Numerical Methods, Cutlip & Shacham
2. J. M. Smith, Chemical Engineering Kinetics, 3rd Edition, McGraw Hill, 1981.
3. T. J. Carberry, Chemical and Catalytic Reaction Engineering, McGraw Hill, 1976.

Online Resources:

1. http://umich.edu/~elements/5e/
2. https://nptel.ac.in/courses/103/101/103101008/

CH255	PROCESS INSTRUMENTATION	3-0-0	3 Credits	PCC

Pre-Requisites:None

Course Outcomes:

At the end of the course, the student will be able to

CO1	Characterize the performance of instruments
CO2	Identify the instrument for pressure and temperature measurements
CO3	Select instruments for flow and level measurements
CO4	Choose suitable recording, indicating and signaling instruments

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	-	1	3	2	-	-	-	-	-	-	1	-	3	1
CO2	3	-	1	3	1	-	-	-	-	-	-	1	-	3	1
CO3	3	-	1	3	1	-	-	-	-	-	-	1	-	3	1
CO4	3	-	1	3`	2	-	-	-	-	-	-	1	-	3	1

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Characteristics of measurement system-Elements of instruments, static and dynamic characteristics, calibration, basic concepts of response of first order instruments, mercury in glass thermometer, bimetallic thermometer, pressure spring thermometer, static accuracy and response of thermometers.

Temperature measurement-Industrial thermocouples, thermocouple wires, thermal wells and response of thermocouples, resistance temperature detector.

Pressure measurement-Pressure, vacuum and head manometers, measuring elements for gage pressure and vacuum, measuring pressure in corrosive liquids, Measurement of absolute pressure, static accuracy and response of pressure gages.

Flow measurement-open channel meters, flow of dry materials, Viscosity measurement.

Level measurement-Direct measurement of liquid level, level measurement in pressure vessels, measurement of interface level, level of dry materials.

Concentration measurements-Turbidity meter, refractometer, colorimeter.

Instruments for analysis – recording instruments, transducers, indicating and signaling instruments, instrumentation diagram.

Learning Resources:

Text Books:

1. Principles of Industrial instrumentation, Patranabis D, McGraw Hill education, 2017,3rd Edition.
2. Industrial instrumentation, Eckman Donald P., Wiley Eastern Ltd., 2004.

Reference Books:

1. Fundamentals of industrial instrumentation and process control, William C.Dunn, McGraw Hill Education, 2017.

CH256	CHEMICAL TECHNOLOGY	3-0-0	3 Credits	PCC

Pre-Requisites:None

Course Outcomes:

At the end of the course, the student will be able to

CO1	Selection of a process for manufacture of chemicals
CO2	Drawprocess flow diagrams.
CO3	Identify the engineering problems in chemical processes
CO4	List chemical reactions and their mechanism involved.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	1	1	3	1	2	3	3	-	-	-	-	-	3	2	-
CO2	2	2	2	2	2	-	-	-	-	-	-	-	3	2	-
CO3	3	3	2	1	2	-	-	-	-	-	-	-	3	2	-
CO4	2	2	2	2	-	-	-	-	-	-	-	-	3	2	-

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction: Chemical industries-facts and figures, Unit operation and unit process concepts, chemical processing and role of chemical engineers.

Chloro-Alkali Industries: Soda ash, Solvay process, dual process, Natural soda ash from deposits, Electrolytic process, Caustic soda.

Phosphorus Industries: Phosphoric acid, Wet process, Electric furnace process, Calcium phosphate, Ammonium phosphates, Nitrophosphates, Sodium phosphate. Potassium Industries: Potassium recovery from sea water.

Nitrogen Industries: Ammonia, Nitric acid, Urea from ammonium carbonate, Ammonium nitrate. Sulfur and Sulfuric Acid Industries: Elemental sulfur mining by Frasch process, Sulfur production by oxidation-reduction of H_2S, Sulfur and sulfur dioxide from pyrites, Sulfuric acid. Contact process, Chamber process.

Soap and Detergents: Batch saponification production, Continuous hydrolysis and saponification process, Sulfated fatty alcohols, Alkyl-aryl sulfonates

Sugar and Starch Industries: Sucrose, Extraction of sugar cane to produce crystalline white sugar, Extraction of sugar cane to produce sugar, Starch production from maize, Production of dextrin by starch hydrolysis in a fluidized bed. Fermentation Industries: Ethyl alcohol by fermentation, Fermentation products from petroleum.

Pulp and Paper Industries: Sulfate pulp process, Chemical recovery from sulfate pulp digestion liquor, Types of paper products, Raw materials, Methods of production.

Plastic Industries: Polymerization fundamentals, Polymer manufacturing processes, Ethenic polymer processes, Polycondensation processes, Polyurethanes. Rubber: Elastomer polymerization processes, Rubber polymers, Butadiene-Styrene copolymer, Polymer oils and rubbers based on silicon.

Cement Industries: Classification- based on source of cement, based on broad sense cement, based on the application, appearance and constituent of cement. Manufacturing methods- Wet method, Dry method.

Learning Resources:

Text Books:

1. Austin G.T., Shreve's Chemical Process Industries - International Student Edition, McGraw Hill Inc., 5th Edition, 1998.
2. Sittig M. and Gopala Rao M., Dryden's Outlines of Chemical Technology for the 21st Century, 3rd Edition, WEP East West Press, 2010.

Reference Books:

1. B.K. Sharma, Industrial chemistry, 15th edition, Goel Publishing House (Krishna Prakashan Media P. LTD.-Meerut), 2016.
2. James A. Kent, Riegel's Hand Book of Industrial Chemistry, Springer Science Business Media, LLC, 9th Edition, Volume-1, 2013.
3. Andreas Jess, Peter Wasserscheid, Chemical Technology, Wiley-VCH, 2013. 6. Smith W. and Chapman R., Chemical Process Industries, Vol 1 & 2, CBS Publishers, 1st Edition, 2016.

Online Resources:

1. NPTEL : Chemical Technology - I (Chemical Engineering) (digimat.in)
2. NPTEL :: Chemical Engineering - Chemical Technology - I

CH257	INDUSTRIAL SAFETY AND HAZARDS MITIGATION	3-0-0	3 Credits	PCC

Pre-Requisites: Thermodynamics, Chemical reaction engineering,Plant design.

Course Outcomes:

At the end of the course, the student will be able to

CO1	Analyze the effects of toxic releases
CO2	Select the methods for prevention of fires and explosions
CO3	Identify the hazards and preventive measures
CO4	Assess the risks using fault tree diagram.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	2	2	3	-	-	3	3	2	-	-	-	-	2	3	1
CO2	2	2	3	-	-	3	3	2	-	-	-	-	2	3	1
CO3	2	2	3	-	-	3	3	2	-	-	-	-	2	3	1
CO4	2	2	3	-	-	3	3	2	-	-	-	-	2	3	1

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction and Industrial hygiene: Safety programs, Engineering ethics, Accident and loss Statistics, Acceptable risk, Public perceptions, Nature of the accident process, Inherent safety, Anticipation and identification, Hygiene evaluation and control.

Fires and Explosions and concepts to prevent fires and explosions: Fire triangle, Distinction between fires and explosions, Flammability characteristics of liquids and vapors, Limiting oxygen concentration and inerting, Flammability diagram, Inerting, Controlling static electricity, Explosion-proof equipment and instruments, Ventilation, Sprinkler systems.

Introduction to reliefs: Relief concepts, location of reliefs, relief types, relief scenarios, Data for sizing reliefs, relief systems.

Hazards Identification: Process hazards checklists, Hazards surveys, Hazards and Operability studies, safety reviews.

Safety procedures and designs: Process safety Hierarchy, Managing safety, Best practices, procedures- operating, Procedures-permits, Procedures- safety reviews and accident investigations, Designs for process safety

Learning Resources:

Text Books:

1. Chemical process safety (Fundamentals with Applications) D.A.Crowl and J.F Louvar, Prentice Hall, 2013,3rd Edition.

Reference Books:

1. Chemical Engineering, Volume 6, John Metcalf Coulson, John Francis Richardson, R.K.SinnottButterwoth-Heinemann 1999.
2. Safety in the process Industries, Rulph king, Butterworth-Heinemann, 1990.

CH258	HEAT TRANSFER LABORATORY	0-0-3	1.5 Credits	PCC

Pre-Requisites:None

Course Outcomes:

At the end of the course, the student will be able to

CO1	Determine thermal conductivity of solids and fluids
CO2	Calculate efficiency of fins
CO3	Verify Newton's law of cooling of hot objects
CO4	Determine efficiency of Double Pipe and Shell & Tube Heat exchangers
CO5	Determine the Stefan's Boltzmann Constant for Radiation Heat Transfer

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	3	1	1	2	3	-	2	3	1	1	3	3	2
CO2	3	2	3	1	1	2	3	-	2	3	1	1	3	3	2
CO3	3	2	3	1	1	2	3	-	2	3	1	1	3	3	2
CO4	3	2	3	`1	1	2	3	-	2	3	1	1	3	3	2
CO5	3	2	3	1	1	2	3	-	2	3	1	1	3	3	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

List of experiments:

1. Demonstration of the analogue between heat conduction in solids and electric conduction in an L-shaped network of electrical resistances.
2. Determination of overall and individual plate thermal conductivity for a composite wall.
3. Determination of a rod type fin efficiency.
4. Determination of thermal conductivity of metal Rod.
5. Determination of heat transfer coefficient during natural convection from a heated vertical cylinder.
6. Determination of Pin – Fin efficiency.
7. Determination of overall heat transfer coefficient of a double pipe heat exchanger.
8. Determination of overall heat transfer coefficient of a shell and tube heat exchanger.
9. Determination of radiation emissivity of a test plate.
10. Determination of Stefan-Boltzmann constant for radiation.

Learning Resources:

Text Books:Lab Manuals

CH259	CHEMICAL REACTION ENGINEERING LABORATORY	0-1-2	2 Credits	PCC

Pre-Requisites: None

Course Outcomes:

At the end of the course, the student will be able to

CO1	Determine the kinetics of a reaction in a Batch reactor, Semi-batch reactor, CSTR, & PFR
CO2	Determine the kinetics of a variable volume reaction
CO3	Determine the kinetics by fractional life method
CO4	Determine the temperature dependency of a reaction
CO5	Evaluate the performance of reactors through RTD studies
CO6	Compare the performance of single reactor with combination of reactors

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	1	1	1	-	1	-	2	-	-	-	2	3	1
CO2	3	2	1	1	1	-	1	-	2	-	-	-	2	3	1
CO3	3	2	1	1	1	-	1	-	2	-	-	-	2	3	1
CO4	3	2	1	`1	1	-	1	-	2	-	--	-	2	3	1
CO5	3	2	1	1	1	-	1	-	2	-	-	-	2	3	1
CO6	3	2	1	1	1	-	1	-	2	-	-	-	2	3	1

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

1) Determine the concentration dependency of a reaction in a Batch reactor (BR)
2) Determine the concentration dependency of a reaction in a CSTR
3) Determine the concentration dependency of a reaction in a PFR
4) Determine the concentration dependency of a reaction in a Semi-batch reactor (SBR)
5) Determination of rate constant and temperature dependency of a reaction
6) Determination of rate constant in a combined reactor (PFR followed by CSTR)
7) Determination of rate constant in a Cascade CSTR (or CSTRs in series)
8) Determination of RTD characteristics of a packed bed reactor
9) Determine the kinetics by fractional life method
10) Determine the kinetics of a variable volume reaction by Dilatometry
11) Determine the kinetics of Polymerization of acrylic acid in a batch reactor.
12) Determination of RTD characteristics of a PFR

Learning Resources:

Text Books:

1. Laboratory Manuals
2. Chemical Reaction Engineering, Octave Levenspiel, Wiley India, 2006, 3rd Edition.

Reference Books:

1 Elements of Chemical Reaction Engineering, H. Scott Fogler, Prentice Hall India Learning Private Limited, 2016, 5th Edition.

Online resources

http://umich.edu/~elements/5e/software/reactorlab.html

III-Year I-Sem
Programme Core Courses (PCC)

CH301	MASS TRANSFER - II	3-0-0	03 Credits	PCC

Pre-Requisites: CH253- Mass Transfer – I

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

CO1	Analyze VLE, LLE, and SLE data
CO2	Select a suitable mass transfer operation for a given separation
CO3	Determine number of stages in absorption, distillation, extraction and adsorption operations
CO4	Design packed column for absorption, distillation, extraction and adsorption operations
CO5	Calculate drying rates and moisture content for batch and continuous drying operations

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	2	2	2	-	-	-	-	-	-	2	2	2	1
CO2	3	2	2	2	2	-	-	-	-	-	-	2	2	2	1
CO3	3	2	3	2	2	-	-	-	-	-	-	2	3	2	1
CO4	3	2	3	2	2	-	-	-	-	-	-	2	3	2	1
CO5	3	2	2	2	2	-	-	-	-	-	-	2	2	3	1

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Gas Absorption: Equilibrium solubility of gases in liquids, one component transferred - material balances, one component transferred counter-current multistage operation, stage efficiency, continuous contact equipment.

Distillation: Vapor-Liquid Equilibria, single stage operation - flash vaporization, differential or simple distillation, continuous rectification - binary systems, Design of multistage tray towers: McCabe-Thiele method. Steam distillation, Continuous contact equipment (packed towers), Extractive distillation, Azeotropic distillation.

Liquid-Liquid Extraction: Liquid-Liquid equilibria, Extraction equipment, stage-wise contact, design of stage type extractors and differential (continuous contact) extractors: immiscible and partially miscible systems.

Drying: Equilibrium, drying operations - batch drying, mechanism of batch drying and continuous drying, drying equipment.

Adsorption and Ion exchange: Adsorption equilibria, Batch and continuous adsorption, Selection of adsorbent, Specific surface area of an adsorbent, Adsorption Dynamics, Thermal regeneration of adsorbents.

Learning Resources:

Text Books:

1. Mass Transfer Operations, Treybal R.E., McGrawHill, 1981, 3rd Edition.
2. Principles of Mass Transfer and Separation Processes, Binay K. Dutta, Prentice-Hall India, 2007, 2nd Edition.
3. Mass Transfer – Theory and Applications, K V Narayanan and B Lakshmikutty, CBS Publishers & Distributors pvt. ltd., 2014.

Reference Books:

1. Transport processes and Separation Process Principles, Geankoplis C.J., Prentice-Hall India, 2003, 4th Edition.
2. Diffusion – Mass transfer in fluid systems, E. L. Cussler, Cambridge University Press, 2009, 3rd Edition.
3. Separation Process Principles, Ernest J. Henley, J. D. Seader, D. Keith Roper, Wiley, 2011,3rd Edition.

Online Resources:

1. https://nptel.ac.in/courses/103/104/103104046/

CH302	ELEMENTS OF TRANSPORT PHENOMENA	3-0-0	3 Credits	PCC

Pre-Requisites: CH202 - Fluid and particle mechanics, CH252 - Heat Transfer, CH253 – Mass Transfer-I

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

CO1	Estimate the transport properties of solids, liquids and gases.
CO2	Formulate mathematical representation of momentum / energy / mass transport phenomena.
CO3	Solve flow/heat/mass transfer problems either individually or coupled for simple geometries analytically.
CO4	Apply analogy between momentum, energy and mass transport.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	1	2	2	1	2	-	1	-	1	-	-	2	1	3	1
CO2	3	2	2	2	1	-	1	-	1	1	-	2	2	3	2
CO3	3	3	3	2	1	-	1	-	1	1	-	2	2	3	2
CO4	3	2	2	2	1	-	1	-	1	1	-	2	2	3	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction to Transport phenomena.

Momentum Transport: Viscosity & mechanisms of momentum transport – Newton's law of viscosity and its generalization, Pressure and temperature dependence of viscosity, Viscosity of suspensions and emulsions, convective momentum transport; Shell momentum balances and velocity distributions in laminar flow; Equations of change for isothermal systems - Continuity equation, Equation of motion, Navier-Stokes Equation, Laminar velocity profiles in simple geometries such as flow between parallel plates, flow in a circular pipe, flow down an inclined plane, Dimensional analysis of equations of change; Time dependent flow of Newtonian fluids.

Energy Transport: Thermal conductivity & mechanisms of heat transport – Fourier's law of heat conduction, temperature and pressure dependence of thermal conductivity, Thermal of conductivity of solids, Effective thermal conductivity of composite solids, Convective transport of energy; Shell energy balances and temperature distributions in solids and laminar flow; Equations of change for non-isothermal systems – Energy equation and its special forms, Boussinesq equation of motion, Use of equations of change to solve steady state problems - Temperature profile for simple geometries with/without heat generation, Temperature profile in laminar flowing fluids with/without heat generation, free convection; Dimensional analysis of the equations of change for non-isothermal systems; Time dependent Temperature profile in solids.

Mass Transport: Diffusivity & mechanisms of mass transport – Fick's law of binary diffusion, temperature and pressure dependence of diffusivities, Mass and molar transport by convection, summary of mass and molar fluxes; Concentration distributions in solids and laminar flow - Shell mass balances; boundary conditions; Diffusion through stagnant gas film; Diffusion with chemical reaction; Diffusion into a falling liquid film; Diffusion and chemical reaction inside a porous catalyst; Equation of continuity for a multicomponent mixture; Summary of multicomponent equations of change and fluxes; Simultaneous heat and mass transport.

Analogies: Analogies between momentum, heat & mass transfer correlations for friction factor/Nusselt Number/Sherwood Number.

Learning Resources:

Text Books:

1. Transport Phenomena, R.B. Bird, W.E. Stewart, E.N. Lightfoot, John Wiley & Sons, 2007, 2nd Edition.
2. Transport Processes and Separation Process Principles, C.J. Geankoplis, Prentice Hall Inc., 2009, 4th Edition.

Reference Books:

1. Heat and Mass Transfer: A Transport Phenomena Approach, K.S. Gandhi, New Age International Publishers, 2017.
2. Analysis of Transport Phenomena, W.M. Deen, Oxford University Press, 2013, 2nd Edition.
3. Introduction to Transport Phenomena: Momentum, Heat, and Mass, Bodh Raj, Prentice Hall India Learning Private Limited, 2012.
4. Transport Phenomena: Chemical Processes, T. Sunil Kumar, Studium Press (India) Pvt. Ltd. 2016.

Online Resources:

1. https://nptel.ac.in/courses/103/105/103105128/

CH303	PROCESS EQUIPMENT DESIGN (Open Book)	3-0-0	3 Credits	PCC

Pre-Requisites: CH202-Fluid and Particle Mechanics; CH252-Heat Transfer; CH254-Chemical Reaction Engineering-II; CH301-Mass Transfer-II

Course Outcomes:

At the end of the course, the student will be able to

CO1	Evaluate the process design considerations of separation columns and heat transfer equipment
CO2	Design heat exchangers, evaporators, absorbers, distillation columns and reactors
CO3	Apply mechanical design concepts to process equipment
CO4	Draw process equipment and flowsheets

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	2	3	1	1	-	-	-	-	2	3	3	3	2
CO2	3	2	3	3	2	2	-	-	-	-	-	-	3	3	2
CO3	2	2	3	2	1	2	-	-	-	-	-	-	3	1	-
CO4	1	1	2	-	2	1	-	-	-	-	-	-	3	-	-

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Process design of Separation columns: Design variables, general design considerations, process design methods, Column sizing, Plate and packed column hydraulics design. Design of an absorber, Design of a distillation column.

Process design of heat-transfer equipment: Types of heat exchanger, Design of double pipe heat exchanger, design of shell and tube heat exchanger, Design of Condenser, and reboilers. Design of evaporator, and crystallizer.

Design of auxiliary equipment: Design of agitator and reactor vessel. Design of cylindrical and spherical vessels under internal pressure, external pressure and combined loading. Computational tools for chemical process equipment.

Detailed description and drawing of process equipment.

Learning Resources:

Text Books:

1. Coulson & Richardson's Chemical Engineering, R.K. Sinnott, Volume 06, Elsevier, 2005, 3rd Edition.
2. Process Heat Transfer, Donald Q. Kern, Tata McGraw-Hill Education, Indian Edition, 2017.
3. Introduction to Chemical Equipment Design- Mechanical Aspects, Bhattacharya B.C., CBS Publishers and Distributors, 2008.
4. Joshi's process equipment design, Mahajani V.V. and Umarji S.B., Trinity Press, 2014, 4th Edition.

Reference Books:

1. Process Equipment and Plant Design - Principles and Practices, Ray. Subhabrata, Das, Gargi, 2020, Elsevier Inc.
2. Shah RK, Sekulic DP. Fundamentals of heat exchanger design, John Wiley & Sons, 2003.
3. Process Equipment Design - Vessel Design, Brownell L.E, Wiley Eastern Ltd., 1986.
4. Mass Transfer Operations, Robert E. Treybal, McGraw Hill Education, 1980, 3rd Edition.
5. Chemical Engineering Design, Principles, Practice and Economics of Plant and Process Design, Towler G. P. and R. K. Sinnott, Butterworth Heinemann, 2012, 2nd Edition.
6. Handbook of chemical process equipment, Nicholas O Cheremisinoff, Butterworth-Heinemann, 2000.

Online Resources:

1. https://nptel.ac.in/courses/103/107/103107207/
2. https://onlinecourses.nptel.ac.in/noc21_ch52/course

CH304	POLLUTION CONTROL IN PROCESS INDUSTRIES	3-0-0	3 Credits	PCC

Pre-Requisites: CH256-Chemical Technology

Course Outcomes:

At the end of the course, the student will be able to

CO1	Analyze the effects of pollutants on the environment
CO2	Distinguish air pollution control methods
CO3	Design gas equipment for pollution control
CO4	Assess treatment technologies for wastewater
CO5	Identify solid waste treatment technologies

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PS03
CO1	3	1	2	2	-	1	2	1	1	1	1	1	1	-	-
CO2	3	1	2	2	-	1	2	1	1	1	1	1	1	-	-
CO3	2	2	3	2	1	1	1	-	-	-	-	1	1	2	1
CO4	3	2	3	2	2	3	3	1	1	1	1	1	3	3	-
CO5	3	2	3	2	2	3	3	1	1	1	1	1	3	3	

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction: Biosphere, Hydrological cycle, Nutrient cycle, Consequences of population growth, Pollution of air, Water and soil.

Air pollution sources & effects: Classification and properties of air pollutants, Emission sources, Behavior and fate of air pollutants, Effect of air pollution.

Meteorological aspects of air pollutant dispersion: Temperature lapse rates and stability, Wind velocity and turbulence, Plume behavior, Dispersion of air pollutants, Estimation of plume rise.

Air pollution sampling and measurement: Types of pollutant sampling and measurement, Ambient air sampling, Stack sampling, Analysis of air pollutants.

Air pollution control methods & equipment: Control methods, Source correction methods, Cleaning of gaseous effluents, Particulate emission control, Selection of a particulate collector, Control of gaseous emissions, Design methods for control equipment.

Control of specific gaseous pollutants: Control of sulphur dioxide emissions, Control of nitrogen oxides, Carbon monoxide control, Control of hydrocarbons and mobile sources.

Water pollution: Water resources, Origin of wastewater, types of water pollutants and their effects.

