NATIONAL INSTITUTE OF TECHNOLOGY
ANDHRA PRADESH

RULES AND REGULATIONS
SCHEME OF INSTRUCTION AND SYLLABI
B.Tech. – Chemical Engineering
Effective from 2024-25

NATIONAL INSTITUTE OF TECHNOLOGY ANDHRA PRADESH

VISION

To nurture and produce highly competent engineers, scientists and entrepreneurs committed towards catering to futuristic societal challenges through holistic education synergetic with innovations and vibrant research eco-system.

MISSION

- To implement best practices in teaching-learning methodologies for establishing dynamic knowledge-connected society.
- To create a conducive environment for carrying out research in multi-disciplinary areas and thereby nurturing novel thinking capabilities.
- To strengthen industry-institute interface to inculcate entrepreneurship abilities.
- To address all technological needs of the Nation for self-sustenance.

DEPARTMENT OF CHEMICAL ENGINEERING

VISION

To offer academic and research programs that prepare students to address a global society's challenges and needs by solving complex problems associated with Chemical and Allied Engineering

MISSION

M 1. To deliver high-quality technical education that enables the students to lead productive careers in the chemical and allied industries.

M 2. To develop a state-of-the-art infrastructure that promotes internationally recognized research, creativity, and entrepreneurial culture.

M 3. To offer credible solutions to problems prevalent in the Chemical and allied industries by building a robust interface.

M 4. To make students contribute to the nation's sustainable development through leadership in professionalism, education, research, and public services.

Department of Chemical Engineering:

About the Department: The Department of Chemical Engineering at NIT Andhra Pradesh was established in 2015-16, with a mission to impart high-quality engineering education and mould the students to meet the ever-growing demand for technical human resources in Chemical Engineering.

The Department currently offers B.Tech. M.Tech. and Ph.D. programmes in Chemical Engineering. We have revised our academic curriculum to be in tune with the current developments in the field while retaining the core concepts from the discipline. In addition, faculty introduced new electives related to their research, and these are pretty well subscribed.

Our students are highly encouraged to participate in national and international conferences, seminars, workshops, and symposia. The last few years have seen a dramatic increase in industrial associations, research projects, publications, and faculty awards

B.Tech. – CHEMICAL ENGINEERING

Program Outcomes (POs)

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

PO1	Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and chemical engineering to the solution of complex engineering problems.
PO2	Problem analysis: Identify, formulate, research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
PO3	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.
PO4	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.
PO5	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.
PO6	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.
PO7	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.
PO8	Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
PO9	Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
PO10	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.
PO11	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.
PO12	Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Program Specific Outcomes (PSOs)

PSO1	Apply the knowledge of unit operations and unit processes for designing a chemical plant.
PSO2	Analyze the processes & equipment using conservation and phenomenological laws, reaction kinetics, thermodynamics, process control, and economics for a sustainable environment
PSO3	Develop mathematical models& simulation tools to design and/or optimize chemical processes

(Note: a maximum of 4 PSOs only)

SCHEME OF INSTRUCTION

B.Tech. (Chemical Engineering) Course Structure

Note:

1. **All BSC Courses must be offered within V Semester (Including).**
2. **All ESC Courses must be offered within VI Semester (Including).**
3. **For all courses in the HSC basket, slots are reserved in the template.**
4. **Open electives/DAC approved Free Electives (MOOCS/NPTEL etc.) shall be offered from IV semester.**
5. **Department electives shall be offered from IV semester.**
6. **VIII semester is reserved for a semester-long internship or an additional courses/project at the institute.**

Degree Requirements for B.Tech. (Ch.E) Programme

Category	Category Description	Credits	Percentage
BSC	Basic Science Courses (BSC)	**15**	10%
ESC	Engineering Science Courses (ESC)	**15**	10%
Professional Major Courses (PMC)	Professional Major Core Courses (PCC)	**60**	60%
	Professional Major Elective Courses (DEC)	**18**	
	Professional Major Work (PRC)	**6**	
	Semester-Long Internship (SLI)	**6**	
Open/Free Electives	Open Elective Courses (OEC) and DAC approved Free Electives (NPTEL, MOOCs, etc.)	**15**	10%
HSC Courses	Liberal Arts/Creative Arts Courses (LCA)	**6**	10%
	Sports Courses (Any two sports of 1 Credit each)	**2**	
	NCC/Social Service	**1**	
	Yoga	**1**	
	English Communication	**2**	
	Personality Development/Life Skills	**1**	
	Introduction to Entrepreneurship	**1**	
	Introduction to Design Thinking	**1**	
	Total Credits	**150**	**100%**

	I	II	III	IV	V	VI	VII	VIII	TOT
BSC	5	8	2	0	0	0	0	0	**15**
ESC	10	5	0	0	0	0	0	0	**15**
HSC	3	1	2	1	1	4	3	0	**15**
PCC	0	4	17	16	12	6	5	0	**60**
DEC	0	0	0	3	6	9	0	0	**18**
OEC/ MOOCS (MOE)	0	0	0	3	3	3	6	0	**15**
PRC/ SLI	0	0	0	0	0	0	6	6	**12**
	18	**18**	**21**	**23**	**22**	**22**	**20**	**6**	**150**

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	HS1011	English for Engineers-I	2	0	0	2	HSC
2	MA1031	Calculus of Several Variables	2	0	0	2	BSC
3	CY1011	Engineering Chemistry	2	0	0	2	BSC
3	CE1051	Environmental Science and Engineering	2	0	0	2	ESC
5	CS1011	Problem Solving through Computer Programming	3	0	0	3	ESC
6	CH1011	Introduction to Chemical Engineering	3	0	0	3	ESC
7	CS1012	Problem Solving through Computer Programming lab	0	1	2	2	ESC
8	CY1042	Engineering Chemistry Lab	0	0	2	1	BSC
9	HS1022	Physical Education (Sports Course – I)	0	0	2	1	HSC
		Total				**18**	

I – Year: II – Semester

S. No.	Course Code	Course Title	L	T	P	Credits	Cat. Code
1	PH1011	Engineering Physics	2	0	0	2	BSC
2	MA1041	Fundamentals of Matrices & Differential Equations	2	0	0	2	BSC
4	EE1601	Basic Electrical & Electronics Engineering	2	0	0	2	ESC
4	CY1031	Industrial Organic Chemistry	3	0	0	3	BSC
5	CH1021	Chemical Process Calculations	3	1	0	4	PCC
6	ME1011	Engineering Drawing with CAD	0	1	2	3	ESC
7	PH1012	Engineering Physics Lab	0	1	2	1	BSC
8	HS1032	Health Education (Sports Course – II)	0	0	2	1	HSC
		Total				**18**	

Note:

BSC: Basic Science Courses

PCC: Professional Major Core Courses

OEC: Open Elective Courses

PRC: Professional Major Work

ESC: Engineering Science Courses

DEC: Professional Major Elective Courses

HSC: Humanities and Social Science Courses

SLI: Semester Long Internship

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	MA2021	PDEs, Numerical Methods and Statistics	2	0	0	2	BSC
2	CH2011	Chemical Engineering Thermodynamics – I	3	0	0	3	PCC
3	CH2021	Heat Transfer	3	1	0	4	PCC
4	CH2031	Fluid Mechanics	3	1	0	3	PCC
5	CH2041	Mechanical Operations	3	1	0	4	PCC
6	CH2052	Fluid Mechanics Laboratory	0	1	2	2	PCC
7	CH2062	Mechanical Operations Laboratory	0	0	2	1	PCC
8	HS2011	Personality Development / Life Skills (for BTE, CHEM, CE, ME, MME Depts)	2	0	0	1	HSC
9	HS2022	Yoga (for BTE, CHEM, CE, ME, MME Depts.)	0	0	2	1	HSC
		Total				**21**	

II – Year: II – Semester

S. No.	Course Code	Course Title	L	T	P	Credits	Cat. Code
1	-	Open Elective /DAC approved Free Electives (NPTEL, MOOCs, etc.)	3	0	0	3	OEC
2	CH2071	Chemical Engineering Thermodynamics – II	3	1	0	3	PCC
3	CH2081	Process Dynamics and Control	3	1	0	4	PCC
4	CH2091	Chemical Reaction Engineering – I	3	1	0	3	PCC
5	CH2101	Mass Transfer Operations – I	3	1	0	4	PCC
6	CH31X1	Departmental Elective-1	3	0	0	3	DEC
7	CH2112	Heat Transfer Laboratory	0	0	2	1	PCC
8	CH2122	Process Dynamics and Control Lab	0	0	2	1	PCC
9	HS2012	NCC/Social Service (for BTE, CHEM, CE, ME, MME Depts.)	0	0	2	1	HSC
		Total				**23**	

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	-	Open Elective /DAC approved Free Electives (NPTEL, MOOCs, etc.)	3	0	0	3	OEC
2	CH3011	Chemical Technology	3	0	0	3	PCC
3	CH3021	Chemical Reaction Engineering – II	3	0	0	3	PCC
4	CH3031	Mass Transfer Operations – II	3	1	0	4	PCC
5	CH41X1	Departmental Elective-2	3	0	0	3	DEC
6	CH42X1	Departmental Elective-3	3	0	0	3	DEC
7	CH3042	Mass Transfer Operations Laboratory	0	0	2	1	PCC
8	CH3052	Chemical Reaction Engineering Laboratory	0	0	2	1	PCC
9	SM3011	Introduction to Entrepreneurship (for BTE, CHEM, CE, ME, MME Depts.)	1	0	0	1	HSC
		Total				**22**	

III – Year: II – Semester

S. No.	Course Code	Course Title	L	T	P	Credits	Cat. Code
1	-	Open Elective /DAC approved Free Electives (NPTEL, MOOCs, etc.)	3	0	0	3	OEC
2	CH3061	Transport Phenomena	3	1	0	4	PCC
3	CH43X1	Departmental Elective – 4	3	0	0	3	DEC
4	CH44X1	Departmental Elective – 5	3	0	0	3	DEC
5	CH45X1	Departmental Elective – 6	3	0	0	3	DEC
6	CH3072	Design and Simulation Laboratory	0	1	2	2	PCC
7	HS3011	English for Engineers- II/ Liberal Arts/Creative Arts Courses – I	-	-	-	3	HSC
8	SM3021	Introduction to Design Thinking (for BTE, CHEM, CE, ME, MME Depts.)	-	-	-	1	HSC
		Total				**22**	

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	-	Open Elective /DAC approved Free Electives (NPTEL, MOOCs, etc.)	3	0	0	3	OEC
2	-	Open Elective /DAC approved Free Electives (NPTEL, MOOCs, etc.)	3	0	0	3	OEC
3	CH4011	Process Equipment Design and Economics	3	0	0	3	PCC
4	CH4024	Professional Major Work	-	-	-	6	PRC
5	CH4032	Computational Methods in Chemical Engineering Laboratory	0	1	2	2	PCC
6	XXXX	Liberal Arts/Creative Arts Courses – II	-	-	-	3	HSC
		Total				**20**	

IV – Year: II – Semester

S.No.	Course Code	Course Title	L	T	P	Credits	Cat. Code
1	CH4044	Semester-Long Internship (SLI) /Additional Project at the institute/Additional departmental elective courses for 6 credits	-	-	-	6	-
		Total				**6**	

Basket – 1: Departmental Elective Courses:

Course Code	Credits	Course Title
Departmental Elective-1		
CH3101	3	Bioprocess Engineering
CH3111	3	Fertilizer Technology
CH3121	3	Water and Wastewater Treatment
CH3131	3	Food Process Engineering
CH3141	3	Fluidization Engineering
CH3151	3	Material Science and Technology
Departmental Elective-2		
CH4101	3	Non-Newtonian Fluid Mechanics
CH4111	3	Biochemical Engineering
CH4121	3	Design and Analysis of Experiments
CH4131	3	Advanced Separation Processes
CH4141	3	Catalysis
CH4151	3	Process Instrumentation
Departmental Elective-3		
CH4201	3	Process Modeling and Simulation
CH4211	3	Statistical Design of Experiments
CH4221	3	Multiphase Flow
CH4231	3	Interfacial Science
CH4241	3	Statistical Thermodynamics
CH4251	3	Polymer Technology
Departmental Elective-4		
CH4301	3	Process Intensification
CH4311	3	Energy Resources and Systems
CH4321	3	Petroleum Refining Processes
CH4331	3	Fuel Cell Technology
CH4341	3	Scale up Methods
CH4351	3	Mathematical methods in Chemical Engineering
Departmental Elective-5		
CH4401	3	Process and Product Design
CH4411	3	Industrial Safety and Hazard Mitigation
CH4421	3	Computational Fluid Dynamics
CH4431	3	Nanotechnology for Chemical Engineers
CH4441	3	Carbon Capture, Sequestration, and Utilization
CH4451	3	Optimization Techniques

Departmental Elective-6		
CH4501	3	Characterization of Materials
CH4511	3	Soft Computing Techniques
CH4521	3	Solid and Hazardous Waste Management
CH4531	3	Air Pollution Control
CH4541	3	Membrane Technology
CH4551	3	Industrial Energy Systems
CH4561	3	Fuel & Combustion
CH4571	3	Renewable Energy and Sustainable Development
CH4581	3	Climate Change and Net Zero

Basket – 2: Open Elective Courses (offered to other departments):

Course Code	Credits	Course Title
CH2901	3	Industrial Pollution Control
CH3901	3	Nanotechnology and Applications
CH4901	3	Industrial Safety and Management

Special Notes/Instructions:

Minor/Double Major Programs

- Each engineering department should identify the list of courses for the minor & Double Major degree programmes. These identified courses will be offered to the Minor/Double Major degree students in every branch.
- To get Minor degree in any engineering branch, a student has to earn 12 Credits (6 Core credits + 6 Elective Credits) prescribed for the programme.
- To get Double Major degree in any engineering branch, a student has to earn 24 Credits (12 Core credits + 12 Elective Credits) prescribed for the programme.
- The Minor & Double Major choices start from the beginning of 3rd Semester.
- The students of Minor & Double Major courses will sit with regular students in the class.
- There will a separate time table slots for Minor & Double Major courses identified by each department to enable the students to register for these courses. Courses other than Minor & Double Major courses will not be offered during these slots.
- A student is permitted to do one Minor and one Double Major at max.
- Each department will choose a CGPA cut off (based on II Sem. CGPA) such that the total of Minor and Double Major students in any branch do not cross maximum of 30 seats.

Minor Program Course Distribution

S. No.	Course Code	Course Title	Credits	Offered Sem.
1	CH2011/CH2031	Chemical Engineering Thermodynamics-I/ Fluid Mechanics	03	III
2	CH2071/CH2091/ CH31X1	Chemical Engineering Thermodynamics-II/Chemical Reaction Engineering-I/Departmental Elective-1	03	IV
3	CH3011/CH3021/ CH41X1/CH42X1	Chemical Technology/ Chemical Reaction Engineering-II/Departmental Elective-2/ Departmental Elective-3	03	V
4	CH43X1/CH44X1	Departmental Elective-4/ Departmental Elective-5	03	VI
		TOTAL (6 Core Credits + 6 Elective Credits)	**12**	

Double Major Program Course Distribution

S. No.	Course Code	Course Title	Credits	Offered Sem.
1	CH2011/CH2031	Chemical Engineering Thermodynamics-I/Fluid Mechanics	06	III
2	CH2071/CH2091/ CH31X1	Chemical Engineering Thermodynamics-II/Chemical Reaction Engineering-I/Departmental Elective-1	06	IV
3	CH3011/CH3021/ CH401X1/CH42X 1	Chemical Technology/ Chemical Reaction Engineering-II/Departmental Elective-2/ Departmental Elective-3	06	V
4	CH43X1/CH44X1	Departmental Elective-4/ Departmental Elective-5	06	VI
		TOTAL (12 Core Credits + 12 Elective Credits)	**24**	

DETAILED SYLLABUS

Course Code: HS1011	ENGLISH FOR ENGINEERS-I	L-T-P: 2 – 0 – 0	Credits 2 Cr

Pre-Requisites: None

Course Outcomes:

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

CO1	Develop a strong foundation in grammar
CO2	Develop vocabulary and write effective paragraphs and formal letters
CO3	Improve reading comprehension and team-skills/collaborative skills
CO4	Cultivate interpretive and critical thinking skills

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Basics of Language: Tense, Concord, Error Detection, Reading Comprehension - Writing: Paragraphs, Precis Writing, Formal Letters, and Email etiquette - Interpretation and Critical Thinking: Cross Cultural Communication, Identifying Biases, Interpretation of Visual Data and Information, and Logical Reasoning - Understanding Audience/Profiling Readers, Introduction to Workplace Communication, Group Contract/Team Contract, Presentation Skills, and Techniques to Enhance Listening skills

Course Code: MA1031	CALCULUS OF SEVERAL VARIABLES	L-T-P: 2 – 0 – 0	Credits 2 Cr

Pre-Requisites: None

Course Outcomes:

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

CO1	Understand the concepts of differentiability of multivariable functions
CO2	Understand the concepts of double and triple integrals
CO3	Apply the concepts of gradient, divergence and curl to formulate engineering problems
CO4	Convert line integrals into area integrals and surface integrals into volume integrals

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Differential Calculus: Functions of single variable, Limit, continuity and differentiability, Taylor series, Mean value theorems, Evaluation of definite and improper integrals, Partial derivatives, Total Derivative, Maxima and minima. (8)

Integral Calculus: Double and Triple integrals, Change of order of integration, change of variables in double and triple integrals. (8)

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; Stokes' theorem; Gauss Divergence theorem. (10)

Text Books:

1. Joel R. Hass, Maurice D. Weir, George B. Thomas, Thomas' Calculus, 12th edition, Pearson, 2010.
2. Erwin Kreyszig, *"Advanced Engineering Mathematics"*, Eighth Edition, John Wiley and Sons, 2015
3. B. S. Grewal, *"Higher Engineering Mathematics"*, Khanna Publications, 2015
4. R. K. Jain and S. R. K. Iyengar, *"Advanced Engineering Mathematics"*, Fifth Edition, Narosa Publishing House, 2016.

Reference Books:

1. Brown and Churchill, *Complex Variables and Applications*, McGraw-Hill and Higher Education, 9th Edition.
2. M. Spiegel, S. Lipschutz, J. Schiller, and D. Spellman, *Complex Variable (Schaum's Outlines)*, Revised 2nd edition, 2017.

Course Code: CY1011	ENGINEERING CHEMISTRY	L-T-P: 2 – 0 – 0	Credits 2 Cr

Pre-Requisites: None

Course Outcomes:

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

CO1	Gain foundational knowledge on how chemical principles influence the electrochemical properties of matter
CO2	Understand how basic chemical principles relate to everyday materials
CO3	Understand the electronic, and vibrational properties of materials
CO4	Analyze and solve problems associated with hardness of water and address the societal issues related to the quality of water

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Chapter-I: Electrochemistry (8 hours)
Redox reactions; Electrode potential; Electrochemical cells; Electromotive force (EMF); Nernst equation; Batteries, Primary batteries: Daniel and Leclanche cell; Rechargeable batteries: lead acid, nickel-cadmium and lithium-ion; Fuel Cells: hydrogen-oxygen and methanol-oxygen; Corrosion: dry & wet corrosion, corrosion controlling methods.

Chapter-II: Polymer Chemistry and Engineering Materials (6 hours)
Polymers: degree of polymerization, functionality, tacticity, classification, types of polymerization & their mechanism, molecular weight of polymers, polydispersity index, Recycling of Polymers, conducting polymers and their classification; Engineering materials: organic light-emitting diode (OLED).

Chapter-III: Spectroscopy (8 hours)
Origin of spectroscopy; Electromagnetic radiation; Quantized energy levels of matter; UV-Vis spectroscopy: electronic transitions, Beer-Lambert's law, instrumentation, Woodward-Fieser rules and applications; Infrared (IR) spectroscopy: vibrational transitions, principle, influencing factors, instrumentation and applications.

Chapter-IV: Water Technology (6 hours)
Soft and hard water; Estimation of hardness by EDTA method and numerical problems; Boiler troubles; Softening of water: lime-soda process, ion-exchange process, reverse osmosis; Internal treatment of water: carbonate conditioning, phosphate conditioning, colloidal conditioning, Calgon conditioning.

Text Books:

1. Engineering Chemistry by Jain and Jain, Dhanpat Rai Publishing Company.
2. Introduction to Spectroscopy by Donald L. Pavia, 5th edition, Cengage Learning India Private Limited, 2015.
3. Polymer Science and Technology by Premamoy Ghosh, 3rd edition, McGraw-Hill, 2010.

Reference Books:

1. Elements of Physical Chemistry by P. W. Atkins, Oxford University Press, 2007.
2. A textbook of Polymer Chemistry by M. S. Bhatnagar, S. Chand, ISBN-13:978-8121932301.
3. Organic Spectroscopy by William Kemp, 2nd edition, Macmillan publishers, 2019.

Course Code: CE1051	ENVIRONMENTAL SCIENCE AND ENGINEERING	L-T-P: 2 – 0 – 0	Credits 2 Cr

Pre-Requisites: None

Course Outcomes:

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

CO1	Identify environmental problems arising due to engineering and technological activities
CO2	To understand the environmental impact of various episodes and also the effects of different types of pollutants
CO3	Assess water demand and design components of water treatment systems
CO4	Assess sources and effects of air and noise pollution and identify appropriate control
CO5	Understand the techniques and methods used in transformation, conservation, and recovery of materials from solid wastes

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	-	-	-	-	1	1	2
CO2	3	3	3	-	-	2	3	1	-	-	-	-	2	-	2
CO3	3	3	3	-	-	2	3	1	-	-	-	-	2	1	1
CO4	3	3	3	-	-	2	3	1	-	-	-	-	2	-	1
CO5	3	3	3	-	-	2	3	1	-	-	-	-	1	-	-

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction: Introduction to environmental pollution; evolution of pollution control strategies and environmental infrastructure; major environmental episodes; evolution of environmental acts and policies; environmental ethics; sustainability concepts

Water & Wastewater Treatment: Water quality standards, overview of water treatment, sources and types of pollutants, their effects, principles of wastewater treatment

Air & Noise Pollution: Sources, classification and their effects, national ambient air quality standards (NAAQS), air quality index, control of air pollution, understanding and improving indoor air quality, sources of noise pollution, effects, quantification of noise pollution.

Solid Waste Management: characteristics of solid waste, 3R concept, sustainable practices in waste management, Guidelines for solid waste management, transition to zero waste lifestyle.

Text Books:

1. G.B. Masters, Introduction to Environmental Engineering and Science, Pearson Education, 2013.
2. Gerard Kiely, Environmental Engineering, McGraw Hill Education Pvt Ltd, Special Indian Edition, 2007.
3. Rajagopalan, Environmental Studies, Oxford IBH Pub,2011.

Reference Books:

1. W P Cunningham, M A Cunningham, Principles of Environmental Science, Inquiry and Applications, Tata McGraw Hill, Eighth Edition, 2016.
2. Environmental Studies: A Practitioner's Approach by by S. J Arceivala and S. R Asolekar, Tata McGraw- Hill Education Private Limited, 2012.
3. Rosencranz, A., Divan, S. and Noble, M.L., Environmental Law and Policy in India: Cases, Materials and Statutes, Tripathi Pvt. Ltd, Bombay, 1992.