Waste water sampling, analysis and treatment: Sampling, Methods of analysis, Determination of organic matter, Determination of inorganic substances, Physical characteristics, Bacteriological measurement, Basic processes of water treatment, Primary treatment, Secondary treatment, Advanced wastewater treatment, Recovery of materials from process effluents, Zero liquid discharge, Membrane based treatment, industrial case studies.

Solid waste management: Sources and classification, Public health aspects, Methods of collection, Disposal Methods, Potential methods of disposal.

Hazardous waste management: Definition and sources, Hazardous waste classification, Treatment methods, Disposal methods.

Learning Resources:

Text Books:

1. Environmental Pollution Control Engineering, Rao C.S., New Age International Publishers, 2018, 3rd Edition.
2. Air Pollution and Control Engineering, Noel de Nevers, Waveland Press, Inc., 2016, 3rd Edition
3. Environmental Science and Engineering, Glynn Henry J., Gary W. Heinke, Prentice Hall of India, 2004, 2nd Edition.
4. Air Pollution, Rao M.N, Rao H.V.N, Tata McGraw Hill Education, 2017, 1st Edition.

Reference Books:

1. Environmental Chemistry, De A.K, New Age International Publishers, 2007, 7th Edition.
2. Waste water engineering: treatment and reuse, George Tchobanoglous, Franklin Louis Burton, H. David Stensel, Metcalf & Eddy, Inc., McGraw Hill Education., 2003, 4th Edition.
3. E-waste recycling, NPCS Board of consultants and Engineers, Asia Pacific Business Press Inc. 2015.
4. Handbook of Pollution Prevention Practices, Nicholas P. Cheremisinoff, CRC press, 2001, 1st Edition.

Online Resources:

1. https://nptel.ac.in/courses/105/102/105102089/
2. https://nptel.ac.in/courses/103/107/103107084/
3. https://cpcb.nic.in/

4. http://moef.gov.in/en/
5. https://mnre.gov.in/
6. https://tspcb.cgg.gov.in/default.aspx

MA336	SCIENTIFIC COMPUTING WITH R AND PYTHON	2-0-2	3 Credits	ESC

Pre-Requisites: None

Course Outcomes:

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

CO1	Understand the basics of Python programming.
CO2	Develop programs using R
CO3	Gain knowledge in various data pre-processing techniques
CO4	Understand the basics of Data Science

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	1	3	3	3	3	3	3	3	-	-	-	-	-	-	-
CO2	1	3	3	3	3	3	3	3	-	-	-	-	-	-	-
CO3	1	3	3	3	3	3	3	3	-	-	-	-	-	-	-
CO4	1	3	3	3	3	3	3	3	-	-	-	-	-	-	-

Syllabus:

R Basics: Basic objects in R, operations on the objects, Vector, working with null values, Import & Export files in R, Data-frame, Joins, One-way and Two-way tables, Vectors, Matrices

Statistics using R: Mathematics for Data science Probability, Statistics, Linear Algebra, Gradient Descent, Calculus for data science, ANOVA, Hypothesis testing.

Python Basics: Python Basics Objects and Functions, Identifiers, Variables and Datatypes, Operators, Python Flow, Function Arguments, Recursive functions, Lambda, Exception Handling, Iterators, Generators and Decoders.

Numpy and Pandas: NumPy and Pandas Numpy: Arrays, Vectorization, Boolean Indexing, Matrix multiplication, Tuple, Join/Merge data, Unicode strings etc.

Pandas: Data Structure, Data frame, reading data, handling missing data.

Learning Resources:

Text Books:

1. R for Everyone: Advanced Analytics and Graphics, Jared P. Lander, Addison-Wesley, 2017, Second Edition
2. Python Cookbook: Recipes for Mastering Python 3, David Beazley, Brian K. Jones,

O'Reilly Media Inc., 2013, Third Edition

ReferenceBooks:

1. Hands on programming with R, Garrett Grolemund, O'Reilly, SPD (Shroff Publications and Distributors Pvt Ltd), 2014
2. Python Crash Course: A Hands-on, Project-Based Introduction to Programming, Eric Matthes, No Starch Press Inc., 2019, Second Edition
3. Head First Python: A Brain-Friendly Guide, Paul Barry, O'Reilly, 2016

CH305	MASS TRANSFER LABORATORY	0-0-3	1.5 Credits	PCC

Pre-Requisites: CH253- Mass Transfer-I

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

CO1	Determine separation performance of batch distillation, steam distillation and sieve plate distillation.
CO2	Determine the efficiency of liquid-liquid extraction.
CO3	Determine the critical moisture content in drying.
CO4	Determine the effect of mass transfer with and without chemical reaction.
CO5	Estimate the diffusion coefficient of vapour in gas.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	2	2	1	1	1	2	1	-	-	-	2	1	2	3	-
CO2	2	2	2	1	1	2	1	-	-	-	2	1	2	3	-
CO3	3	2	2	2	1	2	1	-	-	-	2	1	2	2	-
CO4	2	2	2	1	2	2	1	-	-	-	2	1	2	3	-
CO5	2	2	3	1	1	2	1	-	-	-	2	1	2	3	-

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

1. Verify the law of steam distillation
2. Verify the Rayleigh's equation for differential distillation
3. Determine the number of theoretical plates of a given sieve plate distillation column for the given system at total reflux
4. Determine the diffusivity of a vapor in air
5. Determine the drying characteristics of a given sample (wet sand) by drying in a force draft tray drier.
6. Find the overall recovery of solute in a single as well as two stage cross current extraction unit
7. Determine distribution coefficient for liquid-liquid extraction
8. Determine the saturation isotherm for the ternary liquid – liquid system
9. Calculate the theoretical and experimental mass transfer coefficient for vaporization of naphthalene in air using a packed bed of spherical particles of naphthalene

10. Study the dissolution of benzoic acid in water and in aqueous solution of sodium hydroxide.
11. Study the absorption of carbon dioxide by aqueous sodium hydroxide solution in a packed bed absorption tower.
12. Study the adsorption in a packed bed for a solid liquid system

Learning Resources:

Text Books:

1. Lab manuals
2. Mass Transfer Operations, Treybal R.E., McGrawHill, 1981, 3rdEdition.
3. Principles of Mass Transfer and Separation Processes, Binay K. Dutta, Prentice-Hall India, 2007, 2ndEdition.
4. Mass Transfer – Theory and Applications, K V Narayanan and B Lakshmikutty, CBS Publishers & Distributors pvt. ltd., 2014.

CH306	COMPUTATIONAL METHODS IN CHEMICAL ENGINEERING	0-1-2	2 Credits	PCC

Pre-Requisites: None

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

CO1	Find roots of algebraic equations and solution of simultaneous equations
CO2	Apply regression analysis, interpolation, extrapolation, numerical differentiation and numerical integration
CO3	Write program for solving a given chemical engineering problem
CO4	Solve initial value problems, boundary value problems, & Initial and boundary value problems.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	-	-	2	3	3	-	-	-	-	-	3	3	3
CO2	3	3	-	-	3	1	3	-	-	-	-	-	3	3	3
CO3	3	3	-	-	-	1	3	-	-	-	-	-	3	3	3
CO4	3	3	-	-	-	-	3	-	-	-	-	-	3	3	3

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:
Numerical problems required to be solved using C++ and MATLAB.

Numerical Methods: Roots of algebraic equations and solution of simultaneous equations. Regression analysis, Interpolation and Extrapolation, Differentiation and Numerical Integration. Solution of ordinary differential equations, Initial and Boundary Value Problems. Solutions of partial differential equations.

Applications of Numerical Methods to Chemical Engineering Problems: Material and Energy Balance, Fluid flow operations, Heat transfer, Mass Transfer, Thermodynamics, Mechanical operations, Prediction of properties.

Learning Resources:
Text Books:
1. Computational Techniques for Process Simulation and Analysis using MATLAB, Niket S. Kaisare, Taylor & Francis, CRC press, 2018.
2. *Problem Solving with C++,* Walter Savitch, Pearson, 2014, 9th Edition.
3. Lab Manuals

Reference Books:
1. Applied Numerical Analysis using MATLAB, Laurene V. Fausett, Pearson, 2009, 2nd Edition.
2.Numerical Methods for Chemical Engineers with MATLAB Applications, AlkisConstantinides, NavidMoustoufi, Prentice Hall, 1999.
3. Getting started with MATLAB: A quick introduction for scientists & Engineers, Rudra Pratap, Oxford University Press, 2010.

Online Resources:
https://nptel.ac.in/courses/103/106/103106118/
https://nptel.ac.in/courses/111/102/111102137/

III-Year I-Sem

Professional Elective Courses (PEC)

Electives -1 & 2

CH311	PHARMACEUTICALS AND FINE CHEMICALS	3-0-0	3 Credits	PEC

Pre-Requisites: None

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

CO1	Understand the grades of chemicals.
CO2	State properties, uses and testing of pharmaceuticals and fine chemicals
CO3	Draw flow sheets for manufacture of pharmaceuticals and fine chemicals
CO4	Understand tablet making and coating, preparation of capsules and extraction of crude drugs.
CO5	Understand sterilization.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	3	2	-	2	2	2	-	-	-	-	2	2	-
CO2	3	2	3	2	-	2	2	2	-	-	-	-	2	2	-
CO3	3	2	3	2	-	2	2	2	-	-	-	-	2	2	-
CO4	3	2	3	2	-	2	2	2	-	-	-	-	2	2	-
CO5	3	2	3	2	-	2	2	2	-	-	-	-	2	2	-

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:
A brief outline of different grades of chemicals – Reagent grade and Laboratory grade.

Outlines of preparation – Different methods of preparation of Reagent grade and Laboratory grade Chemicals.

Uses and testing of the pharmaceuticals and fine chemicals – Applications of medicinal value Chemicals and their quality testing procedures.

Properties, assays and manufacture of Pharmaceuticals and fine chemicals with flow sheets Physical and Chemical properties, methods of assessing the quality and industrial methods of formulating the drugs and fine chemicals that have no medicinal value but are used as the intermediates.

Compressed Tablet making and coating – Types of tablets and Methods of compressed tablet making and coating.

Preparation of capsules and extraction of crude drugs – Industrial procedures of capsule formulation and methods of recovering the drugs formulated from the reaction mixture.

Sterilization – Need for sterilization, Sterilization methods, batch and continuous sterilization.

Learning Resources:

Text Books:

1. Remington: The Science and Practice of Pharmacy, AdeboyeAdejare, Elsevier, 2021, 23rd Edition.
2. Industrial Chemicals, William Lawrence Faith, Donald B. Keyes and Ronald L. Clark, John Wiley & Sons, 1975, 4th Edition.

CH312	RENEWABLE ENERGY SOURCES	3-0-0	3 Credits	PEC

Pre-Requisites:None

Course Outcomes:

At the end of the course, the student will be able to

CO1	Identify the challenges and problems associated with the use of energy sources.
CO2	Illustrate the renewable energy technologies.
CO3	Distinguish conversion technologies for solar, wind, biomass and hydrogen energies
CO4	Evaluate the performance of energy conversion technologies

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	2	3	1	-	-	1	3	-	-	-	-	-	1	2	-
CO2	2	3	1	2	-	2	3	-	-	-	-	-	3	1	-
CO3	1	2	2	1	-	2	2	-	-	-	-	-	3	2	-
CO4	2	3	2	1	1	2	3	-	-	-	-	-	2	3	-

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Sources of energy: Energy sources and their availability, renewable energy sources. Energy from Biomass: Introduction, Biomass as a source of energy, Biomass conversion technologies, Biogas generation, classification of biogas plants, Biomass gasification.

Solar Energy: Sun and solar energy, solar radiation and its measurement, solar energy collectors, solar energy storage, Photovoltaic systems, Application of solar energy

Wind Energy: Wind as an Energy source, Basic principles of wind energy conversion, Types of Wind machines, Components of wind energy conversion system, Performance of wind machines, application of wind energy.

Geothermal Energy: Introduction, Origin and distribution of geothermal energy, types of geothermal resources, Hybrid geothermal power plant, Application of geothermal energy Hydrogen energy: Introduction, Hydrogen production, Hydrogen storage, Hydrogen transportation Energy from the Oceans: Introduction, Ocean Thermal Electric Conversion (OTEC), Energy from Tides, Ocean Waves Chemical Energy Sources. Introduction to Fuel cells, and Batteries

Learning Resources:

Text Books:

1. Non-Conventional Energy Sources, Rai, G.D, Khanna Publishers, New Delhi, 2010.
2. Non-Conventional Energy Sources, Rajesh Kumar Prasad, T.P. Ojha, Jain Brothers, 2012.
3. Solar energy – Thermal Collection and storage, Sukhatme S.P and J. Nayak, Tata McGraw Hill Education Pvt. Ltd., 2008, 3rdEdition.
4. Power Plant Technology, MM. El Wakil, Tata McGraw Hill, New York, 1999

CH313	FUEL CELLS AND FLOW BATTERIES	3-0-0	3 Credits	PEC

Pre-Requisites: None

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

CO1	Understand working principles of fuel cells and flow batteries
CO2	Analyze the performance of fuel cell systems.
CO3	Apply fuel processing techniques
CO4	Identify intricacies in operation of fuel cells and flow batteries.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	2	2	3	2	1	1	2	-	2	2	-	1	1	3	1
CO2	2	2	3	2	1	1	2	-	2	2	-	1	1	3	1
CO3	2	2	3	2	1	1	2	-	2	2	-	1	1	3	1
CO4	2	2	3	2	1	1	2	-	2	2	-	1	1	3	1

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction - Electrochemical Flow Systems - Fuel cells and Flow Batteries.

Overview of Fuel Cells: Introduction, brief history, classification, working principle, applications, Fuel cell basic chemistry and thermodynamics, heat of reaction, theoretical electrical work and potential, theoretical fuel cell efficiency.

Fuel cell electrochemistry: electrode kinetics, types of voltage losses, polarization curve, fuel cell efficiency, Tafel equation, exchange currents.

PEM Fuel cell process design: Main PEM fuel cell components, materials, properties and processes, Fuel cell operating conditions.

Fuels & Fuel processing: Hydrogen, Hydrocarbon fuels, Direct and in-direct internal reforming, Reformation of hydrocarbons by steam, CO_2 and partial oxidation, Direct electro-catalytic oxidation of hydrocarbons, carbon deposition, Sulphur tolerance and removal.

Flow batteries: Introduction, Redox flow battery technology - brief history, working principle, redox flow battery components and systems, flow battery testing

Flow Battery Types and Challenges: iron/chromium, Bromine/ polysulphide, Vanadium/ bromine, Zinc/cerium and All Vanadium flow batteries, current research trends and challenges.

Learning Resources:

Text Books:

1. PEM Fuel Cells: Theory and Practice, F. Barbir, Elsevier/Academic Press, 2013, 2nd Edition.
2. Redox flow batteries: Fundamentals and Applications, Huamin Zhang, Xianteng Li, Jiujun Zhang, CRC Press, 2017.

Reference Books:

1. Fuel Cell Fundamentals, O'Hayre, R. P., S. Cha, W. Colella, F. B. Prinz, Wiley, New York, 2006.
2. Polymers for Energy storage and Delivery: Polyelectrolytes for Batteries and Fuel cells, Kirt A. Page, Christopher L. Soles, James Runt, OUP USA, 2012.
3. Fuel Cell Systems Explained, James Larminie, Andrew Dicks, Wiley, 2003, 2nd Edition.
4. Fuel Cell Technology Hand Book, Hoogers G., CRC Press, 2003.

Online Resources:

https://nptel.ac.in/courses/103/102/103102015/

CH314	ENERGY MANAGEMENT	3-0-0	3 Credits	PEC

Pre-Requisites:None

Course Outcomes:

At the end of the course, the student will be able to

CO1	Understand energy management policies, methods and planning
CO2	Carry out energy audit and economic analysis
CO3	Assess energy management control schemes
CO4	Design energy utilization systems for heat recovery
CO5	Select energy security and reliability methods

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	-	-	3	-	-	3	3	-	-	1	2	1	1	-	-
CO2	1	1	2	1	1	3	3	-	-	1	2	1	1	2	2
CO3	1	1	2	1	1	3	3	-	-	1	2	1	1	2	-
CO4	2	3	2	`1	1	3	3	-	-	1	2	1	1	2	2
CO5	-	-	3	1	1	3	3	-	-	1	2	1	1	2	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction: The value of Energy management, suggested principles of energy management

Effective Energy Management: Energy Policy and planning.

Energy auditing and Economic analysis: Energy auditing services, Basic components of an energy audit, Industrial, commercial and residential audits, General characteristics of capital investments, project measures of worth.

Boilers and fired systems, Steam and condensate systems, Cogeneration, Waste heat recovery.

Energy systems: Energy management control systems, energy systems maintenance.

Thermal Energy Storage: Storage system, Storage mediums.

Energy security and Reliability: Risk analysis methods, economics of energy security and reliability, links to energy management.

Financing and commissioning energy management projects.

Learning Resources:

Text Books:

1. Energy Management, Murphy W.R and Mckay G., Elsevier, 2007.
2. Energy Management Handbook, Wayne C. Turner, Steve Doty, CRC Press., 2007, 6th Edition.

Reference Books:

1. Energy Engineering and Management, AmlanChakrabarti, PHI, Eastern Economy Edition, 2018, 2nd Edition.
2. Energy Management Principles, Craig B. Smith Kelly Parmenter, Elsevier, 2015, 2nd Edition.

CH315	CORROSION ENGINEERING	3-0-0	3 Credits	PEC

Pre-Requisites:None

Course Outcomes:

At the end of the course, the student will be able to

CO1	Identify various forms of corrosion.
CO2	Determine corrosion rates for metals from their polarization curves.
CO3	Analyze corrosion rate characteristics from electrochemical impedance spectroscopy.
CO4	Select suitable corrosion resistant coatings, oxide layers for various applications.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	1	2	1	2	2	1	2	-	1	-	-	2	1	3	1
CO2	2	2	1	2	2	1	2	-	1	-	-	2	1	3	1
CO3	2	2	1	2	2	1	2	-	1	-	-	2	1	3	1
CO4	1	2	3	2	2	1	2	-	1	-	-	2	1	3	1

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction & Corrosion Principles: Definition of corrosion, Impact on economy, Electrochemical reactions, Corrosion rate expressions, Polarization, Passivity, Metallurgical aspects.

Forms of Corrosion: Galvanic corrosion, crevice corrosion, pitting, intergranular corrosion, erosion corrosion, stress corrosion, hydrogen damage.

Corrosion testing: Specimen preparation, exposure tests, open corrosion potential, linear polarization, Tafel slopes, corrosion current, stress corrosion cracking, AC impedance/EIS.

Corrosion Prevention: Cathodic protection, sacrificial anode methods of corrosion prevention, Anti-corrosion coatings.

Modern Theory-Principles & Applications: Alloy evaluation, Nobel metal alloying, flow accelerated corrosion, galvanic corrosion as a moving boundary problems.

Learning Resources:

Text Books:

1. Corrosion Engineering, Fontana M, Tata McGraw Hill Education Pvt. Ltd., 2010, 3rd Edition.
2. Corrosion Engineering: Principles and Practice, Pierre Roberge, McGraw Hill, 2008, 1st

Edition.

Reference Books:

1. Electrochemistry and Corrosion Science, Nestor Perez, Springer, 2016, 2nd Edition.
2. Corrosion Engineering: Principles and Solved Problems, Branko N. Popov, Elsevier, 2015, 1st Edition.

CH316	NANOTECHNOLOGY	3-0-0	3 Credits	PEC

Pre-Requisites: None

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

CO1	Understand the properties of nanomaterials and their applications
CO2	Apply chemical engineering principles to nanoparticles production and scale-up
CO3	Analyze the nanomaterials characterization.
CO4	Identify the applications of nanotechnology in electronics and chemical industries

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	1	1	1	-	-	-	-	-	-	-	-	3	0	-
CO2	3	2	2	2	-	-	-	-	-	-	-	-	3	1	-
CO3	3	3	3	3	1	2	-	-	-	-	-	-	3	1	-
CO4	3	1	1	1	-	-	-	-	-	-	-	-	3	0	-

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction to Nanotechnology: Introduction to nanotechnology and materials, Nanomaterials, Introduction to nanosizes and properties comparison with the bulk materials, different shapes and sizes and morphology.

Fabrication of Nanomaterials: Top Down Approach, Grinding, Planetary milling and Comparison of particles, Bottom Up Approach, Wet Chemical Synthesis Methods, Microemulsion Approach, Colloidal Nanoparticles Production, Sol Gel Methods, Sonochemical Approach, Microwave and Atomization

Gas phase Production Methods: Chemical Vapour Depositions. Kinetics at Nanoscale: Nucleation and growth of particles, Issues of Aggregation of Particles, Oswald Ripening, Stearic hindrance, Layers of surface Charges, Zeta Potential and pH.

Carbon Nanomaterials: Synthesis of carbon buckyballs, List of stable carbon allotropes extended fullerenes, metallofullerenes solid C60, bucky onions nanotubes, nanocones Difference between Chemical Engineering processes and nanosynthesis processes.Introduction - Nanoclay Synthesis method, Applications of nanoclay.

Nanomaterials characterization: Instrumentation Fractionation principles of Particle size measurements, Particle size and its distribution, XRD, Zeta potential Microscopies SEM, TEM, Atomic Forced Microscopy, Scanning and Tunneling Microscopy.

Applications in Chemical Engineering: Self-assembly and molecular manufacturing, Surfactant based system Colloidal system applications, ZnO,TiO_2,Silver Nanoparticles Functional materials Applications, Production Techniques of Nanotubes, Carbon arc, bulk synthesis, commercial processes of synthesis of nanomaterials, Nanoclay, Commercial case study of nano synthesis - applications inchemical engineering, Nanoinorganic materials - $CaCO_3$ synthesis, Hybrid wastewater treatment systems, Electronic Nanodevices, sensor applications, Nanobiology: biological methods of synthesis. Applications in drug delivery, Nanocontainers and Responsive Release of active agents, Layer by Layer assembly for nanospheres, Safety and health Issues of nanomaterials, Environmental Impacts, Case Study for Environmental and Societal Impacts

Learning Resources:

Text Books

1. Kulkarni Sulabha K., Nanotechnology: Principles and Practices, Capital Publishing Company, 2015.3rd ed
2. Gabor L. Hornyak., Harry F. Tibbals, Joydeep Dutta, John J. Moore, Introduction to Nanoscience and Nanotechnology, CRC Press, 2009. 1st ed
3. Robert Kelsall, Ian Hamley, Mark Geoghegan, Nanoscale Science and Technology, John Wiley & Sons, 2005. 1st ed

Reference Books

4. Stuart M. Lindsay, Introduction to Nanoscience, Oxford University Press, 2009. 1st ed
5. Davies, J.H. The Physics of Low Dimensional Semiconductors: An Introduction, Cambridge University Press, 1998. 1st ed
6. B. Viswanathan, Nano Materials, Alpha Science 2009. 1st ed
7. T. Pradeep, Nano - The essentials understanding nanoscience and nanotechnology, The McGraw Hill, 2007. 1st ed

Online Resources:

https://nptel.ac.in/courses/118/104/118104008/

CH317	POLYMER ENGINEERING	3-0-0	3 Credits	PEC

Pre-Requisites:None

Course Outcomes:

At the end of the course, the student will be able to

CO1	Explain the thermodynamics of polymer structures
CO2	Select a reactor for polymerization reactions
CO3	Characterize polymers using different techniques
CO4	Choose additives for polymers, blends and composites
CO5	Identify suitable processing method for a given polymer

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	1	1	1	1	-	-	-	-	-	-	-	3	2	1
CO2	2	2	3	1	1	-	-	-	-	-	-	-	2	3	1
CO3	2	1	-	-	-	-	-	-	-	-	-	-	2	-	-
CO4	2	-	-	-	-	-	-	-	-	-	-	-	1	-	-
CO5	2	-	2	-	-	-	-	-	-	-	-	-	2	-	-

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction and Classification of Polymers: Thermosets, Factors influencing the polymer properties, Monomers used for polymer synthesis, synthesis procedure for monomers Styrene, ethylene, Vinyl monomers etc., Thermoplastics, Linear Branch, Cross Linked Polymers, Ewart Kinetics for emulsion polymerization.