Course Code: CS1011	PROBLEM SOLVING THROUGH COMPUTER PROGRAMMING	L-T-P: 3 – 0 – 0	Credits 3 Cr

Pre-Requisites: None

Course Outcomes:

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

CO1	Construct algorithms for solving problems that requires solutions involving searching, sorting, selection and / or a numerical method as a sub-routine
CO2	Analyze the suitability of different algorithmic design paradigms for solving problems with an understanding of the time and space complexities incurred
CO3	Construct algorithms for solving problems with an understanding of the internals of a computing system and its components like processor, memory and I/O sub-systems
CO4	Construct efficient modular programs for implementing algorithms by leveraging suitable control structures
CO5	Construct efficient programs by selecting and using suitable in-built Data Structures and programming language features available

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	S	M	L	-	-	-	-	-	-	-	-	-
CO2	S	M	L	-	-	-	-	-	-	-	-	-
CO3	S	M	L	-	L	-	-	-	-	-	-	-
CO4	S	M	L	-	S	-	-	-	-	-	-	-
CO5	S	M	L	-	S	-	-	-	-	-	-	-

S - Strong correlation; M - Medium correlation; L – Low correlation

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: 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.

Reading List:

1. R.G. Dromey, "How to solve it by Computer", Pearson, 2008.
2. Brian W.Kernighan, Dennis Ritchie, “The C Programming Language”, 2nd edition, Person Education India, 2015
3. Walter Savitch, "Problem Solving with C++", Ninth Edition, Pearson, 2014.
4. Cay Horstmann, Timothy Budd, "Big C++", 2nd Edition, Wiley, 2009.

Course Code: CH1011	INTRODUCTION TO CHEMICAL ENGINEERING	L-T-P: 3 – 0 – 0	Credits 3 Cr

Pre-Requisites: None

Course Outcomes:

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

CO1	Apply Fundamental Principles- Demonstrate core chemical engineering concepts to analyze and solve process-related problems
CO2	Design and Optimize Processes- Develop process flow diagrams and use simulation tools to design, troubleshoot, and optimize chemical processes
CO3	Analyze Transport Phenomena- Model and evaluate momentum, heat, and mass transfer mechanisms in industrial systems
CO4	Integrate Computational Tools - Utilize software for data analysis, process modeling, and equipment design, ensuring alignment with industry standards
CO5	Address Ethical and Economic Constraints - Evaluate process solutions considering ethical, safety, and economic factors

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction: The Impact of Chemical Engineering, The Chemical Engineering Discipline, role of chemical processing, Chemical Process, Representing Chemical Processes Using Process Diagrams, Strategies for Solving Problems, Ethical Considerations in Solving Problems, Physical quantities- Units and Important Process Variables

Material balances: Conservation of Total Mass, Material Balances for Multiple Species, Spreadsheets- The Calculation Scheme, Setting Up a Spreadsheet

Fluid flow: The Concept of Pressure, Non-flowing Fluids, Principles of Fluid Flow, Pumps and Turbines

Mass transfer: Molecular Diffusion, Mass Convection, Mass Convection with Transfer Across Phase Boundaries, Multi-step Mass Transfer

Reaction engineering: Describing Reaction Rates, Designing the Reactor

Heat transfer: Energy Balances for Steady-State Open Systems, Applications of the Steady-State Energy Balance, Heat-Exchange Devices

Materials: Metals and Corrosion, Ceramics, Polymers, Composites, Strength of Materials

Process control: The Need for Process Control, Feedback Control, Feedforward Control, Comparison of Strategies

Economics: Costs, Profitability, Economics of the Acid-Neutralization Problem

Chemical Engineering computer software tools and applications: Introduction to Chemical Engineering Software, Process Simulation (Aspen HYSYS & PRO/II), Data Analysis & Modeling (Microsoft Excel), Engineering Programming (MATLAB), CAD & Piping Design (AutoCAD & CAESAR II)

Text Books:

1. Introduction to Chemical Engineering: Tools for Today and Tomorrow, Kenneth A. Solen and John N. Harb, Wiley, 2010 and 5th edition.
2. Introduction to Chemical Engineering: For Chemical Engineers and Students, Uche P. Nnaji, Wiley, 2019 and 1st edition.
3. Elementary principles of Chemical processes, RM Felder, Ronald W. Rousseau, Lisa G. Bullard, John Weily & Sons, 2017 and 14th edition

Reference Books:

1. Anderson, L.B., Wenzel, L.A., “Introduction to Chemical Engineering", McGraw-Hill Book Company, Inc., New York (1961).
2. Denn Morton M., “Chemical Engineering; An Introduction”, Cambridge, University Press, 2012.
3. Himmelblau D.M. and Riggs J.B., “Basic Principles and Calculations in Chemical Engineering”. 7th Edition., Prentice Hall 2003.
4. Groggins, P.H., “Unit processes in organic synthesis”, Tata McGraw Hill Education Private Limited, 5th Edition 1995.
5. Pushpavanam, S., "Introduction to Chemical Engineering", PHI Learning Pvt. Ltd. (2012).
6. Ghosal, S.K., Sanyal, S.K., Datta, S., “Introduction to Chemical Engineering”, Tata McGraw-Hill Publishing Company Ltd., New Delhi (1997).

Online Resources:

1. https://onlinecourses.nptel.ac.in/noc22_ch02/preview

Course Code: CS1012	PROBLEM SOLVING THROUGH COMPUTER PROGRAMMING LAB	L-T-P: 0 – 1 – 2	Credits 2 Cr

Pre-Requisites: None

Course Outcomes:

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

CO1	Construct, debug, test and run efficient programs by leveraging suitable flow of control constructs and syntactic units of the programming language
CO2	Construct efficient programs by constructing and translating algorithms for solving problems using sorting, searching, selection and / or arithmetic computations
CO3	Implement, refactor, test and debug functional programs in a shell-based run time environment
CO4	Construct efficient programs by demonstrating problem-solving skills and out-of-the-box algorithmic thinking

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	S	M	L	-	S	-	-	-	M	-	-	L
CO2	S	M	L	-	S	-	-	-	M	-	-	L
CO3	S	M	L	-	S	-	-	-	M	-	-	L
CO4	S	M	L	-	S	-	-	-	M	-	-	L
CO5	S	M	L	-	S	-	-	-	M	-	-	L

S - Strong correlation; M - Medium correlation; L – Low correlation

Syllabus:

List of Experiments:

1. Familiarization with basic shell commands, execution of and debugging programs in Linux environment
2. Programs on conditional control constructs.
3. Programs on iterative constructs. (while, do-while, for).
4. Programs using user defined functions and in-built function calls
5. Programs related to Recursion.
6. Programs on single and multi-dimensional arrays
7. Programs related to String processing
8. Programs related to Pointers
9. Programs on Structures and Unions
10. Programs related to Files and I/O.

Reading List:

1. R.G. Dromey, "How to solve it by Computer", Pearson, 2008.
2. Brian W.Kernighan, Dennis Ritchie, “The C Programming Language”, 2nd edition, Person Education India, 2015
3. Walter Savitch, "Problem Solving with C++", Ninth Edition, Pearson, 2014.
4. Cay Horstmann, Timothy Budd, "Big C++", 2nd Edition, Wiley, 2009

Course Code: CY1042	ENGINEERING CHEMISTRY LAB	L-T-P: 0 – 0 – 2	Credits 1 Cr

Pre-Requisites: None

Course Outcomes:

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

CO1	Select a suitable methodology and compare the strategies involved in the estimation of hardness of water for various applications
CO2	Apply a selective instrumental method to alternate tedious and complex titration processes for repeated and regulated analysis of acids, bases, etc.
CO3	Work independently and in teams to solve problems with effective communication

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

1. Standardization of potassium permanganate solution
2. Determination of hardness of water
3. Determination of the concentration of a coloured solution using the colorimetric method
4. Synthesis of Bakelite
5. Conductometric titration of a strong acid *vs* a strong base
6. pH-metric titration of a strong acid *vs* a strong base

References:

1. Vogel's Textbook of Quantitative Chemical Analysis (Latest ed.), Revised by G. H. Jeffery, J.Bassett, J. Mendham & R. C. Denney.
2. David Collins, Investigating Chemistry: Laboratory Manual, Freeman & Co., 1st Edition, 2006.

Course Code: HS1022	PHYSICAL EDUCATION (SPORTS COURSE - I)	L-T-P: 0 – 0 – 3	Credits 1 Cr

Pre-requisites:

Course Outcomes:

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

CO1	-
CO2	-
CO3	-
CO4	-
CO5	-

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

I. Introduction to Physical Education & EAA = Sports and Games:
Meaning & Definition of Physical Education, Aims & Objectives of Physical Education, Importance of Physical Education

II. Physical Fitness & Wellness Lifestyle:
Meaning & Importance of Physical Fitness, Components of Physical Fitness (Cardiovascular Endurance, Strength Endurance Muscular Endurance, Flexibility, Body Composition), Components of Motor Fitness (Agility, Balance, Power, Speed, Coordination), Development of Fitness Components

III. Training Methods in Physical Education:
Circuit Training (Circuit Training), Continues Training (Endurance), Interval Training (Speed & Endurance), Fartlek Training (Speed Endurance), Weight Training (Maximum Strength), Plyometric Training (Power), Flexibility Training

IV. Test & Measurements:
Measurements: Height, Weight, Age, Calculation of BMI, Motor Fitness and Physical Fitness Tests (Pre - Test & Post-Test), Cardiovascular Endurance - 9/12 Minute Run or Walk, Muscular Endurance — Sit Ups for abdominal strength, Strength Endurance — Flexed arm hang for girls / Pull ups for boys, (Speed — 50m Dash or 30mts Fly Start, Strength — Broad Jump, Vertical Jump for Lower Body, Medicine Ball Put for Shoulder Strength, Endurance - 800mts, Flexibility - Bend and Reach, Agility (Coordination)) — Shuttle Run and Box Run

V. Formal Activities:
Calisthenics (free hand exercises), Dumbbells, Woops, Wands, Laziums (Rhythmic activities), Aerobic Dance and Marching

VI. Sports / Games
Following sub topics related to any one Game/Sport of choice of student out of: Athletics, Badminton, ball badminton, Kabaddi, Kho-Kho, Table Tennis, Yoga etc., Teaching & Coaching of the Game/Sport, Latest General Rules of the Game/Sport. Specifications of Play Grounds and Related Sports Equipment

Course Code: PH1011	ENGINEERING PHYSICS	L-T-P: 2 – 0 – 0	Credits 2 Cr

Pre-Requisites: None

Course Outcomes:

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

CO1	Solve engineering problems using the concepts of wave and particle nature of radiant energy
CO2	Understand the use of lasers as light sources for low and high energy applications
CO3	Construct quantum mechanical model to explain the behavior of a system at microscopic level
CO4	Apply the concepts of energy harvesting and understand the mechanisms of photo-voltaic cells
CO5	Understand the nature and characterization of magnetic and Nano-materials for applications

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
CO2	3	2	1	2	-	-	-	-	-	-	-	-	-	1	1
CO3	3	3	2	3	-	-	-	-	-	-	-	-	-	1	2
CO4	3	3	2	`1	-	-	-	-	-	-	-	-	-	1	1
CO5	3	3	2	1	-	-	-	-	-	-	-	-	-	1	1

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

UNIT- I WAVE OPTICS (7)

Interference: Superposition principle, coherence of light, methods to produce coherent light: division of amplitude and wavefront, Young's double slit and Newton's rings experiment: concept, working principle, and applications.

Diffraction: Introduction to Fresnel and Fraunhofer diffraction, Fraunhofer's single-slit diffraction, double-slit diffraction and diffraction grating (quantitative), and resolving power of a grating.

Polarization: Introduction to polarization, Types of polarization, Methods to produce polarization: Reflection, refraction, scattering, selective absorption and double refraction.

UNIT - II LASERS (5)

Basic theory of LASER, Einstein's coefficients and their relations, concept of population inversion, components of lasers, three and four level lasing systems, construction and working principle of various types of lasers: Nd-YAG, Helium-Neon and semiconductor lasers and their applications.

UNIT - III QUANTUM PHYSICS (7)

Origin of quantum theory and related experiments: Black-Body radiation and photo-electric effect. Heisenberg's uncertainty principle, de- Broglie's wave concept, wave function, and its properties, operators, Schrödinger's time-dependent and time-independent equations (Quantitative), particle in one-dimensional, infinite potential well, quantum tunneling phenomena and their applications in alpha decay, and scanning tunnelling microscopy (STM). Introduction to Quantum Technology (Q-switching, interaction of radiation with matter).

UNIT - IV PHOTOVOLTAICS (4)

Introduction to semiconductors, Solar spectrum, photovoltaic (PV) effect, materials, structure and working principle, I-V characteristics, power conversion efficiency, quantum efficiency, emerging PV technologies, and applications.

UNIT - V MAGNETIC AND NANO MATERIALS (5)

Magnetic Materials:

Introduction to Weiss theory of ferromagnetism, concepts of magnetic domains, spontaneous magnetization, Curie transition, hard and soft magnetic materials and their applications.

Nanomaterials:

Introduction, classification, and properties of nanomaterials, various methods of synthesizing nanomaterials: top-down (ball milling) and bottom-up (sol-gel) approaches.

Text Books:

1. A Textbook of Engineering Physics, Revised Edition, M. N. Avadhanulu, P. G. Kshirsagar, S. Chand and Company (2014).
2. Concepts of Modern Physics, 7th Edition, Beiser A., Mc. Graw Hill Publishers (2017).
3. Optics, Ajoy Ghatak, 7th Edition, Tata Mc Graw Hill (2020).
4. Lasers- Fundamentals and Applications, Ajoy Ghatak and K. Thyagarajan, 2nd Edition, Laxmi Publications (2019).

Reference Books:

1. Materials Science and Engineering: An Introduction (Tenth edition), William D. Callister, John Wiley & Sons (2018).
2. Introduction to Solid State Physics, 8th Edition, Charles Kittel, Wiley Publishers (2012).

Course Code: MA1041	FUNDAMENTALS OF MATRICES & DIFFERENTIAL EQUATIONS	L-T-P: 2 – 0 – 0	Credits 2 Cr

Pre-Requisites: Calculus of Several Variables (MA1031)

Course Outcomes:

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

CO1	Solve the consistent system of linear equations
CO2	Understand the concepts of eigenvalues and eigenvectors.
CO3	Solve arbitrary order linear differential equations with constant coefficients
CO4	Apply the concepts in solving physical problems arising in engineering
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	PS03
CO1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

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; Review of complex variables, Properties of complex matrices - Hermitian, Skew-Hermitian and Unitary matrices. (9)

Ordinary Differential Equations of Higher Order: Higher order linear differential equations with constant coefficients - homogeneous and non-homogeneous; Euler and Cauchy's differential equations; Method of variation of parameters. (10)

Laplace Transforms: Laplace transforms; inverse Laplace transforms; Properties of Laplace transforms; Laplace transforms of unit step function, impulse function, periodic function; Convolution theorem, Solving certain initial value problems

Text Books:

1. E. Kreyszig, Advanced Engineering Mathematics, Eighth Edition, John Wiley and Sons, 2015.
2. B. S. Grewal, Higher Engineering Mathematics, Khanna Publications, 2015.
3. R. K. Jain and S. R. K. Iyengar, Advanced Engineering Mathematics, Fifth Edition, Narosa Publishing House, 2016.

Reference Books:

1. G. Strang, Linear Algebra and Its Applications, 4th Edition, Brooks/Cole India, 2006.
2. T. M. Apostol, Calculus, Volume 2 (2nd Edition), Wiley Eastern, 1980.
3. G. F. Simmons, Differential equations with applications and historical notes. CRC Press, 2016.

Course Code: EE1601	BASIC ELECTRICAL & ELECTRONICS ENGINEERING	L-T-P: 2 – 0 – 0	Credits 2 Cr

Pre-Requisites: None

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	Identify the type of electrical machines for a given application
CO4	Acquire the knowledge on electrical safety
CO5	Analyze basic electronic circuits.

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

DC Circuits: Kirchoff's voltage and current laws, superposition theorem, star delta transformations.

AC Circuits: Complex representation of impedance, phasor diagrams, power & power factor, solution of 1-phase series & parallel circuits.

Single Phase Transformers: Principle of operation of a single-phase transformer, emf equation, phasor diagram, equivalent circuit of a 1-phase transformer, voltage regulation & efficiency.

Electrical Machines: DC Machines- principle of operation, classification, emf and torque equations, characteristics of DC generators and motors. 3-Phase induction motor- principle of operation, torque – speed characteristics & applications.

Electrical Safety: Electrical shock and precautions, concept of fuses, and application; concept of earthing.

Electronic Devices & Circuits: P-N junction diode, I-V characteristics, bipolar junction transistor operation and characteristics.

Text Books:

1. Fundamentals of Electrical Circuits by Charles k. Alexander, Mattew N.O. Sadiku, Tata McGraw Hill company.
2. V.N. Mittle, Basic Electrical Engineering, MC Graw Hill Education, 10 Sep 2005
3. Ravish R Singh, Basic Electrical Engineering, MC Graw Hill Education, 3rd edition, 2018.
4. R. Boylested and L. Nashelsky, "Electronics Devices and Circuits", Prentice Hall India.

Reference Books:

1. J. A. Edminister, Electric Circuit Theory, Schaum's Outline series: 6th ed., McGraw Hill, 2014.
2. D.P.Kothari & I.J. Nagrath, Basic Electrical Engineering, MC Graw Hill Education, 20 Jun 2006

Course Code: CY1031	INDUSTRIAL ORGANIC CHEMISTRY	L-T-P: 3 – 0 – 0	Credits 3 Cr

Pre-Requisites: None

Course Outcomes:

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

CO1	Understand the importance of the stereochemistry of organic molecules and separation of the racemic mixtures using resolution methods
CO2	Differentiate the structure and properties of heterocyclic compounds
CO3	Identify the role of chemical engineers in modern drug discovery programs
CO4	Understand the applications of organic reactions for basic chemicals synthesis
CO5	Understand the applications of catalysis in organic synthesis

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Chapter-I: Application of stereochemistry in the pharmaceutical industry (8 hours):
Introduction to stereochemistry; Stereoisomerism; R- and S-nomenclature; Fischer, Newman and Sawhorse Projections; Conformational analysis of ethane, propane, butane, cyclohexane and its derivatives; Racemization; Resolution techniques.

Chapter-II: Chemistry of heterocyclic compounds and drugs (10 hours):
Introduction to heterocyclic compounds; Preparation, reactivity and properties of furan, pyrrole, thiophene and pyridine. Synthesis of drugs: antipyretics (paracetamol), anti-inflammatory drugs (ibuprofen), antibiotics (penicillin) and antimalarial drugs (quinine).

Chapter III: Separation techniques (6 hours):
Crystallization method: Definition, process and examples. Principles and Chromatography Techniques: Introduction; Retention factor; Stationary & mobile phase; Principle of chromatography, Thin-layer chromatography (TLC); Column chromatography and Gas chromatography (GC).

Chapter-IV: Organic reactions employed in the industrial synthesis of basic chemicals (8 hours): Hydration of alkenes (synthesis of alcohols), hydration of ethylene oxide (synthesis of ethylene glycols), oxidation of olefins to aldehydes (Wacker process), cumene process for the production of acetone and phenol, oxidation and carbonylation reactions (synthesis of acetic acid).

Chapter-V: Advanced techniques in organic synthesis (10 hours):
Alternative energy sources (microwave, sonication and mechanochemistry) for organic reactions; Homogeneous (palladium, nickel and copper-catalyzed coupling reactions) and heterogeneous catalysis (transition metals-catalyzed hydrogenation reaction and catalytic applications of zeolites).

Text Books:

1. K. Weissermel, H.-J. Arpe, Industrial organic chemistry, John Wiley & Sons, 2008.
2. J. Clayden, N. Greeves, S. Warren, Organic chemistry, Oxford University Press, USA, 2012.
3. E.L. Eliel, S.H. Wilen, Stereochemistry of organic compounds, John Wiley & Sons, 1994.
4. W. Carruthers, I. Coldham, Modern methods of organic synthesis, Cambridge University Press, 2004.

Reference Books:

1. F.A. Carey, R.J. Sundberg, Advanced organic chemistry: part A: structure and mechanisms, Springer Science & Business Media, 2007.
2. T. Eicher, S. Hauptmann, A. Speicher, The chemistry of heterocycles: structures, reactions, synthesis, and applications, John Wiley & Sons, 2013.

Course Code: CH1021	CHEMICAL PROCESS CALCULATIONS	L-T-P: 3 – 1 – 0	Credits 4 Cr

Pre-Requisites: None

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

CO1	Convert physicochemical 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	Analyze 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. Himmelblau D.H., James B. Riggs, Basic Principles and Calculations in Chemical Engineering, Prentice Hall, 2012, 8th Edition.
2. Felder R.M., Rousseau R.W., Bullard L.G., Elementary Principles of Chemical Processes, Wiley, 2016, 4th Edition.

Reference Books:

1. Nayef Ghasem, Redhouane Henda, Principles of Chemical Engineering Processes: Material and Energy Balances, CRC Press, 2015, 2nd Edition.
2. Hougen O.A., Watson K.M., Ragatz R.A., Chemical Process Principles (Part-I): Material and Energy Balances, CBS Publishers, 2004, 2nd Edition.
3. Narayanan K.V., Lakshmikutty B., Stoichiometry and Process Calculations, PHI Learning Pvt. Ltd., 2015, 7th Edition.
4. Bhatt B.I., Thakore S.M., Stoichiometry, Tata McGraw-Hill Publishing Company Ltd., 2010, 5th Edition.
5. Richard M. Felder, Ronald W. Rousseau, Elementary Principles of Chemical Processes, Wiley, 2004, 3rd Edition.

Other Suggested Readings:

1. https://nptel.ac.in/courses/103/103/103103165/

Course Code: ME1011	ENGINEERING DRAWING WITH CAD	L-T-P: 2 – 0 – 2	Credits 3 Cr

Pre-requisites: Nil

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 reference planes
CO3	Construct orthographic views of an object when its position with respect to the reference planes is defined
CO4	Analyze the internal details of an object through sectional views
CO5	Analyze the details of an object through the development of surfaces and the intersection of surfaces

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction: Significance of engineering drawing, BIS conventions of engineering drawing, selection of drawing sheet size and scale, types of lines, lettering, dimensioning, geometrical construction of polygons, and scales. Coordinate systems and reference planes.

Introduction to Orthographic Projections: Principles of orthographic projection, orthographic projections of points in 1st and 3rd quadrants, orthographic projections of lines, orthographic projections of planes viz. triangle, square, rectangle, pentagon, hexagon, and circular laminae.

Orthographic Projection of Solids: Orthographic projection of right regular solids: Prisms, Pyramids, Cylinders, Cones, Cubes, and Tetrahedron.