Addition polymers: kinetics, synthesis and reactions, Condensation polymers, Kinetics reaction and processes, Polymerization Techniques - Emulsion polymerization and Suspension polymerization, Interfacial Polymerization with their merits

Polymer properties: Molecular Weights, Polydispersity Index, Different Methods of determination of Molecular weight, Effect of Molecular weight on Engineering Properties of Polymers, Smith Ewart Kinetics for emulsion polymerization, Kinetics of free radical polymerization, Chain transfer agents,Kinetics of Step growth polymerization: Ziegler Natta polymerization Processes, Differentiation based on kinetics of Anionic and cationic polymers

Polymerization reactors types and mode of operation: Polymerization reactor design, control of polymerization, Post polymerization unit operations and unit processes

High Performance and Specialty Polymers: Polymer additives, compounding. Fillers, plasticizers, lubricants, colorants, UV stabilizers, fire retardants and antioxidants.

Impact, flexural tensile testing methods of polymers, Mechanical Properties of Polymers, Thermodynamics of Polymer Mixtures, ASTM and ISO methods for testing of polymers.

Polymer processing: Extrusion process, Twin and Single Screw extrusion, Blow moulding, injection moulding, Wet and Dry spinning processes, thermo set moulding. Processing of polymer nanocomposites.

Manufacturing of polymers: flow-sheet diagrams, properties & applications of PE, PP, PS, Polyesters, Nylons, ABS and PC

Learning Resources:

Text Books:

1. Fried J R, Polymer Science and Technology, Prentice Hall of India Pvt. Ltd., New Delhi, Eastern Economy Edition, 2000.
2. Premamoy Ghosh, Polymer Science and Technology, Tata McGraw Hill Publishing Company, New Delhi, 3rd Edition, 2010

Reference Books:

1. R. Sinha, Outlines of Polymer Technology: Manufacture of Polymers, Prentice Hall of India Pvt. Ltd., New Delhi, 2002.
2. George Odian, Principles of Polymerization, John Wiley & Sons, Inc., 2004.

Online Resources:

1. https://nptel.ac.in/courses/103/106/105106205/

2. https://nptel.ac.in/courses/103/107/103107139/

CH318	MECHANICAL DESIGN AND DRAWING	2-1-0	3 Credits	PEC

Pre-Requisites: None

Course Outcomes:

At the end of the course, the student will be able to

CO1	Understand mechanical aspects involved in process equipment design
CO2	Design pressure vessels of varying shapes and pressure conditions
CO3	Select suitable components for the process equipment
CO4	Evaluate the mechanical aspects for designing chemical process equipment
CO5	Draw piping and instrumentation diagram for chemical processes

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	2	2	2	1	-	1	-	-	-	-	-	-	-	-	-
CO2	3	3	3	1	1	-	-	-	-	-	-	-	1	1	1
CO3	3	3	3	1	1	-	-	-	-	-	-	-	1	1	-
CO4	3	3	3	1	1	-	-	-	-	-	-	-	2	2	-
CO5	1	2	1	1	3	-	-	-	-	-	-	-	-	-	-

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction to design procedure: General design procedure. Material of construction, material properties, corrosion and mechanical strength criteria. Design consideration, Stress analysis, Yield/Ultimate/Proof/Code Stresses, Elastic and Plastic, Deformation, Strain Hardening, Safety measures in equipment design, economic considerations.

Pressure vessel: Classification, application of pressure vessels, Design considerations of pressure vessels, pressure vessel codes and standards. Design of external pressure, internal pressure and combined loading pressure vessels. Design of cylindrical and spherical vessels. Design of pressure vessels operating at low and elevated temperatures. Design of shell and its components. Design and selection of process vessel heads, supports, nozzles, flanges, gaskets. Numerical problems on pressure vessel design.

Drawing: Symbols for fluid handling, heat transfer, mass transfer, and mechanical operations. Introduction and drawing of Process block diagram (PBD), Process flow diagram (PFD), Piping and instrumentation diagram (P&ID), Utility flow diagram (UFD), Vessel and piping layout isometrics, basic mechanical data sheet.

Computer aided design: Introduction to compute aided design of equipment and process flow sheets

Text Books:

1. Process Equipment Design, M.V. Joshi, McMillan India, New Delhi, 1976.
2. Chemical Engineering Design, Principles, Practice and Economics of Plant and Process Design, Towler G. P. and R. K. Sinnott, Butterworth Heinemann, 2012, 2ndEdition.

Reference Books:

1. Introduction to Chemical Equipment Design: Mechanical Aspects, B. C. Bhattacharyya, CBS Publishers & Distributors, 2008
2. Process Equipment Design, Brownell L. E. and Young H. E, John Wiley, 2009.
3. Introduction of Chemical Equipment Design, Bhattacharya B. C., CBS Publisher, 2017, 1stedition.
4. Pressure Vessel Design Manual, Moss D. R. Butterworth-Heinemann, 2012, 4thedition.
5. Pressure Vessel Handbook, Megyesy E.F, Pressure Vessel Publishing, 2008, 14thedition.
6. Chemical Process Equipment Design and drawing, Suresh C Maidargi, Volume 1, PHI Learning Pvt. Ltd. 2012

Online Resources:

1. https://nptel.ac.in/courses/103/107/103107143/

CH 319	FUELS AND COMBUSTION	3-0-0	3 Credits	PEC

Pre-requisites: None

Course Outcomes:

At the end of the course, the student will be able to

CO1	Differentiate between various fuels
CO2	analyse exhaust and flue gases
CO3	understand design considerations of burners
CO4	Preparation of Rocket propellants and Explosives

Course Articulation Matrix:

PO / CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	2	3	-	-	-	-	3	-	-	-	-	-	3	2	-
CO2	1	3	2	3	-	-	3	-	-	-	-	-	3	3	-
CO3	1	3	2	2	-	-	3	-	-	-	-	-	3	3	-
CO4	1	3	-	3	-	1	3	-	-	-	-	-	3	3	-

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Classification of coal, analysis and properties of coal, oxidation of coal, hydrogenation of coal, agro fuels, solid fuel handling.

Classification of petroleum products, Handling and storage of petroleum products, Refining and other conversion processes, property and testing of petroleum products, other liquid fuels. Types of gaseous fuels, natural gases, methane from coal mines, manufactured gases, producer gas, water gas, blast furnace gas, refinery gas, LPG, cleaning and purification of gaseous fuels.

Stoichiometry relations, theoretical and minimum air required for complete combustion, calculation of dry flue gases, exhaust gas analysis, flue gas analysis.

Principles of combustion, rapid methods of combustion, flame propagation, various methods of flame stabilization.Basic features of burner, types of solid, liquid and gaseous fuel burners, design consideration of different types of burners, recuperative and regenerative burners, Pulverised fuel furnaces–fixed, entrained, and fluidized bed systems.Emissions, Emission index, corrected concentrations, control of emissions for premixed and non-premixed combustion.

Rocket propellants and Explosives - classification, brief methods of preparation, characteristics; storage and handling.

Learning Resources:

Text Books:

1. Fuels and combustion, S. Sarkar, 3rd Edition, Universities Press, 2009.
2. An Introduction to Combustion: Concepts and Applications, S.R. Turns, McGraw Hill Education , 2012

References

1. Fuels, solid, liquid and gaseous – Their analysis and valuation, H. Joshua Phillips, General Books, 2010.
2. Principles of combustion, K. Kanneth, Wiley and Sons, 2005.
3. Fuels and combustion, S.P. Sharma and C. Mohan, Tata McGraw-Hill, 198
4. *Geology of Petroleum*, A.I. Levorsen, CBS , 2004

III-Year II-Sem
Programme Core Courses (PCC)

CH 351	PROCESS DYNAMICS AND CONTROL	3-0-0	3 Credits	PCC

Pre-Requisites: MA236Partial Differential Equations, Statistics andNumerical Methods, CH255 Process Instrumentation

Course Outcomes:

At the end of the course, the student will be able to

CO1	Understand the dynamic behavior of processes
CO2	Analyze components of a control loop
CO3	Evaluate the stability of feedback control system
CO4	Design controllers for first and second order processes
CO5	Determine the frequency response for controllers and processes

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	3	3	3	-	-	-	-	-	-	1	2	3	3
CO2	3	3	3	2	3	-	-	-	-	-	-	1	2	3	3
CO3	3	2	3	3	3	-	-	-	-	-	1	1	2	3	3
CO4	3	3	2	3	3	-	-	-	-	-	-	1	1	3	3
CO5	3	3	3	3	3	-	-	-	-	-	1	1	2	3	3

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Motivation and Introduction to the course: Open and closed loop control, Review of Laplace transforms, Hierarchical levels in process control

State space models: Transfer Functions, Linearization, Forcing Functions and Responses. Physical examples of First and Second order systems.

Block Diagram: Controllers and Final Control Elements. Control Valves: Valve Characteristics, Valve Positioner.

Closed loop Transfer functions: Transient response of control systems: Servo Problem, Regulatory Problem, Controllers: Proportional, Proportional-Integral, Proportional-Integral – Derivative (PID) Controllers.

Stability: Routh Test, Root Locus, Direct substitution method.

Controller Design: Ziegler-Nichols and Cohen-Coon Controller Settings. Direct synthesis method, Internal model control (IMC),

Frequency Response: Substitution Rule, Bode Diagrams. Control system design based on frequency response: Bode and Nyquist Stability Criterion, Gain and Phase Margins.

Advanced Regulatory Control Strategies: Cascade Control, Feed-forward Control, Ratio Control, Dead-Time Compensation (Smith Predictor), Split-range control, Override control and inferential control.

Introduction to model predictive control.

Learning Resources:

Text Books:

1. Coughanowr D.R., Process System analysis and Control, McGraw Hill, 2012, 3rd Edition.

2. Seborg D.E., Edgar T. E and Millichamp D.A, Process Dynamics and Control, John Wiley & Sons, 2016, 4th Edition.

3. RaghunathanRengaswamy, Babji Srinivasan, NiravPravinbhai Bhatt, Process Control Fundamentals: Analysis, Design, Assessment, and Diagnosis, CRC Press, 2020.

Reference Books:

1. Stephanopolis G., Chemical Process Control, Prentice Hall India, 2008.

2. Bequette, B.W., Process Control: Modeling, Design and Simulation, 2007.

CH352	CHEMICAL PROCESS OPTIMIZATION	3-0-0	3 Credits	PCC

Pre-Requisites: CH201-Chemical Process Calculations, CH202-Fluid and Particle Mechanics, CH252-Heat Transfer, CH254-Chemical Reaction Engineering II, CH301-Mass Transfer II

Course Outcomes:

At the end of the course, the student will be able to

CO1	Formulate objective function for a given problem
CO2	Solve unconstrained & constrained optimization problems involving single and multi-variables
CO3	Apply linear programming and nonlinear programming techniques
CO4	Use dynamic programming for optimization

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	-	-	2	3	3	-	-	-	-	-	3	3	3
CO2	3	3	-	-	3	1	3	-	-	-	-	-	3	3	3
CO3	3	3	-	-	-	1	3	-	-	-	-	-	3	3	3
CO4	3	3	-	-	-	-	3	-	-	-	-	-	3	3	3

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

The Nature and Organization of Optimization Problems: What Optimization is all about, Why Optimize? Scope and Hierarchy of Optimization, Examples of applications of Optimization, The Essential Features of Optimization Problems, General Procedure for Solving Optimization Problems, Obstacles to Optimization.

Basic Concepts of Optimization: Continuity of Functions, Unimodal vs multimodal functions, Convex and concave functions, convex region, Necessary and Sufficient Conditions for an Extremum of an Unconstrained Function, Interpretation of the Objective Function in terms of its Quadratic Approximation.

Optimization of Unconstrained Functions: One Dimensional search Numerical Methods for Optimizing a Function of One Variable, Scanning and Bracketing Procedures, Newton and Quasi-Newton Methods of Unidimensional Search, Polynomial approximation methods, How One-Dimensional Search is applied in a Multidimensional Problem, Evaluation of Unidimensional Search Methods.

Unconstrained Multivariable Optimization: Direct methods, Indirect methods – first order, Indirect methods – second order

Linear Programming and Applications: Basic concepts in linear programming, Degenerate LP's – Graphical Solution, Natural occurrence of Linear constraints, The Simplex methods of solving linear programming problems, standard LP form, Obtaining a first feasible solution, Sensitivity analysis, Duality in linear programming.

Nonlinear programming with constraints: The Lagrange multiplier method, Necessary and sufficient conditions for a local minimum, introduction to quadratic programming.

Optimization of Staged and Discrete Processes: Dynamic programming, Introduction to integer and mixed integer programming

Learning Resources:

Text Books:

1. Optimization of Chemical Processes, Edgar T.F. and D. M. Himmelblau, McGraw Hill, 2001, 2nd Edition.
2. Design of Thermal Systems, Stoecker W. F., McGraw-Hill, 2011, 3rd Edition.
3. Engineering Optimization: Theory and Practice, Singiresu S Rao, John Wiley & Sons Ltd., 2019, 5th Edition.
4. Optimization: Theory and Practice, Mohan C. Joshi, Kannan M. Moudgalya, Alpha Science International Limited, 2004.
5. Convex optimization, Stephen Boyd, LievenVandenberghe, Cambridge University Press, 2004.
6. Applied Optimization with MATLAB Programming, P. Venkataraman, Wiley, 2009, 2nd Edition.

CH353	PETROLEUM REFINING PROCESSES	3-0-0	3 Credits	PCC

Pre-Requisites: None

Course Outcomes:

At the end of the course, the student will be able to

CO1	Characterize the petroleum and petroleum products
CO2	Design the fractionating column for crude
CO3	Differentiate the treatment techniques involved in post processing of crude
CO4	Apply the process flow technologies for crude conversion to fuels

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	-	-	2	3	3	-	-	-	-	-	3	3	3
CO2	3	3	-	-	3	1	3	-	-	-	-	-	3	3	3
CO3	3	3	-	-	-	1	3	-	-	-	-	-	3	3	3
CO4	3	3	-	-	-	-	3	-	-	-	-	-	3	3	3

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Origin, formation and composition of petroleum: Origin and formation of petroleum, Reserves and deposits of world, Petro Glimpses and petroleum industry in India, Composition of petroleum.

Petroleum processing data: Evaluation of Petroleum, Thermal properties of petroleum fractions, important products-properties and test methods.

Fractionation of petroleum: Dehydration and desalting of crudes, heating of crudes, Distillation of petroleum, blending of gasoline.

Treatment techniques: Fractions-Impurities, Gasoline treatment, Treatment of kerosene, Treatment of lubes, Wax and purification.

Thermal and catalytic processes: Cracking, Catalytic cracking, Catalytic reforming-introduction and theory, Naptha cracking, Coking, Hydrogen processes, Alkylation, Isomerization processes, Polymer gasoline.

Learning Resources:

Text Books:

1. Modern Petroleum Refining Processes, B.K. Bhaskara Rao, Oxford& IBH Publishing Co. Pvt. Ltd., 2008, 4th Edition.
2. Handbook of petroleum refining, James G. Speight, CRC Press, 2017.
3. Fundamentals of Petroleum Refining, Mohamed A. Fahim, Taher A. Al-Sahhaf, AmalElkilani, Elsevier Science, 2010
4. Handbook of Petroleum Refining Processes, R. A. Meyers, McGraw Hill, 2003, 3rd Edition.

CH354	DESIGN AND SIMULATION LABORATORY	0-1-3	2.5 Credits	PCC

Pre-Requisites: None

Course Outcomes:

At the end of the course, the student will be able to

CO1	Carry out thermodynamic property estimations
CO2	Simulate Mixer, splitter, pumps, compressors and flash units
CO3	Apply sensitivity, design specification and case study tools
CO4	Design heat exchangers, reactors and distillation columns
CO5	Optimize process flowsheets using sequential modular and equation oriented approaches.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	3	3	3	3	-	-	-	-	-	-	3	3	3
CO2	3	3	3	3	3	1	-	-	-	-	-	-	3	3	3
CO3	3	3	3	3	3	3	-	-	-	-	-	-	3	3	3
CO4	3	3	3	3	3	2	-	-	-	-	-	-	3	3	3
CO5	3	3	3	3	3	2	-	-	-	-	-	-	3	3	3

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Solve the following simulation exercises using **Aspen:**

1. Physical property estimations.
2. Simulation of individual units like, mixers, splitters, heat exchangers, flash columns and reactors
3. Design and rating of heat exchangers
4. Design and rating of distillation columns.
5. Mass and Energy balances.
6. Handling user specifications on output streams – Sensitivity and design Spec tools.
7. Simulation of a flowsheet
8. Simulation exercises using calculator block
9. Optimization Exercises
10. Simulation using equation oriented approach
11. Demonstration of Aspen Dynamics
12. Demonstration of HEN synthesis

Learning Resources:

Text Books:

1. Lab manuals / Exercise sheets
2. Chemical Process Modelling and Computer Simulation, A. K. Jana, Prentice Hall India, 2018, 3rd Edition.
3. Learn Aspen Plus in 24 Hours, Thomas A. Adams II, McGraw Hill Education, 2018.
4. Chemical Process Design and Simulation - Aspen Plus and Aspen HYSYS Applications, JumaHaydary, Wiley, 2019.

Online Resources:

1. https://www.youtube.com/channel/UClqMObzFdVn8_pz3pltMIuw/videos

CH355	MINOR RESEARCH PROJECT	0-0-2	1 Credit	PCC

Pre-Requisites: None

Course Outcomes:

At the end of the course, the student will be able to

CO1	Conduct an independent research project involving experimentation/modelling/simulation/optimization in chemical engineering
CO2	Analyze the results
CO3	Communicate the research results orally to an audience
CO4	Present a detailed written report

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	3	3	3	1	1	2	2	1	2	2	2	3	2
CO2	3	3	3	3	3	1	1	2	2	1	2	2	2	3	2
CO3	-	-	-	-	-	-	-	2	2	3	-	-	2	3	2
CO4	-	-	-	-	-	-	-	2	2	3	-	-	2	3	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

The student is required to choose any one of the following:

1. Project involving experimentation/modelling/simulation/design/optimization in chemical engineering and allied areas related to research/industry/society
2. Develop prototype/lab experiments.
3. Generation and interpretation of additional experimental data using existing UG/PG lab experimental setups
4. Develop virtual model

i. Introduction
ii. Literature review
iii. Problem definition / scope and motivation for the work
iv. Experimental work / mathematical modeling and Analysis / Simulation
v. Results and Discussion
vi. Conclusions
Nomenclature.
References
Minimum number of pages in the report should be 25.
Written report shall adhere to the prescribed format

Learning Resources:

1. Relevant Journal and Magazines

III-Year II-Sem
Professional Elective Courses (PEC)
Electives-3 &4

CH361	ENERGY TECHNOLOGIES	3-0-0	3 Credits	PEC

Pre-requisites: None

Course Outcomes:

At the end of the course, the student will be able to

CO1	Identify the Energy sources and its exploration
CO2	Design process equipment for alternative energy sources
CO3	Explain the principles of solar cells and fuel cells
CO4	Analysis for energy accounting & auditing

Course Articulation Matrix:

	PO1	PO2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO10	PO11	PO12	PSO 1	PSO 2	PSO 3
CO1	2	3	-	-	-	-	3	-	-	-	-	-	3	2	-
CO2	1	3	2	3	-	-	3	-	-	-	-	-	3	3	-
CO3	1	3	2	2	-	-	3	-	-	-	-	-	3	3	-
CO4	1	3	-	3	-	1	3	-	-	-	-	-	3	3	-

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Conventional Energy Sources: Formation of fossil fuels & resources. Energy sources: Coal; Oil; Natural gas; Hydropower. Coal Gasification & Liquefaction; Synthetic fuels; Hydrogen; Methods & applications of Cogeneration; Fluidized-bed combustion, combined cycle plants. Role of coal in energy crisis.

Non-conventional Energy Sources: Study of power plants using energy sources like solar, wind, geothermal, ocean thermal, tide. Design of Biogas plant; Biomass energy; Alternative fuels from biomass.

Direct Energy Conversion: Solar cells; Photovoltaic cells; Theory of junction-type cells & construction details. Fuel cells: types; practical considerations; construction & working details. Principles of MHD power generation. Nuclear energy: Nuclear fuels; Fission-type reactor.

Waste heat recovery: Heat pump; Demand of energy & Forecasting; Principles of energy accounting & auditing; economics; Principles of energy management; Technology assessment with reference to case studies.

Energy Conservation & Management: Energy Scenario in the World and India in 21st century. Exploration of energy resources based on combustion.

Learning Resources:

Text Books:

1. Energy Technology – Non conventional, Renewable & conventional, S. Rao, Khanna Publishers, New Delhi.
2. An Introduction to Power Plant Technology, G.D. Rai, Khanna Publishers, New Delhi.
3. Non-conventional Energy Sources, G.D. Rai, Khanna Publishers, New Delhi

CH362	FERTILIZER TECHNOLOGY	3-0-0	3 Credits	PEC

Pre-Requisites: None

Course Outcomes:

At the end of the course, the student will be able to

CO1	Classify fertilizers
CO2	Explain manufacturing processes for production of fertilizers
CO3	Identify the effect of technologies on the health, safety and environment
CO4	Explain the mechanism of chemical reactions

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	1	3	-	-	-	-	3	-	-	-	-	-	3	1	-
CO2	1	3	-	-	-	2	3	-	-	-	-	-	3	1	-
CO3	1	3	-	-	-	3	3	-	-	-	-	-	3	3	-
CO4	2	3	-	-	-	1	3	-	-	-	-	-	3	1	-

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction: Elements required for plants growth, Classification of fertilizers, Compound, Complex and bulk blended fertilizers. N-P-K values and calculations. Long-term effects of fertilizer use. Fertilizer and environmental pollution.

Nitrogenous Fertilizers: Manufacturing Processes for Ammonia, Manufacture of ammonium sulphate, ammonium chloride, Ammonium phosphate, Ammonium nitrate, nitric acid, Urea etc. Economics and other strategies, Material of construction and corrosion problem.

Phosphatic fertilizers: Calculation of percentage tricalcium phosphate of lime in phosphatic rock: Manufacture of triple super phosphate and single super phosphate, Nitro phosphate, Sodium phosphate, phosphoric acid and other phosphatic fertilizers.

Potash Fertilizers: Manufacture of potash fertilizers like potassium sulphate, potassium chloride.

Complex Fertilizers: Processes for nitro-phosphates and complex NPK fertilizers liquid fertilizers

Learning Resources:

Text Books:

1. Dryden's Outlines of Chemical Technology for the 21st Century, Sittig M and GopalaRao M., WEP East West Press, 2010, 3rd Edition.
2. Fertilizer Technology and Management, Brahma Mishra, I K International Publishing house Pvt. Ltd, 2012

Reference Books:

1. A Text Book of Chemical Technology, Vol I & II, Shukla S D and Pandey G N, Vikas Publishing House Pvt. Ltd., New Delhi, 2018, 2nd edition.
2. The Fertilizer Encyclopedia, Vasant Gowariker, V. N. Krishnamurthy, SudhaGowariker, ManikDhanorkar, KalyaniParanjape Wiley, 2008
3. Shreve's Chemical Process Industries, Austin G T., McGraw Hill Book Company, New Delhi, 2017, 5th Edition.
4. Handbook on Fertilizer Technology, Fertilizer Association of India, JNU, New Delhi, 1977, 2nd Edition.
5. Fertilizers: Science and Technology, Eugene Perry, Callisto Reference Publisher, 2018.
6. Manures and Fertilizers, A.K. Kolay, Atlantic, 2008.

Online Resources:

1. https://nptel.ac.in/courses/103/107/103107086/

CH 363	FOOD TECHNOLOGY	3-0-0	3 Credits	PEC

Pre-Requisites: None

Course Outcomes:

At the end of the course, the student will be able to

CO1	Explain techniques in food processing
CO2	Design process equipment to achieve the desired quality of food
CO3	Develop novel food processes that have a minimal effect on food quality
CO4	Select control strategies to maintain food quality

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	2	3	-	-	-	-	3	-	-	-	-	-	3	2	-
CO2	1	3	2	3	-	-	3	-	-	-	-	-	3	3	-
CO3	1	3	2	2	-	-	3	-	-	-	-	-	3	3	-
CO4	1	3	-	3	-	1	3	-	-	-	-	-	3	3	-

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction: General aspects of food industry, World food demand Constituents of food, Quality and nutritive aspects, Product and Process development, engineering challenges in the Food Processing Industry.

Basic principles: Properties of foods and processing theory, Heat transfer, Effect of heat on micro- organisms, Basic Food Biochemistry and Microbiology: Food Constituents; Food fortification, Water activity, Effects of processing on sensory characteristics of foods, Effects of processing on nutritional properties, Food safety, good manufacturing practice and quality Process Control in Food Processing.

Ambient Temperature Processing: Raw material preparation, Size reduction, Mixing and forming, Separation and concentration of food components, Centrifugation, Membrane concentration, Fermentation and enzyme technology, Irradiation, Effect on micro-organisms, Processing using electric fields, high hydrostatic pressure, light or ultrasound. Heat processing using steam, water and air: Blanching, Pasteurisation, Heat sterilization, Evaporation and distillation, Extrusion, Dehydration, Baking and roasting.

Heat processing by direct and radiated energy: Dielectric heating, Ohmic heating, Infrared heating, Gamma irradiation.

Post Processing Applications Packaging: Coating or enrobing, Theory and Types of packaging materials, Printing, Interactions between packaging and foods, Environmental considerations.

Learning Resources:

Text Books:

1. Food Processing Technology: Principles and Practice, Fellows P., Woodhead Publishing, 2016, 4thEdition.
2. Fundamentals of Food Process Engineering, Toledo R, Springer, 2010, 3rdEdition.
3. Introduction to Food Engineering, Singh R.P. & Heldman D.R., Academic Press, 2001, 3rdEdition.

Online Resources:

https://nptel.ac.in/courses/103/107/103107088/

CH 364	GREEN TECHNOLOGY	3-0-0	3 Credits	PEC

Pre-Requisites: None

Course Outcomes:

At the end of the course, the student will be able to

CO1	Understand principles and concepts of green chemistry
CO2	Develop manufacturing processes to reduce wastage and energy consumption
CO3	Design the technologies to reduce the level of emissions from buildings and core infrastructure
CO4	Analyze the effects of pollutants on the environment

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	1	1	1	2	3	1	-	-	-	-	3	2	1
CO2	3	3	3	1	1	2	3	-	-	-	-	-	3	2	2
CO3	3	3	3	1	1	2	3	-	-	-	-	-	3	2	2
CO4	3	3	2	2	2	2	3	1	-	-	-	-	3	2	3

1 - Slightly; 2 - Moderately; 3 – Substantially

Detailed Syllabus:

Principles and concepts of Green Chemistry: Introduction, Sustainable Development and Green Chemistry, Rearrangement Reactions, Addition Reactions, Atom Un-economic Reactions, Substitution Reactions, Elimination Reactions, Wittig Reactions, Toxicity. Waste- Production, Problems and Prevention: Introduction, Some Problems Caused by Waste, Sources of Waste from the Chemical Industry, The Cost of Waste, Waste Minimization Techniques.

Measuring and controlling environmental performance: The Importance of Measurement, Lactic Acid Production, Safer Gasoline, Introduction to Life Cycle Assessment, Green Process Metrics, Environmental Management Systems.

Catalysis and green chemistry: Introduction to Catalysis, Comparison of Catalyst Types, Heterogeneous Catalysts, Basics of Heterogeneous Catalysis and Homogeneous Catalysis. Organic solvents, Environmentally benign solutions: Organic Solvents and Volatile Organic Compounds, Solvent-free Systems, Supercritical Fluids, Supercritical Carbon Dioxide, Supercritical Water, Water as a Reaction Solvent, Water-based Coatings, Ionic Liquids, Ionic Liquids as Catalysts, Ionic Liquids as Solvents, FluorousBiphase Solvents.

Renewable Energy as a means of Green energy: Role of Renewable energy sources in promoting Green Technology.

Emerging Greener technologies and Alternative energy solutions: Design for Energy Efficiency, Photochemical Reactions, Advantages of and Challenges Faced by Photochemical, Processes, Examples of Photochemical Reactions, Chemistry Using Microwaves, Microwave Heating, Microwave-assisted Reactions, Sonochemistry, Sonochemistry and Green Chemistry, Electrochemical Synthesis, Examples of Electrochemical Synthesis.

Designing greener processes: Conventional Reactors, Batch Reactors, Continuous Reactors, Inherently Safer Design, Minimization, Simplification, Substitution, Moderation, Limitation, Process Intensification, Some PI Equipment, Examples of Intensified Processes, In-process Monitoring, Near-infrared Spectroscopy. Inherent safety-safety in design, case studies of major accidents

An integrated approach to a greener chemical industry: Society and Sustainability, Barriers and Drivers, The Role of Legislation, EU White Paper on Chemicals Policy, Green Chemical Supply Strategies.

Learning Resources:

Text Books:

1. Green Chemistry, Mike Lancaster, Royal Society of Chemistry, 2010.
2. John C. Warner, Green Chemistry: Theory and Practice, Paul T. Anastas, Oxford University Press, 2000.
3. Annie Warmke, Green Technology, Jay Warmke, Educational Technologies Group, 2009.
4. Handbook of Green Chemistry & Technology, James Clark and Duncan Macquarrie, Blackwell Publishing, 2002.
5. Green Chemical Engineering: An introduction to Catalysis, Kinetics, and Chemical Processes, S. Suresh and S. Sundaramoorthy, CRC Press, 2015.

CH365	PULP AND PAPER TECHNOLOGY	3-0-0	3 Credits	PEC

Pre-Requisites: None

Course Outcomes:

At the end of the course, the student will be able to

CO1	Explain process for manufacturing paper
CO2	Identify harmful impacts of paper and pulp industries on environment
CO3	Describe mechanical-chemical pulping processes
CO4	Distinguish methods for pulp treatment

Course articulation matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	2	3	2	2	2	2	2	-	-	2	-	1	3	2	1
CO2	2	3	3	2	2	2	3	-	2	2	-	2	2	2	1
CO3	2	3	2	2	2	2	2	-	-	2	-	1	3	2	1
CO4	2	3	2	-	-	2	2	-	-	2	-	1	3	3	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction and Paper making raw materials: History of Paper Making, Paper making raw materials: Wood anatomy and chemistry, Wood chip preparation and handling at the pulp mill, Solid wood measurement, Properties of selected wood species.

Pulping processes and Pulp treatment: Introduction to pulping, Mechanical pulping, Chemical pulping, Semi-chemical pulping, Soda pulping, Kraft pulping, Sulfite pulping, Other pulping methods, Bleaching mechanical pulps, Measurement of lignin content, Bleaching chemical pulps, Chemical recovery, Refining, Pulp characterization.

Paper making equipment and process: Fiber preparation and approach, Raw materials, Functional additives, Control additives, Wet end chemistry, Paper manufacture, Paper machine, headbox, fourdrinier wet end, Twin wire formers, cylinder machine, press section, dryer section, Post drying operations, Coating.

Environmental protection: Water pollution, Water quality tests, aqueous effluent treatments, Air pollution, Air quality tests and control, Solid waste disposal. Properties of paper: General grades of paper, Structure, Mechanical and chemical properties, Basic optical tests of paper

Learning Resources:

Text books:

1. Pulp and Paper: Chemistry and Chemical Technology, J.P. Casey, Volumes 1 & 2, Wiley Interscience, 1980, 3rd Edition.
2. Handbook for Pulp and Paper Technologists, G.A. Smook, Angus Wilde Publ, Inc, 2002, 3rd Edition.
3. Handbook of Pulping and Paper Making, Christopher J. Biermann, Academic Press, 1996.

References:

1. Pulping Chemistry and Technology, Monika EK, Goran Gellerstedt, Gunnar Henrikson, Walter De Gruyter & Co, 2009.
2. Shreve's Chemical Process Industries, George T. Austin, McGraw Hill Education, 2017, 5thEdition.

CH366	HETEROGENEOUS CATALYSIS	3-0-0	3 Credits	PEC

Pre-Requisites: None

Course Outcomes:

At the end of the course, the student will be able to

CO1	Understand the basic concepts of catalysis
CO2	Analyze the role of heat and mass transfer in the catalytic reactor design
CO3	Describe the methods of preparation and characterization of catalysts
CO4	Distinguish the performance of catalytic reactors
CO5	Identify the role of catalysts in the environmental protection

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	2	1	-	-	-	-	-	-	-	-	3	2	-
CO2	2	3	2	1	-	-	-	-	-	-	-	-	3	1	-
CO3	2	1	2	1	-	-	-	-	-	-	-	-	1	1	-
CO4	2	3	1	1	-	-	-	-	-	-	-	-	1	1	-
CO5	-	-	-	-	-	-	3	-	-	-	-	-	1	1	-

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction: Basic concepts in heterogeneous catalysis and green chemistry. Catalyst preparation, Catalyst characterization, BET surface area and pore size distribution. Optimal distribution of catalyst in a pellet.

Adsorption: Adsorption in solid catalyst, adsorption isotherms. Surface reactivity and reaction kinetics on surfaces, reaction mechanism and rate equations, poisoning and regeneration.

Heat and mass transfer effects: Heat and mass transfer and its role in heterogeneous catalysis. Calculations of effective diffusivity and thermal conductivity of porous catalysts. Selection and design of catalyst.

Industrial catalysis: Industrially important catalysts and processes such as oxidation, processing of petroleum and hydrocarbons, synthesis gas and related processes. Design and characterization of photocatalysts, Biocatalyst, Electro-catalysts. Environmental catalysts, Monolithic reactors. Catalysis for petroleum and polymer industries: Organometallic catalyst, Zeolite catalysts, preparation, characterization and applications.

Reactors: Commercial Catalytic Reactors, Adiabatic, fluidized bed, trickle bed, slurry reactor. Novel catalysts and catalytic reactors.

Learning Resources:

Text Books:

1. Heterogeneous Catalysts: Advanced Design, Characterization, and Applications, Wey Yang Teoh, Atsushi Urakawa, Yun Hau Ng, Patrick Sit, Wiley, 2021
2. Chemical and Catalytic Reaction Engineering, James John Carberry, Dover Publications, INC, 1976.

Reference Books:

1. Modeling and Simulation of Heterogeneous Catalytic Reactions from the Molecular Process to the Technical System, Olaf Deutschmann, Wiley, 2011
2. Handbook of Heterogeneous Catalysis, G. Ertl, H. Knozinger and J. Weitkamp, Wiley - VCH, 2008, 2nd edition.
3. Principles and Practice of Heterogeneous Catalysis, John Meurig Thomas, W. J. Thomas, Wiley VCH; 2014, 2ndEdition.
4. Heterogeneous Reactions: Fluid-fluid-solid Reactions, Volume 1, L. K. Doraiswamy, M. M. Sharma, John Wiley and Sons, 1984.
5. Catalysis: Principles and Applications, B. Viswanathan, S. Sivasanker, and A.V. Ramaswamy, Narosa Publishing House, 2002.
6. Catalysts and Surfaces: Characterization Techniques, B. Viswanathan, S. Kannan, R.C. Deka, Alpha Science International, 2010.

Online Resources:

1. https://nptel.ac.in/courses/103/102/103102012/
2. https://nptel.ac.in/courses/103/103/103103026/

CH367	ANALYTICAL TECHNIQUES FOR CHEMICAL ENGINEERS	3-0-0	3 Credits	PEC

Pre-Requisites: None

Course Outcomes:

At the end of the course, the student will be able to

CO1	Differentiate Microscopy techniques
CO2	Identify the spectroscopy methods
CO3	Select the electro-analytical techniques
CO4	Choose the separation techniques

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	-	3	2	-	-	-	-	3	-	1	-	-	-
CO2	3	3	-	3	2	-	-	-	-	3	-	1	-	-	-
CO3	3	3	-	3	2	-	-	-	-	3	-	1	-	-	-
CO4	3	3	-	3	2	-	-	-	-	3	-	1	-	-	-

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Microscopy Techniques: scanning electron microscopy (SEM); secondary Auger microscopy(SAM); scanning probe microscopy (SPM); scanning tunneling microscopy (STM); transmission electron microscopy (TEM); upright microscope, inverted microscope, image analysis.

Spectroscopy Methods: FTIR, AAS, UV-VIS, UV-fluorescent, Wavelength and energy dispersive X-ray fluorescence spectroscopy (WDS and EDS); X-ray absorption spectroscopy (XANES and EXAFS); secondary ion mass spectrometry (SIMS); temperature programmed desorption (TPD); thermal desorption spectroscopy TDS), ICP-OES, XRD. Atomic absorption spectroscopy (AAS); inductively coupled plasma-atomic emission spectroscopy (ICP-AES).

Electro-Analytical Techniques: Voltametry; coulometry; amperometry; potentiometry; polarography; electrolytic conductivity; impedance spectroscopy, rotating disc electrode, rotating ring disc electrode

Separation Methods: Normal and reversed phase liquid chromatography (NP- & RP-LC); Gas Chromatography (GC); GC-MS; High Performance Liquid Chromatography (HPLC); Size- Exclusion Chromatography (SEC); Ion Chromatography (IC).

Learning Resources:

Text Books:

1. R. Wiesendanger, Scanning Probe Microscopy and Spectroscopy, Cambridge University Press, 1994.
2. Frank A. Settle, Handbook of instrumental techniques for analytical chemistry, Prince Hall, New Jersey, 1997.
3. D. A. Skoog, D. M. West, F. J. Holler and S. R. Couch, Fundamentals of analytical chemistry. Belmont: Brooks/Cole: Cengage Learning, New Delhi, 2014, 9th Edition.
4. P. Atkins and J. de Paula, Atkins' physical chemistry, Oxford University Press, New Delhi, 2008, 8th Edition.

Reference Books:

1. K. W. Kolasinski, Surface Science: Foundations of Catalysis and Nanoscience, John Wiley and Sons, 2002.
2. Gregory S. Patience, Experimental Methods and Instrumentation for Chemical Engineers, Elsevier, 2018, 2nd Edition.

CH368	COMPLEX FLUIDS	3-0-0	3 Credits	PEC

Pre-Requisites: None

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

CO1	Distinguish the complex fluids from classical fluids
CO2	Understand the macroscopic behavior of the complex fluids.
CO3	Identify forces involved in complex fluids.
CO4	Analyze rheology of polymers, glassy liquids and gels
CO5	Understand rheology of suspensions, surfactant solutions and block copolymers

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	2	2	1	2	1	-	-	-	2	2	-	1	2	1	2
CO2	2	2	1	2	1	-	-	-	2	2	-	1	2	1	2
CO3	2	2	1	2	1	-	-	-	2	2	-	1	2	1	2
CO4	2	2	1	2	1	-	-	-	2	2	-	1	2	1	2
CO5	2	2	1	2	1	-	-	-	2	2	-	1	2	1	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction to Complex fluids: Complex fluids vs. classical solids and liquids; Examples; Rheological measurements and properties; Kinematics and Stress;Structural probes of complex fluids; Computational methods; Stress tensor

Basic forces: Excluded volume interactions; Vander Waals interactions; Electrostatic interactions; Hydrogen bonding; hydrophilic and other interactions.

Rheology of Polymers, glassy liquids and polymer gels: Polymers –Theory and Rheology of polymers; Glassy liquids – Theory and rheology of glassy liquids; Polymer gels – Theory and rheology of gels.

Suspensions: Particulate gels – particle interactions, Rheology of particulate gels; Foams, Emulsions and Blends – Emulsion preparation, Rheology of emulsions, immiscible blends and foams;

Rheology of surfactant solutions and block copolymers

Learning Resources:

Text Books:

1. The Structure and Rheology of Complex Fluids, Larson RG, Oxford University Press,1999.
2. Non-Newtonian Flow and Applied Rheology: Engineering Applications, Chhabra RP, Richardson JF, Butterworth-Heinemann,2008, 2nd Edition.
3. Rheology of Complex Fluids, Abhijit PD, Murali Krishna J, Sunil Kumar PB, Springer,2010.

Reference Books:

1. Rheology: Principles, Measurements and Applications, Christopher W. Macosko, Wiley - VCH,1994.
2. Rheology Fundamentals, Alexander Ya. Malkin, Chem Tech Publishing,1994.

Online resources:

1. https://nptel.ac.in/courses/103/106/103106131/

CH369	NATURAL GAS ENGINEERING	3-0-0	3 Credits	PEC

Pre-Requisites: None

Course Outcomes:

At the end of the course, the student will be able to

CO1	Understand the properties, phase behavior of natural gas.
CO2	Evaluate oil and gas reserves, and bottom hole pressure.
CO3	Design the compressors used in the natural gas industry.
CO4	Illustrate the production economics and production trends of natural gas.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	3	1	2	3	3	-	2	2	-	1	2	2	-
CO2	3	2	3	1	2	3	3	-	2	2	-	1	2	2	-
CO3	3	2	3	1	2	3	3	-	2	2	-	1	2	2	-
CO4	3	2	3	1	2	3	3	-	2	2	-	1	2	2	-

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Basics of natural gas reservoir: Composition of associated and non-associated gas, retrograde condensate wells, Physical properties of natural gas and associated liquid

Phase Behavior: Physical properties of natural gas, Phase behavior of two-phase hydrocarbon systems, vapor liquid equilibria, pressure gradient in gas column, well head and bottom hole pressure.

Compression and Compressor: Various types of compressors, multi-phase compression. Flow measurement: orifice meter, flow formula, critical flow meter, flow prover.

Field separation of oil from gas: Type of separators and Sizing, Oil absorption, low temperature separation.

Natural Gas conversion technologies.

Learning Resources:

Text Books:

1.Chi U.Ikoku, Natural Gas Production Engineering, John Wiley & Sons.

2. Sanjay Kumar, Gas Production Engineering, Volume 4, Gulf Publishing Company, Houston, Texas.

Reference Books:

1.Katz, Natural Gas Production Engineering, McGraw Hill.
2.Donald Katz, Hand Book of Natural Gas engineering, Mc Graw Hill.
3.H.K. Abdel and Mohammed Aggour, Marcel Dekker, Petroleum and Gas field processing

Online Resources:

https://nptel.ac.in/noc/courses/noc20/SEM2/noc20-ch24/

CH370	BIOMASS AND BIOFUELS TECHNOLOGY	3-0-0	3 Credits	PEC

Pre-Requisites: None

Course Outcomes:

At the end of the course, the student will be able to

CO1	Identify potential biomass sources for renewable energy generation
CO2	Understand the production process for liquid biofuels.
CO3	Understand the production process of gas, bio hydrogen and electricity
CO4	Understand the concept of strain improvement for biofuels production
CO5	Forecast the entrepreneurial opportunities in Bioenergy

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	1	3	-	-	-	-	3	-	-	-	-	-	2	2	3
CO2	1	3	-	-	-	-	3	-	-	-	-	-	2	2	3
CO3	1	-	3	-	-	-	3	-	-	-	-	-	2	2	3
CO4	3	-	-	-	-	-	3	-	-	-	-	-	2	2	3

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction to oil economy: working principle of IC engines, Effects of emissions of greenhouse gases and other pollutants, National Biofuel Policy and law, Biomass to Biofuels: An overview.

Biomass formation on the earth: photosynthesis; Chemistry and composition of Biomass.

Biomass conversion technologies: Pretreatment technologies, Biomass to liquid fuels. Biomass degrading enzymes and microorganisms. Bioethanol production from lignocellulosic feedstocks, algae and sea weeds. Genetic and metabolic engineering of bacteria and yeast for bioethanol production. Strain engineering for ethanol and inhibitor tolerance.

Vegetable oils and chemically processed biofuels: Biodiesel composition and production processes, Biodiesel economics, Fischer-Tropsch Diesel: Chemical Biomass–to–Liquid Fuel Transformations. Algae Biodiesel; Technical challenges in biodiesels production.

Biomass to gaseous fuel production: Bio hydrogen Production, Microbial Fuel Cells. Concept of Bio refinery: Lignocellulose-Based Chemical Products.
Entrepreneurial Opportunities in Bioenergy.

Learning Resources:

Text Books:

1.Bioenergy Research: Advances and Applications,Vijai K. Gupta. Maria Tuohy. Christian Kubicek, Jack Saddler, Feng Xu, Elsevier B.V. Netherlands 119, 2014.

2. Bioenergy: biomass to biofuels,Dahiya, A. Elsevier, 2015.

3. Introduction to Bioenergy (Energy and the Environment), Vaughn C. Nelson, Kenneth L. Starcher, CRC Press, 2016

Reference Books:

1. Biofuel Technologies-Recent Developments,Vijai K. Gupta et al.,Springer-Verlag Berlin Heidelberg, Elsevier, 2013.
2. Metabolic Regulation and Metabolic Engineering for Biofuel and Biochemical Production,Kazuyuki Shimizu, CRC Press, 2017.
3. Biofuel-Biotechnology, Chemistry, and sustainable Development, David M. Mousdale, 1stEdition, CRC Press Taylor & Francis Group, 2008.
4. Green Energy and Technology, Biofuels, Securing the Planet's Future Energy Needs, AyhanDemirbas, 1stedition, Springer, 2009.