Sections of Solids: Sectional planes, Sectional views - Prism, pyramid, cylinder and cone, true shape of the section.

Isometric Projections: Isometric scale, Isometric projection of hexahedron, right regular prisms, pyramids, cylinders, cones and spheres. Isometric projection of combination of two simple solids.

Development of Surfaces of Solids: Development of lateral surfaces of right regular prisms, cylinders, pyramids and cones resting with base on HP only. Development of lateral surfaces of their frustums and truncations. Problems related to applications of development of lateral surfaces like funnels and trays.

Introduction to Computer Aided Drafting software (AutoCAD): Draw entities, complex entities and edit entities, coordinate systems, and reference lines and planes.

Text Books:

1. Engineering Graphics, N.D. Bhatt and V.M. Panchal, Charotar Publishers, 2013.
2. AutoCAD 2017 for Engineers & Designers, Sham Tickoo, Dreamtech Press, 2016, 23rd Edition.

Reference Books:

1. Engineering Drawing, Agarwal, B, McGraw Hill Education, 2015, Second edition.

Course Code: PH1012	ENGINEERING PHYSICS LAB	L-T-P: 0 – 0 – 2	Credits 1 Cr

Pre-requisites: Nil

Course Outcomes:

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

CO1	Understand the basic properties of light by performing experiments on interference, diffraction and polarization
CO2	Acquire the experimental knowledge by performing the experiment using light-emitting diode (LED) for energy conversion applications
CO3	Understand the nature and characteristics of ferromagnetic and dielectric materials for memory device and sensor applications
CO4	Apply the knowledge of Solar/ PV cells for choice of materials in efficient alternate energy generation
CO5	Apply the concepts of wave propagation through optical fibers and communication systems

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

List of experiments (any six experiments from the following list):

1. Determination of radius of curvature of plano-convex lens using Newton’s ring experiment.
2. Determination of the width of narrow-slit by diffraction method
3. Determination of wavelength of spectral lines of Mercury light by normal incidence method using diffraction grating
4. Determination of Planck’s constant using light emitting diode
5. Study the B-H loop hysteresis and find the coercivity and retentivity of magnetic materials
6. To study the current-voltage characteristics of a photovoltaic material using solar cell
7. Determination of wavelength of diode laser using diffraction by metal scale
8. Determination of dielectric constant of various dielectric materials
9. Determination of numerical aperture of an Optical fiber
10. Estimation of specific rotation of an optically active material-using Laurent’s half shade polarimeter

Exposure to Virtual Lab (any two of the following):

1. B-H Loop tracer
2. Planck's Constant
3. Numerical aperture of Optical Fibre
4. Newton's ring

Reference:

1. Physics Laboratory Manual, 2024, Department of Physics, School of Sciences, National Institute of Technology Andhra Pradesh, Tadepalligudem.
2. Shukla R K, Srivastava A, 2011, Practical Physics, New Age International Pvt. Ltd., New Delhi.
3. Arora, CL, 2012, B.Sc. Practical Physics, S Chand and Company Ltd., New Delhi.
4. A Textbook of Engineering Physics, M. N. Avadhanulu, P. G. Kshirsagar, S. Chand and Company (2015).
5. A Course of Experiments with He-Ne Lasers by R. S. Sirohi, New Age International (P) Ltd. (2009)

Course Code: HS1032	HEALTH EDUCATION (SPORTS COURSE – II)	L-T-P: 0 – 0 – 2	Credits 1 Cr

Pre-requisites: None

Course Outcomes:

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

CO1	-
CO2	-
CO3	-
CO4	-
CO5	-

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Health Education & Personal Hygiene:

Introduction & Meaning of Health Education, Definition of Health Education, Principles of Health Education, Importance of Health Education, Meaning of Personal Hygiene, Importance of Personal Hygiene, Personal cleanliness (teeth, ears, eyes, nose & throat, nails & fingers, skin, cloths, and hair).

Nutrition:

Introduction of Nutrition, Balanced Diet, Daily Energy Requirements, Nutrient Balance, Nutritional Intake, Eating and Competition, Ideal Weight

First Aid & Injury Management:

Introduction, Types and Principles of First Aid, Functions of First Aider, Reasons for Sports Injuries, The First Aid and Emergency Treatment in Various cases (drowning, dislocation & fractures, burns, electric shock, animal bite, snake bite, poison, etc.

Human Posture:

Introduction, Meaning of Posture, types of Good Posture, causes of Poor Posture, preventive and Remedial Poor Posture, common Postural Deformities, Body Types, Advantages of Good Posture

Yoga:

Introduction, Meaning & Importance of Yoga, Elements of Yoga, Introduction - Asanas, Pranayama, Meditation & Yogic Kriyas, Yoga for concentration & related Asanas (standing asanas, sitting asanas, supine and prone postures.), Relaxation Techniques for improving concentration — Yoga — nidra, Pranayama

Sports / Games:

Following sub topics related to any one Game/Sport of choice of student out of: Athletics, Badminton, ball badminton, Kabaddi, Kho-Kho, Table Tennis, Yoga etc., Teaching & Coaching of the Game/Sport., Latest General Rules of the Game/Sport, Specifications of Play Grounds and Related Sports Equipment.

Course Code: MA2021	PDEs, NUMERICAL METHODS AND STATISTICS	L-T-P: 2 – 0 – 0	Credits: 2 Cr

Pre-Requisites: Calculus and Complex variables (MA1041), Matrices & Differential Equations (MA1031).

Course Outcomes:

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

CO1	Interpret an experimental data using interpolation / curve fitting
CO2	Solve numerically algebraic/transcendental and ordinary differential equations
CO3	Provides a solid foundation about the concept of probability and its features
CO4	Provide the idea of important results used in statistical Inference

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Partial Differential Equations: Solutions of one-dimensional heat and wave equations and Laplace equation. (6)

Numerical Methods: Numerical solution of algebraic and transcendental equations by Regula-Falsi method and Newton-Raphson's method -Gauss-Seidal iteration method to solve a system of equations - 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, modified Euler's method, 4th order Runge-Kutta method for solving first order ordinary differential equations. (14)

Probability and Statistics: Random variables, discrete and continuous random variables, Mean and variance of Binomial, Poisson and Normal distributions and applications. (8)

Text Books:

1. M. K. Jain, S. R. K.Iyengar and R. K. Jain, Numerical methods for Scientific and Engineering Computation, New Age International Publications, 2008.
2. S. C. Gupta and V. K. Kapoor, Fundamentals of Mathematical Statistics, S.Chand & Co, 2006.
3. E. Kreyszig, Advanced Engineering Mathematics, John Wiley and Sons, 8th Edition, 2008.
4. B. S. Grewal, Higher Engineering Mathematics, Khanna Publications, 2009.

Reference Books:

1. J. E. Freund,and M. Miller, M. John E. Freund's Mathematical Statistics: With Applications. Pearson Education India, (2004).

Course Code: CH2011	CHEMICAL ENGINEERING THERMODYNAMICS - I	L-T-P: 3 – 0 – 0	Credits 3 Cr

Pre-requisites: None

Course Outcomes:

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

CO1	Provide a fundamental overview of the thermodynamic laws and its application
CO2	Compute the properties of ideal and real gas mixtures
CO3	Evaluate the efficiency of expansion and compression 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	3	2	3	-	-	-	-	-	-	-	-	-	1	3	3
CO2	3	2	3	2	1	-	-	-	-	-	-	-	3	2	3
CO3	2	1	2	1	-	-	-	-	-	-	-	-	2	1	3
CO4	3	2	3	1	-	1	-	-	-	-	-	-	3	1	2
CO5	2	2	3	1	1	-	-	-	-	-	-	-	3	3	1

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

First Law, Volumetric Properties of Pure Fluids, and Heat Effects: Definitions and fundamental concepts, property, energy, work, zeroth law of thermodynamics, first law: energy balance in open, closed, and isolated systems; steady state and transient processes; volumetric properties of pure fluids – PVT behavior, virial and cubic equation of state and their applications, sensible heat effects; temperature dependency of heat capacity; latent heat of pure substance; standard heats of reaction; formation and combustion

Second Law of Thermodynamics: Statements of the second law, heat engines, thermodynamic temperature scales, entropy, entropy changes of an ideal gas, mathematical statement of the second law, reversible and irreversible processes; entropy balance for open, closed, and isolated systems; third law: molecular basis for zero entropy at zero temperature.

Thermodynamic Properties of Fluids: Phase diagrams, equations of state, compressibility factor, generalized correlations, residual properties, equations of state for liquids; ideal gas and real fluids: cubic equations; departure functions; relationship among thermodynamic functions: fundamental relationships between thermodynamic properties; Maxwell's equations; and thermodynamic property calculations.

Thermodynamics of fluid flow and devices: Expansion and compression of fluids; turbines, tubes, throttling, nozzles, pumps; thermodynamics of energy conversion: power production (e.g. Carnot cycle; Rankine cycle, internal combustion engine; diesel engine); refrigeration and liquefaction: Carnot and actual cycles; vapor compression and absorption; refrigerants; liquefaction of gases. Refrigeration and liquefaction: Carnot refrigerator, vapor-compression cycle, choice of refrigerant, absorption refrigeration, heat pump, liquefaction processes.

Text Books:

1. Introduction to Chemical Engineering Thermodynamics, Smith J. M, H. C. Van Ness and M. M. Abbott, McGraw-Hill, 2004 and 7th Edition.
2. Chemical, Biochemical and Engineering Thermodynamics, S.I. Sandler, Wiley India, 2006 and 4th Edition.
3. Chemical Engineering Thermodynamics, K. V. Narayanan, Prentice Hall of India Pvt. Ltd., 2009 and 2nd Edition

Reference Books:

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

Online Resources:

1. https://archive.nptel.ac.in/courses/103/103/103103144/

Course Code: CH2021	HEAT TRANSFER	L-T-P: 3 – 1 – 0	Credits 4 Cr

Pre-requisites: CH1021 Chemical Process Calculations

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	Analyze the heat exchanger performance for co-current and counter-current flows
CO5	Design 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	-	-	-	-	-	-	-	3	3	2
CO2	3	2	3	1	1	-	-	-	-	-	-	-	3	3	2
CO3	3	2	3	1	1	-	-	-	-	-	-	-	3	3	2
CO4	3	2	3	1	1	-	-	-	-	-	-	-	3	3	2
CO5	3	2	3	1	1	-	-	-	-	-	-	-	3	3	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction and Conduction Heat Transfer: Modes of heat transfer, material properties of importance in heat transfer; heat transfer by conduction in solids & principles of heat flow in fluids; steady state heat conduction; conduction through bodies in series; unsteady state heat conduction; concept of heat transfer coefficient; individual and overall heat transfer coefficient; concept of fins; critical insulation thickness.

Convective Heat Transfer: 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 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; preliminary design of heat exchangers; effectiveness-NTU method.

Evaporators and Crystallizers: Basics of evaporation; performance of tubular evaporators; capacity & economy; multiple effect evaporator; principles of crystallization; crystallization equipment; single and multiple effect evaporators

Text Books:

1. Heat Transfer, Holman J. P, McGraw Hill, 2010 and 7th Edition
2. Process Heat Transfer, Kern D. Q., McGraw Hill, 2001 and 1st Edition
3. Unit Operations of Chemical Engineering, McCabe W.L., Smith J.C., Harriott P, McGraw Hill, 2005 and 7th Edition

Reference Books:

1. Heat Transfer: A Basic Approach, Ozisik N, McGraw Hill,1985 and 1st Edition
2. Heat Transfer: A Practical Approach, Cengel Y. A, McGraw Hill, 2001 and 2nd Edition
3. Process Heat Transfer: Principles, Applications and Rules of Thumb, Serth R.W, Serth R.W, 2014 and 2nd Edition
4. Fundamentals of Heat and Mass Transfer, Frank P. Incropera, Theodore L. Bergman, David P. DeWitt, Bergmann, Adrienne S. Lavine, John Wiley & Sons, 2013 and 7th Edition.

Online Resources:

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

Course Code: CH2031	FLUID MECHANICS	L-T-P: 3 – 1 – 0	Credits 3 Cr

Pre-requisites: NONE

Course Outcomes:

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

CO1	Understand the basic concepts of fluid mechanics and statics
CO2	Solve problems related to conservation equations, dimensional analysis, and equations of motion
CO3	Analyze the motion of fluid flow in laminar and turbulent conditions
CO4	Enunciate the flow through fluidized beds and pipes and its transportation
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	PSO2
CO1	3	1	1	2	-	-	-	-	-	-	-	-	3	1	1
CO2	3	2	1	3	-	-	-	-	-	-	-	-	3	2	2
CO3	3	3	1	3	-	-	-	-	-	-	-	-	3	1	1
CO4	3	2	1	2	-	-	-	-	-	-	-	-	3	1	1
CO5	3	1	1	2	-	-	-	-	-	-	-	-	3	1	1

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction, Fluid Statics, and Kinematics of Fluid: Fundamental concepts: definitions of stress and fluid, distinction between a solid and a fluid, fluid properties. Nature of fluids, forces on fluid elements, normal stresses in a stationary fluid, fundamental equation of fluid statics, pressure measurement, buoyancy; scalar and vector fields, flow field and description of fluid motion, existence of flow.

Conservation Equations and Analysis of Finite Control Volumes: System, the continuity equation, conservation of momentum; momentum theorem, Euler's equation; the equation of motion for an ideal flow, conservation of energy; applications of equations of motion and mechanical energy; Bernoulli's equation in irrotational flow, steady flow along curved streamlines, measurement of flow rate through pipe, flow through orifices and mouthpieces.

Viscous Incompressible Flows: Navier-stokes equations, low Reynolds number flow; Laminar boundary layers; boundary layer equations, wall shear and boundary layer thickness, momentum-integral equations for boundary layer, separation of boundary layer.

Turbulent Flow: Characteristics of turbulent flow, laminar-turbulent transition, eddy viscosity, skin friction coefficient for boundary layers on a flat plate.

Applications of Viscous Flows Through Pipes: Concept of friction factor in a pipe flow, variation of friction factor, concept of flow potential and flow resistance, flow through branched pipes, losses in pipe bends, and losses in pipe fittings.

Flow Past Immersed Bodies: Friction in flow through beds of solids, motion of particles through fluids, fluidization.

Transportation of Fluids: Positive displacement pumps and centrifugal pumps, fans, blowers, and compressors.

Text Books:

1. Unit Operations of Chemical Engineering, McCabe W.L., Smith J.C., Harriott P, McGraw Hill, 2005 and 7th Edition.
2. Chemical Engineering Volume I and II, Coulson J.M, Richardson. J.F, Elsevier India, 2006 and 5th Edition.

Reference Books:

1. Fluid Mechanics for Chemical Engineers, De Nevers N H-, McGraw Hill, 2004 and 3rd Edition, 2004.
2. Fluid Mechanics for Chemical Engineers, Wilkes James O., Prentice Hall, 2017 and 3rd Edition.
3. Introduction to Fluid Mechanics and Fluid Machines, Som S. K., Biswas G., Tata McGraw-Hill Education, 2003 and 2nd Edition.

Online Resources:

1. https://archive.nptel.ac.in/courses/103/104/103104044/
2. https://archive.nptel.ac.in/courses/103/106/103106158/

Course Code: CH2041	MECHANICAL OPERATIONS	L-T-P: 3 – 1 – 0	Credits 4 Cr

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	Analyze particle size distribution of solids and solid conveying methods
CO4	Evaluate solid-fluid separation equipment.
CO5	Determine the power required for agitation, blending and mixing

Course Articulation Matrix:

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

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, storage of solids, mixing of solids; handling of solids, bulk solids, conveyers-belt conveyors, screw conveyors, chain and flight conveyors, bucket elevators, and pneumatic conveyors.

Size Reduction: Mechanism of size reduction, crushing efficiency, energy and power requirement, crushing laws, size reduction equipment.

Mechanical Separations: Screening equipment, screen analysis, standard screens, capacity and effectiveness of screen, ideal and actual screens, screening equipment; classification of solid particles, liquid clarification, magnetic separation, floatation, sedimentation, cyclone separator.

Filtration: Cake filters, centrifugal filters, filter media, principles of cake filtration, washing filter cakes. Clarifying filters, liquid clarification, principles of clarification. Cross flow filtration, types of membranes, permeate flux for ultrafiltration, concentration polarization, applications of ultrafiltration, diafiltration, microfiltration.

Agitation and Mixing of Liquids: Agitated vessels, blending and mixing, suspension of solid particles, dispersion operations, agitator selection and scale-up, power number, mixing index.

Text Books:

1. Unit Operations of Chemical Engineering, McCabe W.L., Smith J.C., Harriott P, McGraw Hill, 2005 and 7th Edition.

Reference Books:

1. Chemical Engineering Volume I and II, Coulson J.M, Richardson. J.F, Elsevier India, 2006 and 5th Edition.
2. Principles of Unit Operations, Alan S. Foust, Leonard A. Wenzel, Curtis W. Clump, Louis Maus, L. Bryce Andersen, Wiley, 2008 and 2nd Edition.

3. Introduction to Chemical Engineering, Walter L. Badger, Julius T. Banchero, Tata McGraw Hill, 2001 and 1st Edition.
4. Transport Processes and Separation Process Principles (Includes Unit Operations), Christie John Geankoplis, Prentice Hall India Learning Private Limited, 2004 and 4th Edition.

Online Resources:

1. https://archive.nptel.ac.in/courses/103/103/103103155/

Course Code: CH2052	FLUID MECHANICS LABORATORY	L-T-P: 0 – 1 – 2	Credits 2 Cr

Pre-requisites: NONE

Course Outcomes:

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

CO1	Determine properties of fluid and flow
CO2	Apply Bernoulli's theorem and Stokes law to fluid and fluid-solid systems
CO3	Determine the characteristics of various flow meters
CO4	Determine the characteristics of packed and fluidized beds and centrifugal pump
CO5	Calculate pressure drop across pipes, valves and fittings

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Detailed syllabus (List of Experiments)

1. Determination of viscosity on laminar and turbulent flow.
2. Distinguish between laminar and turbulent flow using the Reynolds Experiment.
3. Verification of Bernoulli's theorem experimentally.
4. Determination of losses in pipes.
5. Determination of drag coefficient.
6. Study the characteristics of a packed bed.
7. Point velocity measurement and velocity profile determination using a pitot tube.
8. Determination of discharge coefficients of orifice and venturi meters.
9. Study the characteristics of the fluidized bed.
10. Flow through an open channel by weirs and notches

Reference Books:

1. Laboratory Manuals.
2. Unit Operations of Chemical Engineering, McCabe W.L., Smith J.C., Harriott P, McGraw Hill, 2005 and 7th Edition

Course Code: CH2062	MECHANICAL OPERATIONS LABORATORY	L-T-P: 0 – 0 – 2	Credits 1 Cr

Pre-requisites: NONE

Course Outcomes:

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

CO1	Select suitable methods for size reduction of minerals or other intermediates
CO2	Calculate the reduction ratio and product crushing efficiency of the ball mill
CO3	Evaluate suitable mechanical separations of powders, solid-liquid and solid-gas mixtures
CO4	Calculate the filtration area, cake resistance and membrane resistance of filter
CO5	Acquaint with theories of sedimentation and to study settling characteristics of batch settling

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

List of experiments:

1. Measurement of particle size distribution by sieve analysis.
2. Measurement of effectiveness of vibrating screen.
3. Measurement of crushing efficiency of Jaw crusher.
4. Finding the critical speed and crushing efficiency of Ball Mill.
5. Study the operation of Sigma Mixer
6. Study of constant pressure filtration and washing of cake in a plate and frame filter press
7. Operation of a Cyclone separator.
8. Study the batch Sedimentation Process.
9. Ore crushing with roll crusher and average size determination by sieving
10. Ore beneficiation using froth flotation technique
11. Analyze the influence of inlet pressure and feed concentration on separation efficiency of hydrocyclone

Reference Books:

1. Laboratory Manuals.
2. Unit Operations of Chemical Engineering, McCabe W.L., Smith J.C., Harriott P, McGraw Hill, 2005 and 7th Edition

Course Code: HS2011	PERSONALITY DEVELOPMENT / LIFE SKILLS	L-T-P: 2 – 0 – 0	Credits 1 Cr

Pre-requisites: None

Course Outcomes:

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

CO1	Students will develop a deeper self-awareness, gaining insights into their strengths, weaknesses, values, and emotional triggers
CO2	Students will enhance their communication skills, enabling them to express themselves more clearly and engage effectively with others
CO3	Students will improve their emotional intelligence and cultivate a growth mindset, equipping them to navigate challenges with resilience and adaptability
CO4	Students will strengthen their abilities in conflict management, adaptability, and networking, preparing them for successful interactions in personal and professional contexts

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Module 1

Introduction to personality development - self assessment- SWOT - personal values statement - (punctuality, attitude, responsibility, ethics, integrity, values, and trust, and self-confidence) - imposter syndrome, communication skills (verbal and non-verbal, body language and posture, avoiding miscommunication) - techniques for persuasive communication - key principles to increase clarity of communication

Module 2

Emotional Intelligence - ways to improve emotional intelligence - application of emotional intelligence - identifying emotional triggers - Building rapport and maintaining positive interactions - Fixed and growth mindset - emotions in personal and professional relationships, strategies for effective networking - social and dining etiquette - greetings - dress code.

Reference Books:

1. Mitra, Barun K. *Personality Development and Soft Skills.* 2nd ed. Oxford Higher Education, 2016.
2. Sharma, Prashant. Soft Skills: Personality Development for Life Success. 3rd ed. BPB Publications, India, 2022.
3. Goleman, D. (1995). Emotional intelligence: Why it can matter more than IQ. Bantam Books.
4. Carnegie, D. (2020). *How to win friends and influence people*. Srishti Publishers and Distributors.
5. Khera, S. (2014). *You can win: A step-by-step tool for top achievers*. Bloomsbury India

Course Code: HS2022	YOGA (for BTE, CHEM, CE, ME, MME Depts.)	L-T-P: 0 – 0 – 0	Credits 1 Cr

Note: Course details will be updated by the HSC department after BOS approval

Pre-requisites:

Course Outcomes:

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

CO1	-
CO2	-
CO3	-
CO4	-
CO5	-

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Text Books:

1. Title of the Text Book, Author(s), Publisher, Year and Edition
2. Title of the Text Book, Author(s), Publisher, Year and Edition

Reference Books:

1. Title of the Text Book, Author(s), Publisher, Year and Edition
2. Title of the Text Book, Author(s), Publisher, Year and Edition

Online Resources:

1. Website reference links

Course Code: CH2071	CHEMICAL ENGINEERING THERMODYNAMICS – II	L-T-P: 3 – 0 – 0	Credits 3 Cr

Pre-requisites: CH2011 Chemical Engineering Thermodynamics – I

Course Outcomes:

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

CO1	Calculate 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	3	3	3	3	-	-	3	-	-	-	-	-	2	3	1
CO2	3	3	3	3	-	-	3	-	-	-	-	-	1	2	2
CO3	3	3	3	3	-	-	3	-	-	-	-	-	1	2	2
CO4	3	3	3	3	-	-	1	1	-	-	-	-	2	2	2
CO5	3	3	3	3	-	-	-	-	-		-	-	1	2	1

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Solution Thermodynamics: Fundamental property relation, chemical potential, partial properties, the ideal gas mixture model, fugacity and fugacity coefficient, the ideal solution model, and excess properties.

Mixing Processes: Heat effects of industrial reactions, property changes of mixing, heat effects of mixing process.

Phase Equilibrium: The nature of equilibrium, criteria of equilibrium, the phase rule, Duhem's theorem, activity coefficient, excess Gibbs energy, models for the excess Gibbs energy, Raoult's law, henry's law, modified Raoults's law, dew point and bubble point calculations, liquid phase properties from VLE data, residual properties by cubic equations of state, VLE from cubic equations of state flash calculations.

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, multi-reaction equilibria.

Stability of Thermodynamic Systems: Liquid-liquid equilibria; vapor-liquid-liquid equilibrium; solid-liquid equilibria; solid-gas equilibria. Thermodynamic properties and VLE from equations of state.

Text Books:

1. Introduction to Chemical Engineering Thermodynamics, Smith J. M, H. C. Van Ness and M. M. Abbott, McGraw-Hill, 2004 and 7th Edition.
2. Chemical, Biochemical and Engineering Thermodynamics, S.I. Sandler, Wiley India, 2006 and 4th Edition.
3. Chemical Engineering Thermodynamics, K. V. Narayanan, Prentice Hall of India Pvt. Ltd., 2009 and 2nd Edition

Reference Books:

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

Online Resources:

1. https://archive.nptel.ac.in/courses/103/103/103103144/

Course Code: CH2081	PROCESS DYNAMICS AND CONTROL	L-T-P: 3 – 1 – 0	Credits 4 Cr

Pre-requisites: MA1041 Fundamentals of Matrices and Differential Equations

Course Outcomes:

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

CO1	Evaluate the dynamic behavior of processes
CO2	Analyze stability of feedback control system
CO3	Design PID controllers
CO4	Determine frequency response for controllers and processes
CO5	Apply advanced control schemes for 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:

Introduction to Process Control: Laplace transforms. Response of first-order systems, transfer function, transient response, forcing functions and responses; examples of first and second-order systems; linearization, transportation lag.

State Space Models: Linear and nonlinear models; linearization; components of a control system, development of block diagrams, controllers, and final control elements; closed loop transfer functions; standard block-diagram symbols, transfer functions for single- loop systems, and multi-loop systems; transient response of simple control systems; servo problem, regulatory problem.

Controllers and Stability: Proportional, proportional-integral, PID controllers. Ziegler-Nichols and Cohen-Coon controller settings; model-based controller design methods: direct synthesis method and IMC method; Routh test and root locus techniques.

Frequency Response: Substitution rule, bode diagrams; control system design based on frequency response; Bode and Nyquist stability criterion, gain and phase margins.

Advanced Control Strategies: Cascade control, feed-forward control, ratio control, dead-time compensation (smith predictor), split range control.

Control Valves: Types of control valves, valve sizing, valve characteristics, valve positioner.

Text Books:

1. Process System analysis and Control, D.R. Coughanowr, McGraw Hill, 2012 and 3rd Edition.
2. Process Dynamics and Control, D.Seborg, T. E. Edgar, D.A. Millichamp. and F. Doyle, John Wiley & Sons, 2010 and 3rd Edition.
3. Chemical Process Control, G. Stephanopoulos, Prentice Hall India,2008.

Reference Books:

1. Process Control: Modeling, Design and Simulation, B. Wayne Bequette, Prentice Hall India Learning Private Limited,2003.
2. Introduction to Process Control, J.A. Romagnoli, and A. Palazoglu, CRC Press, 2012 and 2nd Edition.
3. Process Control: Theory and Applications, J.P. Corriou, Springer, 2018 and 2nd Edition.
4. Process Control, K. Krishnaswamy, New age publishers, 2009.

Online Resources:

1. https://nptel.ac.in/courses/103106148
2. https://nptel.ac.in/courses/103105130

Course Code: CH2091	CHEMICAL REACTION ENGINEERING - I	L-T-P: 3 – 1 – 0	Credits 3 Cr

Pre-requisites: CH1021 Chemical Process Calculations

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 and fractional life methods
CO3	Design reactors for homogenous reactions under isothermal and non- isothermal conditions
CO4	Select optimal sequence in multiple reactor systems
CO5	Analyze the performance of non-ideal reactors

Course Articulation Matrix:

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

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, interpretation of batch reactor data, method of initial rates, method of half-lives.

Isothermal Reactor Design: Mole balances in terms of conversion, 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.

Non-Isothermal Reactor design: Energy balances, Adiabatic tubular reactor design.

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, modelling real reactors with combinations of ideal reactors, Other models of non-ideal reactors using CSTRs and PFRs

Text Books:

1. Chemical Reaction Engineering, Levenspiel O, Wiley, 2019 and 3rd Edition.
2. Elements of chemical reaction engineering, Fogler S.H, Prentice Hall, 2020 and 6th Edition.
3. Chemical Reactor Design, Optimization and Scaleup, E. Bruce Nauman, Wiley, 2008 and 2nd Edition.

Reference Books:

1. Introduction to Chemical Reaction Engineering & Kinetics, Ronald W. Missen, Charles A. Mims, Bradley A. Saville, Wiley, 1998.
2. Fundamentals of Chemical Reaction Engineering, Mark E. Davis & Robert J. Davis, McGraw Hill, 2002.
3. Chemical Reaction Engineering: Essentials, Exercises and Examples, Martin Schmal, CRC Press, 2014.
4. Green Chemical Engineering: An introduction to Catalysis, Kinetics, and Chemical Processes, S. Suresh and S. Sundaramoorthy, CRC Press, 2015

Online Resources:

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

Course Code: CH2101	MASS TRANSFER OPERATIONS – I	L-T-P: 3 – 1 – 0	Credits 4 Cr

Pre-requisites: CH1021 Chemical Process Calculations, CH2031 Fluid Mechanics

Course Outcomes:

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

CO1	Learn the concept of diffusion in gas, liquid & solid
CO2	Understand the basics of interphase mass transfer
CO3	Design equipment for gas-liquid mass transfer operations
CO4	Analyze different mass transfer operations such as absorption and adsorption
CO5	Calculate rate of mass transfer in humidification

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	-	-	-	-	-	2	3	2	2
CO5	3	3	3	2	2	2	-	-	-	-	-	2	3	2	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

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

Fundamentals of mass transfer: Definition, Molecular and eddy diffusion, Ficks law, Diffusion in gaseous mixtures, liquid mixtures and solids, Types of solid diffusion, Pseudo steady state diffusion, measurement and calculation of diffusivities. Ordinary diffusion in multicomponent gaseous mixtures. Unsteady state Diffusion.

Inter-Phase Mass Transfer: Equilibria, Mass transfer coefficients- Individual and overall with relations, Theories of mass transfer, Analogies between momentum, heat and mass transfer to predict mass transfer coefficients.

Absorption: Solubility, theory of gas absorption, Design of absorption towers, Concept of Equilibrium and operating lines. Mass Transfer Equipments - Batch and continuous Stage wise contactors and Differential contactors, Concept of HTU and NTU, Tower packings and packing characteristics, non-isothermal absorbers, absorption with chemical reactions.

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

Humidification Operations: Terminology and definitions, Psychrometric charts, Adiabatic operation, Equipment & components, non-adiabatic operation, Design of cooling tower.

Text Books:

1. Treybal R.E., Mass Transfer Operations, 3rd Edition, McGraw Hill, 1981.
2. Geankoplis C.J., Transport processes and Separation Process Principles, 4th Edition, Prentice-Hall India, 2003.
3. Binay K. Dutta, Principles of Mass Transfer and Separation Processes, 2nd Edition, Prentice- Hall India, 2007.

Reference Books:

1. E. L. Cussler, Diffusion – Mass transfer in fluid systems, 3rd Edition, Cambridge University Press, 2009.
2. KV Narayanan and B Lakshmikutty, Mass Transfer – Theory and Applications, CBS Publishers & Distributors Pvt. Ltd., 2014.
3. Ernest J. Henley, J.D. Seader, D. Keith Roper, Separation Process Principles, Wiley, 3rd Edition, 2011.

Online Resources:

1. https://nptel.ac.in/courses/103103145
2. https://nptel.ac.in/courses/103103154
3. https://nptel.ac.in/courses/103103034
4. https://nptel.ac.in/courses/103104046

Course Code: CH2112	HEAT TRANSFER LABORATORY	L-T-P: 0 – 0 – 2	Credits 1 Cr

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	Analyze condensation and boiling phenomena

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

List of experiments:

1. Temperature Measuring Devices.
2. Determination of thermal conductivity for a metal in Cartesian coordinate and cylindrical coordinate systems.
3. Heat Transfer from a Pin Fin by Natural & Forced Convection.
4. Heat Transfer in Natural Convection.
5. Determination of overall heat transfer coefficient of a shell and tube heat exchanger.
6. Determination of overall heat transfer coefficient of a double pipe heat exchanger.
7. Determination of radiation emissivity of a test plate.
8. Boiling Experimental Setup/Heat Flux.
9. Determination of characteristics of drop-wise and film-wise condensation.
10. Determination of thermal conductivity for a composite wall.

Reference Books:

1. Lab Manual
2. http://htv-au.vlabs.ac.in/

Course Code: CH2122	PROCESS DYNAMICS AND CONTROL LAB	L-T-P: 0 – 0 – 2	Credits 1 Cr

Pre-requisites: None

Course Outcomes:

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

CO1	Calculate the characteristics of control valves
CO2	Determine the dynamics of level and temperature measurement process
CO3	Determine the dynamics of two capacity liquid level process without interaction and with interaction, U-tube manometer
CO4	Determine the performance of controllers for a flow process, pressure process, level process, temperature process

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

List of experiments:

1. Control valve characteristics
2. Dynamics of Interacting and Non-interacting process
3. Dynamics of Flow measurement process
4. Dynamics of Temperature measurement process
5. Flapper nozzle system
6. Dynamics of Cascade control system
7. Characteristics of I &P converters
8. Dynamics of Level measurement system
9. Dynamics of First and second order process
10. Dynamics of pressure measurement process

Reference Books:

1. Lab Manuals.
2. Process Dynamics and Control, D.Seborg, T. E. Edgar, D.A. Millichamp. and F. Doyle, John Wiley & Sons, 2010 and 3rd Edition.

Course Code: HS2012	NCC/SOCIAL SERVICE (for BTE, CHEM, CE, ME, MME Depts)	L-T-P: 0 – 0 – 0	Credits 1 Cr

Note: Course details will be updated by the HSC department after BOS approval

Pre-requisites:

Course Outcomes:

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

CO1	-
CO2	-
CO3	-
CO4	-
CO5	-

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Text Books:

1. Title of the Text Book, Author(s), Publisher, Year and Edition
2. Title of the Text Book, Author(s), Publisher, Year and Edition

Reference Books:

1. Title of the Text Book, Author(s), Publisher, Year and Edition
2. Title of the Text Book, Author(s), Publisher, Year and Edition

Online Resources:

1. Website reference links

Course Code CH3011	CHEMICAL TECHNOLOGY	L-T-P 3 – 0 – 0	Credits 3 Cr

Pre-requisite: None

Course Outcomes:

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

CO1	Selection of a process for the manufacture of chemicals
CO2	Draw process 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, Chlorine- Caustic soda, Electrolytic process.

Phosphorus Industries: Phosphoric acid, Wet process, Electric furnace process, Calcium phosphate, Ammonium phosphates, Nitrophosphates, Sodium phosphate.

Nitrogen Industries: Ammonia, Nitric acid, Urea from ammonium carbonate, Ammonium nitrate.

Sulfur Industries: Elemental sulfur mining by Frasch process, Sulfur production by oxidation-reduction of H2S, 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.

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

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.

Petroleum: Occurrence, chemical composition, Refinery crude petroleum classification, production of crude petroleum, petroleum refinery products, characteristics of refineries, refinery operations, pyrolysis and cracking, reforming, polymerization, alkylation, isomerization, hydrodealkylation.

Bio-Fuels: Biofuel feedstocks: sugar, starch, lignocelluolosic, plant and animal fats feedstock; Market and product process of bioethanol; Raw materials to produce low cost bio-diesel; Harvesting energy from biochemical resources.

Learning Resources:

Text Books:

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

Reference Books:

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

Other Suggested Readings:

1. https://archive.nptel.ac.in/courses/103/107/103107082/
2. https://archive.nptel.ac.in/courses/103/107/103107081/

Course Code CH3021	CHEMICAL REACTION ENGINEERING – II	L-T-P 3 – 0 – 0	Credits 3 Cr

Pre-Requisites: CH2091 Chemical Reaction Engineering – 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

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

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, Catalyst Deactivation.

External Diffusion Effects on Heterogeneous Reactions: Diffusion Fundamentals, Binary Diffusion, External Resistance to Mass Transfer, Parameter Sensitivity, Shrinking Core Model.

Diffusion and Reaction: Diffusion and Reaction in Spherical Catalyst Pellets, 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.

Non-catalytic systems: Fluid-Fluid reactions: Kinetics, Fluid-Fluid Reactors: Design.

Learning Resources:

Text Books:

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

Reference Books:

1. J. M. Smith, Chemical Engineering Kinetics, McGraw Hill, 1981, 3rd Edition.
2. T. J. Carberry, Chemical and Catalytic Reaction Engineering, McGraw Hill, 1976.

Other Suggested Readings:

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

Course Code CH3031	MASS TRANSFER OPERATIONS – II	L-T-P 3 – 1 – 0	Credits 4 Cr

Pre-Requisites: CH2101: Mass Transfer Operations – I; CH2021: Heat Transfer

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 distillation and extraction operations
CO4	Estimate the height of packed column in distillation, and extraction 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:

Distillation: Vapor-Liquid Equilibria, Single Stage Operation - Flash Vaporization, Differential or Simple Distillation, Continuous Rectification - Binary Systems, Multistage Tray Towers: Ponchon Savarit Method, McCabe-Thiele Method. Steam Distillation, Continuous Contact Equipment (Packed Towers), Multicomponent Systems, Extractive Distillation, Azeotropic Distillation, Hybrid Distillation.

Liquid-Liquid Extraction: Liquid-Liquid Equilibria, Extraction Equipments, 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.

Ion – Exchange Processes: Principles, Techniques and Applications.

Leaching: Methods of Operation and Equipment, Unsteady State and Steady State Operation

Membrane separations: Micro-filtration, ultra-filtration, nanofiltration and reverse osmosis.

Learning Resources:

Text Books:

1. Treybal R.E., Mass Transfer Operations, McGraw Hill, 1981, 3rd Edition.
2. Binay K. Dutta, Principles of Mass Transfer and Separation Processes, Prentice-Hall India, 2007, 2nd Edition.

Reference Books:

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

Other Suggested Readings:

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

Course Code CH3042	MASS TRANSFER OPERATIONS LABORATORY	L-T-P 0 – 0 – 2	Credits 1 Cr

Pre-requisites: CH2101-Mass Transfer-I, CH3031-Mass Transfer - II

Course Outcomes:

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

CO1	Determine separation performance of batch distillation, steam distillation, sieve plate and packed bed 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 vapor in gas
CO6	Determine the performance of gas-liquid and liquid-solid operations

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	3	-
CO4	2	2	2	1	2	2	1	-	-	-	2	1	2	3	-
CO5	2	2	3	1	1	2	1	-	-	-	2	1	2	2	-
CO6	2	2	2	2	1	2	1	-	-	-	2	1	2	2	-

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

List of experiments:

1. Determine the diffusivity of a vapor in air.
2. Solid in air diffusion apparatus.
3. Absorption studies in packed bed.
4. Adsorption studies in a packed bed for a solid liquid system.
5. Study the operation of sieve plate distillation column: verify the Rayleigh equation.
6. Study the operation of a packed bed distillation column.
7. Calculate the vaporizing efficiency using stem distillation column.
8. Study the performance of a Rotary Disc Liquid-Liquid Extraction Column.
9. Liquid-liquid extraction studies in a packed bed.
10. Solid liquid extraction operation in a packed bed extraction unit.
11. Mass transfer with & without chemical reaction (solid-liquid system).
12. To determine membrane filtration type and effect of pressure on rates.

Learning Resources:

Reference Books:

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

Course Code CH3052	CHEMICAL REACTION ENGINEERING LABORATORY	L-T-P 0 – 0 – 2	Credits 1 Cr

Pre-Requisites: CH2091 Chemical Reaction Engineering – I

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

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

1. Analysis of batch reactor for equimolar constant volume.
2. Analysis of batch reactor for non-equimolar constant volume.
3. Determine the concentration dependency of a reaction in a CSTR.
4. Determine the concentration dependency of a reaction in a PFR.
5. Determine the concentration dependency of a reaction in a semi-batch reactor.
6. Determination of rate constant and temperature dependency of a reaction.
7. Determination of rate constant in a combined reactor (PFR followed by CSTR).
8. Determination of rate constant in a Cascade CSTR (or CSTRs in series).
9. Determination of rate constant of a packed bed reactor.
10. Determine the kinetics by fractional life method.
11. Determination of RTD characteristics of a CSTR.
12. Determination of RTD characteristics of a PFR.

Learning Resources:

Reference Books:

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

Other Suggested Readings:

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

Course Code SM3011	INTRODUCTION TO ENTREPRENEURSHIP (for BTE, CHEM, CE, ME, MME Depts.)	L-T-P 3 – 1 – 0	Credits 4 Cr

Pre-requisites:

Course Outcomes

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

CO1	Acquaint themselves with starting new ventures and introducing new products and service ideas
CO2	Explore the processes of establishing a start-up and develop strategies and methods to mobilize resources
CO3	Create venture capitalists, consultants to new firms or new business development units of larger corporates

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

The entrepreneur's role, task, and personality- typology of entrepreneurs: entrepreneurship as a style of management

Identify problems worth solving-political economical, and social- technical analysis- opportunity recognition-business model identification-new product franchising- sponsorship and acquisition-internal & external entry strategies

Startup ecosystem and support system- role of incubators- government initiatives

Writing and pitching business plan-entrepreneurial tool-venture capital and other forms of financing-sources of external support-developing entrepreneurial marketing-competencies-maintaining competitive advantage

References

1. B.D.Singh. *Managing Conflict and Resolution.* Excel Books.2008
2. B. R. Barringer and D. Ireland, *Entrepreneurship*, Prentice Hall,2009.
3. G. Kawasaki, L. Filby, *The Art of the Start 2.0: The Time-Tested, Battle-Hardened Guide for Anyone Starting Anything* , Penguin,2015.
4. R. Bansal, *Connect the Dots,* Westland, 2011.
5. Ries, Eric *The Lean Startup: How Today's Entrepreneurs Use Continuous Innovation to Create Radically Successful Businesses,* Crown Business, 2011.
6. S. S. Khanka, *Entrepreneurial Development,* S. Chand & Co.2006

Course Code CH3061	TRANSPORT PHENOMENA	L-T-P 3 – 1 – 0	Credits 4 Cr

Pre-requisites: CH2021 Heat Transfer, CH2031 Fluid Mechanics, CH2091 Chemical Reaction Engineering-I, CH2101 Mass Transfer Operations-I

Course Outcomes

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

CO1	Identify the transport properties of solids, liquids and gases
CO2	Formulate a mathematical representation of flow / heat / mass transfer phenomena
CO3	Solve flow/heat/mass transfer problems either individually or coupled for simple geometries analytically
CO4	Identify the similarities among the correlations for flow, heat and mass transfer at interfaces

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 of Momentum transport: Convective Momentum Flux, Molecular Momentum Flux, Total Momentum Flux. Shell Momentum Balance and velocity profile in Laminar Flow: Momentum Balance formulation, Flow of a falling film, Flow through circular tube, Flow through Annulus, Flow of Two Adjacent Immiscible Fluids, Flow in a Cone and Plate Viscometer.

The Equations of Change for Isothermal Systems: The Equation of Continuity, The Equation of Motion, The Equation of Change for Mechanical Energy, The Equation of Change for Angular Momentum, Common Simplifications of the Equation of Motion, The Equations of Change and Solving Steady-State Problems with Variables.

Velocity Distributions in Turbulent Flow: Comparisons of Laminar and Turbulent Flows, Time smoothed Equations of Change for Incompressible Fluids, The Time-Smoothed Velocity Profile Near a Wall, Empirical Expressions for the Turbulent Momentum Flux.

Interphase Transport in Isothermal Systems: Definition of Friction Factors, Friction Factors for Flow in Tubes, Friction Factors for Flow Around Spheres, Friction Factors for Packed Columns.

Introduction of Energy Transport: Convective Energy-Flux Vector, Conductive Heat-Flux Vector—Fourier's Law, Work-Flux Vector, Total Energy-Flux Vector.

Shell Energy Balances and Temperature Distributions in Solids and Laminar Flow: Shell Energy Balances, Heat Conduction in a Steam Pipe, Heat Conduction Through Composite Walls, Electrical Energy Conversion in a Wire,Chemical Energy Conversion in a Reactor, Mechanical Energy Conversion by Viscous Dissipation, Forced Convection, Free Convection, Macroscopic Balances for Nonisothermal Systems.

Mechanisms of Mass Transport: Species Concentrations, Convective Mass and Molar Flux Vectors, Diffusive Mass and Molar Flux Vectors—Fick's Law, Total Mass and Molar Flux Vectors.

Shell Mass Balances and Concentration Distributions in Solids and in Laminar Flow: Diffusion of Gases Through Solids, Diffusion Away from a Slightly Soluble Sphere, Diffusion with a Homogeneous Chemical Reaction, Diffusion with a Heterogeneous Chemical Reaction, Diffusion

Through a Stagnant Gas Film, The Equations of Change for Binary Mixtures, Concentration Distributions in Turbulent Flow.

Learning Resources:

Text Books:

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

Reference Books:

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

Other Suggested Readings:

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

Course Code CH3072	DESIGN AND SIMULATION LABORATORY	L-T-P 0 – 0 – 2	Credits 2 Cr

Pre-Requisites: CH2011-Chemical Engineering Thermodynamics-I, CH2021-Heat Transfer, CH2031-Fluid Mechanics, CH2071-Chemical Engineering Thermodynamics-II, CH2091-Chemical Reaction Engineering-I, CH2101-Mass Transfer Operations-I, CH3031-Mass Transfer Operations-II

Course Outcomes:

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

CO1	Carry out thermodynamic property estimations using Aspen
CO2	Simulate Mixer, splitter, pumps, compressors and flash units
CO3	Apply sensitivity, design specification and case study tools in Aspen
CO4	Design heat exchangers, reactors and distillation columns
CO5	Optimize process flow sheets 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:

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 and creating a digital twin of the plant.
8. Simulation exercises using calculator block.
9. Optimization exercises: PID tuning for CSTR temperature control, Petroleum Fractionation for crude oil distillation, Batch Process Simulation for aniline hydrogenation, Economic Analysis for ammonia processes.
10. Simulation using equation-oriented approach.
11. CAD drawing of Chemical Equipment.