III YEAR I SEM

Open Electives Courses (OEC)

ELECTIVE-1

Offered to Other B.Tech Programs

CH395	NANOTECHNOLOGY AND APPLICATIONS	3-0-0	03	OEC

Pre-Requisites: None

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

CO1	Understand the properties of nanomaterials
CO2	Synthesize nanoparticles
CO3	Evaluate safety and health related issues of nanoparticles
CO4	Characterize nanoparticles
CO5	Identify the applications of nanotechnology in Industries

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	1	1	1	-	-	-	-	-	-	-	-	3	0	
CO2	3	2	2	2	-	-	-	-	-	-	-	-	3	1	
CO3	3	1	3	3	1	2	-	-	-	-	-	-	3	1	
CO4	3	3	3	3	1	2	-	-	-	-	-	-	3	1	
CO5	3	1	1	1	-	-	-	-	-	-	-	-	3	0	

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction to Nanotechnology: Introduction to nanotechnology and materials, Nanomaterials, Introduction to nanosizes and properties comparison with the bulk materials, different shapes and sizes and morphology.

Fabrication of Nanomaterials: Top Down Approach, Grinding, Planetary milling and Comparison of particles, Bottom Up Approach, Wet Chemical Synthesis Methods, Microemulsion Approach, Colloidal Nanoparticles Production, Sol Gel Methods, Sonochemical Approach, Microwave and Atomization, Gas phase Production Methods: Chemical Vapour Depositions.

Kinetics at Nanoscale: Nucleation and growth of particles, Issues of Aggregation of Particles, Oswald Ripening, Stearic hindrance, Layers of surface Charges, Zeta Potential and pH.

Carbon Nanomaterials: Synthesis of carbon buckyballs, List of stable carbon allotropes extended fullerenes, metallofullerenes solid C60, bucky onions nanotubes, nanocones Difference between Chemical Engineering processes and nanosynthesis processes.

Quantum mechanics: Quantum mechanics Quantum dots and its Importance, Pauli exclusion principle Schrödinger's equation, Application of quantum Dots: quantum well, wire, dot, characteristics of quantum dots, Synthesis of quantum dots, Semiconductor quantum dots, Introduction - Nanoclay Synthesis method, Applications of nanoclay.

Nanomaterials characterization: Instrumentation Fractionation principles of Particle size measurements, Particle size and its distribution, XRD, Zeta potential Microscopies SEM, TEM, Atomic Forced Microscopy, Scanning and Tunneling Microscopy

Applications in Chemical Engineering: Self-assembly and molecular manufacturing: Surfactant based system Colloidal system applications, ZnO,TiO2,Silver Nanoparticles Functional materials Applications, Production Techniques of Nanotubes, Carbon arc, bulk synthesis, commercial processes of synthesis of nanomaterials, Nanoclay, Commercial case study of nano synthesis - applications inchemical engineering, Nanoinorganic materials - $CaCO_3$ synthesis, Hybrid wastewater treatment systems, Electronic Nanodevices, sensor applications.

Nanobiology: biological methods of synthesis. Applicationsin drug delivery, Nanocontainers and Responsive Release of active agents, Layer by Layer assembly for nanospheres, Safety and health Issues of nanomaterials, Environmental Impacts, Case Study for Environmental and Societal Impacts

Learning Resources:

Text Books

1. Kulkarni Sulabha K., Nanotechnology: Principles and Practices, Capital Publishing Company, 2015, 3rd edition.
2. Gabor L. Hornyak., Harry F. Tibbals, JoydeepDutta, John J. Moore, Introduction to Nanoscience and Nanotechnology, CRC Press, 2009, 1st edition.
3. Robert Kelsall, Ian Hamley, Mark Geoghegan, Nanoscale Science and Technology, John Wiley & Sons, 2005, 1st edition.

Reference Books

1. Stuart M. Lindsay, Introduction to Nanoscience, Oxford University Press, 2009, 1st edition.
2. Davies, J.H. The Physics of Low Dimensional Semiconductors: An Introduction, Cambridge University Press, 1998, 1st edition.
3. B. Viswanathan, Nano Materials, Alpha Science,2009, 1st edition.
4. T. Pradeep, Nano - The essentials understanding nanoscience and nanotechnology, The McGraw Hill,2007, 1st edition.

Online Resources:

https://nptel.ac.in/courses/118/104/118104008/

CH396	INDUSTRIAL POLLUTION CONTROL	3-0-0	3 Credits	OEC

Pre-Requisites: None

Course Outcomes:

At the end of the course, the student will be able to

CO1	Analyze the effects of pollutants on the environment
CO2	Distinguish air pollution control methods
CO3	Assess treatment technologies for wastewater
CO4	Identify treatment technologies for solid waste
CO5	Select treatment methodologies for hazardous and E-waste

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	1	2	2	-	1	2	1	1	1	1	1	1	-	-
CO2	3	1	2	2	-	1	2	1	1	1	1	1	1	-	-
CO3	3	2	3	2	2	3	3	1	1	1	1	1	3	3	-
CO4	3	2	3	2	2	3	3	1	1	1	1	1	3	3	-
CO5	3	2	1	2	1	2	2	2	1	1	-	1	3	3	-

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction: Biosphere, Hydrological cycle, Nutrient cycle, Consequences of population growth, Pollution of air, Water and soil.

Air pollution sources & effects: Classification and properties of air pollutants, Emission sources, Behavior and fate of air pollutants, Effect of air pollution.

Meteorological aspects of air pollutant dispersion: Temperature lapse rates and stability, Wind velocity and turbulence, Plume behavior, Dispersion of air pollutants, Estimation of plume rise.

Air pollution sampling and measurement: Types of pollutant sampling and measurement, Ambient air sampling, Stack sampling, Analysis of air pollutants.

Air pollution control methods & equipment: Control methods, Source correction methods, Cleaning of gaseous effluents, Particulate emission control, Selection of a particulate collector, Control of gaseous emissions, Design methods for control equipment.

Control of specific gaseous pollutants: Control of sulphur dioxide emissions, Control of nitrogen oxides, Carbon monoxide control, Control of hydrocarbons and mobile sources.

Water pollution: Water resources, Origin of wastewater, types of water pollutants and their effects.

Waste water sampling, analysis and treatment: Sampling, Methods of analysis, Determination of organic matter, Determination of inorganic substances, Physical characteristics, Bacteriological measurement, Basic processes of water treatment, Primary treatment, Secondary treatment, Advanced wastewater treatment, Recovery of materials from process effluents, Zero liquid discharge, Membrane based treatment, industrial case studies.

Solid waste management: Sources and classification, Public health aspects, Methods of collection, Disposal Methods, Potential methods of disposal.

Hazardous waste management: Definition and sources, Hazardous waste classification, Treatment methods, Disposal methods.

E-waste: Sources, environmental and social issues, management practices

Learning Resources:

Text Books:

1. Environmental Pollution Control Engineering, Rao C.S., New Age International Publishers, India, 2018, 3rd Edition.
2. Air Pollution and Control Engineering, Noel de Nevers, Waveland Press, Inc., 2016, 3rdEdition
3. Environmental Science and Engineering, Glynn Henry J., Gary W. Heinke, Prentice Hall of India, 2004, 2nd Edition.
4. Air Pollution, Rao M.N, Rao H.V.N, Tata McGraw Hill Education, 2017, 1st Edition.

Reference Books:

1. Environmental Chemistry, De A.K, New Age International Publishers, 2007, 7th Edition.
2. Waste water engineering: treatment and reuse, George Tchobanoglous, Franklin Louis Burton, H. David Stensel, Metcalf & Eddy, Inc., McGraw Hill Education., 2003, 4th Edition.
3. E-waste recycling, NPCS Board of consultants and Engineers, Asia Pacific Business Press Inc. 2015.
4. Handbook of Pollution Prevention Practices, Nicholas P. Cheremisinoff, CRC press, 2001, 1st Edition.

Online Resources:

7. https://nptel.ac.in/courses/105/102/105102089/

8. https://nptel.ac.in/courses/103/107/103107084/
9. https://cpcb.nic.in/
10. http://moef.gov.in/en/
11. https://mnre.gov.in/
12. https://tspcb.cgg.gov.in/default.aspx

CH397	SOFT COMPUTING METHODS FOR ENGINEERS	3-0-0	3 Credits	OEC

Pre-Requisites:None

Course Outcomes:

At the end of the course, the student will be able to

CO1	Use neural networks to model the process plants
CO2	Develop fuzzy logic based controllers for different processes
CO3	Combine fuzzy logic with neural networks for hybrid systems
CO4	Design controllers using fuzzy logic
CO5	Apply genetic algorithms for optimization

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	1	2	3	3	2	3	1	-	1	3	1	3	3
CO2	3	3	3	3	3	3	3	3	1	-	1	3	1	3	3
CO3	3	1	2	3	3	3	2	3	1	-	1	3	1	3	3
CO4	3	1	3	3	3	3	3	3	1	-	1	3	1	3	3
CO5	3	1	3	3	3	3	3	3	1	-	1	3	1	3	3

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction: Soft Computing, Neural Networks, Fuzzy Logic, Genetic Algorithms.

Artificial Neural Network: Fundamental Concept, Evolution of Neural Networks, Basic Models of Artificial Neural Network, Important Terminologies of ANNs

Supervised Learning Network: Perceptron Networks, Adaptive Linear Neuron (Adaline), Multiple Adaptive Linear Neurons, Back-Propagation Network, Radial Basis Function Network, Time Delay Neural Network, Functional Link Networks, Tree Neural Networks

Unsupervised Learning Networks: Fixed Weight Competitive Nets, Kohonen Self-Organizing Feature Maps, Learning Vector Quantization, Counter propagation Networks, Adaptive Resonance Theory Network

Stability Analysis of a Class of Artificial Neural Network Systems: Stability Conditions of a Class of Non-Linear Systems, Formation of Main Matrices and Sub-Matrices for an ANN System, Methodology Developed for Stability Analysis of ANN.

Introduction to Fuzzy Logic: Classical Sets and Fuzzy Sets, Fuzzy Relations, Tolerance and Equivalence Relations, Noninteractive Fuzzy Sets, Membership Functions, Fuzzification - Methods of Membership Value Assignments, Defuzzification - Lambda-Cuts for Fuzzy Sets (Alpha-Cuts), Defuzzification Methods, Fuzzy Arithmetic and Fuzzy Measures.

Fuzzy Rule Base and Approximate Reasoning: Truth Values and Tables in Fuzzy Logic, Fuzzy Propositions, Formation of Rules, Decomposition of Rules, Aggregation of Fuzzy Rules, Fuzzy Reasoning, Fuzzy Inference Systems, Fuzzy Expert System, Fuzzy Decision Making

Fuzzy Logic Control Systems: Control System Design, Architecture and Operation of FLC System, FLC System Models, Application of FLC Systems

Stability Analysis of Certain Classes of Fuzzy Systems: Stability Analysis of Fuzzy Systems given by System Matrices, Numerical Illustrations for Fuzzy System Stability

Genetic Algorithm: Biological Background, Traditional Optimization and Search Techniques, Genetic Algorithm and Search Space, Basic Terminologies in Genetic Algorithm, Operators in Genetic Algorithm, Constraints in Genetic Algorithm, The Schema Theorem, Classification of Genetic Algorithm, Holland Classifier Systems, Genetic Programming.

Differential Evolution Algorithm: Differential Evolution – Process Flow and Operators, Selection of DE Control Parameters, Schemes of Differential Evolution

Hybrid Soft Computing Techniques: Neuro-Fuzzy Hybrid Systems, Genetic Neuro-Hybrid Systems, Genetic Fuzzy Hybrid and Fuzzy Genetic Hybrid Systems

Applications of Soft Computing to different engineering systems.

Learning Resources:

Text Books:

1. Principles of Soft Computing, S. N. Sivanandam and S. N. Deepa, John Wiley & Sons, 2018, 3rd Edition.

2. Artificial Neural Networks, Bose and Liang,Tata McGraw Hill, 1996.

Reference Books:

1. Fuzzy Modeling and Fuzzy Control, Huaguang Zhang, Derong Liu, Birkhauser Publishers, 2006.

2. Neural Networks and Fuzzy Systems: A Dynamic Approach to Machine Intelligence, Kosco B, Prentice Hall of India, 1992.

3. Fusion of Neural Networks, Fuzzy Systems and Genetic Algorithms: Industrial Applications, Lakshmi C. Jain, N. M. Martin, CRC Press, 1998.

CH398	INDUSTRIAL SAFETY AND MANAGEMENT	3-0-0	3 Credits	OEC

Pre-Requisites: None

Course Outcomes:

At the end of the course, the student will be able to

CO1	Analyze the effects of release of toxic substances
CO2	Select the methods for prevention of fires and explosions
CO3	Identify the hazards and preventive measures
CO4	Assess the risks using fault tree diagram.

Course Articulation Matrix:

PO / CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	2	2	3	-	-	3	3	2	-	-	-	-	2	3	1
CO2	2	2	3	-	-	3	3	2	-	-	-	-	2	3	1
CO3	2	2	3	-	-	3	3	2	-	-	-	-	2	3	1
CO4	2	2	3	-	-	3	3	2	-	-	-	-	2	3	1

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction and Industrial hygiene: Safety programs, Engineering ethics, Accident and loss Statistics, Acceptable risk, Public perceptions, Nature of the accident process, Inherent safety, Anticipation and identification, Hygiene evaluation and control.

Fires and Explosions and concepts to prevent fires and explosions: Fire triangle, Distinction between fires and explosions, Flammability characteristics of liquids and vapors, Limiting oxygen concentration and inerting, Flammability diagram, Inerting, Controlling static electricity, Explosion-proof equipment and instruments, Ventilation, Sprinkler systems.

Introduction to reliefs: Relief concepts, location of reliefs, relief types, relief scenarios, Data for sizing reliefs, relief systems.

Hazards Identification: Process hazards checklists, Hazards surveys, Hazards and Operability studies, safety reviews.

Safety procedures and designs: Process safety Hierachy, Managing safety, Best practices, procedures- operating, Procedures-permits, Procedures- safety reviews and accident investigations, Designs for process safety

Learning Resources:

Text Books:

1. Chemical process safety(Fundamentals with Applications) D.A.Crowl and J.F Louvar, Prentice Hall, 2013,3rd Edition.

References:

1. Chemical Engineering, Volume 6, John Metcalf Coulson, John Francis Richardson,
2. R.K.SinnottButterwoth-Heinemann 1999.
Safety in the process Industries, Rulph king, Butterworth-Heinemann, 1990.

IV-Year I-Sem
Programme Core Courses (PCC)

SM436	INDUSTRAIL ENGINEERING & MANAGEMENT	3-0-0	3 Credits	HSC

Pre-Requisites: None

Course Outcomes:

At the end of the course, the student will be able to

CO1	Explain the four evolutionary phases of the organizational theories their circumstances and the consequences
CO2	Examine organizational systems, inventory and quality for productivity improvements
CO3	Understand the marketing management process to discuss marketing mix in formulation of marketing strategies
CO4	Calculate project schedule along with the interdependencies using PERT/CPM techniques

Course Articulation Matrix:

CO \ PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	1	1	1	1	1	1	1	1	3	1	1	1	1	3	-
CO2	1	1	2	2	3	1	1	1	1	1	1	1	1	3	-
CO3	1	1	1	1	1	1	2	1	3	2	1	1	1	3	-
CO4	1	1	1	1	3	1	1	1	2	1	3	1	1	3	-

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction - Overview of organizational theory and theoretical perspectives

Rational and natural systems The evolution of organizational theory - rational systems and Natural systems
Quality management: Dimensions of quality; Process control charts both attributes and variables. Sampling Plan - LTPD and AOQL concepts. Taguchi's Quality Philosophy; Quality function deployment; Introduction to TQM
Inventory Management: Purpose of inventories; Inventory costs; ABC classification; Economic Order Quantity (EOQ); P and Q systems of inventory control.

Organizational behavior – I and II The individual, The Group, Organization system (structure and culture) Organization its environment, design, and change

Open systems and behavioral decision-making

Other management topics Marketing management process; 4P's of marketing mix; Target marketing; Product life cycle and marketing strategies

Project Management: Project activities; Network diagrams; Critical path method (CPM); Programme Evaluation and Review Technique (PERT). Project crashing. Slack computations, Resource leveling

Learning Resources:

Text Books:

1. Robbins, S. P., & Judge, T. A. Organizational behavior.2001.
2. Jones, G. R., & Jones, G. R. (2013). *Organizational theory, design, and change*. Upper Saddle River, NJ: Pearson
3. Taylor, F.W. 1916. Principles of Scientific Management, 30-144

ReferenceBooks:

1. Besterfield (2015). Total Quality Management. Pearson Education India; 4 editions
2. Khanna, O. P. (1980). *Industrial engineering and management*. Dhanpat Rai.
3. Kottler, P., & Keller, K. L. (2011). Marketing Management 14e Global Edition.
4. Weber, M. Economy and Society 1978 pp.212-254, 956-975

OnlineResources:

1. https://nptel.ac.in/courses/112/107/112107142/
2. https://nptel.ac.in/courses/112/107/112107292/

CH401	PROCESS ENGINEERING ECONOMICS	3-0-0	3 Credits	PCC

Pre-Requisites: None

Course Outcomes:

At the end of the course, the student will be able to

CO1	Analyze alternative processes and equipment for manufacturing a product
CO2	Determine costs involved in process plants
CO3	Perform economic analysis and optimum design of processes
CO4	Evaluate project profitability

Course Articulation Matrix:

PO / CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	1	3	2	-	-	2	2		2	3	3	-	2	3	-
CO2	2	-	-	2	2	-	-	-	2	2	3	-	1	3	-
CO3	3	2	2	-	2	-	-	-	2	2	3	-	-	3	3
CO4	2	3	3	1	2	-	-	-	2	3	3	-	2	3	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction: Chemical Engineering plant design, Overall design consideration, Practical considerations in design, engineering ethics in design.

General Design Considerations: Health and Safety hazards, Loss prevention, Environmental Protection, Plant Location, Plant Layout, Plant Operation and Control.

Process Design Development: Development of design database, Process creation, Process design criteria, Process flow diagram (PFD), Equipment design specifications. Flow sheet synthesis and development: General procedure, Process information, Functions diagram, Flow sheet synthesis, Software use in process design.

Cost and asset accounting: General accounting procedure, Balance sheet and Income statements.

Analysis of Cost Estimation: Cash flow for industrial operations, Factors affecting investment and production costs, Capital investments, Fixed capital and working capital, Estimation of capital investment, Cost indices, Estimation of total cost, Gross profit, Net profit and cash flow, Cost scaling factors, Net present value analysis.

Interest and Insurance: Interest, Simple interest, Compound interest, Nominal and effective interest rates, Continuous interest, Costs of capital, Time value of money, Annuity, Cash flow patterns, Income taxes, Present worth, Future worth, Taxes and Insurance.

Depreciation: Depreciable investments, Methods for calculating Depreciation.

Profitability Analysis: Profitability standards, Costs of capital, Minimum acceptable rate of return, Methods of calculating profitability, Rate of return on investment, Payback period, Net return, Discounted cash flow rate of return, Net present worth, Payout period, Alternative investments, Replacements.

Optimum design and design strategy: Defining the optimization problem, Selecting an objective function, Structural optimization, Parametric optimization, Variable screening and selection, Optimization Applications. Design Report.

Learning Resources:

Textbooks:

1. Peters M.S., K.D. Timmerhaus and R.E. West, Plant Design and Economics for Chemical Engineers, McGraw Hill, 5th Edition, 2011.
2. Turton R., R.C. Baile, W.B. Whiting, J. A. Shaeiwitz. Analysis, Synthesis and Design of Chemical Processes, PHI, New Delhi, 3rd Edition, 2011.

Reference Books:

1. Seider W.D., J.D. Seader, D.R. Lewin, Product and Process Design Principles: Synthesis, Analysis, and Evaluation, Wiley, 2nd Edition, 2004.
2. James R. Couper, W. Roy Penny, James R. fair, Stanley M. Walas, Chemical Process Equipment: Selection and Design, Elsevier Butterworth-Heinemann, 2012.
3. R. Panneerselvam, Engineering Economics, Prentice Hall India, 2013.

Online resources

https://nptel.ac.in/courses/103/105/103105166/

CH402	PROCESS INTERGRATION	3-0-0	3 Credits	PCC

Pre-Requisites: None

Course Outcomes:

At the end of the course, the student will be able to

CO1	Synthesize mas-exchange networks
CO2	Synthesize reactive and recycle mass-exchange networks
CO3	Integrate heat, and reactive mass-exchange networks
CO4	Optimize mass, heat and recycle networks

Course Articulation Matrix:

PO / CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	3	3	3	3	3	-	-	-	3	2	3	3	3
CO2	3	3	3	3	3	3	3	-	-	-	3	2	3	3	3
CO3	3	3	3	3	3	3	3	-	-	-	3	2	3	3	3
CO4	3	3	3	3	3	3	3	-	-	-	3	2	3	3	3

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction to Sustainability, Sustainable Design, and Process Integration. Benchmarking Process Performance through Overall Mass Targeting.

Synthesis of mass-exchange networks: Graphical, algebraic and mathematical programming approach. Synthesis of reactive mass-exchange networks.

Direct recycle networks: Algebraic approach.

Heat integration. Integration of combined heat and power systems. Property Integration.

Overview of Optimization. Combining mass integration strategies. Mathematical optimization techniques for mass integration. An optimization approach to direct recycle.

Mathematical techniques for synthesis of heat-exchange networks. Synthesis of combined heat and reactive mass-exchange networks.

Launching successful process-integration initiatives and applications

Learning Resources:

Text Books:

1. Sustainable design through Process Integration Fundamental applications to Industrial pollution prevention, resource conservation, and profitability enhancement, Mahmoud M. El-Halwagi, Butterworth-Heinemann (Imprint of Elsevier), 2012, 2nd edition.
2. Process Integration, Mahmoud M. El-Halwagi, Academic press, 2006.
3. Integrated design and simulation of chemical processes, Alexandre C. Dimian, Volume 13, Computer aided chemical engineering, Elsevier, 2003

Reference Books

1. Process Integration for resource conservation, Dominic C Y Foo., CRC Press, 2013.
2. Hand book of Process Integration: Minimisation of energy and water use, waste and emissions, Jiri J Klemes, Woodhead Publishing Limited, 2013.
3. Recent advances in sustainable process design and optimisation, Dominic C Y Foo, Mahmoud M. El-Halwagi, Raymond R Tan, World scientific publishing co.pvt. Ltd, 2012.
4. Chemical process Design and Integration, Robin Smith, John Wiley & Sons Ltd, 2005.