Learning Resources:

Reference Books:

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

Course Code: HS3011	ENGLISH FOR ENGINEERS- II	L-T-P: 3 – 0 – 0	Credits 3 Cr

Pre-Requisites: None

Course Outcomes:

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

CO1	To equip students to develop Questionnaire and to pitch ideas
CO2	To cultivate delegation skills and strategic planning
CO3	To equip students to creating career related documents
CO4	To equip students with technical and business writing
CO5	To improve oral communication and interview readiness

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Module 1
Cover letter - resume - statement of purpose

Module 2
Technical report writing - proposal writing - minutes of the meeting

Module 3
Pitching ideas - client correspondence - preparation of questionnaire

Module 4
Diplomacy skills - strategic planning - delegation skills - feedback

Language Laboratory
Group presentation-presentation with emphasis on body language- public speaking-extempore speech Pronunciation practice (Automatic Speech Recognition).

Mock interview: Interview etiquette, common interview questions

Text Books

1. Brown, Carla L. *Essential Delegation Skills*. Routledge, 2017.
2. Carter, Ronald and Michael McCarthy. *Cambridge Grammar of English: A Comprehensive Guide.* Cambridge University Press, 2006.
3. Harris, David.F. *Complete Guide to Writing Questionnaires*. I& M Press, 2014.
4. Hering, Lutz and Heike Hering. *How to Write Technical Reports: Understandable Structure, Good Design, Convincing Presentation*. Springer; 2010.
5. Mohan, Krishna and Meera Banerji. *Developing Communication Skills.* Macmillan India Limited, 2000.
6. Muralikrishna and Sunitha Mishra. *Communication Skills for Engineers*.Pearson, 2011.

References

1. Busan, Tony. *Mind Map Mastery*. Walkins, 2018.
2. Huckin N. Thomas and Leslie A. OlsenTechnical *Writing and Professional Communication for Non-native Speakers*. McGraw-Hill Education,1991.
3. Laplante, Phillip A. *Technical Writing: A Practical Guide for Engineers, Scientists, and Nontechnical Professionals*. CRC Press, 2018.
4. Mc Quail, Dennis. *Audience Analysis*. Sage, 1997
5. Ogden, Richard. *Introduction to English Phonetics*. Edinburgh University Press, 2017.
6. Parker, Glenn M. *Team Players and Teamwork: New Strategies for Developing Successful Collaboration*. Wiley, 2011.
7. Seely, John. *Oxford Guide to Effective Writing and Speaking: How to Communicate Clearly*. Oxford University Press: 2013.

Course Code: SM3021	INTRODUCTION TO DESIGN THINKING (for BTE, CHEM, CE, ME, MME Depts.)	L-T-P: 3 – 0 – 0	Credits 3 Cr

Pre-Requisites: None

Course Outcomes:

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

CO1	Understand and apply advanced Design Thinking techniques for problem-solving
CO2	Develop proficiency in ideation and visualization tools to structure innovative concepts, analyze biases in user and developer perspectives to enhance communication
CO3	Implement frameworks to sustain a culture of innovation, apply Design Thinking principles to real-world challenges through exercises and case-based discussions

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Listening and empathizing techniques, observation techniques, structured open-ended approaches, overcoming cognitive fixedness, behavior models, innovation heuristics, case-based discussions-exercises.

Use of diagrams and maps in design thinking, empathy map, affinity diagram, mind map, journey map-combining ideas into complex innovation concepts, storytelling and scenario planning-improvisation, scenario development, evaluation tools, frog design-prototyping, interactive workshops, case-based discussions.

References:

1. Roger Martin, The Design of Business: Why Design Thinking is the Next Competitive Advantage, Harvard Business Press , 2009.
2. Christoph Meinel, Larry Leifer, and Hasso Plattner (eds), Design Thinking: Understand – Improve– Apply, Springer, 2011.
3. Idris Mootee, Design Thinking for Strategic Innovation: What They Can't Teach You at Business or Design School, John Wiley & Sons, 2013.

Course Code: CH4011	PROCESS EQUIPMENT DESIGN AND ECONOMICS	L-T-P: 3 – 0 – 0	Credits 3 Cr

Pre-Requisites: CH2021 Heat Transfer, CH2101 Mass Transfer Operations-I, CH3031 Mass Transfer Operations-II

Course Outcomes:

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

CO1	Design heat exchangers, evaporators and distillation column
CO2	Apply mechanical design concepts to process equipment
CO3	Determine costs involved in process plants
CO4	Perform economic analysis and Evaluate project profitability

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Process equipment design: Design of double pipe heat exchanger, design of shell and tube heat exchanger, Design of Condenser and reboilers, Design of evaporator, Column sizing, Plate and packed column hydraulics design, Design of a distillation column.

Chemical Plant Design: Overall design consideration, Practical considerations in design, Plant Layout, Plant Operation and Control, Development of design databases, Process creation, Process design criteria, Process flow diagram (PFD), Equipment design specifications, Flow sheet synthesis and development

Cost Estimation and Economic Analysis: Balance sheet and Income statements, 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, Simple interest, Compound interest, Costs of capital, Time value of money, Annuity, Cash flow patterns, Present worth, Future worth, Methods for calculating Depreciation, Profitability standards, 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.

Learning Resources:

Text Books:

1. R.K. Sinnott, Coulson & Richardson's Chemical Engineering, Volume 06, Elsevier, 2005, 3rd Edition.
2. D. Q. Kern, Process Heat Transfer, Tata McGraw-Hill Education, 2017.
3. Bhattacharya B.C., Introduction to Chemical Equipment Design-Mechanical Aspects, CBS Publishers and Distributors, 2008.
4. Mahajani V.V. and Umarji S.B., Joshi's process equipment design, Trinity Press, 2014, 4th Edition.
5. Peters M.S., K.D. Timmerhaus and R.E. West, Plant Design and Economics for Chemical Engineers, McGraw Hill, 2011, 5th Edition.
6. Turton R., R.C. Baile, W.B. Whiting, J. A. Shaeiwitz. Analysis, Synthesis and Design of Chemical Processes, PHI New Delhi, 2011, 3rd Edition.

Reference Books:

1. Subhabrata Ray and Gargi Das, Process Equipment and Plant Design - Principles and Practices, Elsevier, 2020.
2. Shah R. K., Sekulic D. P., Fundamentals of heat exchanger design, John Wiley & Sons, 2003.
3. Brownell L.E, Process Equipment Design - Vessel Design, Wiley Eastern Ltd., 1986.
4. Robert E. Treybal, Mass Transfer Operations, McGraw Hill Education, 1980, 3rd Edition.
5. Towler G. P., and Sinnott R. K., Chemical Engineering Design, Principles, Practice and Economics of Plant and Process Design, Butterworth Heinemann, 2012, 2nd Edition.
6. Nicholas O. Cheremisinoff, Handbook of chemical process equipment, Butterworth-Heinemann, 2000.
7. Seider W.D., J.D. Seader, D.R. Lewin, Product and Process Design Principles: Synthesis, Analysis, and Evaluation, Wiley, 2004, 2nd Edition.
8. James R. Couper, W. Roy Penny, James R. fair, Stanley M. Walas, Chemical Process Equipment: Selection and Design, Elsevier Butterworth-Heinemann, 2012.
9. R. Panneerselvam, Engineering Economics, Prentice Hall India, 2013.
10. Donald G. Newnan.,TedG. Eschenbach., Jerome P. Lavelle, Engineering Economic Analysis, Oxford University Press, 2012, 11th Edition.

Other Suggested Readings:

1. https://nptel.ac.in/courses/103/105/103105166/
2. https://nptel.ac.in/courses/103/107/103107207/
3. https://onlinecourses.nptel.ac.in/noc21_ch52/course

Course Code: CH4024	PROFESSIONAL MAJOR WORK	L-T-P: 0 – 0 – 0	Credits: 6 Cr

Pre-Requisites: Professional Major Core Courses (PCC)

Course Outcomes:

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

CO1	Identify a contemporary and domain-specific research topic relevant to current industry or academic needs
CO2	Conduct a comprehensive literature review to recognize research gaps and define clear objectives and scope
CO3	Develop a prototype, experimental setup, or software system to effectively achieve the defined objectives
CO4	Analyze experimental or simulation results to derive meaningful conclusions and insights

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Description:

Students will select a real-world contemporary problem and apply engineering principles to develop prototypes, simulations, software, or process models. A department-appointed panel will assess project suitability. The B.Tech. Professional Major Work will be evaluated for 100 marks, with the following weightages:

Sub-component	**Weightage**
Periodic evaluation by Guide	40 marks
Midterm review	20 marks
End-Semester viva-voce examination	40 marks

Evaluation Criteria:

Refer to B.Tech. Regulations for detailed guidelines on mid-term review, end-semester evaluation, report preparation, and plagiarism policies.

Course Code: CH4032	COMPUTATIONAL METHODS IN CHEMICAL ENGINEERING LABORATORY	L-T-P: 0 – 1 – 2	Credits 2 Cr

Pre-Requisites: MA1031-Calculus for Several Variables, MA1041-Fundamentals of Matrices and Differential Equations, MA2021-PDEs, Numerical Methods and Statistics

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 MATLAB/Python/C++.

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.

Reference Books:

1. Niket S. Kaisare, Computational Techniques for Process Simulation and Analysis using MATLAB, Taylor & Francis, CRC Press, 2018.
2. Walter Savitch, Problem Solving with C++, Pearson, 2014, 9th Edition.
3. Alkis Constantinides, NavidMoustoufi, Numerical Methods for Chemical Engineers with MATLAB Applications, Prentice Hall, 1999.
4. Rudra Pratap, Getting started with MATLAB: A quick introduction for scientists & Engineers, Oxford University Press, 2010.

Other Suggested Readings:

1. https://nptel.ac.in/courses/103/106/103106118/
2. https://nptel.ac.in/courses/111/102/111102137/

Course Code: CH4044	SEMESTER-LONG INTERNSHIP (SLI) /ADDITIONAL PROJECT AT THE INSTITUTE/ADDITIONAL DEPARTMENT ELECTIVE COURSES FOR 6 CREDITS	L-T-P: 0 – 0 – 0	Credits: 6 Cr

Pre-Requisites: Professional Major Core Courses (PCC)

Course Outcomes:

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

CO1	Formulate and define a relevant, domain-specific problem aligned with current industrial or research trends
CO2	Critically analyze existing literature to identify research gaps and clearly establish the objectives and scope of the work
CO3	Design and implement a functional prototype, experimental system, or software tool tailored to address the defined problem
CO4	Evaluate the outcomes through data analysis or testing and derive valid, evidence-based conclusions

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Description:

This module offers flexibility for students to either undertake a Semester-Long Internship (SLI) in industry or research institutions, or carry out an Additional Project under faculty supervision, or pursue Departmental Elective Courses worth 6 credits. The primary objective is to provide hands-on experience and exposure to real-world applications of engineering concepts.

Students are expected to identify a relevant problem or topic, review existing literature, and develop a viable solution through experimental work, simulation, or software development. The chosen work must be original, and students are required to submit a report adhering to academic integrity standards, including plagiarism limitations.

Evaluation Criteria:

As per the B.Tech. regulations prescribed for internships, projects, or elective courses by the respective department.

Elective Courses offered by the Chemical Engineering Department

Departmental Elective-1

Course Code CH3101	BIOPROCESS ENGINEERING	L-T-P 3 – 0 – 0	Credits 3 Cr

Pre-requisite: None

Course Outcomes:

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

CO1	Get knowledge on fermentation processes and its characteristics
CO2	Understand the concepts of enzyme kinetics.
CO3	Define stoichiometry of the fermentation process
CO4	Understand the working principle of bioreactor and product recovery operations and its monitoring instruments

Course Articulation Matrix

	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	1
CO2	3	3	2	1	-	1	2	1	-	-	-	-	3	3	1
CO3	3	3	2	1	-	1	2	1	-	-	-	-	3	3	1
CO4	3	3	2	1	-	1	2	1	-	-	-	-	3	3	1

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction: Fermentation processes general requirements of fermentation processes- an overview of aerobic and anaerobic fermentation processes and their application in industry - medium requirements for fermentation processes - examples of simple and complex media design and usage of commercial media for industrial fermentation. Sterilization: Thermal death kinetics of micro-organisms - batch and continuous heat-sterilization of liquid media filter sterilization of liquid media and air.

Enzyme Technology, Microbial Metabolism: Enzymes: Classification and properties-applied enzyme catalysis - kinetics of enzyme catalytic reactions-metabolic pathways - protein synthesis in cells.

Stoichiometry and Kinetics of Substrate Utilization and Biomass and Product Formation: Stoichiometry of microbial growth, substrate utilization and product formation-batch and continuous culture, fed batch culture.

Bioreactor and Product Recovery Operations: Operating considerations for bioreactors for suspension and immobilized cultures, selection, scale-up, operation of bioreactors-mass transfer in heterogeneous biochemical reaction systems; oxygen transfer in submerged fermentation processes; oxygen uptake rates and determination of oxygen transfer rates and coefficients; role of aeration and agitation in oxygen transfer; heat transfer processes in biological systems; recovery and purification of products.

Introduction to Instrumentation and Process Control in Bioprocesses: Measurement of physical and chemical parameters in bioreactors- monitoring and control of dissolved oxygen, pH, impeller speed and temperature in a stirred tank fermenter.

Reference Books:

1. M.L. Shuler and F. Kargi, Bio-process Engineering, 2nd Edition, Prentice Hall of India, New Delhi. 2002.
2. J.E. Bailey and D.F. Ollis, Biochemical Engineering Fundamentals, 2nd Edn., McGraw Hill, Publishing Co. New York, 1985.
3. P. Stanbury A. Whitakar and S.J.Hall, Principles of Fermentation Technology, 2ndEdn., Elsevier-Pergamon Press, 1995.
4. J.M. Lee, Biochemical engineering, Prentice Hall, 1992.

Course Code CH3111	FERTILIZER TECHNOLOGY	L-T-P 3 – 0 – 0	Credits 3 Cr

Pre-requisite: 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	-	-	-	-	-	-	-	-
CO2	1	3	-	-	-	-	3	-	-	-	-	-	-	-	-
CO3	1	3	-	-	-	-	3	-	-	-	-	-	-	-	-
CO4	1	3	-	-	-	-	3	-	-	-	-	-	-	-	-

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.

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.

Biofertilizers: Types of Biofertilizers, Biofertilizers Nitrogen-fixing biofertilizers Phosphate solubilizing biofertilizers, Preparation of a biofertilizers, Composting, Vermi-composting

Reference Books:

1. Sittig M and Gopala Rao M., Dryden's Outlines of Chemical Technology for the 21st Century, WEP East West Press, 3rd Edition, 2010.
2. Austin G T., Shreve's Chemical Process Industries, McGraw Hill Book Company, New Delhi, 5th Edition, 1986.
3. Handbook on Fertilizer Technology, Fertilizer Association of India, JNU, New Delhi, 2nd Edition, 1977.
4. Shukla S D and Pandey G N, A Text Book of Chemical Technology, Vol I & II, Vikas Publishing House Pvt. Ltd., New Delhi, 2000.
5. Eugene Perry, Fertilizers: Science and Technology, Callisto Reference Publisher, 2018.
6. A.K. Kolay, Manures and Fertilizers, Atlantic, 2008.

Course Code CH3121	WATER AND WASTEWATER TREATMENT	L-T-P 3 – 0 – 0	Credits 3 Cr

Pre-requisite: None.

Course Outcomes:

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

CO1	Describe different methods for wastewater treatment and environmental effects of wastewater
CO2	Know the five stages of wastewater treatment and alternative strategies for providing these levels of treatment
CO3	Impart knowledge on the various advances in waste water treatment process across the industries
CO4	Analyze the various waste water treatment processes and operations, and optimization

Course Articulation Matrix

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction: An overview of water and waste-water treatment, need for waste water treatment: water scenario - escalating demand – pollution of existing sources. Waste water sources – industrial, agricultural & domestic. Assessment of waste water composition – general characteristics – TSS, TDS, BOD, COD, pH – specific characteristics – analysis for various ionic species, heavy metals and other identified pollutants. Regulations for treatment – Alara concept – pollution control board regulations.

Conventional Treatment of Waste Water: Primary – secondary - aim of the treatment; particulate removal (primary) - screens – filters – rapid & gravity filters; secondary treatment-aerobic treatment; suspended growth aerobic treatment processes, activated sludge process and its modifications; attached growth aerobic processes, tricking filters and rotating biological contactors, membrane biological reactor; anaerobic treatment- suspended growth, attached growth, fluidized bed and sludge blanket systems, nitrification, denitrification, phosphorus removal; sludge treatment-thickening; digestion; dewatering; sludge drying; composting, low cost wastewater systems ponds and lagoons; wetlands and root-zone systems (qualitative treatment only).

Chemically Induced Mechanical Operations: Coagulation – clarifiers – oxygenation – precipitation – adsorption – ion exchange and membrane processes. Removal of trace level pollutants – disinfection using chlorine – UV – UF.

Advanced Treatment Processes: Advanced oxidation systems – Fenton process, electrochemical oxidation, Sono-chemical oxidation; Membrane processes, Wet air oxidation, Adsorption and ion-exchange, Sludge treatment.

Reference Books:

1. G. Tchobanoglous and Metcalf & Eddy, "Wastewater Engineering Treatment and Reuse", 4th Edn., Tata McGraw-Hill Publishing Company, New Delhi, 2003.
2. S.J. Arceivala, Waste Water Treatment for Pollution Control, Tata McGraw Hill, 1998.
3. W.W. Eckenfelder, "Industrial Water Pollution Control", 3rd edition., McGraw Hill, Boston, MA, 2000.
4. E.F. Eldridge, "Industrial Waste Treatment Practice", McGraw-Hill Book Company, Inc., New York, NY, 1942.
5. C.P.L. Grady,, G. T. Daigger, and H. C. Lim., "Biological Wastewater Treatment", 2nd edition., Rev. and Expanded, Marceldekker, New York, 1999

Course Code CH3131	FOOD PROCESS ENGINEERING	L-T-P 3 – 0 – 0	Credits 3 Cr

Pre-requisites: CY1011-Engineering Chemistry, CH2021-Heat Transfer

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 and Indian scenario, 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 microorganisms, 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, pasteurization, 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.

Reference Books:

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

Course Code CH3141	FLUIDIZATION ENGINEERING	L-T-P 3 – 0 – 0	Credits 3 Cr

Pre-requisites: Fluid Mechanics (CH 2031), Heat Transfer (CH 2021), Mass Transfer Operations I (CH 2112) and Mass Transfer Operations II (CH 3031).

Course Outcomes:

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

CO1	Evaluate the fluidization behavior
CO2	Estimate pressure drop, bubble size, TDH, voidage, heat and mass transfer rates for fluidized beds
CO3	Develop model equations for fluidized beds
CO4	Design gas solid fluidized bed reactors

Course Articulation Matrix

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Applications of Fluidized Beds: Introduction, industrial application of fluidized beds, physical operations and reactions.

Fluidization and Analysis of Different Phases: Gross behavior of fluidized beds; bubbles in dense beds; the emulsion phase in dense bubbling beds; flow pattern of gas through fluidized beds.

Heat and Mass Transfer in Fluidized Bed Systems: Mass and heat transfer between fluid and solid; gas conversion in bubbling beds; heat transfer between fluidized bed and surfaces.

Elutriation and Entrainment: TD and also distribution of solid in a fluidized bed; circulation systems.

Design of Fluidized Bed Systems: Design of fluidization columns for physical operations, catalytic and non- catalytic reactions, three phase fluidization.

Reference Books:

1. D. Kunii and O. Levenspiel, Fluidization Engg., 2nd Ed., Butterworth Heinemann, 1991.
2. J. F. Davidson and Harrison, Fluidization, 10th Ed, Academic Press, London, 1994.
3. R. Jackson, The Dynamics of Fluidized Particles, Cambridge University Press, New York, 2000.
4. L.S. Fan, and C. Zhu, Principles of Gas-Solid Flows, Cambridge University Press, New York, 1998.
5. L.G. Gibilaro, Fluidization Dynamics, 1st Edition, Butterworth-Heinemann, 2001.

Course Code CH3151	MATERIAL SCIENCE AND TECHNOLOGY	L-T-P 3 – 0 – 0	Credits 3 Cr

Pre-requisites: None

Course Outcomes:

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

CO1	Understand the basics knowledge such as internal structure, crystal geometry, crystal imperfection of the engineering materials
CO2	Understand the various properties and corrosion behavior of the selected materials in chemical industries
CO3	Understand the relationships between the structures, properties, processing and applications of various engineering materials
CO4	Experience the metallic and nonmetallic material selection and handling material in chemical engineering in the areas of equipment design

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction: Materials Science and Engineering, Classification of Engineering Materials, Levels of Structure, Structure–Property Relationships in Materials

Atomic Bonding: Classes of engineering materials - engineering requirement of materials - selection of materials - structure of atoms and molecules - bonding in solids - types of bonds and comparison of bonds.

Structure and Imperfections in Crystals: Crystal structure crystal geometry, structure of solids, methods of determining structures. imperfection in crystals - types of imperfection. point imperfection, diffusion in solids - self-diffusion fick's law, applications of diffusion.

Phase Diagrams & Phase Transformations: The Phase Rule, Single-component Systems, Binary Phase Diagrams, Microstructural Changes during Cooling, The Lever Rule, Some Typical Phase Diagrams, Nucleation and Growth, Applications

Properties of Materials: Mechanical, electrical, and magnetic properties of materials, elastic behavior, viscoelastic behavior, plastic deformation, creep

Fracture: Ductile fracture, brittle fracture, fracture toughness, the ductile-brittle transition, fracture mechanism maps, methods of protection against fracture, fatigue fracture

Oxidation & Corrosion:
Oxidation, mechanisms of oxidation, oxidation resistant materials, corrosion, theories of corrosion - control and prevention of corrosion.

Metals: Engineering materials - ferrous metals - iron and their alloys iron and steel iron carbon equilibrium diagram. Non-ferrous metals and alloys - aluminium, copper, zinc, lead, nickel and their alloys with reference to the application in chemical industries.

Non Metals: Inorganic materials: Ceramics, glass and refractories - organic materials: wood, plastics, and rubber and wood - advanced materials (biomaterials, nanomaterials and composites) with special reference to the applications in chemical industries.

Reference Books:

1. Lawrence H. Van Vlack, "Elements of Material Science and Engineering", 1971.
2. S.K. Hajra Choudhury, "Material Science and processes", 1st Edn., 1977. Indian Book Distribution Co., Calcutta.
3. William D. Callister, “Materials Science and Engineering”, 7th edn, John Wiley & Sons, Inc.
4. V. Raghavan, Materials Science and Engineering, Prentice Hall.