CH403	PROCESS INSTRUMENTATION AND CONTROL LABORATORY	0-1-2	2 Credits	PCC

Pre-Requisites: CH255-Process Instrumentation, CH351-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
CO2	Implement PID controller on a level control process
CO3	Evaluate the characteristics of I-P and P-I converters
CO4	Apply cascade and feedforward control schemes
CO5	Determine control valve characteristics

Course Articulation Matrix:

PO / CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	1	2	3	1	-	-	-	-	3	3	2	3	3	2
CO2	3	1	2	3	3	-	-	-	-	1	3	2	1	3	2
CO3	3	1	1	3	3	-	-	-	-	1	3	2	1	3	2
CO4	3	1	2	3	3	-	-	-	-	1	3	2	1	3	2
CO5	3	1	2	3	2	-	-	-	-	1	3	2	1	3	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

The list of experiments include

1. Dynamics of non-interacting process
2. Dynamics of interacting process
3. Dynamics of first and second order processes

4(a). Flapper nozzle system
4(b). Measurement of liquid level using DPT
4(c). Characteristics of I&P and P&I converters

5. Control valve characteristics
6. Identification and Control of liquid level in a cylindrical/spherical/conical tank process
7. Cascade control
8. Feed-forward control of jacketed heating process
9. Ratio control
10. Simulation of open loop and closed loop control configurations using MATLAB/SIMULINK

Learning Resources:

Text Books:

1. Lab manuals
2. Jean-Pierre Corriou, Process Control: Theory and Applications, Second Edition, Springer, 2018.
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. RaghunathanRengaswamy, Babji Srinivasan, NiravPravinbhai Bhatt, Process Control Fundamentals: Analysis, Design, Assessment, and Diagnosis, CRC Press, 2020.

Online Resources:

http://techteach.no/simview/

IV-Year II-Sem

Seminar and Project Work

CH498	SEMINAR	0-0-2	1 Credit	SEM

Pre-Requisites: None

Course Outcomes:

At the end of the course, the student will be able to

CO1	Select a topic from extensive literature review.
CO2	Communicate orally with a group of people.
CO3	Demonstrate comprehension of the topic.
CO4	Prepare a consolidated seminar report.

Course Articulation Matrix:

CO \ PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	2	3	1	2	1	1	1	-	-	2	-	-	2	2	-
CO2	3	3	1	1	1	1	2	-	-	2	-	-	3	2	-
CO3	3	3	3	3	2	1	1	1	2	1	-	-	3	3	3
CO4	3	3	3	3	2	1	1	1	2	1	-	-	3	3	3

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Any topic of relevance to Chemical engineering and allied areas.

Leading Chemical Engineering journals and conferences, paper referencing and critiquing, ethics and plagiarism, improving presentation and communication skills, Technical paper and report writing.

Learning Resources:

1. Chemical Engineering Journals and Conference proceedings.
2. Technical communication, Mike Markel, S.A. Selber, Bedford/St. Martin's, 2017, 12th Edition.
3. The essentials of Technical Communication, E. Tebeaux, Sam Dragga, Oxford University Press, 2017, 4th Edition.
4. Technical writing process, K. Morgan, S. Spajic, Better on Paper publications, 2015.
5. Managing your documentation projects, J.T. Hackos, Wiley, 1994, 1st Edition.

CH499	PROJECT WORK	0-0-8	4 Credits	PW

Pre-Requisites: None

Course Outcomes:

At the end of the course, the student will be able to

CO1	Carry out literature review
CO2	Formulate the problem involving manufacture of a chemical product/ experimentation/ modelling/simulation/optimization/design
CO3	Analyse and discuss the results
CO4	Present the results orally
CO5	Prepare a detailed written report

Course Articulation Matrix:

PO / CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	2	3	1	2	1	1	1	-	-	2	-	-	2	2	-
CO2	3	3	1	1	1	1	2	-	-	2	-	-	3	2	-
CO3	3	3	3	3	2	1	1	1	2	1	-	-	3	3	3
CO4	3	3	3	`3	2	1	1	1	2	3	-	-	3	3	3
CO5	3	1	-	-	-	1	1	2	3	-	-	2	1	1	-

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

The student is required to choose any one of the following

1. Project involving experimentation/modelling/simulation/Design/optimization in chemical engineering related to research/industry/society At the end of the semester, the student is required to present (i) Literature survey, (ii) Problem formulation, (iii) Methodology, (iv) Preliminary results, (v) Results and Discussion, (vi) Conclusions (vii) Future work (viii) References(ix) Proposed work for the next semester, (x) References

2. Project involving manufacture of any chemical product on industrial scale At the end of the semester, the student is required to present (i) market survey, (ii) Properties and Applications (iii) different processes for production, (iv) selection of process, (v) detained process description (vi) material and Energy balance, (vii) design of equipment, (viii) cost and profitability analysis, (ix) plant layout and location, (x) environmental considerations and safety and (xi) References

Minimum number of pages in the report should be 50.

Written report shall adhere to the prescribed format.

Learning Resources:

1. Handbooks
2. Journals and magazines
3. Chemical Engineering Design Project: A Case Study Approach, Martyn S. Ray and Martin G. Sneesby, Gordon and Breach Science Publishers, 1989, 2^{nd} Edition.

IV-Year I-Sem

Professional Elective Courses (PEC)

Electives -5

CH411	BIOCHEMICAL ENGINEERING	3-0-0	3 Credits	PEC

Pre-Requisites: None

Course Outcomes:

At the end of the course, the student will be able to

CO1	Understand cell and enzyme kinetics
CO2	Explain cell disruption Techniques
CO3	Select the methods of enzyme immobilization
CO4	Compare the performance of aeration and bioreactor systems
CO5	Select sterilization methods for a given system

Course Articulation Matrix:

PO / CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	2	1	-	1	2	1	-	-	-	-	3	3	-
CO2	3	3	2	1	-	1	2	1	-	-	-	-	3	3	-
CO3	3	3	2	1	-	1	2	1	-	-	-	-	3	3	-
CO4	3	3	2	1	-	1	2	1	-	-	-	-	3	3	-
CO5	3	3	2	1	-	1	2	1	-	-	-	-	3	3	-

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction: Biotechnology, Biochemical Engineering, Biological Process, Definition of Fermentation.

Enzyme Kinetics: Introduction, Simple Enzyme Kinetics, Enzyme Reactor with Simple Kinetics, Inhibition of Enzyme Reactions, and Other Influences on Enzyme Activity. Immobilized **Enzyme**: Immobilization techniques and effect of mass transfer resistance.

Industrial application of enzymes: Carbohydrates, starch conversion and cellulose conversion. **Cell Cultivation**: Microbial cell cultivation, animal cell cultivation, plant cell cultivation, cell growth measurement and cell immobilization.

Cell Kinetics and Fermenter Design: Introduction, growth cycle for batch cultivation, stirred tank fermenters, multiple fermenters connected series, cell recycling, alternate fermenters and structured model.

Sterilization: Sterilization methods, thermal death kinetics, design criterion, batch sterilization, continuous sterilization and air sterilization.

Agitation and Aeration: Introduction, basic mass transfer concepts, correlation for mass transfer coefficient, measurement of interfacial area, correlations for ‘a’ and D32, gas-holdup, power consumption, determination of oxygen absorption rate, correlation for kLa, scale-up and shear sensitivity.

Learning Resources:

Text Books:

1 Harrison, R. G., Todd, P., Rudge, S. R., &Petrides, D. P. Bioseparations science and engineering. Oxford University Press, USA (2015).
2 Paul A. Belter, Paul A.. Belter, E. L. Cussler, E. L..Cussler, Wei-Shou Hu, Bioseparations: Downstream Processing for Biotechnology, Wiley-Interscience publication (2007).
3 Sivasankar B, Bioseparations: Principles And Techniques, PHI Learning Pvt. Ltd. India, (2005)

Reference:

1 Product Recovery in Bioprocess technology, BIOTOL series, Butterworth–Heinemann (2006).
2 Comprehensive Biotechnology, Volume 2nd Edition: M. Moo–young (1985).
3 Principles of Downstream processing, by Ronald & J. Lee, Wiley Publications (2007).
4 Handbook of Bioseparations, Edited by Satinder Ahuja, Academic Press Volume 2, (2000).
5 Principles of Protein Purification by Thomson, Wiley International Edition (2007).
6 Raja Ghosh, Principles Of Bioseparations Engineering, World Scientific Publishing Company, Singapore 2006
7 R. K. Scopes, Berlin, Protein Purification: Principles and Practice, Springer, 1982.
8 Mishra N, Bioseparation Technology, CRC Press (2008)
9 Bioseparation Engineering, Ajay Kumar, Abhishek Awasthi, I. K. International Pvt Ltd, India (2009).

CH412	INTERFACIAL SCIENCE	3-0-0	3 Credits	PEC

Pre-Requisites: None

Course Outcomes:

At the end of the course, the student will be able to

CO1	Understand concepts such as surfaces, interfaces and their properties.
CO2	Apply inter-molecular and inter-particle forces to model interfaces.
CO3	Quantify interfacial properties at macro scale.
CO4	Evaluate surface excess properties using thermodynamic description of surfaces
CO5	Develop models for processes involving interfacial phenomena

Course Articulation Matrix:

PO / CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	1	2	1	2	-	-	-	-	-	-	-	-	-	1	-
CO2	2	2	1	2	-	-	-	-	-	-	-	-	-	1	-
CO3	3	2	1	2	-	-	-	-	-	-	-	-	-	1	-
CO4	3	2	1	3	-	-	-	-	-	-	-	-	-	1	-
CO5	3	2	1	3	-	-	-	-	-	-		-	-	1	-

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction: The importance of interfaces, Surfaces and interfaces, Stable interfaces

Inter-molecular forces: Introduction, Charge-charge interaction, Ion-dipole interaction, Dipole-dipole interaction, Ion/dipole-polarisable molecule interaction, Dispersion interaction, van der Waals interaction

Inter-particle forces: Introduction, Hamaker's additivity approach, Deryaguin's approximation, Retardation effect

Capillarity and surface tension: Surface tension and work, Measurement of surface tension, The Laplace equation, The Kelvin equation, The surface tension of pure liquids, Surfactants and micelles, Application of surfactants, Adsorption of surfactants, Films and foams, Aerosols

Adsorption and thermodynamics of surfaces: Models of the interface, Adsorption, Adsorption isotherms, Thermodynamic properties of interfaces, Surface excess quantities, Measurement of Adsorption, Adsorption form solution, Kinetics of Adsorption

Liquid/Solid interfaces: Surfaces of solids, Colloidal dispersions, The properties of colloidal dispersions, Coagulation of lyophobic colloids by electrolytes, Solvation effects in colloidal interactions, Stability of colloids, Nanoparticles, Emulsions, Emulsion stability and selection of the emulsifier, Micro-emulsion, Emulsion polymerization

Nucleation and Growth: Classical Nucleation theory, Homogeneous nucleation, Heterogeneous nucleation, Spinodal decomposition

Learning Resources:

Text Books:

1. Interfacial Science: An Introduction, Geoffrey Barnes and Ian Gentle, Oxford University Press, 2011, 2nd Edition
2. Intermolecular and Surface Forces, Jacob N. Israelachvili, Academic Press, 2011, 3rd Edition
3. Physics and Chemistry of Interfaces, Hans-Jürgen Butt, Karlheinz Graf and Michael Kappl, Wiley VCH, 2006, 3rd Edition

Reference Books:

1. Surface Science: An Introduction, John B. Hudson, John Wiley & Sons, 1998

Principles of Colloids and Surface Chemistry, Paul C. Hiemenz and Raj Rajagopalan, Taylor and Francis, 2016, 3rd Edition

CH413	PROCESS MODELLING AND SIMULATIONS	3-0-0	3 Credits	PEC

Pre-Requisites: None

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

CO1	Understand model building techniques and simulation approaches
CO2	Solve model equations using numerical method
CO3	Develop model for simple systems based on first principles, stochastic and empirical
CO4	Model and simulate chemical process using Artificial Neural Networks

Course Articulation Matrix:

PO / CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	2	2	1	-	-	-	-	-	-	-	3	2	-
CO2	3	3	3	2	2	-	-	-	-	-	-	-	3	3	-
CO3	3	3	3	3	2	-	-	-	-	-	-	-	3	3	-
CO4	3	3	3	3	2	-	-	-	-	-	-	-	3	3	-

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction: Introduction to process modelling and simulation, classification of models, tools of simulation, approaches of simulation, Numerical methods for model equations. Application of simulation.

Models: Models, need of models and their classification, models based on transport phenomena principles, population balance, stochastic, and empirical models, unit models. Artificial Neural Network. Model development for simple system.

Models of Reactors: Model for batch and semi-batch reactor, Model for Continuous stirred tank reactor, Classification of fixed bed reactor models, fluidized bed reactor models.

Models of Separation Processes: Model for distillation column, compartmental distillation model, ideal binary distillation, binary batch distillation, binary continuous distillation, multicomponent distillation column, flash calculation under isothermal and adiabatic conditions.

Models of Heat Transfer Equipment: Model for evaporators, Double pipe

Learning Resources:

Text Books:

1. W.L. Luyben, Process Modeling, Simulation and Control for Chemical Engineers, 2nd Edn., McGraw Hill Book Co., New York, 1990.
2. Amiya K. Jana, Chemical Process Modeling and Computer Simulation, Prentice Hall, 2nd Edition, 2011

Reference Books:

1. Holland C. D., "Fundamentals and Modeling of Separation Processes", Prentice Hall., 1975.
2. Denn M. M., "Process Modeling", Longman, 1986
3. Ashok Kumar Verma, Process Modeling and Simulation in Chemical, Biochemical and Environmental Engineering, CRC Press, 2014
4. K. M. Hangos and I. T. Cameron, Process Modelling and Model Analysis, Academic Press, 2001.
5. M. Chidambaram, Mathematical Modelling and Simulation in Chemical Engineering, Cambridge University Press, 2018.

Online Resources:

1.https://nptel.ac.in/courses/103/107/103107096/

CH414	CO_2 CAPTURE & UTILIZATION	3-0-0	3 Credits	PEC

Pre-Requisites: None

Course Outcomes:

At the end of the course, the student will be able to

CO1	Identify the necessity of CO_2 capture, storage and utilization
CO2	Distinguish the CO_2 capture techniques
CO3	Evaluate CO_2 Storage and sequestration methods
CO4	Assess Environmental impact of CO_2 capture and utilization

Course Articulation Matrix:

PO / CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	3	1	2	3	3	-	2	2	-	1	2	2	-
CO2	3	2	3	1	2	3	3	-	2	2	-	1	2	2	-
CO3	3	2	3	1	2	3	3	-	2	2	-	1	2	2	-
CO4	3	2	3	1	2	3	3	-	2	2	-	1	2	2	-

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction: Global status of CO_2 emission trends, Policy and Regulatory interventions in abatement of carbon footprint, carbon capture, storage and utilization (CCS&U)

CO_2 capture technologies from power plants: Post-combustion capture, Pre-combustion capture, Oxy-fuel combustion, chemical looping combustion, calcium looping combustion

CO_2 capture agents and processes: Capture processes, CO_2 capture agents, adsorption, ionic liquids, metal organic frameworks

CO_2 storage and sequestration: Geological sequestration methods, Biomimetic carbon sequestration

CO_2 Utilization: CO_2 derived fuels for energy storage, polymers from CO_2, CO_2 based solvents, CO_2 to oxygenated organics, Conversion into higher carbon fuels, High temperature catalysis

Environmental assessment of CO_2 capture and utilization: Need for assessment, Green chemistry and environmental assessment tools, Life cycle assessment (LCA), ISO standardization of LCA, Method of conducting an LCA for CO_2 capture and Utilization.

Learning Resources:

Text Books:

1. Carbon dioxide utilization: Closing the Carbon Cycle, Peter Styring, Elsje Alessandra Quadrelli, Katy Armstrong, Elsevier, 2015, 1st Edition.
2. Carbon Capture, Storage and, Utilization: A Possible Climate Change Solution for Energy Industry ,Goel M, Sudhakar M, Shahi RV, TERI, Energy and Resources Institute, 2015, 1st Edition.
3. Carbon Capture and Storage, CO2 Management Technologies, AmitavaBandyopadhyay, CRC Press, 2014, 1st Edition.

Reference Books:

1. Calcium and Chemical Looping Technology for Power Generation and Carbon Dioxide (CO_2) Capture, Fennell P, Anthony B, Woodhead Publishing Series in Energy: No. 82, 2015, 1st Edition.
2. Developments in Innovation in Carbon Dioxide Capture and Storage Technology: Carbon Dioxide Storage and Utilization, Mercedes Maroto-Valer M, Vol 2, Woodhead Publishing Series in Energy, 2014, 1st Edition.
3. Fundamentals of Enhanced Oil and Gas Recovery from Conventional and Unconventional Reservoirs, AlirezaBahadori, Elsevier Inc., 2018, 1st Edition.

Online Resources:

1. https://nptel.ac.in/courses/103/107/103107157/
2. https://sequestration.mit.edu/
3. http://www.coal.nic.in/
4. http://moef.gov.in/en/
5. https://mnre.gov.in/
6. https://climate.mit.edu/explainers/carbon-capture
7. https://www.sciencedirect.com/book/9780128130278/fundamentals-of-enhanced-oil-and-gas-recovery-from-conventional-and-unconventional-reservoirs#book-info

CH415	ADVANCED CONTROL SYSTEMS	3-0-0	3 Credits	PEC

Pre-Requisites: None

Course Outcomes:

At the end of the course, the student will be able to

CO1	Identify non-parametric models
CO2	Analyse the controlled and manipulated variables in multivariable processes.
CO3	Estimate states using Kalman filtering
CO4	Apply linear model predictive control.

Course Articulation Matrix:

PO / CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	3	3	-	-	-	-	-	-	-	1	2	3	3
CO2	3	1	3	3	-	-	-	-	-	-	-	1	2	3	3
CO3	3	1	3	3	-	-	-	-	-	-	-	1	2	3	3
CO4	3	1	3	3	1	-	-	-	-	-	-	1	1	3	3

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction, review of basics.

Introduction to Z-transforms. System Identification - Models of Discrete-Time LTI Systems – Convolution theorem.

Non-parametric models - impulse response, step response and frequency response models.

Disturbance models - random processes, representation of stationary processes, white-noise process, auto-covariance function (ACF), ARMA models.

Parametric model structures - ARX, ARMAX, OE, BJ structures.

Multivariable control - Challenges; Control pairing; Interactions in closed-loop systems; Relative Gain Array (RGA) and variants. Centralized, decentralized, decoupled control schemes. Directionality.

State estimation and Kalman filtering.

Model Predictive Control (MPC) - Concepts; Theory and implementation; Relation with LQ-control. Implementation of MPC, State update and model prediction. Receding Horizon implementation; Issues and Challenges.

Introduction to controller performance assessment and diagnosis.

Learning Resources:

Text Books:

1. Jean-Pierre Corriou, Process Control: Theory and Applications, Second Edition, Springer, 2018.
2. Seborg, D. E., Edgar, T. F., Millechamp, D. A., Doyle III, F. J., Process Dynamics and Control, 4th Edition, Wiley, 2016.
3. RaghunathanRengaswamy, Babji Srinivasan, NiravPravinbhai Bhatt, Process Control Fundamentals: Analysis, Design, Assessment, and Diagnosis, CRC Press, 2020.
4. Liuping Wang, Model Predictive Control System Design and Implementation using MATLAB, Springer, 2009.

Reference Books:

1. B. Roffel and B. Betlem, Process Dynamics and Control, Wiley, 2006.
2. Cecil L. Smith, Advanced Process Control, Wiley, 2010.

CH5114	WASTE WATER TREATMENT	3-0-0	3 Credits	PEC

Pre-Requisites: None

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

CO1	Understand the principles and operation of wastewater treatment systems
CO2	Identify suitable treatment processes
CO3	Evaluate process operations and performance
CO4	Differentiate coagulation, flocculation, sedimentation, filtration and disinfection processes

Course Articulation Matrix:

CO \ PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	1	-	-	1	1	-	-	-	-	-	2	1	-
CO2	3	2	1	1	-		1	-	-	-	--	-	2	1	-
CO3	3	3	3	3	-	1	2	1	1	-	-	1	3	3	1
CO4	3	3	3	3	-	1	2	1	1	-	-	1	3	3	1

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction: Sources of wastewater, necessity of treatment, critical wastewater quality parameters, water quality guidelines and standards for various water uses. Wastewater flowrates and constituent loadings.

Wastewater microbiology: Bacteria, Cell composition and structure, Bacterial growth curve, Classification by carbon and energy requirement, Classification by oxygen requirement, Classification by temperature, Bacteria of significance – Archaea, Protozoa, Algae, Fungi, Virus.

Classification of wastewater treatment methods: Physical treatment, Chemical treatment, Biological treatment. Levels of wastewater treatment: Preliminary treatment, Primary treatment, Enhanced primary treatment, Conventional secondary treatment, Secondary treatment with nutrient removal, Tertiary treatment, Advanced treatment.

Preliminary treatment: Screens, Shredder/grinder, Grit chambers. Primary treatment - Types of settling/sedimentation, Primary sedimentation, Chemically enhanced primary treatment.

Secondary treatment: Suspended growth processes - Microbial growth kinetics, Activated sludge process, Aeration requirements, Types of aerators. Types of suspended growth processes. Staged activated sludge process, Extended aeration process, Oxidation ditch, Sequencing batch reactor (SBR), Membrane biological reactor (MBR). Stabilization ponds and lagoons.

Secondary treatment: Attached growth and combined processes - System microbiology and biofilms, Stone media trickling filter, Rotating biological contactor, Hybrid processes, Moving bed biofilm reactor (MBBR), Integrated fixed-film activated sludge (IFAS), Fluidized bed bioreactor (FBBR), Combined processes.

Secondary Clarification: Secondary clarifier for attached growth processes and suspended growth processes.

Anaerobic wastewater treatment: Anaerobic growth kinetics, Anaerobic attached and suspended growth processes.

Solids processing and disposal: Characteristics of municipal sludge, Sludge thickening and stabilization. Biosolids dewatering.

Introduction to advanced treatment processes: membrane processes, ceramic and polymeric membrane processes; microfiltration, ultrafiltration, reverse osmosis.

Learning Resources

Text Books:

1. Wastewater engineering, Treatment and Reuse, MetCalf, Eddy, Tata McGrawHill, 2003, 3rd Edition.
2. Fundamentals of wastewater treatment and engineering, RumanaRiffat, CRC Press, 2013.
3. Wastewatwer Treatment for Pollution Control and Reuse, S.J. Arceivala, S.R. Asolekar, Tata McGraw-Hill, 2007, 3rd Edition.

Reference Books:

1. Water and Wastewater Engineering, Fair, G.M., Geyer J.C and Okun, John Wiley Publications, 2010, 3rd Edition.
2. Wastewater Engineering: Treatment and Reuse, Tchobanoglous G., Burton F. L. and Stensel H.D., Tata McGraw Hill, 2002, 4th Edition.