Departmental Elective-2

Course Code: CH4101	NON-NEWTONIAN FLUID MECHANICS	L-T-P: 2 – 1 – 0	Credits 3 Cr

Pre-Requisites: CH2031 Fluid Mechanics

Course Outcomes:

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

CO1	Classify Non-Newtonian (NN) fluids based on rheological behavior and relate them to real-world applications
CO2	Formulate constitutive models to predict stress-strain relationships in NN fluids
CO3	Analyze single- and multi-phase NN flows using dimensionless and mixture theory
CO4	Operate rheometers and interpret experimental data (flow curves, viscoelastic spectra) to characterize NN fluids

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction to Non-Newtonian (NN) Fluids: Definition and classification, Examples from industrial and natural systems, Microstructural origins of non-Newtonian behavior.

Continuum Mechanics and Constitutive Equations: Basic concepts of stress and strain, Stress-strain relationships, Continuum approximation and kinematics, Frame invariance, Models: Generalized Newtonian (Power Law, Carreau), viscoplatic (Bingham Plastic, Herschel-Bulkley), Viscoelastic (Maxwell, Oldroyd-B, K-BKZ), Mechanics of Liquid Mixtures- Continuum modeling of mixtures, Balance laws (mass, momentum), Constitutive relations.

Single-Phase & Multi-Phase NN Flows: Pipe/channel flows, boundary layer effects, Dimensionless numbers (Deborah, Weissenberg), Pressure drop analysis in NN fluids, Gas-liquid/solid-liquid flows (mixture theory vs. empirical correlations), Particulate systems (suspensions, granular materials), Active matter (biological fluids, synthetic swimmers), Case Study: Drilling muds in petroleum engineering.

Viscometric Flows and Measurements: Types of viscometers, Shear and extensional flows, **Viscoelasticity and Time-Dependent Behavior-** Linear and nonlinear viscoelasticity, Storage and loss moduli, Creep and stress relaxation, Oscillatory Shear Rheology- Linear and nonlinear viscoelasticity, Large Amplitude Oscillatory Shear (LAOS) techniques, Experimental Techniques- Particle Image Velocimetry (PIV) for gas-liquid systems, Stability analysis in complex fluids, Rheometer demonstration and data analysis (Excel/MATLAB).

Mathematical Modelling of Rheological Behavior: Constitutive models for complex fluids, Empirical and theoretical approaches, MATLAB modelling of NN flow curves.

Computational Rheology- Numerical methods in rheology, Simulation of complex fluids

Advanced Topics in Rheology: Nonlinear rheology, Yield stress materials, Recent advancements and research trends

Text Books:

1. Deshpande et al., Rheology of Complex Fluids, Springer (2010).
2. Bird RB, Armstrong RC, Hassager O, Dynamics of Polymeric Liquids, vol1: Fluid Mechanics, 2nd Ed, John Wiley and Sons, 1987
3. Chhabra & Richardson, Non-Newtonian Flow and Applied Rheology, 2nd Ed (2008).
4. Morrison, Understanding Rheology, Oxford (2001).

Reference Books:

1. Chhabra RP, Bubbles, Drops, and Particles in Non-Newtonian Fluids, 2nd Ed, Taylor and Francis (CRC), 2007.
2. Larson, The structure and rheology of complex fluids (1999)
3. Mewis, Wagner, Colloidal suspension rheology (2011)

Course Code CH4111	BIOCHEMICAL ENGINEERING	L-T-P 3 – 0 – 0	Credits 3 Cr

Pre-Requisites: CY1011-Engineering Chemistry; CH2091-Chemical Reaction Engineering – I

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:

	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, 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 Books:

1. Butterworth–Heinemann, Product Recovery in Bioprocess technology, BIOTOL series, 2006.
2. Ronald, J. Lee, Principles of Downstream processing, Wiley Publications, 2007.
3. Satinder Ahuja, Handbook of Bioseparations, Academic Press, Volume 2, 2000.
4. Thomson, Principles of Protein Purification, Wiley International, 2007.
5. Raja Ghosh, Principles of Bioseparations Engineering, World Scientific Publishing Company, Singapore, 2006.

Course Code CH4121	DESIGN AND ANALYSIS OF EXPERIMENTS	L-T-P 3 – 0 – 0	Credits 3 Cr

Pre-Requisites: None

Course Outcomes:

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

CO1	Plan experiments according to a proper and correct design plan
CO2	Analyze and evaluate experimental results (statistically), according to chosen experimental design (ANOVA, regression models)
CO3	Use fundamentals such as hypothesis testing, degrees of freedom, ANOVA, fractional design and other design methods/techniques and so on.
CO4	Know the fundamentals of multivariate analysis and chemometric methods (PCA and PLS) with simple applications.

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction to Probability, Probability Laws, Bayes theorem. Probability Distributions, Parameters and Statistics. Normal and T-Distributions, Central Limit Theorem, Random Sampling and Declaration of Independence Significance Tests.

Randomization and Blocking with Paired Comparisons Significance Tests and Confidence Interval for Means, Variances, Proportions and Frequencies.

Analysis of Variance, Experiments to Compare K-Treatment Means, Two-Way Factorial Designs, Blocking and Yates algorithm

Fractional Factorial Designs at Two Levels, Concept of Design Resolution, Simple Modeling with Least Squares (Regression Analysis), Matrix Versions of Normal Equations.

Mechanistic Model Building, Empirical and Mechanistic Models, Model Building Process, Model Testing with Diagnostic Parameters.

Text Books:

1. D.C. Montgomery, Design and Analysis of Experiments, Wiley, 8 th Edition, 2012.
2. Z.R. Lazic, Design of Experiments in Chemical Engineering: A Practical Guide, Jhon Wiley &Sons Inc, 2004.
3. Statistics for experimenters by G.E.P. Box, William G. Hunter and J.S. Hunter, John Wiley & Sons.

R.L. Mason, R.F. Gunst, J.L. Hess, Statistical Design and Analysis of Experiments: With Applications to Engineering and Science, Jhon Wiley &Sons Inc.2nd ed., 2003.

Course Code CH4131	ADVANCED SEPARATION PROCESSES	L-T-P 3 – 0 – 0	Credits 3 Cr

Pre-Requisites: CH2101 Mass Transfer Operations-I

Course Outcomes:

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

CO1	To build advanced concepts of separation processes carried out in chemical industries
CO2	To understand the designing and functioning of equipment required for the separations in chemical engineering
CO3	To utilize the innovative technological methods in problem solving of separation in industries
CO4	To understand the applications of advanced separative equipments
CO5	To recognize the selection criteria between conventional separation techniques and advanced separation techniques

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	1
CO2	3	3	3	3	1	-	3	-	-	-	-	-	3	2	1
CO3	3	3	3	3	-	-	-	-	-	-	-	-	3	1	1
CO4	3	3	3	3	-	-	-	-	-	-	-	-	3	3	1
CO5	3	3	3	3	-	-	-	-	-	-	-	-	3	3	3

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction: Separation factors and its dependence on different variables. mechanism of separation, separation by phase addition or creation, separation by barrier, separation by solid agent, separation by external field or gradient, component recoveries and product purities, separation power, selection of feasible separation processes.

Advances in Adsorption: Types and choice of adsorptions, Ion exchangers, sorbents for chromatography, equilibria in chromatography, Chromatographic techniques, adsorption chromatography, Retention theory mechanism for slurry adsorption, Fixed bed adsorption (Percolations), thermal swing adsorption, pressure swing adsorption, continuous counter current adsorption systems.

Supercritical Fluid Extraction: Supercritical fluids, phase equilibria, industrial application, important supercritical processes- decaffeination of coffee, extraction of oil from seeds, Residuum Oil Supercritical Extraction (ROSE), supercritical fluid reactions, etc.

Membrane Processes: Fundamentals of separation processes, membrane types and materials, synthetic membrane preparation, transport mechanisms, membrane operations, fouling control, module configurations, gas and surfactant-based separations, and advanced techniques like chromatography, supercritical extraction, and filtration-based separation processes.

Reactive and Catalytic Distillation: Concept and History, advantages and disadvantages, Various methods of applications, manufacturing of MTBE and ETBE and other commercial applications.

Advances in Crystallization: Melt crystallization, Fractional crystallization, zone melting, freeze crystallization, etc.

Advances in Distillation: Soft path distillation, Molecular distillation, Extractive and Azeotropic distillation, Pressure swing distillation, Salt distillation, Osmotic distillation, etc.

Advanced Oxidation Process (AOP): Definition and concept, Importance in wastewater and environmental treatment, Fundamental Principles, Ozone-based AOPs (O_3, O_3/H_2O_2), UV-based AOPs (UV/H_2O_2, UV/O_3), Fenton and Photo-Fenton processes, TiO_2 photocatalysis, Electrochemical AOPs, Hybrid and combined AOP systems, Applications of AOPs

Learning Resources:

Text Books:

1. Mass Transfer by T.K. Sherwood, R.L. Pigford and C.R. Wilke,McGraw- Hill, New York (1975).
2. Mass transfer operations, R.E. Treybal, , McGraw-Hill, New York (1980).
3. R. W. Rousseau, Handbook of Separation Process Technology, John Wiley & Sons, 1987.
4. McHugh, M.A. and Krukonis, V.J., Supercritical Fluid Extraction: Principles and Practice, Butterworth-Heinemann, 2013, 2nd Edition.

Reference Books:

1. Perry Chemical Engineers Handbook, 7th edition by R.H. Perry and D. Green.
2. Ullman’s Encyclopedia of industrial Chemistry.
3. Encyclopedia of Chemical Engineering by Kirk & Othmer.
4. Handbookof separation techniques for Chemical Engineers”, Schweitzer P.A. (Ed.), 3rd Edition, McGraw-Hill, New York, 1997.
5. Reactive Distillation, John Wiley & Sons, New York, 2000.
6. Separation processes by C.J King, Tata McGraw Hill, New Delhi, 1982.
7. New Chemical Engineering separation Techniques’ by H.M. Schoen, Wiley Interscience, New York, 1972.
8. Handbook of separation process Technology by Ronald W. Roussel, John Wiley, New York, 1987.
9. Reactive separation processes by Kulprathipanja S., Taylor and Francis, New York, 2002

Other Suggested Readings:

1. https://nptel.ac.in/courses/103105060

Course Code CH4141	CATALYSIS	L-T-P 3 – 0 – 0	Credits 3 Cr

Pre-Requisites: None

Course Outcomes:

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

CO1	Describe the methods of preparation and characterization of catalysts
CO2	Analyze the role of heat and mass transfer in the catalytic reactor design
CO3	Determine the deactivation kinetic parameters and selectivity
CO4	Distinguish the performance of catalytic reactors
CO5	Identify the role of industrial 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	-	1	1	-	-	-	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 catalysts, 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 catalysts. Catalyst deactivation kinetics, various deactivation models.

Monolithic reactors: Catalysis for petroleum and polymer industries: Organometallic catalyst, Zeolite catalysts, preparation, characterization and applications, Commercial Catalytic Reactors.

Industrial catalysis: Industrially important catalysts and processes such as oxidation, processing of petroleum and hydrocarbons, greenhouse gas conversion, reforming reactions for hydrogen production and related processes. Design and characterization of photocatalysts, biocatalysts, and electro-catalysts. Environmental catalysis, value added chemicals, autoexhaust catalysts.

Learning Resources:

Text Books:

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

Reference Books:

1. K.K. Pant, S.K. Gupta, E. Ahmad, Catalysis for Clean Energy and Environmental Sustainability: Petrochemicals and Refining Processes - Volume 2, Springer, 2021, 1st Edition.
2. M.R. Cesario, D.A. Macedo, Heterogeneous Catalysis Materials and Applications, Elsevier, 2022, 1st Edition.
3. John Meurig Thomas, W. J. Thomas, Principles and Practice of Heterogeneous Catalysis, Wiley VCH; 2014, 2nd Edition.
4. L. K. Doraiswamy, M. M. Sharma, Heterogeneous Reactions: Fluid-fluid-solid Reactions, Volume 1, John Wiley and Sons, 1984.
5. B. Viswanathan, S. Sivasanker, A.V. Ramaswamy, Catalysis: Principles and Applications, Narosa Publishing House, 2002.
6. B. Viswanathan, S. Kannan, R.C. Deka, Catalysts and Surfaces: Characterization Techniques, Alpha Science International, 2010.

Other Suggested Readings:

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

Course Code CH4151	PROCESS INSTRUMENTATION	L-T-P 3 – 0 – 0	Credits 3 Cr

Pre-Requisites: None.

Course Outcomes:

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

CO1	To understand the fundamentals of process variable measurements.
CO2	To understand the principles of various pressure, temperature, flow, and level measurement techniques
CO3	Improve ability to select suitable process instrument for specific measurement
CO4	To make the students knowledgeable in the design, installation and troubleshooting of process instruments.

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction to Process instrumentation: Elements of instrumentation systems and their functions, Characteristics of instruments and their classifications

Principle and construction of instruments and their applications: Indicators, Recorders, Process switches, Alarms, Sensors, Transducers, Converters, Process and Instrument diagrams, Loop Diagrams, Functional Diagrams

Vibration and Acceleration measurement: Standards, working principle, types, materials, design criterion: Eddy current type, piezoelectric type, Seismic Transducer, Accelerometer: Potentiometric type, LVDT type, Piezo-electric type.

Pressure and Vacuum Measurement: Elastic types-Resistive- Capacitive and Inductive pressure pickups. Piezoelectric- Piezoresistive types. Vacuum measurement: McLeod gauges-Ionization gauges, High Pressure measurement. Force balance and Motion balance type transmitters – P/I and I/P converters. IC pressure sensors and calibration of pressure measuring devices.

Temperature Measurement: Temperature scales, Methods of temperature measurement, Thermocouples, Bimetallic thermometers, Liquid-in-glass, Pressure thermometer, Semiconductor sensors, Digital thermometers, Pyrometers

Flow Measurement: Methods of flow measurement, Variable area: Weirs and flumes, Velocity based: Electromagnetic flow meter, Anemometers, Laser Doppler anemometer, Positive displacement flow meters, Mass flow meter

Level measurement: Conductive and Capacitive methods –Ultrasonic, Microwave and RADAR level sensors - Solid level measurement by Paddlers method. Capacitance method for powder level measurement. Density, Viscosity and PH measurement.

Allied Sensors: leak detector, flame detector, smoke detector, density, Sound sensors, and Proximity sensors, Gas Sensors and digital transducers.

Reference Books:

1. D. Patranabis, Principles of Industrial Instrumentation, Tata McGraw Hill Publishing Company, New Delhi, 2010
2. R.K. Jain, Mechanical and Industrial Measurements, Khanna Publishers, 2005
3. Tony R. Kuphaldt , Lessons in Industrial Instrumentation, Creative Commons Attribution 4.0 International Public License (2015).
4. William C. Dunn, Fundamentals of Industrial Instrumentation and Process Control, Tata McGraw-Hill Education Private Limited, 2009.
5. Ernest.O. Doebelin and Dhanesh.N. Manik, Doebelin's Measurement Systems, McGraw Hill Education, 6th Edition, 2011
6. Spitzer D. W., Industrial Flow measurement, ISA press, 3rd Edition, 2005.

Departmental Elective-3

Course Code CH4201	PROCESS MODELING AND SIMULATION	L-T-P 3 – 0 – 0	Credits 3 Cr

Pre-Requisites: CH2071 Chemical Engineering Thermodynamics - II, CH2091 Chemical Reaction Engineering – I, CH3061 Transport Phenomena

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:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO-1	3	2	2	2	1	-	-	-	-	-	-	-	3	2	-
CO-2	3	3	3	2	2	-	-	-	-	-	-	-	3	3	-
CO-3	3	3	3	3	2	-	-	-	-	-	-	-	3	3	-
CO-4	3	3	3	3	2	-	-	-	-	-	-	-	3	3	-

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction: Introduction to process modelling and simulation, Use and scope of mathematical modeling, Principles of model formulation, Role and importance of steady-state and dynamic simulation, classification of models, tools of simulation, Model building, Modeling difficulties, Degree-of-freedom analysis, Selection of design variables, 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. 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. Centrifugal Separation processes and their calculations, Ion exchange and chromatographic separation processes, Supercritical fluid extraction, Advanced oxidation processes, vapor permeation, pervaporation, electrolysis, microfiltration, Ultrafiltration, Nanofiltration, Reverse osmosis, Electrolysis.

Models of Heat Transfer Equipment: Model for evaporators, Double pipe.

Simulation: Simulation of the models, Sequential modular approach, Equation oriented approach, Partitioning and tearing, Introduction and use of process simulation software (Aspen Plus/ Aspen HYSYS) for flow sheet simulation

Learning Resources:

Text Books:

1. W.L. Luyben, Process Modeling, Simulation and Control for Chemical Engineers, McGraw Hill Book Co., New York, 1990, 2nd Edition.
2. Amiya K. Jana, Chemical Process Modeling and Computer Simulation, Prentice Hall, 2011, 2nd Edition.

Reference Books:

1. Holland C. D., Fundamentals and Modeling of Separation Processes, Prentice Hall., 1975.
2. Denn M. M., Process Modeling, Longman, 1986.
1. Ashok Kumar Verma, Process Modeling and Simulation in Chemical, Biochemical and Environmental Engineering, CRC Press, 2014.
2. K. M. Hangos and I. T. Cameron, Process Modelling and Model Analysis, Academic Press, 2001.
3. M. Chidambaram, Mathematical Modelling and Simulation in Chemical Engineering, Cambridge University Press, 2018.

Other Suggested Readings:

1. https://nptel.ac.in/courses/103/107/103107096/

Course Code CH4211	STATISTICAL DESIGN OF EXPERIMENTS	L-T-P 3 – 0 – 0	Credits 3 Cr

Pre-Requisites: MA1031-Calculus of Several Variables; MA2021-PDEs, Numerical Methods and Statistics

Course Outcomes:

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

CO1	Plan experiments for a critical comparison of outputs
CO2	Include statistical approach to propose hypothesis from experimental data
CO3	Implement factorial and randomized sampling from experiments
CO4	Estimate parameters by multi-dimensional optimization

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	3	3	2	-	-	-	-	-	-	-	2	2	3
CO2	3	3	3	3	2	-	-	-	-	-	-	-	2	2	3
CO3	3	3	3	3	2	-	-	-	-	-	-	-	2	2	3
CO4	3	3	3	3	2	-	-	-	-	-	-	-	2	2	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, Youden’s Squares, Basic experiment-mathematical modeling, Statistical Analysis

Experimental optimization of research subject: Problem of optimization, Gradient optimization methods, Non-gradient methods of optimization, Simplex sum rotatable design, Canonical analysis of the response surface, Examples of complex optimizations.

Reference 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, 5th Edition, 2010.
4. Doebelin E. O., Engineering Experimentation: Planning, Execution, Reporting, McGraw-Hill, 1995.

Course Code CH4221	MULTIPHASE FLOW	L-T-P 3 – 0 – 0	Credits 3 Cr

Pre-Requisites: CH2031 Fluid Mechanics, MA1031Calculus of Several Variables

Course Outcomes:

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

CO1	Understand the fundamentals of multi-phase flow
CO2	Analyze multi-phase flow with inertia effects
CO3	Analyze flow regimes with appropriate models
CO4	Measure parameters in multi-phase flow

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction: multiphase flow, types and applications, Common terminologies, flow patterns and flow pattern maps.

Homogeneous Flow Model: One dimensional steady homogenous flow, Concept of choking and critical flow phenomena.

Separated Flow Model: One dimensional steady separated flow model, phases are considered together but their velocities differ, Phases are considered separately, flow with phase change, Flow in which inertia effects dominate, energy equations, the separated flow model for stratified and annular flow.

Drift Flux Model: General theory of drift flux model, Application of drift flux model to bubbly and slug flow.

Hydrodynamics of solid-liquid and gas-solid flow: Principles of hydraulic and pneumatic transportation.

Introduction to three phase flow, Measurement techniques for multiphase flow. Flow regime identification, pressure drop, void fraction and flow rate measurement.

Reference Books:

1. C. E. Brennen, Fundamentals of Multiphase Flow, Cambridge University Press, New York, 2005.
2. M. E. Weber, R. Clift, J. R. Grace, Bubbles, Drops, and Particles, Dover Books, New York, NY. 2013.
3. V. P. Carey, Liquid-Vapor Phase-Change Phenomena, Hemisphere Pub. Corp. 1992.

Course Code CH4231	INTERFACIAL SCIENCE	L-T-P 3 – 0 – 0	Credits 3 Cr

Pre-Requisites: None

Course Outcomes:

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

CO1	Identify the interfacial phenomena occurring at macro scale and quantify the effect owing to interfacial properties.
CO2	Analyze ab-initio calculations for inter-colloidal forces
CO3	Identify equipment and sensors for characterizing various interfaces
CO4	Design processes that utilize interfacial phenomena to achieve a desired effect.

Course Articulation Matrix:

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

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

Monolayers formation: Introduction, Formation of floating monolayers, Surface pressure area relationships, Deposition of Langmuir Blodgett (LB) films, The study of film structure, the structure and properties of floating monolayers, Interactions in monolayers, the structures of LB films, characterization and application.

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. Geoffrey Barnes and Ian Gentle, Interfacial Science: An Introduction, Oxford University Press, 2011, 2nd Edition.
2. Jacob N. Israelachvili, Intermolecular and Surface Forces, Academic Press, 2011, 3rd Edition.
3. Paul C. Hiemenz and Raj Rajagopalan, Principles of Colloids and Surface Chemistry, Taylor and Francis, 1997, 3rd Edition.

Reference Books:

1. John B. Hudson, Surface Science: An Introduction, John Wiley & Sons, 1998.

Course Code CH4241	STATISTICAL THERMODYNAMICS	L-T-P 3 – 0 – 0	Credits 3 Cr

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:

	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:

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. Terrell L. Hill, An Introduction to Statistical Thermodynamics, Courier Corporation, 2012.
2. Donald A. McQuarrie, Statistical Mechanics, Viva Books Pvt. Ltd., 2018.
3. Normand M. Laurendeau, Statistical Thermodynamics: Fundamentals and Applications, Cambridge University Press, 2005

Course Code CH4251	POLYMER TECHNOLOGY	L-T-P 3 – 0 – 0	Credits 3 Cr

Pre-Requisites: None

Course Outcomes:

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

CO1	Understand the polymerization reaction mechanism & kinetics
CO2	Identify suitable processing method for a given polymer
CO3	Choose additives for polymers, blends
CO4	Characterize polymers using different techniques

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	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: Thermoplastics, Thermosets, Natural polymers, Monomers used for polymer synthesis, Linear, Branch, Cross Linked Polymers, Addition polymers-kinetics, synthesis and reactions, Condensation polymers- kinetics reaction and processes, Polymerization Techniques - Emulsion polymerization and Suspension polymerization, Interfacial Polymerization with their merits, Ewart Kinetics for emulsion polymerization.

Polymer processing & manufacturing methods: Polymer additives, compounding, Fillers, plasticizers, lubricants, colorants, UV stabilizers, fire retardants and antioxidants. Extrusion process, Twin and Single Screw extrusion, Blow moulding, injection moulding, Wet and Dry spinning processes, thermoset moulding. Manufacturing of polymers: flow-sheet diagrams, properties & applications of PE, PP, PS, Polyesters, Nylons, ABS and PC.