Online Resources:

1. https://onlinecourses.nptel.ac.in/noc19_ce32/preview

IV-Year II-Sem
Professional Elective Courses (PEC)
Electives – 6 &7

CH461	MICROSCALE UNIT OPERATIONS	3-0-0	3 Credits	PEC

Pre-Requisites: None

Course Outcomes:

At the end of the course, the student will be able to

CO1	Identify the microscale phenomena in various miniaturized equipment like MEMS
CO2	Solve fluid flow phenomena for single and two immiscible liquids in microchannels
CO3	Design architectures of microfluidic devices for chemical & medical applications
CO4	Integrate theoretically the modular components for assembling of Lab-on-a-chip devices
CO5	Understand applications of microdevices for chemical and biomedical applications

Course Articulation Matrix:

PO / CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	1	1	1	-	-	-	-	-	-	-	-	3	0	-
CO2	3	2	2	2	-	-	-	-	-	-	-	-	3	1	-
CO3	3	1	3	3	1	2	-	-	-	-	-	-	3	1	-
CO4	3	3	3	3	1	2	-	-	-	-	-	-	3	1	-
CO5	3	1	1	1	-	-	-	-	-	-	-	-	3	0	-

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Physics and Chemistry at microscale:

Introduction, Introduction to forces of microscopic origin; Physics of miniaturization of mechanical, thermal and chemical systems Ranges of forces of microscopic origin, Microscopic length scales intervening in liquids and gases, Micromanipulation of molecules.

Fluid dynamics in micro channels:

Introduction, hypotheses of hydrodynamics, Hydrodynamics of gases in Microchannels, Flow of liquids with slip at the surface, Microhydrodynamics, Microfluidics. Fluid dynamics in microchannels: flow of liquids with and without slip, capillarity, two phase flow, preparation of microemulsions; Microreactor; Mixing and separation at microscale; cells in Microsystems, The physics of miniaturization, miniaturization of electrostatic systems.

Reaction Diffusion at microscopic level:

The microscopic origin of diffusion process, Advection-diffusion equation and its properties, Analysis of dispersion phenomena, chaotic mixing, mixing in Microsystems, Adsorption phenomena, Dispersion with chemical kinetics, Chromatography.

Miniaturization

Miniaturization of electromagnetic systems, miniaturization of mechanical systems, miniaturization of thermal systems, miniaturization of systems for chemical analysis. Interfacial phenomena: a few ideas about capillarity, Microfluidics of drops and bubbles,

Applications

Application to chromatography; Examples of microfluidic structures, connectors, valves and pumps; Fabrication methods and applications of micro devices. Mixing at microscale: Gas - Gas, Liquid-Liquid. Fundamentals and Applications of Microfluidics, featuring new material on nanoparticle suspensions through microdevices, carbon nanotubes application in microfluidics devices, performance benefits of microfluidics

Learning Resources:

Text Books:

1. Nguyen N T, Wereley S and Shaegh S A M, Fundamentals and Applications of Microfluidics, 3rd Edition, Artech House (2018).
2. Tabeling P, Introduction to Microfluidics, 1st Edition, Oxford University Press (2006).
3. Gad-el-Huk M, MEMS: Applications, 1st Edition, CRC Press (2005).

Reference Books:

1. McGuire F, Microfluidics Handbook, 1st Edition, NY Research Press (2015).
2. Seiffert S, Microfluidics: Theory and Practice for Beginners, 1st Edition, De Gruyter (2019).
3. Wirth T, Microreactors in Organic Chemistry and Catalysis, 2nd Edition, Wiley-VCH (2013)

Online Resources:

https://nptel.ac.in/courses/103/105/103105057/

CH462	PROCESS AND PRODUCT DESIGN	3-0-0	3 Credits	PEC

Pre-Requisites: None

Course Outcomes:

At the end of the course, the student will be able to

CO1	Understand Chemical product design principles
CO2	Select processes and flowsheets
CO3	Assess energy requirements and safety/sustainability indicators of processes
CO4	Execute computer aided molecular and mixture design
CO5	Design chemical devices

Course Articulation Matrix:

PO / CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	2	1	2	-	-	-	-	-	-	-	1	1	2
CO2	3	3	3	2	1	-	-	-	-	-	-	-	2	2	2
CO3	2	3	3	2	1	2	2	-	-	-	-	-	3	3	3
CO4	3	3	3	2`	3	-	-	-	-	-	-	-	2	3	3
CO5	3	3	3	2	1	-	-	-	-	-	-	-	2	3	3

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction to Chemical Product Design : Introduction, The Diversity of Chemical Products,TheChain of Chemical Products, Companies Engaging in Production of Chemical Products, B2B andB2C Chemical Products, Market Sectors and Classes of Chemical Products, Product Design andDevelopment, Tasks and Phases in Product Design and Development Project Management, Market Study, Product Design, Feasibility Study, Prototyping

Introduction to Process Design : Objectives, Introduction, Information Gathering, Environmental and Safety Data, Chemical Prices, Experiments, Preliminary Process Synthesis, Chemical State,Process Operations, Synthesis Steps, Continuous or Batch Processing, Next Process Design Tasks, Flowsheet Mass Balances, Process Stream Conditions, Flowsheet Material and EnergyBalances, Equipment Sizing and Costing, Economic Evaluation, Heat and Mass Integration, Environment, Sustainability, and Safety, Controllability Assessment, Optimization, PreliminaryFlowsheet Mass Balances, Flow Diagrams.

Design Literature, Stimulating Innovation, Energy, Environment, Sustainability, Safety, Engineering Ethics : Objectives, Design Literature, Information Resources, General Search Engines and Information Resources, Stimulating Invention and Innovation, Energy Sources -

Coal, Oil, and Natural Gas, Shale Oil, Shale Gas, Hydrogen, Hydrogen Production, Fuel Cell Energy Source, Hydrogen Adsorption, Biofuels, Solar Collectors, Wind Farms, Hydraulic Power, Geothermal Power, Nuclear Power, Selection of Energy Sources in Design, Environmental Protection, Environmental Issues, Environmental Factors in Product and Process Design, Sustainability—Key Issues, Sustainability Indicators, Life-Cycle Analysis, Safety Considerations, Safety Issues, Design Approaches Toward Safe Chemical Plants, Engineering Ethics

Molecular and mixture design: Framework for Computer-Aided Molecular-Mixture Design, Molecular Structure Representation, Generation of Molecule-Mixture Candidates, Mathematical Formulations of Molecular and/or Mixture Design Problems, Solution Approaches, Case Studies - Refrigerant Design, Large Molecule (Surfactant) Design, Active Ingredient Design/Selection, Polymer Design, Dichloromethane (DCM) Replacement in Organic Synthesis, Azeotrope Formation, Solvent Substitution, Mixture Design Design of Chemical Devices, Functional Products, and Formulated Products: Objectives, Design of Chemical Devices and Functional Products, The Use of Models in Design of Devices and Functional Products, Design of Formulated Products, Design of Processes for B2C Products

Learning Resources:

Text Books:

1. Warren D. Seider, Daniel R. Lewin, J. D. Seader, S. Widagdo, R. Gani, K.A. Ming Ng, Product and Process design principles, Synthesis, Analysis and Evaluation, Wiley,4th Edition,1999.

2. E. L. Cussler and G. D. Moggridge, Chemical Product Design (Cambridge Series in Chemical Engineering), Cambridge University Press, 2nd Edition, 2011.

CH463	MATHEMATICAL METHODS IN CHEMICAL ENGINEERING	3-0-0	3 Credits	PEC

Pre-Requisites: None

Course Outcomes:

At the end of the course, the student will be able to

CO1	Formulate lumped and distributed parameter mathematical models for chemical processes
CO2	Evaluate degrees of freedom for the developed mathematical models
CO3	Solve the model equations describing chemical processes and equipment
CO4	Analyze the results of the solution methods.
CO5	Perform nonlinear analysis

Course Articulation Matrix:

PO / CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	1	3	3	-	3	-	-	-	-	-	-	3	3	3
CO2	3	2	3	3	-	-	-	-	-	-	-	-	3	3	3
CO3	3	3	3	3	-	-	-	-	-	-	-	-	3	3	3
CO4	3	3	3	3	-	-	-	-	-	-	-	-	3	3	3
CO5	3	-	-	3	3	-	-	-	-	-	-	-	3	-	3

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Mathematical Formulation of the Physical Problems- Introduction, Representation of the problem, blending process, continuous stirred tank reactor, Unsteady state operation, heat exchangers, distillation columns, biochemical reactors.

Analytical (explicit) Solution of Ordinary Differential Equations encountered in Chemical Engineering Problems-Introduction, Order and degree, first order differential equations, second order differential equations, Linear differential equations, Simultaneous differential equations. Differential algebraic equations.

Non-linear analysis: Phase plane analysis, Bifurcation behaviour.

Formulation of partial differential equations- Introduction, Interpretation of partial derivatives, Formulation partial differential equations, particular solutions of partial differential equations, Orthogonal functions, Method of separation of variables, The Laplace Transform method, Other transforms.

Unsteady state heat conduction in one dimension - Mass transfer with axial symmetry – Continuity equations; Boundary conditions - Iterative solution of algebraic equations- The difference operator - Properties of the difference operator- Linear finite difference equations- Non-linear finite difference equations- Simultaneous linear differential equations - analytical solutions - Application of Statistical Methods.

Learning Resources:

Text Books:

1. Introduction to Chemical Engineering Computing, B. A. Finlayson, Wiley India Edition, 2010.
2.Mathematical methods in chemical and biological engineering, Dutta, Binay K, CRC Press, 2017
3. Applied Mathematics and Modeling for Chemical Engineers, R. G. Rice, D. D. Do, Wiley, 2012, 2nd Edition.

Reference Books:

1. Mathematical Method in Chemical Engineering by A. Varma & M. Morbidelli, Oxford University Press, 1997.
2. Applied Numerical Methods for Engineers and Scientists, Singaresu S. Rao, Prentice Hall, 2002.
3.Chemical Process Modelling and Computer Simulation, Amiya K. Jana, Prentice Hall India, 2011, 2nd Edition.
4. Process Dynamics- Modelling, Analysis and Simulation, B.W. Bequette -Prentice Hall, 1998.
5.Numerical Methods for Engineers, S.K.Gupta, New Age International Publishers, 2015.
6. Mathematical Modelling and Simulation in Chemical Engineering, M. Chidambaram, Cambridge University Press, 2018.
7. Mathematical methods in chemical engineering, V.G.Jenson, G.V. Jeffrys, Academic Press, 2000, 2nd edition.
8. Mathematical Methods in Chemical Engineering by S. Pushpavanam, Prentice Hall of India Pvt. Ltd, 2005.
9. Applied Mathematical Methods for Chemical Engineers, Norman W. Loney, CRC Press, 2015, 3rd Edition.

CH464	MOLECULAR SIMULATIONS IN CHEMICAL ENGINEERING	3-0-0	3 Credits	PEC

Pre-Requisites: None

Course Outcomes:

At the end of the course, student will be able to

CO1	Understand force field used in molecular dynamics and Monte Carlo simulations
CO2	Solve the newton's equation of motion for molecular system
CO3	Compute the transport and structural properties
CO4	Simulate a real life problem using molecular dynamics and Monte Carlo methods

Course Articulation Matrix:

PO / CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	2	2	2	1	2	-	1	-	-	1	1	1	2
CO2	3	2	2	2	2	-	-	-	1	-	-	1	1	2	1
CO3	3	2	2	2	1	1	2	-	2	-	-	2	1	2	1
CO4	3	2	1	2	1	1	1	-	1	-	-	2	1	2	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Statistical Mechanics: Macroscopic and Microscopic state, Boltzmann energy distribution, Partition functions, Partition functions of ideal monoatomic gas, Ensembles, Partition Function in various Ensemble (NVE, NVT, NPT and μVT)

Molecular Simulations: Basics of molecular simulation, Periodic box and minimum image convention, Non-bonded Interactions: Lennard-Jones potential and Ewald summation for Coulombic Interactions, Bonded Interactions: Bond Stretch, Bond bend, Dihedral and Improper.

Molecular Dynamics Simulation: Governing equations in molecular dynamics simulation for solving equation of motion, Calculation of force, Thermostat and Barostat, Various ensembles in molecular dynamics, case study for SPCE model of water to mimic its experimental values like density and viscosity.

Basics of Monte Carlo Techniques: Importance Sampling, Metropolis method, Monte Carlo algorithm, Different random trial moves, various ensembles in Monte Carlo, A case study for prediction of thermodynamic properties for small gaseous molecule using Monte Carlo simulation.

Structural Properties: Radial Distribution function, Calculation of number of hydrogen bonding.

Transport Properties: Residence time distribution for H-bond, Calculation of Mean squared displacement, Calculation of Viscosity and electrical conductivity.

Learning Resources:

Text Books:

1. Understanding Molecular Simulation: From Algorithms to Applications, Berend Smit and Daan Frenkel, Academic Press, 2001.
2. Computer Simulation of Liquids, D. J. Tildesley and M.P. Allen, Oxford University Press, 2017.

Reference Books:

1. Molecular Modelling: Principles and Applications, Andrew Leach, Prentice Hall, 2001.

Online Resources:

https://nptel.ac.in/courses/103/103/103103036/

CH465	STATISTICAL THERMODYANMICS	3-0-0	3 Credits	PEC

Pre-Requisites: None

Course Outcomes:

At the end of the course, the student will be able to

CO1	Identify the molecular level properties influencing the macroscopic thermodynamic properties.
CO2	Develop models to estimate thermodynamic properties of real gases, liquids and solids
CO3	Design molecular level architecture to enhance macroscopic properties.
CO4	Estimate macroscopic properties based on molecular level interactions.

Course Articulation Matrix:

PO / CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	1	2	1	2	2	1	2	-	1	-	-	2	1	3	1
CO2	2	2	2	2	3	-	-	-	1	-	-	2	1	3	2
CO3	1	2	1	2	2	1	2	-	1	-	-	2	1	3	1
CO4	1	2	1	2	2	1	2	-	1	-	-	2	1	3	1

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Syllabus:

Basics of Statistical Thermodynamics: The Statistical Foundation of Classical Thermodynamics, Classification Scheme for Statistical Thermodynamics, Importance of Statistical Thermodynamics.

Ensembles: Ensembles and Postulates, Canonical Ensemble, Canonical Ensemble and Thermodynamics, Grand Canonical Ensemble, Micro Canonical Ensemble, Thermodynamic Equivalence of Ensembles.

Evaluation of Probabilities: Probability- Definitions and Basic Concepts, Permutations and Combinations, Distribution Functions: Discrete and Continuous, Binomial Distribution, Poisson Distribution, Gaussian Distribution, Combinatorial Analysis for Statistical Thermodynamics. Criteria for Equilibrium: Equilibrium Principles, States of Equilibrium: Neutral, Metastable, and Unstable equilibrium, Maximizing Multiplicity.

Model for Mono-atomic and Polyatomic Ideal Gases: Energy Levels and Ensembles, Partition Function, Thermodynamic Functions for Mono-atomic Ideal Gases, Internal Degrees of Freedom, Independence of Degrees of Freedom, Potential Energy Surface, Vibration, Rotation, Thermodynamic Functions for Poly-atomic Ideal Gases, Hindered Internal Rotation in Ethane, Hindered Translation on a Surface, Fluctuation Theory.

Einstein's and Debye's Model of the Solid, Simple Liquids, Phase Equilibrium, Models for Multi Component Systems: Ideal Lattice Gas, Lattice Gas with Interactions, Solutions (Bragg-William Model and Regular Solutions, Quasi-Chemical Model).

Learning Resources:

Text Books:

1. An Introduction to Statistical Thermodynamics, Terrell L. Hill, Courier Corporation, 2012
2. Statistical Mechanics, Donald A. McQuarrie, Viva Books Pvt. Ltd., 2018
3. Statistical Thermodynamics: Fundamentals and Applications, Normand M. Laurendeau, Cambridge University Press, 2005.

Reference Books:

1. Elements of Statistical Thermodynamics, Leonard K. Nash, Dover Publications, 2006, 2nd Edition.
2. An Introduction to Applied Statistical Thermodynamics, Stanley I. Sandler, John Wiley &Sons, 2010.
3. Thermodynamics and Introduction to Thermo-statistics, Herbert B. Callen, Wiley, 1985, 2nd Edition.

Online Resources:

1. https://nptel.ac.in/courses/115/106/115106126/

CH466	PLANT UTILITIES	3-0-0	3 Credits	PEC

Pre-requisites: None

Course Outcomes:

At the end of the course, the student will be able to

CO1	List utilities in a plant.
CO2	Understand properties of steam and operation of boilers for steam generation.
CO3	Understand refrigeration methods used in industry.
CO4	Compare power generation methods.
CO5	Classify and describe the types of water, water treatment methods, storage anddistribution techniques

Course Articulation Matrix:

CO \ PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	3	3	-	3	-	-	-	-	-	-	3	3	1
CO2	2	2	3	3	-	3	-	-	-	-	-	-	3	3	2
CO3	2	2	3	3	-	3	-	-	-	-	-	-	3	3	3
CO4	2	-	3	3	-	3	-	-	-	-	-	-	3	3	3
CO5	2	-	3	3	-	3	3	-	-	-	-	-	3	3	3

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Importance of Process utilities in Chemical Plant: Different utilities - water, steam, compressed air, vacuum, refrigerants, their properties and requirements, selection and application of different utilities.

Compressed air and Vacuum: Use of Compressed air, process air and instrument air, Process of getting instrument air, Vacuum.

Steam: Properties of steam, types of steam generator / Boiler, steam handling and distribution, steam traps, steam nozzles, Scaling, trouble shooting, preparing boiler for inspection, Boiler Act.

Refrigeration: Refrigeration cycles, Different methods of refrigeration used in industry, different refrigerants, Simple calculation of C.O.P. Refrigerating effects. Liquefaction processes: Liquefaction process, liquefaction of air, liquefaction of natural gas.

Power Generation: Internal Combustion engines, Gas turbines, steam power plants. Water: Hard and soft water, water treatment, Water Resources, storage and distribution of water resources and conservation of water.

Learning Resources:

Text Books:

1. Fan Engineering, Jorgenson R., Buffalo Rorge Co., 1983, 8th Edition.
2. Efficient Use of Steam, Lyle, O., HMSO, London, 1974.
3. Refrigeration and Air Conditioning, Stoecker, W.F., Mc-Graw Hill, 1983, 2nd Edition.
4. Boiler operations engineering, Chattopadhyay, P., Tata McGraw Hill, 1998.
5. Perry's chemical Engineer's Handbook, Perry R.H., Green D.W., McGraw Hill, NewYork 2007, 8th Edition.

CH467	BIOSEPARATION TECHNIQUES	3-0-0	3 Credits	PEC

Pre-Requisites: None

Course Outcomes:

At the end of the course, the student will be able to

CO1	Characterize the petroleum and petroleum products
CO2	Design the fractionating column for crude
CO3	Differentiate the treatment techniques involved in post processing of crude
CO4	Apply the process flow technologies for crude conversion to fuels

Course Articulation Matrix:

CO \ PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	2	1	-	1	2	1	-	-	-	-	3	3	-
CO2	3	3	2	1	-	1	2	1	-	-	-	-	3	3	-
CO3	3	3	2	1	-	1	2	1	-	-	-	-	3	3	-
CO4	3	3	2	1	-	1	2	1	-	-	-	-	3	3	-

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction to Bioseparations. Range and characteristics of fermentation broth and microorganisms. Economic significance of bioseparation processes. The RIPP scheme: Recovery, isolation, purification and polishing. Examples and current trends in Bioseparations.

Removal of insolubles: Properties of biological materials Size, molecular weight, diffusivity, sedimentation coefficient, osmotic pressure, solubility, partition coefficient, light absorbance.
Filtration, pretreatment of fermentation broth, continuous filtration equipments, microfiltration.
Centrifugation, settling of solids, scaleup of centrifugation, centrifugal filtration.
Cell disruption: Intracellular products, cell wall, cell disruption using bead mill, French press, ultrasonic vibrations, detergents, enzymes, solvents, and osmotic shock.
Liquid- liquid extractions, Liquid chromatographic methods- Medium Pressure Liquid Chromatography, HPLC (different principles: ion exchange; affinity, gel permeation).

Isolation: Extraction. The chemistry of extraction, batch, staged and differential extractions, fractional extraction with stationary and moving phases.
Adsorption in Continuous stirred tank reactors and fixed beds.

Product purification: Elution chromatography, adsorbents, yield and purity, HPLC (different principles: ion exchange; affinity, gel permeation). Kinetic analysis.

Precipitation using organic solvents, nonsolvents, anti-chaotropic salts, temperature. Large-scale precipitation.
Affinity ultrafiltration, field flow fractionation and Electrophoresis

Polishing using Crystallization and Drying.

Learning Resources:

Text Books:

1. Harrison, R. G., Todd, P., Rudge, S. R., &Petrides, D. P. Bioseparations science and engineering. Oxford University Press, USA (2015).
2. Paul A. Belter, Paul A.. Belter, E. L. Cussler, E. L..Cussler, Wei-Shou Hu, Bioseparations: Downstream Processing for Biotechnology, Wiley-Interscience publication 2007.
3. Sivasankar B, Bioseparations: Principles And Techniques, PHI Learning Pvt. Ltd. India, 2005

Reference:

1. Product Recovery in Bioprocess technology, BIOTOL series, Butterworth–Heinemann (2006).
2. Comprehensive Biotechnology, Volume 2nd Edition: M. Moo–young (1985).
3. Principles of Downstream processing, by Ronald & J. Lee, Wiley Publications (2007).
4. Handbook of Bioseparations, Edited by Satinder Ahuja, Academic Press Volume 2, (2000).
5. Principles of Protein Purification by Thomson, Wiley International Edition (2007).
6. Raja Ghosh, Principles Of Bioseparations Engineering, World Scientific Publishing Company, Singapore 2006
7. R. K. Scopes, Berlin, Protein Purification: Principles and Practice, Springer, 1982.
8. Mishra N, Bioseparation Technology, CRC Press (2008)
9. Bioseparation Engineering, Ajay Kumar, Abhishek Awasthi, I. K. International Pvt Ltd, India (2009).

CH468	SCALE UP METHODS	3-0-0	3 Credits	PEC

Pre-Requisites: None

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

CO1	Understand principles of scale up.
CO2	Apply dimensional analysis technique for scale up problems.
CO3	Carry out scale up of mixers, heat exchangers and chemical reactors
CO4	Scale up distillation columns and packed towers.

Course Articulation Matrix:

PO / CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	2	1	1	-	1	-	2	2	-	1	3	3	1
CO2	3	2	2	1	1	-	1	-	2	2	-	1	3	3	1
CO3	3	2	2	1	1	-	1	-	2	2	-	1	3	3	1
CO4	3	2	2	1	1	-	1	-	2	2	-	1	3	3	1

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Principals of Similarity, Pilot Plants & Models: Introduction to scale-up methods, pilot plants, models and principles of similarity, Industrial applications.

Dimensional Analysis and Scale-Up Criterion: Dimensional analysis, regime concept, similarity criterionandscaleupmethodsusedinchemicalengineering,experimentaltechniquesforscale- up.

Scale-Up of Mixing and Heat Transfer Equipment: Typical problems in scale up of mixing equipment and heat transfer equipment.

Scale-Up of Chemical Reactors: Kinetics, reactor development & scale-up techniques for chemical reactors.

Scale-Up of Distillation Column & Packed Towers: Scale-up of distillation columns and packed towers for continuous and batch processes.