Polymer properties and characterization techniques: Factors influencing the polymer properties, Molecular Weights, Polydispersity Index, Different Methods of determination of Molecular weight, Effect of Molecular weight on Engineering Properties of Polymers, Viscoelastic behavior of plastics; Time - temperature superposition; Stress-strain behavior; fracture; creep; hardness; impact behavior; Basics of polymer rheology; Permeability; electrical; optical and flammability properties, Thermodynamics of Polymer Mixtures, ASTM and ISO methods for testing of polymers. Characterization techniques- DSC, TGA, TMA, DMA, UV visible, FTIR, NMR, SEM, TEM, optical microscopy, XRD.

Learning Resources:

Text Books:

1. Fried J. R., Polymer Science and Technology, Prentice Hall of India Pvt. Ltd., 2005, 2nd Edition.
2. Premamoy Ghosh, Polymer Science and Technology, Tata McGraw Hill, 2010, 3rd Edition.

Departmental Elective-4

Course Code CH4301	PROCESS INTENSIFICATION	L-T-P 3 – 0 – 0	Credits 3 Cr

Pre-Requisites: CH2021 Heat Transfer, CH2031 Fluid Mechanics, CH3031 Mass Transfer Operations – II

Course Outcomes:

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

CO1	Identify the scope for process intensification in chemical processes.
CO2	Implement methodologies for process intensification
CO3	Understand scale up issues in the chemical process.
CO4	Solve process challenges using intensification technologies

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	3	1
CO2	3	2	2	1	1	-	-	-	-	-	-	-	1	2	3
CO3	2	1	3	1	1	-	-	-	-	-	-	-	2	3	1
CO4	3	3	2	2	1	-	-	-	-	-	-	-	2	1	1

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction: Theory of Process Intensification, Process Intensification Applications, Main benefits from process intensification, Process Intensifying Equipment, Process intensification toolbox, Techniques for Process Intensification application.

Process Intensification through micro reaction technology: Effect of miniaturization on unit operations and reactions, Design rules, Implementation of Micro-reaction Technology, Inherent Process Restrictions in Miniaturized Devices and Potential Solutions, Microfabrication of Reaction and unit operation Devices - Wet and Dry Etching Processes.

Mixing and Intensified Reactor Systems: Scales of Mixing, Flow Patterns in Reactors, Mixing in Stirred Tanks, Scale-up of Mixing, Heat Transfer, Mixing in Intensified Equipment, Chemical Processing in High-Gravity Fields, Atomizer, Ultrasound Atomization, Nebulizers, High-Intensity Inline Mixers, Static Mixers, Design Principles of Static Mixers, Applications of Static Mixers, Ejectors, Tee Mixers, Impinging Jets, Rotor-Stator Mixers, Higee Reactors.

Combined chemical reactor heat exchangers and reactor separators: Principles of operation, Applications, Reactive absorption, Reactive distillation, Applications of Reactive distillation Processes, Fundamentals of Process Modelling, Reactive Extraction Case Studies: Absorption of NOx Coke Gas Purification.

Compact heat exchangers: Classification of compact heat exchangers, Plate heat exchangers, Spiral heat exchangers, Flow pattern, Heat transfer and pressure drop, Flat tube-and-fin heat exchangers, Microchannel heat exchangers, Phase-change heat transfer, Selection of heat exchanger technology, Feed/effluent heat exchangers, Integrated heat exchangers in separation processes, Design of compact heat exchanger- example.

Enhanced fields: Energy based intensifications, Sono-chemistry, Basics of cavitation, Cavitation Reactors, Flow over a rotating surface, Hydrodynamic cavitation applications, Cavitation reactor design, Nusselt-flow model and mass transfer, The Rotating Electrolytic Cell, Microwaves, Electrostatic fields, Sono-crystallization, Reactive separations, Super critical fluids, Membrane bioreactors, Microwave pyrolysis, Pulsed compression reactor.

Reference Books:

1. Stankiewicz, A. and Moulijn, (Eds.), Reengineering the Chemical Process Plants, Process Intensification, Marcel Dekker, 2003.
2. Reay D., Ramshaw C., Harvey A., Process Intensification, Butterworth Heinemann, 2008.
3. Reay, Ramshaw, Harvey, Process Intensification, Engineering for Efficiency, Sustainability and Flexibility, Butterworth-Heinemann, 2013.
4. Segovia-Hernández, Juan Gabriel, Bonilla-Petriciolet, Adrián (Eds.), Process Intensification in Chemical Engineering Design Optimization and Control, Springer, 2016.

Course Code CH4311	ENERGY RESOURCES AND SYSTEMS	L-T-P 3 – 0 – 0	Credits 3 Cr

Pre-requisites: None

Course Outcomes:

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

CO1	Understand the basic sources of energy
CO2	Understand Conversion routes of energy
CO3	Understand energy Management
CO4	Develop and solve energy balance equation for industry

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Energy and Development: Units and Measurements, Conventional and Non- Conventional Sources of Energy, Fossil and Mineral Energy Resources, Details of Coal, Peat, Oil, Natural Gas and Nuclear Resources, Recovery of Fossil Fuels, Classification and Characterization of Fossil fuels, Basic of Solar, Wind, Bio, Hydro, Tidal, Ocean Thermal and other Renewable Energy Sources, Impact of Energy on Environment, Flow of Energy in Ecological System, Environmental Degradation due to energy, Control of Pollution from Energy.

Energy, Conversion routes, Direct and indirect way of Energy Conversion, Principles of heat and mass transfer, Thermodynamics, Fluid statics and dynamics, Electricity generation, distribution and use, Basic of Solar Thermal Conversion, Technology of Selective Coating, Fundamentals of Flat Plate Collector and Evacuated Collector, Basic of Wind Energy Conversion, Wind machine, Wind electric generator, Wind pump.

Energy Management and Audit, Basics of Energy Demand and Supply, Principles of Economic analysis in the Energy Management and Audit Programme, Supply side and demand side energy management, Boilers and Firing System, Steam, Condensation Systems, Energy Conservation and Management in power plant, Energy conservation in Buildings, Heating, Ventilation and Air Conditioning System.

Material and energy balance in the industries, Products and the process, industrial demand and supply networking, Optimization techniques, efficiency analysis, methods, Energy monitoring and ongoing information dissertation in terms of energy consumption, production and cumulative sum of differences.

Basic concept of power plants, types of power plants, thermal power stations, various components of thermal power stations, power plant cycles, fuel handling, combustion, waste disposal methodologies, economizers, turbo alternators, heat balance and efficiencies.

Reference Books:

1. Tushar K. Ghosh, Mark A. Prelas, Energy Resources and Systems, Springer, 2011.
2. Nikolai V. Khartchenko, Vadym M. Kharchenko, Advanced Energy Systems, CRC Press, 2^{nd} Edition, 2013.
3. P. Venkataseshaiah and K.V. Sharma, Energy Management and Conservation, Wiley, 2020.

Course Code CH4321	PETROLEUM REFINING PROCESSES	L-T-P 3 – 0 – 0	Credits 3 Cr

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

Other Suggested Readings:

1. https://archive.nptel.ac.in/courses/103/102/103102022/

Course Code CH4331	FUEL CELL TECHNOLOGY	L-T-P 3 – 0 – 0	Credits 3 Cr

Pre-Requisites: CH2011 Chemical Engineering Thermodynamics I, CH2071 Chemical Engineering Thermodynamics II, CH2101 Mass Transfer Operations I

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	Demonstrate the operation of fuel cell stack and fuel cell system.
CO4	Apply the modeling techniques for fuel cell systems

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:

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 Modeling.

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.

Reference 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, 2nd Edition, 2013.
4. Subhash C. Singal and Kevin Kendall, High Temperature Fuel Cells: Fundamentals, Design and Applications.
5. Larminie J, Dicks A, Fuel Cell Systems Explained, 2nd Edition, John Wiley, New York, 2003.

Course Code CH4341	SCALE UP METHODS	L-T-P 3 – 0 – 0	Credits 3 Cr

Pre-Requisites: CH1011-Introduction to Chemical Engineering; CH2041-Mechanical Operations; CH2101-Mass Transfer Operations – I; CH3011-Chemical Technology

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:

	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 criterion and scale up methods used in chemical engineering, experimental techniques for scaleup.

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.

Reference Books:

1. Marko Zlokamik, Scale-up in Chemical Engineering, Wiley-VCH, 2nd Ed, 2006.
2. Johnstone, Thring, Pilot Plants Models and Scale-up methods in Chemical Engineering, McGraw Hill, New York, 1962.
3. Hoyle W, Pilot Plants and Scale-Up, Royal Society of Chemistry, 1999.
4. Bruce Nauman E, Chemical Reactor Design, Optimization and Scale-up, McGraw Hill Handbooks, New York, 2002.

Course Code CH4351	MATHEMATICAL METHODS IN CHEMICAL ENGINEERING	L-T-P 3 – 0 – 0	Credits 3 Cr

Pre-Requisites: None

Course Outcomes:

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

CO1	Understand vector space and its application in chemical Engineering
CO2	Application of linear equations in chemical Engineering
CO3	Understand initial value problems and its application
CO4	Understand the solution procedure of homogeneous PDE
CO5	Understand the solution procedure of homogeneous non homogeneous PDE

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Vectors: Linear combination of vectors, dependent/independent vectors; Orthogonal and orthonormal vectors; Gram-Schmidt Orthogonalization; Examples.

Contraction Mapping: Examples Onto, into, one to one function, Definition; Applications in Chemical Engineering; Examples, Matrix, determinants and properties.

Introduction of vector space: Metric, Norm, Inner Product space; completeness of space. Eigen value Problem: Various theorems; Solution of a set of algebraic equations; Solution of a set of ordinary differential equations; Solution of a set of non-homogeneous first order ordinary differential equations (IVPs).

Applications of eigenvalue problems: Stability analysis; Bifurcation theory; Examples Partial Differential equations: Classification of equations; Boundary conditions; Principle of Linear superposition.

Special odes and Adjoint operators: Properties of adjoint operator; Theorem for eigenvalues and eigen functions. Solution of linear.

Homogeneous PDEs by separation of variables: Cartesian coordinate system & Different classes of PDEs; Cylindrical coordinate system; Spherical Coordinate system, Solution of non-homogeneous PDEs by Green's theorem, Solution of PDEs by Similarity solution method, Solution of PDEs by Integral method, Solution of PDEs by Laplace transformation, Solution of PDEs by Fourier transformation.

Reference Books:

1. S. Pushpavanam, Mathematical methods in chemical engineering. Taylor & Francis, 1st edition (2007).
2. B.K. Dutta, Mathematical Methods in Chemical and Biological Engineering. CRC Press; 1st edition (2016)
3. N.W. Loney, Applied mathematical methods for chemical engineers. CRC Press; 3rd edition (2015).

Departmental Elective-5

Course Code CH4401	PROCESS AND PRODUCT DESIGN	L-T-P 3 – 0 – 0	Credits 3 Cr

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:

	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, the chain of chemical products, companies engaging in production of chemical products, b2b and b2c chemical products, market sectors and classes of chemical products, product design and development, 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 energy balances, equipment sizing and costing, economic evaluation, heat and mass integration, environment, sustainability, and safety, controllability assessment, optimization, preliminary flowsheet 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, 1999, 4th Edition.
2. E. L. Cussler, G. D. Moggridge, Chemical Product Design (Cambridge Series in Chemical Engineering), Cambridge University Press, 2011, 2nd Edition

Course Code CH4411	INDUSTRIAL SAFETY AND HAZARD MITIGATION	L-T-P 3 – 0 – 0	Credits 3 Cr

Pre-Requisites: CE1051-Environmental Science and Engineering; CH3011-Chemical Technology

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 the prevention of fires and explosions
CO3	Identify the hazards and preventive measures
CO4	Assess the risks using a 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 & Explosions and concepts to prevent Fires & 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. Daniel A. Crowl and Joseph F. Louvar, Chemical Process Safety Fundamentals with Applications, Prentice Hall, 2013, 3rd Edition.

Reference Books:

1. John Metcalf Coulson, John Francis Richardson, R.K. Sinnott, Chemical Engineering Design, Elsevier Butterworth-Heinemann, 2005, 4th Edition.
2. Ralph King, Safety in the Process Industries, Butterworth-Heinemann Ltd., 1990.

Course Code CH4421	COMPUTATIONAL FLUID DYNAMICS	L-T-P 3 – 0 – 0	Credits 3 Cr

Pre-Requisites: CH2031 Fluid Mechanics, CH3061 Transport Phenomena

Course Outcomes:

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

CO1	Develop governing equations of fluid flow and heat transfer
CO2	Discretize the equations using finite difference and finite volume formulation
CO3	Solve the discretized equations
CO4	Implement pressure velocity coupling algorithms
CO5	Generate grid for a given geometry

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction: CFD approach, Need for CFD.

Governing equations of fluid flow and heat transfer: Introduction to Laws of conservation: Mass, Momentum, Energy equations; Initial and boundary conditions; Conservative form – Differential and Integral forms of general transport equations; Application of Navier-Stokes equations; Classification of physical behaviours – Classification of fluid flow equations.

Discretization of equations: Finite difference / volume methods – 1D, 2D and 3D Diffusion problems, Convection and diffusion problems; Properties of discretization schemes- Central, upwind, hybrid and higher order differencing schemes.

Solution methods of discretised equations: Tridiagonal matrix algorithm (TDMA); Application of TDMA for 2D and 3D problems.

Pressure – velocity coupling algorithms in steady flows: Staggered grid; SIMPLE, SIMPLEC and PISO

Unsteady flows: Explicit scheme, Crank Nicholson scheme, fully implicit scheme, Pressure-velocity coupling algorithms in unsteady flows.

Turbulence modelling: Prandtl mixing length mode - One equation model, k - ε model.

Grid generation: Structured and unstructured grids, Grid generation methods.

Learning Resources:

Text Books:

1. H.K. Versteeg, W. Malalasekera, An Introduction to Computational Fluid Dynamics – The Finite Volume Method, Prentice Hall, 2007, 2nd Edition.
2. John D. Anderson, Jr., Computational Fluid Dynamics – The Basics with Applications, McGraw Hill Education, 2017.

Reference Books:

1. C. Hirsch, Numerical Computation of Internal and External Flows: The Fundamentals of Computational Fluid Dynamics: 1, Wiley, 2007, 2nd Edition.
2. J.H. Ferziger, M. Peric, R.L. Street, Computational Methods for Fluid Dynamics, Springer, 2019, 4th Edition.
3. Sreenivas Jayanti, Computational Fluid Dynamics for Engineers and Scientists, Springer, 2018, 1st Edition.

Other Suggested Readings:

1. https://nptel.ac.in/courses/103106119
2. https://www.cfd-online.com

Course Code CH4431	NANOTECHNOLOGY FOR CHEMICAL ENGINEERS	L-T-P 3 – 0 – 0	Credits 3 Cr

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	Understanding about carbon allotropes, quantum dots, clays
CO4	Analyze the nanomaterials characterization techniques
CO5	State the applications of nanotechnology in catalysis, 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	-	-	-	-	-	-	-	-	1	1	1
CO2	3	2	2	1	-	-	-	-	-	-	-	-	3	2	1
CO3	3	3	1	1	-	-	-	-	-	-	-	-	2	-	-
CO4	2	1	1	1	-	-	-	-	-	-	-	-	1	-	-

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, Classification of Nanomaterials (Shape, Size, Morphology, Origin Etc.)

Preparation Techniques of Nanomaterials: Top-Down Approach, Grinding, Planetary Milling and Comparison of Particles, Bottom-Up Approach, Wet Chemical Synthesis Methods, Microemulsion Approach, Co-Precipitation, Hydrothermal, Colloidal Nanoparticles Production, Sol Gel Methods, Sonochemical Approach, Microwave and Atomization, Lithography, Electrospinning, Sputtering, Arc Discharge Method, Laser Ablation, Drying, Gas Phase Production Methods: Chemical Vapour Depositions. Template (Hard & Soft) Based Nanomaterials, Biosynthesis of Nanomaterials, Electro and Electro Less Deposition Techniques.

Characterization of Nanomaterials: XRD, DLS, Microscopy (SEM, TEM Etc.), Spectroscopy (UV, FTIR & Raman).

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.

Representative Nanomaterials: Carbon Allotropes (Graphene, CNT, CNF, Fullerene etc.), Clays, Quantum Dots, Wells and Wires, Bio Materials (Cellulose Nanocrystals-CNC, Bio Nanofibers).

Applications: Nanomaterials and Catalysis, Nanocomposites, Semiconductors, Nanosensors, Nanomedicine, Energy conservation and storage, Nanoelectronic devices.

Learning Resources:

Text Books:

1. Elnashaie, S. S., Danafar, F., & Rafsanjani, H. H., Nanotechnology for Chemical Engineers, Springer Singapore, 2015.

Reference Books:

1. Kulkarni Sulabha K, Nanotechnology: Principles and Practices, Capital Publishing Company, 2007.
2. Stuart M. Lindsay, Introduction to Nanoscience, Oxford University Press, 2009.
3. Robert Kelsall, Ian Hamley, Mark Geoghegan, Nanoscale Science and Technology, John Wiley & Sons, 2005.
4. Gabor L. Hornyak, H. F. Tibbals, Joydeep Dutta, John J. Moore, Introduction to Nanoscience and Nanotechnology, CRC Press, 2008.
5. Davies, J.H., The Physics of Low Dimensional Semiconductors: An Introduction, Cambridge University Press, 1998.

Course Code CH4441	CARBON CAPTURE, SEQUESTRATION, AND UTILIZATION	L-T-P 3 – 0 – 0	Credits 3 Cr

Pre-Requisites: None.

Course Outcomes:

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:

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

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.

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 in to value added product: 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. CO_2 conversion using solar thermal and photo catalytic processes.

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.

Reference Books:

1. Peter Styring, Elsje Alessandra Quadrelli, Katy Armstrong, Carbon dioxide utilization: Closing the Carbon Cycle, Elsevier, 2015.
2. Goel M, Sudhakar M, Shahi RV, Carbon Capture, Storage and, Utilization: A Possible Climate Change Solution for Energy Industry, TERI, Energy and Resources Institute, 2015.
3. Amitava Bandyopadhyay, Carbon Capture and Storage, CO_2 Management Technologies, CRC Press, 2014.
4. Fennell P, Anthony B, Calcium and Chemical Looping Technology for Power Generation and Carbon Dioxide (CO2) Capture, Woodhead Publishing Series in Energy: No. 82, 2015.

5. Mercedes Maroto-Valer M, Developments in Innovation in Carbon Dioxide Capture and Storage Technology: Carbon Dioxide Storage and Utilization, Vol 2, Woodhead Publishing Series in Energy, 2014.

Course Code CH4451	OPTIMIZATION TECHNIQUES	L-T-P 3 – 0 – 0	Credits 3 Cr

Pre-Requisites: MA1031 Calculus of Several Variables; CS1011 Problem Solving through Computer Programming; MA2021-PDEs, Numerical Methods and Statistics

Course Outcomes:

CO1	Formulate and solve linear Programming Problems
CO2	Determine the optimum solution to constrained and unconstrained
CO3	Apply dynamic programming principle to Linear programming problems.
CO4	Determine the integer solutions to Linear Programming Problems.

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Linear Programming: Introduction and formulation of models, Convexity, Simplex method, Big-M method, Two-phase method, Degeneracy, non-existent and unbounded solutions, revised simplex method, duality in LPP, dual simplex method, sensitivity analysis, transportation and assignment problems, traveling salesman problem.

Nonlinear Programming: Introduction and formulation of models, Classical optimization methods, equality and inequality constraints, Lagrange multipliers and Kuhn-Tucker conditions, quadratic forms, quadratic programming problem, Wolfe's method.

Dynamic Programming: Principle of optimality, recursive relations, solution of LPP Integer Linear Programming: Gomory's cutting plane method, Branch and bound algorithm, Knapsack problem, linear 0-1 problem.

Reference Books:

1. Kanti Swarup, Man Mohan and P.K. Gupta, Introduction to Operations Research, S. Chand & Co., 2006.
2. J.C.Pant, Introduction to Operations Research, Jain Brothers, New Delhi, 2008.
3. N.S. Kambo, Mathematical Programming Techniques, East-West Pub., Delhi, 1991.

Departmental Elective - 6

Course Code CH4501	CHARACTERIZATION OF MATERIALS	L-T-P 3 – 0 – 0	Credits 3 Cr

Pre-Requisites: None.

Course Outcomes:

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

CO1	Exposed to impart the knowledge of experimental methods for characterization of various synthesized materials
CO2	Expected to be conversant with various characterization techniques
CO3	Competent to carry out experiments to find out the structural, thermal, chemical and mechanical properties of materials of concern
CO4	Analyze various characteristics of materials and its suitability in desired applications

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:

Materials characterization: importance and applications; principles of X-ray diffraction (XRD) methods.

Microscopy techniques: optical and electrons (SEM and TEM) microscopy; Introduction to spectroscopy (UV-vis, IR and Raman).

Thermal stability analysis: thermogravimetric analysis (TGA) and differential scanning calorimetry (DSC). Mechanical property characterization: principles and characterization of tensile, compressive, hardness, fatigue, and fracture toughness properties.

Principles of characterization of other materials properties: BET surface area; chemisorption; particle size; zeta potential; rheology; and interfacial tension.

Reference Books:

1. Y. Leng, Materials Characterization: Introduction to microscopic and spectroscopic methods, 1st Ed., John Wiley & Sons, 2008.
2. A.W. Adamson and A.P. Gast, Physical Chemistry of Surfaces, John Wiley, New York, 1997.
3. D. G. Baird and D. I. Collias, Polymer Processing Principles and Design, Butterworth Heinemann, Massachusetts, 1995.
4. A.J. Milling, Surface Characterization Methods: Principles, techniques, and applications, Marcel Dekker, 1999.
5. G. Ertl, H. Knozinger and J. Weitkamp, Handbook of Heterogeneous Catalysis, Vol. 2, Wiley VCH, 1997. 6. W.D. Callister (Jr.), Material Science and Engineering: An introduction, 8th Ed., John Wiley & Sons, 2010.

Course Code CH4511	SOFT COMPUTING TECHNIQUES	L-T-P 3 – 0 – 0	Credits 3 Cr

Pre-Requisites: MA1031 Calculus of Several Variables; CS1011 Problem Solving through Computer Programming; MA2021-PDEs, Numerical Methods and Statistics

Course Outcomes:

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

CO1	Understand the concept of neural networks
CO2	Use neural networks to control the process plants
CO3	Develop fuzzy logic-based controllers for different processes
CO4	Combine fuzzy logic with neural networks for plant control
CO5	Optimize solutions using evolutionary principles via genetic algorithm-based techniques

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction to Neural Networks: Artificial Neural Networks: Basic properties of Neurons, Neuron Models, and Feed forward networks. Computational complexity of ANNs.

Neural Networks Based Control: ANN based control: Introduction: Representation and identification, modeling the plant, control structures - supervised control, Model reference control, Internal model control, Predictive control: Examples - Inferential estimation of viscosity a chemical process, Auto - tuning feedback control, industrial distillation tower.