Learning Resources:

Text Books:

1. Scale-up in Chemical Engineering, Marko Zlokamik, Wiley-VCH, 2006, 2nd Edition.
2. Pilot Plants Models and Scale-up methods in Chemical Engineering, Johnstone, Thring, McGraw Hill, New York, 1962.

Reference Books:

1. Pilot Plants and Scale-Up, Hoyle W, Royal Society of Chemistry,1999.
2. Chemical Reactor Design, Optimization and Scale-up, Bruce Nauman E, McGraw Hill Handbooks, New York,2002.

CH5162	HEAT INTERGRATION AND PROCESS SCHEDULING	3-0-0	3 Credits	PEC

Pre-Requisites: None

Course Outcomes:

At the end of the course, the student will be able to

CO1	Identify the objectives of heat integration and process scheduling.
CO2	Apply the concepts of pinch technology and retrofitting.
CO3	Develop models for batch process scheduling.
CO4	Analyse heat exchanger networks and process scheduling models.

Course Articulation Matrix:

CO \ PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	1	-	1	-	-	1	1	-	-	-	-	1	-	2
CO2	3	1	-	2	-	-	2	1	-	-	-	-	1	1	2
CO3	3	2	1	2	3	1	3	1	1	1	1	1	2	2	3
CO4	3	2	1	3	3	1	3	1	1	1	1	1	2	2	3

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Heat Integration:

Introduction: What is pinch analysis, history and industrial experience, why does pinch analysis work, the concept of process synthesis, the role of thermodynamics in process design.

Key concepts of Pinch analysis: Heat recovery and heat exchange, the pinch and its significance, heat exchanger network design, choosing ΔT_{min}, methodology of pinch analysis.

Data extraction and energy targeting: Data extraction, case study: organics distillation plant, energy targeting, multiple utilities, targeting heat exchanger units, area and shells, super targeting, targeting organics distillation plant case study.

HEN Design Utilities: Heat exchange equipment, stream splitting and cyclic matching, network relaxation, more complex designs, multiple pinches and near pinches, retrofit design.

Process Scheduling:

Introduction to Batch Chemical Processes.

Short-Term Scheduling: Effective technique for scheduling of multipurpose and multi-product batch plants, different storage policies for intermediate and final products, evolution of multiple time grid models in batch process scheduling, short-term scheduling of multipurpose plants, planning and scheduling in chemical and biopharmaceutical industry.

Heat integration in multipurpose batch plants: direct and indirect heat integration, simultaneous optimization of energy and water use in multipurpose batch plants.

Design and Synthesis: Design and synthesis of multipurpose batch plants, process synthesis approaches for enhancing sustainability of batch process plants, scheduling and design of multipurpose batch facilities.

Learning Resources:

Text Books:

1. Pinch Analysis and Process Integration, Ian C Kemp, Elsevier Publication, 2007, 2nd Edition.
2. Synthesis, Design, and Resource Optimization in Batch Chemical Plants, ThokozaniMajozi, EsmaelReshidSeid, Jui-Yuan Lee, CRC Press Taylor & Francis, 2015.
3. Batch Chemical Process Integration - Analysis, Synthesis and Optimization, ThokozaniMajozi, Spinger, 2010.

Reference Books:

1. Pinch Technology and Beyond Pinch, New Vistas on Energy Efficiency Optimization, MohmoudBahyNoureddin, Booktopia, 2011.
2. Batch Processing Systems Engineering, Gintaras V. Reklaitis, Aydin K. Sunol, David W. T. Rippin, OnerHortacsu, Spinger, 1996.
3. Introduction to Software for Chemical Engineers, Mariano Martin, CRC Press, 2015.

CH5163	NOVEL SEPARATION TECHNIQUES	3-0-0	3 Credits	PEC

Pre-Requisites: None

Course Outcomes:

At the end of the course, the student will be able to

CO1	Select a membrane and membrane process for a given application.
CO2	Evaluate the flux of solvent and solute through membrane.
CO3	Differentiate surfactant based separation
CO4	Design Centrifugal Separation processes

Course Articulation Matrix:

PO / CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	3	3	-	-	-	-	-	-	-	-	3	3	3
CO2	3	3	3	3	1	-	3	-	-	-	-	-	3	3	3
CO3	3	3	3	3	-	-	-	-	-	-	-	-	3	3	3
CO4	3	3	3	3	-	-	-	-	-	-	-	-	3	3	3

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Fundamentals of Separation Processes; Basic definitions of relevant terms.

Membrane separation process, Definition of Membrane, Membrane types, Advantages and limitations of membrane technology compared to other separation processes, Membrane materials and properties.

Preparation of synthetic membranes: Phase inversion membranes, Preparation techniques for immersion precipitation, Synthesis of asymmetric and composite membranes and Synthesis of inorganic membranes.

Transport in membranes: Introduction, Driving forces, Non-equilibrium thermodynamics, Transport through porous membranes, transport through non- porous membranes, Transport through ion-exchange membranes.

Membrane processes: Pressure driven membrane processes, Concentration as driving force, electrically driven membrane processes.

Polarization phenomena and fouling: Concentration polarization, Pressure drop, Membrane fouling, methods to reduce fouling.

Modules: Introduction, membrane modules, Comparison of the module configurations

Gas separation:

Surfactant based separation processes: Liquid membranes: Fundamentals and modelling.. Micellar enhanced separation processes.. Cloud point extraction.

Centrifugal Separation processes and their calculations.

Ion exchange and chromatographic separation processes.

Supercritical fluid extraction

Learning Resources:

Text Books:

1. Basic Principles of Membrane Technology, Mulder M, Kluwer Academic Publishers, London, 1996.
2. Membrane Technology and Research, Baker R. W., Inc.(MTR), Newark, California, USA, 2004.
3. Membrane Separation Processes, Nath K., Prentice-Hall Publications, New Delhi, 2008.
4. Handbook of Separation Process Technology, R W Rousseau, John Wiley & Sons.
5. Supercritical Fluid Extraction, M A Mchugh& V J Krukonis, Butterworth Heinmann.

IV-Year I-Sem
Open Electives Courses (OEC)
ELECTIVE-2
Offered to Other B.Tech Programmes

CH445	DATA DRIVEN MODELLING	3-0-0	3 Credits	OEC

Pre-Requisites: None

Course Outcomes:

At the end of the course, the student will be able to

CO1	Identify disturbance models
CO2	Estimate parametric and non-parametric models
CO3	Determine the model structure
CO4	Validate the developed models

Course Articulation Matrix:

PO / CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	2	2	1	2	2	-	-	-	-	-	1	-	-	-	3
CO2	2	2	1	2	2	-	-	-	-	-	1	-	-	-	3
CO3	2	2	1	2	2	-	-	-	-	-	1	-	-	-	3
CO4	2	2	1	2	2	-	-	-	-	-	1	-	-	-	3

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

System Identification - Motivation and Overview. Models of Discrete-Time LTI Systems – Convolution equation. Difference equations, Transfer functions, State-space models, Discretization, Sampling and Hold operations, Sampling theorem.

Non-parametric models - impulse response, step response and frequency response models.

Disturbance models - random processes, representation of stationary processes, white-noise process, auto-covariance function (ACF), cross-covariance function (CCF), ARMA and ARIMA models. Parametric model structures - ARX, ARMAX, OE, BJ models.

Regression techniques, statistical properties.

Estimation of non-parametric models - impulse / step response coefficients, frequency response models. Estimation of parametric models - notions of prediction and simulation, predictors for parametric models, prediction-error methods, Instrumental Variable method.

Model Structure Selection and Diagnostics - estimation of delay and order, residual checks, properties of parameter estimates, model comparison and selection, model validation.

Learning Resources:

Text Books:

1. Principles of System Identification: Theory and Practice, Arun K. Tangirala, CRC Press, 2015.

2. Nonlinear System Identification,Oliver Nelles, Springer, 2020, 2nd Edition.

References

1. System Identification – An Introduction, Karel J. Keesman, Springer, 2015, 2nd Edition.
2. System Identification: Theory for the User,Lennart Ljung, Pearson education, 1997, 2nd Edition.
3. Identification of Dynamic Systems: An Introduction with Applications, Rolf Isermann and Marco Munchhof, Springer, 2011.

OnlineResources:

1. NPTEL course link: https://nptel.ac.in/courses/103/106/103106149/
2. MATLAB SysID tool webinar by Prof. Ljung: https://in.mathworks.com/videos/introduction-to-system-identification-81796.html

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CH446	FUEL CELL TECHNOLOGY	3-0-0	3 Credits	OEC

Pre-Requisites: None

Course Outcomes:

At the end of the course, the student will be able to

CO1	Understand fuel cell fundamentals.
CO2	Analyze the performance of fuel cell systems.
CO3	Identify the intricacies in the operation of fuel cell stack and fuel cell system.
CO4	Apply fuel processing techniques for fuel cells

Course Articulation Matrix:

PO / CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	1	1	1	-	-	-	-	-	-	-	-	-	-
CO2	3	3	1	1	1	-	-	-	-	-	-	-	-	-	-
CO3	3	2	3	1	2	-	-	-	-	-	-	-	-	-	-
CO4	3	2	1	1	2	-	-	-	-	-	-	-	-	-	-

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Overview of Fuel Cells: What is a fuel cell, brief history, classification, how does it work, why do we need fuel cells, Fuel cell basic chemistry and thermodynamics, heat of reaction, theoretical electrical work and potential, theoretical fuel cell efficiency.

Fuels for Fuel Cells: Hydrogen, Hydrocarbon fuels, effect of impurities such as CO, S and others. Fuel cell electrochemistry: electrode kinetics, types of voltage losses, polarization curve, fuel cell efficiency, Tafel equation, exchange currents.

Fuel cell process design: Main PEM fuel cell components, materials, properties and processes: membrane, electrode, gas diffusion layer, bi-polar plates, Fuel cell operating conditions: pressure, temperature, flow rates, humidity.Main components of solid-oxide fuel cells, Cell stack and designs, Electrode polarization, testing of electrodes, cells and short stacks, Cell, stack and system modelling.

Fuel processing: Direct and in-direct internal reforming, Reformation of hydrocarbons by steam, CO_2 and partial oxidation, Direct electro-catalytic oxidation of hydrocarbons, carbon decomposition, Sulphur tolerance and removal, Using renewable fuels for SOFCs.

Learning Resources:

Text Books:

1. Hoogers G, Fuel Cell Technology Hand Book, CRC Press, 2003.
2. O'Hayre, R. P., S. Cha, W. Colella, F. B. Prinz, Fuel Cell Fundamentals, Wiley, 2006.
3. F. Barbir, PEM Fuel Cells: Theory and Practice, Elsevier/Academic Press, 2 nd Edition, 2013

References:

1. Subhash C. Singal and Kevin Kendall, High Temperature Fuel Cells: Fundamentals, Design and Applications

2. Laminie J, Dicks A, Fuel Cell Systems Explained, 2nd Edition, John Wiley, New York, 2003.

OnlineResources:
https://nptel.ac.in/courses/103/102/103102015/

CH447	CO2 CAPTURE, SEQUESTRATION & UTILIZATION	3-0-0	3 Credits	OEC

Pre-Requisites: None

Course Outcomes:

At the end of the course, the student will be able to

CO1	Identify the necessity of CO_2 capture, storage and utilization
CO2	Distinguish the CO_2 capture techniques
CO3	Evaluate CO_2 Storage and sequestration methods
CO4	Assess Environmental impact of CO_2 capture and utilization

Course Articulation Matrix:

PO / CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	3	1	2	3	3	-	2	2	-	1	2	2	-
CO2	3	2	3	1	2	3	3	-	2	2	-	1	2	2	-
CO3	3	2	3	1	2	3	3	-	2	2	-	1	2	2	-
CO4	3	2	3	1	2	3	3	-	2	2	-	1	2	2	-

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction: Global status of CO_2 emission trends, Policy and Regulatory interventions in abatement of carbon footprint, carbon capture, storage and utilization (CCS&U)

CO_2 capture technologies from power plants: Post-combustion capture, Pre-combustion capture, Oxy-fuel combustion, chemical looping combustion, calcium looping combustion

CO_2 capture agents and processes: Capture processes, CO_2 capture agents, adsorption, ionic liquids, metal organic frameworks

CO_2 storage and sequestration: Geological sequestration methods, Biomimetic carbon sequestration

CO_2 Utilization: CO_2 derived fuels for energy storage, polymers from CO_2, CO_2 based solvents, CO_2 to oxygenated organics, Conversion into higher carbon fuels, High temperature catalysis

Environmental assessment of CO_2 capture and utilization: Need for assessment, Green chemistry and environmental assessment tools, Life cycle assessment (LCA), ISO standardization of LCA, Method of conducting an LCA for CO_2 capture and Utilization.

Learning Resources:

Text Books:

1. Carbon dioxide utilization: Closing the Carbon Cycle, Peter Styring, Elsje Alessandra

Quadrelli, Katy Armstrong, Elsevier, 2015, 1st Edition.

2. Carbon Capture, Storage and, Utilization: A Possible Climate Change Solution for Energy Industry ,Goel M, Sudhakar M, Shahi RV, TERI, Energy and Resources Institute, 2015, 1st Edition.
3. Carbon Capture and Storage, CO2 Management Technologies, AmitavaBandyopadhyay, CRC Press, 2014, 1st Edition.

Reference Books:

1. Calcium and Chemical Looping Technology for Power Generation and Carbon Dioxide (CO_2) Capture, Fennell P, Anthony B, Woodhead Publishing Series in Energy: No. 82, 2015, 1st Edition.
2. Developments in Innovation in Carbon Dioxide Capture and Storage Technology: Carbon Dioxide Storage and Utilization, Mercedes Maroto-Valer M, Vol 2, Woodhead Publishing Series in Energy, 2014, 1st Edition.
3. Fundamentals of Enhanced Oil and Gas Recovery from Conventional and Unconventional Reservoirs, AlirezaBahadori, Elsevier Inc., 2018, 1st Edition.

CH448	DESIGN OF EXPERIMENTS	3-0-0	3 Credits	OPC

Pre-Requisites: None

Course Outcomes:

At the end of the course, the student will be able to

CO1	Design experiments for a critical comparison of outputs
CO2	Propose hypothesis from experimental data
CO3	Implement factorial and randomized sampling from experiments
CO4	Estimate parameters by multi-dimensional optimization

Course Articulation Matrix:

CO \ PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	3	3	3	3	3	3	-	-	-	-	-	3	3
CO2	3	3	-	3	-	-	-	3	-	-	-	-	-	3	-
CO3	-	-	-	-	-	-	-	3	-	-	-	-	-	-	3
CO4	3	3	3	3	3	-	-	-	-	-	-	-	-	-	3

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction: Strategy of experimentation, basic principles, guidelines for designing experiments. Simple Comparative Experiments: Basic statistical concepts, sampling and sampling distribution, inferences about the differences in means: Hypothesis testing, Choice of samples size, Confidence intervals, Randomized and paired comparison design.

Experiments with Single Factor: An example, The analysis of variance, Analysis of the fixed effect model, Model adequacy checking, Practical interpretation of results, Sample computer output, Determining sample size, Discovering dispersion effect, The regression approach to the analysis of variance, Non-parametric methods in the analysis of variance, Problems.

Design of Experiments: Introduction, Basic principles: Randomization, Replication, Blocking, Degrees of freedom, Confounding, Design resolution, Metrology considerations for industrial designed experiments, Selection of quality characteristics for industrial experiments. Parameter Estimation.

Response Surface Methods: Introduction, The methods of steepest ascent, Analysis of a second- order response surface, Experimental designs for fitting response surfaces: Designs for fitting the first-order model, Designs for fitting the second-order model, Blocking in response surface designs, Computer-generated (Optimal) designs, Mixture experiments, Evolutionary operation, Robust design, Problems.

Design and Analysis: Introduction, Preliminary examination of subject of research, Screening experiments: Preliminary ranking of the factors, active screening experiment-method of random balance, active screening experiment Plackett-Burman designs, Completely randomized block design, Latin squares, Graeco-Latin Square, Youdens Squares, Basic experiment-mathematical modelling, Statistical Analysis, Experimental optimization of research subject: Problem of optimization, Gradient optimization methods, Nongradient methods of optimization, Simplex sum rotatable design, Canonical analysis of the response surface, Examples of complex optimizations.

Learning Resources:

Text Books:

1. Lazic Z. R., Design of Experiments in Chemical Engineering, A Practical Guide, Wiley, 2005.
2. Antony J., Design of Experiments for Engineers and Scientists, Butterworth Heinemann, 2004.
3. Montgomery D. C., Design and Analysis of Experiments, Wiley, 5thEdition, 2010.
4. Doebelin E. O., Engineering Experimentation: Planning, Execution, Reporting, McGraw-Hill, 1995.

Service Courses

Offered to Other B.Tech Programs

CH281	POLYMER TECHNOLOGY For B. Tech. (METULLURGICAL AND MATERIALS ENGINEERING) II Year II Sem.	3-0-0	3 Credits	ESC

Pre-Requisites: None

Course Outcomes:

At the end of the course, the student will be able to

CO1	Explain the thermodynamics of polymer structures
CO2	Characterize polymers using different techniques
CO3	Choose additives for polymers, blends and composites
CO4	Identify suitable processing method for a given polymer

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	1	1	1	1	-	-	-	-	-	-	-	3	2	1
CO2	2	1	-	-	-	-	-	-	-	-	-	-	2	-	-
CO3	2	-	-	-	-	-	-	-	-	-	-	-	1	-	-
CO4	2	-	2	-	-	-	-	-	-	-	-	-	2	-	-

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction and Classification of Polymers. Thermosets, Factors influencing the polymer properties, Monomers used for polymer synthesis, synthesis procedure for monomers Styrene, ethylene, Vinyl monomers etc., Thermoplastics, Linear Branch, Cross Linked Polymers, Ewart Kinetics for emulsion polymerization.

Addition polymers – kinetics, synthesis and reactions, Condensation polymers, Kinetics reaction and processes, Polymerization Techniques - Emulsion polymerization and Suspension polymerization, Interfacial Polymerization with their merits

Molecular Weights, Polydispersity Index, Different Methods of determination of Molecular weight, Effect of Molecular weight on Engineering Properties of Polymers, High Performance and Specialty Polymers, Polymer additives, compounding. Fillers, plasticizers, lubricants, colorants, UV stabilizers, fire retardants and antioxidants.

Polymer processing: Extrusion process, Twin and Single Screw extrusion, Blow moulding, injection moulding, Wet and Dry spinning processes, thermo set moulding. Manufacturing of polymers: flow-sheet diagrams, properties & applications of PE, PP, PS, Polyesters, Nylons, ABS and PC

Viscoelastic behavior of plastics; Time – temperature superposition; Stress-strain behavior; fracture; creep; hardness; impact behavior; Methods to improve mechanical properties; Basics of polymer rheology; Permeability; electrical; optical and flammability properties Thermodynamics of Polymer Mixtures, ASTM and ISO methods for testing of polymers.

Introduction to polymer composites: thermoplastic composites, thermoset polymer composites, metal non-filled composites. Processing of polymer nano-composites. Morphological, thermal and mechanical characterizations for nano-composites,

Learning Resources:

Text Books:

1. Fried J R, Polymer Science and Technology, Prentice Hall of India Pvt. Ltd., New Delhi, Eastern Economy Edition, 2000.

2. Premamoy Ghosh, Polymer Science and Technology, Tata McGraw Hill Publishing Company, New Delhi, 3rd Edition, 2010

Reference Books:

1. R. Sinha, Outlines of Polymer Technology: Manufacture of Polymers, Prentice Hall of India Pvt. Ltd., New Delhi, 2002.

2. George Odian, Principles of Polymerization, John Wiley & Sons, Inc., 2004.

Online Resources:

1. NPTEL Lecture: https://nptel.ac.in/courses/103/106/105106205/

2. NPTEL Lecture: https://nptel.ac.in/courses/103/107/103107139/

CH431	**BIOPROCESS ENGINEERING ECONOMICS** **For B. Tech. (BIOTECHNOLOGY) IV Year I Sem.**	3-0-0	3 Credits	ESC

Pre-Requisites: None

Course Outcomes:

At the end of the course, the student will be able to

CO1	Analyze alternative processes and equipment for manufacturing a product
CO2	Determine costs involved in process plants
CO3	Perform economic analysis and optimum design of processes
CO4	Evaluate project profitability

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	1	3	2	-	-	2	2		2	3	3	-	2	3	-
CO2	2	-	-	2	2	-	-	-	2	2	3	-	1	3	-
CO3	3	2	2	-	2	-	-	-	2	2	3	-	-	3	3
CO4	2	3	3	1	2	-	-	-	2	3	3	-	2	3	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction: Chemical Engineering plant design, Overall design consideration, Practical considerations in design, engineering ethics in design.

General Design Considerations: Health and Safety hazards, Loss prevention, Environmental Protection, Plant Location, Plant Layout, Plant Operation and Control.

Process Design Development: Development of design database, Process creation, Process design criteria, Process flow diagram (PFD), Equipment design specifications. Flow sheet synthesis and development: General procedure, Process information, Functions diagram, Flow sheet synthesis, Software use in process design.

Cost and asset accounting: General accounting procedure, Balance sheet and Income statements.

Analysis of Cost Estimation: Cash flow for industrial operations, Factors affecting investment and production costs, Capital investments, Fixed capital and working capital, Estimation of capital investment, Cost indices, Estimation of total cost, Gross profit, Net profit and cash flow, Cost scaling factors, Net present value analysis.

Interest and Insurance: Interest, Simple interest, Compound interest, Nominal and effective interest rates, Continuous interest, Costs of capital, Time value of money, Annuity, Cash flow patterns, Income taxes, Present worth, Future worth, Taxes and Insurance.

Depreciation: Depreciable investments, Methods for calculating Depreciation.

Profitability Analysis: Profitability standards, Costs of capital, Minimum acceptable rate of return, Methods of calculating profitability, Rate of return on investment, Payback period, Net return, Discounted cash flow rate of return, Net present worth, Payout period, Alternative investments, Replacements.

Optimum design and design strategy: Defining the optimization problem, Selecting an objective function, Structural optimization, Parametric optimization, Variable screening and selection, Optimization Applications..

Bioprocess Economics : Introduction to Bioprocess Economics, Scale up and Scale down issues, Facility design aspects of bioprocess economics .

Learning Resources:

Textbooks:

1. Peters M.S., K.D. Timmerhaus and R.E. West, Plant Design and Economics for Chemical Engineers, McGraw Hill, 5th Edition, 2011.
2. Turton R., R.C. Baile, W.B. Whiting, J. A. Shaeiwitz. Analysis, Synthesis and Design of Chemical Processes, PHI, New Delhi, 3rd Edition, 2011.

Reference Books:

1. Seider W.D., J.D. Seader, D.R. Lewin, Product and Process Design Principles: Synthesis, Analysis, and Evaluation, Wiley, 2nd Edition, 2004.
2. James R. Couper, W. Roy Penny, James R. fair, Stanley M. Walas, Chemical Process Equipment: Selection and Design, Elsevier Butterworth-Heinemann, 2012.
3. R. Panneerselvam, Engineering Economics, Prentice Hall India, 2013.

Online resources

https://nptel.ac.in/courses/103/105/103105166/