Introduction to Fuzzy Logic: Fuzzy Controllers: Preliminaries - Fuzzy sets and Basic notions - Fuzzy relation calculations - Fuzzy members - Indices of Fuzziness - comparison of Fuzzy quantities - Methods of determination of membership functions.

Fuzzy Logic Based Control: Fuzzy Controllers: Preliminaries - Fuzzy sets in commercial products - basic construction of fuzzy controller - Analysis of static properties of fuzzy controller - Analysis of dynamic properties of fuzzy controller - simulation studies - case studies - fuzzy control for smart cars.

Neuro - Fuzzy and Fuzzy - Neural Controllers: Neuro fuzzy systems: A unified approximate reasoning approach - Construction of role bases by self-learning: System structure and learning. Introduction to Genetic algorithms. Controller design using genetic algorithms.

Genetic Algorithms: Concept of "Genetics" and "Evolution" and its application to probabilistic search techniques; Basic GA framework and different GA architectures; GA operators: Encoding, Crossover, Selection, Mutation, etc.; Solving single-objective optimization problems using GAs

Textbooks:

1. D. K. Pratihar, Soft Computing, Narosa Publishing House, 2008.
2. S. Haykin, Neural Networks: A Comprehensive Foundation, 2nd Ed, Pearson Education, 1999.
3. G. Chen and T. T. Pham, Introduction to Fuzzy Sets, Fuzzy Logic, and Fuzzy Control Systems, CRC Press, 2001.

Reference Books:

1. Bose and Liang, Artificial Neural Networks, Tata McGraw Hill, 1996
2. Huaguang Zhang, Derong Liu, Fuzzy Modeling and Fuzzy Control, Birkhauser Publishers, 2006.
3. Kosco B, Neural Networks and Fuzzy Systems: A Dynamic Approach to Machine Intelligence, Prentice Hall of India, 1992.
4. S.N. Sivanandam, S.N. Deepa, Principles of Soft Computing, John Wiley & Sons, 2007.

Course Code CH4521	SOLID AND HAZARDOUS WASTE MANAGEMENT	L-T-P 3 – 0 – 0	Credits 3 Cr

Pre-Requisites: None.

Course Outcomes:

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

CO1	Understand the concept of solid waste management
CO2	Recognize the various classifications of solid waste and characteristics of solid waste
CO3	Identify and evaluate the methods of collection and management of solid waste
CO4	Identification, regulation, treatment, and disposal of hazardous waste

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Municipal Solid Waste Management: Legal and Organizational Foundation: Definition of Solid Waste – Waste Generation Technological Society – Major Legislation, Monitoring Responsibilities, Sources and Types of Solid Waste – Sampling and Characterization – Determination of Composition of MSW – Storage and Handling of Solid Waste – Future Changes in Waste Composition.

Collection and Transport of Solid Waste: Collection of Solid Waste: Type of Waste Collection Systems, Analysis of Collection System – Alternative Techniques for Collection System.

Separation and Processing and Transformation of Solid Waste: Unit Operations User for Separation and Processing, Materials Recovery Facilities, Waste Transformation Through Combustion and Aerobic Composting, Anaerobic Methods for Materials Recovery and Treatment– Energy Recovery – Incinerators Transfer and Transport: Need for Transfer Operation, Transport Means and Methods, Transfer Station Types and Design Requirements.

Landfills: Site Selection, Design and Operation, Drainage and Leachate Collection Systems – Requirements and Technical Solution, Designated Waste Landfill Remediation – Integrated Waste Management Facilities.

Hazardous Waste Management: Definition and Identification of Hazardous Wastes-Sources and Characteristics – Hazardous Wastes in Municipal Waste – Hazardous Waste Regulations – Minimization of Hazardous Waste-Compatibility, Handling and Storage of Hazardous Waste-Collection and Transport, e-waste - Sources, Collection, Treatment and Reuse Management.

Hazardous Waste Treatment and Design: Hazardous Waste Treatment Technologies - Design and Operation of Facilities for Physical, Chemical and Thermal Treatment of Hazardous Waste – Solidification, Chemical Fixation and Encapsulation, Incineration. Hazardous Waste Landfills: Site Selection, Design and Operation – Remediation of Hazardous Waste Disposal Sites.

Reference Books:

1. G. Tchobanoglous, H. Theisen, and S. Vigil, Integrated Solid Waste Management: Engineering Principles and Management Issue, McGraw-Hill Publication, 1993.
2. C. A. Wentz, Hazardous Waste Management, McGraw Hill Publication, 1995.

Course Code CH4531	AIR POLLUTION CONTROL	L-T-P 3 – 0 – 0	Credits 3 Cr

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	Understand meteorological aspects of air pollution
CO3	Understand air pollution control methods
CO4	Design unit operations for pollution control.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	2	3	-	-	-	-	3	-	-	-	-	-	-	-	-
CO2	1	3	-	-	-	-	3	-	-	-	-	-	-	-	-
CO3	1	3	-	1	-	-	3	-	-	-	-	-	-	-	-
CO4	1	3	3	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: Control methods, Source correction methods, Cleaning of gaseous effluents, Particulate emission control, Selection of a particulate collector, Control of gaseous emissions.

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

Design of Air Pollution Control Equipment: Design of settling chamber, cyclone separators, wet and dry scrubbers, bag filters, electrostatic precipitators.

Indoor Air Pollution Control: sources and types of indoor air pollutants, control of indoor air pollution

Current Issues: hazardous air pollutants, CO2 budgeting, air pollution effects on climate change, global air pollution, air pollution mitigation and adaptation to climate change

Reference Books:

1. C.S. Rao, Environmental Pollution Control Engineering, Wiley Eastern Limited, India, 1993.
2. Noel de Nevers, Air Pollution and Control Engineering, McGraw Hill, 2000.
3. M.N. Rao and Rao H.V.N - Air Pollution, Tata – McGraw Hill Publishing Ltd., 1993.

Course Code CH4541	MEMBRANE TECHNOLOGY	L-T-P 3 – 0 – 0	Credits 3 Cr

Pre-Requisites: None.

Course Outcomes:

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

CO1	Acquire in-depth knowledge in the areas of membrane separation mechanisms, transport models, membrane permeability computations, membrane types and modules, membrane contactors / reactors and applications
CO2	Develop skills in applying transport models for the calculation of membrane permeability, flux, and the extent of separation for various membrane separation systems
CO3	Be able to determine the types of experimental data needed for the calculation of membrane permeability parameters
CO4	To be able to calculate membrane process performance and analyze membrane separation characteristics
CO5	Be able to select membrane processes for solving separation problems

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Overview of Membrane Science and Technology: Historical Development of Membranes, Types of Membranes, Membrane Processes.

Membrane Transport Theory: The Solution-Diffusion Model, Structure-Permeability Relationships in Solution-Diffusion Membranes, Pore-Flow Membranes.

Membranes and Modules: Isotropic Membranes, Anisotropic Membranes, Inorganic Membranes, Liquid Membranes, Hollow Fiber Membranes, Membrane Modules.

Concentration Polarization and Fouling: Concentration Polarization in Liquid Separation Processes, Gel Layer Model, Osmotic Pressure Model, Boundary Layer Resistance Model, Concentration Polarization in Gas Separation Processes, Membrane Fouling, Fouling Control.

Membrane Processes: Theory, System Design, Applications and Economics: Membrane Processes: Theory, System Design, Applications and Economics, Reverse Osmosis, Pressure-Retarded Osmosis and Nanofiltration, Ultrafiltration, Microfiltration, Gas Separation, Pervaporation, Ion Exchange Membrane Processes like Electrodialysis, Fuel Cell Membranes, Membranes in Chlor-Alkali Processes, Membrane Contactors, Membrane Distillation, Membrane Reactors and Membrane Bioreactors, Carrier Facilitated Transport, Submerged Membranes, Medical Applications of Membranes

Reference Books:

1. O.V. Nakagawal, O. Yoshihito, Membrane Science and Technology, Marcel Dekker, 1992.
2. C.J. King, Separation Processes, Tata Mc Graw Hill Co. Ltd., 1982.
3. R.E. Lacey, S. Looeb, Industrial Processing with membrane, Wiley Inter-Science New

York,1972.
4. Membrane Separation Fundamentals and Applications Dr. Andre R. Da Costa.
5. Mulder M, Basic Principles of Membrane Technology, Kluwer Academic Publishers,1996.
6. Porter, M.C., Handbook of Industrial Membrane Technology. Noyes Publications, 1998.

Course Code CH4551	INDUSTRIAL ENERGY SYSTEMS	L-T-P 3 – 0 – 0	Credits 3 Cr

Pre-Requisites: CH1011-Introduction to Chemical Engineering; CH2011-Chemical Engineering Thermodynamics – I; CH2021-Heat Transfer; CH3011-Chemical Technology

Course Outcomes:

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

CO1	Understand the different technologies and heat distribution configurations for various industrial systems
CO2	Optimize the process parameters and investment cost using process integration methods
CO3	Understand the design a heat exchanger network for maximum heat recovery for a given process
CO4	Identify opportunities for integration of high-efficiency energy conversion technologies and energy-intensive thermal separation operations (distillation, evaporation) at an industrial process site
CO5	Identify the cost-optimal mix of technologies for an industrial process heat demand

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 to Industrial Process Energy Systems: Concepts, Heat Balances, Heat Distribution Systems; Local Heating Vs Central Heating Systems; Illustrating Example from The Pulping Industry.

Energy Conversion Technologies in Industrial Energy Systems: Overview of Technologies and Engineering Thermodynamics for Process Utility Boilers, Heat Pumps, Steam Turbine Combined Heat and Power (CHP) And Gas Turbine CHP. Energy Conversion Performance of Such Systems for Given Energy Conversion Process Parameters, And Given Industrial Process Heat Load Characteristics.

Process Integration: Basics of Process Integration Methodologies with Emphasis On Pinch Analysis (Pinch Temperature, Minimum Process Heating and Cooling Requirements, Composite Curves and Grand Composite Curves, Targeting for Minimum Number of Heat Exchanger Units, And Heat Exchanger Surface Area Costs). Design of Heat Exchanger Networks for Maximum Heat Recovery. Process Integration Principles for Energy-Intensive Thermal Separation Operations (Distillation, Evaporation). Energy Efficiency and Economic Performance Evaluation of Process Integration Measures. Process Integration Methodologies for Retrofit Applications in Existing Industrial Energy Systems.

Economics of Energy Conversion in Industrial Energy Systems: Characteristics of Heat Pumps and Combined Heat and Power (CHP) Units (Performance, Investment Costs). Influence of Operating Conditions On Performance. Optimization of Size and Various Design Parameters Based On Process Integration Principles. Methodology for Identifying the Cost-Optimal Mix of Technologies for Satisfying a Process Heat Demand, Accounting for Heat Load Variation Over the Course of the Year. Greenhouse Gas Emissions Consequences of Energy Efficiency Measures in

Industry. Greenhouse Gas Emissions from Industrial Energy Systems. Optimization of Industrial Energy Systems Considering Future Costs Associated with Greenhouse Gas Emissions.

Reference Books:

1. D.W. Linnhoff et al., User Guide on Process Integration for the efficient use of Energy, Institution of Chemical Engineers, U.K., 1994.
2. R. E. Putman, Industrial Energy Systems: Analysis, Optimization, and Control, ASME Press, 2004.
3. A. Kumar, Chemical Process Synthesis and Engineering Design, Tata McGraw Hill New Delhi, 1977.
4. F.M. Vanek, L.D. Albright, L.T. Angenent, Energy Systems Engineering: Evaluation and Implementation, 2nd Edition, Mc-Graw Hill, 2012.

Course Code CH4561	FUEL & COMBUSTION	L-T-P 3 – 0 – 0	Credits 3 Cr

Pre-Requisites: None.

Course Outcomes:

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

CO1	The concepts of coal origin, classification, preparation and their conversion technologies for energy production
CO2	The different types of unit process involved in petroleum refining
CO3	The manufacturing process of gaseous fuels and their utilization utilization
CO4	The knowledge on various alternate energy technologies and their importance in fulfilling the present-day energy needs

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction: Energy sources (conventional & non-conventional), renewable energy resources, primary & secondary energy sources, energy chain, energy demand, national energy strategy & plan, world energy scenario.

Solid Fuels: Coal, origin, composition & classification of coal, Properties of coal, classification of Indian coals, petrology of coal,washing of coal, storage of coal. Coal carbonisation, Combustion equipments- Fluidised bed combustion, different types of furnaces, gasification of coal, Lurgi process, Winkler process, Kopper–Totzek process, liquefaction of solid fuels, Overview of thermal plant.

Liquid Fuels: Petroleum and related products, origin, occurrence and reserves, nature of petroleum crudes, classification and characteristics of petroleum, Refining Unit Process: Cracking, Hydrocracking, Reforming, Alkylation, Polymerization, Isomerization. Petroleum products: naphtha, motor gasoline, aviation gasoline, kerosene, diesel oil, gas oil, fuel oil, lubricants, petroleum waxes, petroleum coke. Overview of petroleum refinery.

Gaseous Fuels: Gaseous fuels classification, Wobbe Index natural gas, and methane from coal mines, producer, water, carbureted water gas, coal, blast furnace, refinery gases, and LPG.

Alternate Energy Technologies: Nuclear energy-Fission, fusion, nuclear fuel, fast breeder reactor. Solar energy-Solar radiation & related terms, measurement of solar radiation, solar energy collectors, applications & advantages of various collectors. Wind energy-Basic principles, site selection, basic components of wind energy conversion systems (WECS), classification of WECS, Bioenergy-Introduction, classification of biomass, biomass conversion technologies, Ocean energy, Geothermal energy, Hydro energy, fuel cell technology and Energy Storage Technologies

Reference Books:

1. Gupta O. P., “Elements of Fuels, Furnaces and Refractories”, Khanna Publishers
2. Brame J. S., King J. C., “Fuels-Solid, Liquid and Gaseous”, St. Martin Press Sarkar S., “Fuels and combustion”, Longman publishers India Ltd., 2nd Edition.
3. Energy Technology by Rao & Parulaker.
4. Energy Sources 2nd Ed. by G. D. Rai, Khanna Publications, New Delhi

Course Code CH4571	RENEWABLE ENERGY AND SUSTAINABLE DEVELOPMENT	L-T-P 3 – 0 – 0	Credits 3 Cr

Pre-Requisites: None.

Course Outcomes:

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

CO1	To understand the principles of operation of the broad spectrum of renewable energy technologies
CO2	Develop a comprehensive understanding of renewable energy technologies
CO3	Gain insight into renewable energy applications in real world scenarios
CO4	Select suitable sustainable energy technologies

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Principles of renewable energy; energy and sustainable development: Fundamentals and social implications. worldwide renewable energy availability, renewable energy availability in India, brief descriptions on solar energy, wind energy, tidal energy, wave energy, ocean thermal energy, biomass energy, geothermal energy, oil shale.

Classification of energy sources and reserves: Environmental aspects of energy, Global warming, Greenhouse effect, Sustainable Development, Sustainable Development Goals of United Nations. Energy and sustainable development goals. World Energy Scenario, Indian Energy Scenario, Power sector contributions to CO2
emissions, Decarbonizing the energy systems.

Bioenergy: Types and availability of biomass resources, various methods of biomass utilization for energy generation: gasification, briquette, palatization, syn-gas, Anaerobic/Aerobic digestion, ethanol and biodiesel production, types of Bio-gas digesters, Combustion characteristics of bio-gas and its different utilizations.

Fuel Cells and Hydrogen Energy: Introduction, principle of fuel cells, types of fuel cells, fuel cell batteries, Hydrogen as a renewable energy source, sources of hydrogen, fuel for vehicles, hydrogen production- direct electrolysis of water, thermal decomposition of water, methods of hydrogen production-blue, green and grey hydrogen, hydrogen energy storage, applications of hydrogen energy, problem associated with hydrogen energy. Other systems: Geothermal, wave energy, ocean energy.

Solar Energy: Fundamentals; Solar Radiation; Estimation of solar radiation on horizontal and inclined surfaces; Solar radiation Measurement, Principle of Solar cell, Photovoltaic system for electric power generation.

National solar mission: National mission on CO_2 emissions reduction. Energy Efficiency, Energy conservation, Energy efficient appliances, Energy Management, Demand side management, Energy audit, Power factor improvement, Pyramid of Energy Conservation, Green Buildings.

Reference Books:

1. Boyle, Godfrey. Renewable Energy: Power for a Sustainable Future, Third Edition. Oxford University Press, 2012.
2. Tester, et al. Sustainable Energy, Choosing Among Options, 2nd Edition. MIT Press, 2012.
3. Robert A. Huggins, Energy storage, Springer Science & Business Media, 2010
4. Shobh Nath Singh, Non-Convention Energy Resources, Pearson, 2018

Course Code CH4581	CLIMATE CHANGE AND NET ZERO	L-T-P 3 – 0 – 0	Credits 3 Cr

Pre-Requisites: None.

Course Outcomes:

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

CO1	Identify the source and effect of climate change
CO2	Understanding basic science of climate change
CO3	Evaluate availability of technology, international legal and policy
CO4	Pathway to reach net zero emission of carbon

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction to climate change: climate, weather and the greenhouse gas effect, the human contribution to climate change and greenhouse gases main sources, the climate change since the industrial revolution. impacts of climate change on surface temperature, precipitation, ocean pH, sea-level and Arctic sea-ice extent.

The science of climate change Carbon Cycle and Emissions: Natural and anthropogenic carbon cycles, Major greenhouse gases: CO_2, CH_4, N_2O, etc. Emissions sources: transportation, energy production, industry, agriculture, Measuring and Monitoring: Emissions - Carbon accounting and metrics, Tools for emissions measurement and reporting.

Innovation and Technologies for Climate Change Mitigation: Renewable Energy Technologies -Solar, wind, hydro, and geothermal energy, Advancements in battery storage and grid integration, Carbon Capture and Sequestration (CCS)-Technologies for capturing CO_2 emissions, Storage methods: geological and ocean storage, Challenges and potential for large-scale deployment, Climate Smart Technologies, AI and machine learning in climate modeling and prediction, Smart agriculture and precision farming.

Introduction to the International Legal and Policy Framework to Address Climate Change: a brief history of international climate change negotiations and introduces the United Nations Framework Convention on Climate Change (UNFCCC). Paris Agreement and Nationally Determined Contributions (NDCs), Role of international organization. Financing Climate Action Green bonds and climate financing and Funding for renewable energy projects and climate adaptation.

Pathways to Net Zero: Understanding Net Zero - Definition of Net Zero emissions, the role of carbon neutrality in mitigating climate change, Decarbonization Strategies - Renewable energy transition (solar, wind, hydro, etc.) Energy efficiency improvements in buildings, transportation, and industry, Carbon capture, utilization, and storage (CCUS), the role of nature-based solutions (forests, reforestation, etc.), Achieving Net Zero in Different Sectors- Transport, Industry, Agriculture, Urbanization.

Reference Books:

1. Cambridge University (2013). Climate Change: Action, Trends and Implications for Business.
2. IISD, UNITAR & UNEP (2009). IEA Training Material: Vulnerability and Climate Change Impact Assessment for Adaptation.
3. IPCC (2013). Climate Change 2013. The Physical Science Basis - Summary for Policymakers.
4. OECD (2009): Guidance on Integrating Climate Change Adaptation into Development Co-operation.
5. UNEP (2009). Climate Change Science Compendium UNEP (2009). Climate in Peril, a Popular Guide to the Latest IPCC Report.
6. UNEP & UNDP (2011). Mainstreaming Climate Change Adaptation into Development Planning: A Guide for Practitioners.
7. Goel M, Sudhakar M, Shahi RV, Carbon Capture, Storage and, Utilization: A Possible Climate Change Solution for Energy Industry, TERI, Energy and Resources Institute, 2015.

Service Courses offered by ChE to Other Departments

OPEN ELECTIVES COURSES (OEC)

Course Code CH2901	INDUSTRIAL POLLUTION CONTROL	L-T-P 3 – 0 – 0	Credits 3 Cr

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	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	PSO3
CO1	3	1	3	2	1	-	-	-	-	-	-	-	-	2	1
CO2	3	1	3	3	1	-	-	-	-	-	-	-	-	2	1
CO3	3	1	3	3	1	-	-	-	-	-	-	-	-	2	1
CO4	3	1	3	2	1	-	-	-	-	-	-	-	-	2	1
CO5	3	1	3	2	1	-	-	-	-	-	-	-	-	2	1

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.

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.

Text Books:

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

Reference Books:

1. De A.K, Environmental Chemistry, 2007, New Age International Publishers, 7th Edition.
2. George Tchobanoglous, Franklin Louis Burton, H. David Stensel, Metcalf & Eddy, Waste water engineering: treatment and reuse, 2003, McGraw Hill Education, 4th Edition.
3. NPCS Board of consultants and Engineers, E-waste recycling, Asia Pacific Business Press Inc., 2014.
4. Nicholas P. Cheremisinoff, Handbook of Pollution Prevention Practices, 2001, CRC press, 1st Edition.

Other Suggested Readings:

1. https://nptel.ac.in/courses/105/102/105102089/
2. https://nptel.ac.in/courses/103/107/103107

Course Code CH3901	NANOTECHNOLOGY AND APPLICATIONS	L-T-P 3 – 0 – 0	Credits 3 Cr

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	3	3	-	-	3	3	-	-	-	-	3	3	-	-
CO2	3	3	1	-	-	3	3	-	-	-	-	-	3	-	-
CO3	3	1	3	-	-	-	1	-	-	-	-	-	3	3	3
CO4	3	3	3	-	-	-	3	-	-	-	-	-	3	-	-
CO5	3	3	2	-	-	-	3		-	-	-	-	3	-	-

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

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

Fabrication of Nanomaterials: Top-down approach, Grinding, Planetary milling, and particle comparison, Bottom-up Approach, Wet Chemical Synthesis Methods, Microemulsion Approach, production of Colloidal Nanoparticles, Sol-Gel Methods, Sonochemical Approach, Microwave and Atomization, Gas phase Production Methods: Chemical Vapour Deposits.

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

Applications of Nanomaterials: Self-assembly and molecular manufacturing: Surfactant-based system Colloidal system applications, commercial processes of synthesis of nanomaterials, Nanoclay, Commercial case study of nano synthesis - applications in chemical engineering, Hybrid wastewater treatment systems, Electronic Nanodevices, sensor applications, Energy Storage Application.

Safety and Health Issues of Nanomaterials: Environmental Impacts, and Case Studies 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, Joydeep Dutta, 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. T. Pradeep, Nano: The Essentials, McGraw Hill, 2017, 1st Edition

Other Suggested Readings:

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

Course Code CH4901	INDUSTRIAL SAFETY AND MANAGEMENT	L-T-P 3 – 0 – 0	Credits 3 Cr

Pre-Requisites: None.

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 the prevention of fires and explosions
CO3	Identify the hazards and preventive measures
CO4	Assess the risks using a fault tree diagram

Course Articulation Matrix:

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

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 Liquid and Vapors, Explosion-proof Equipment and Instruments, Ventilation, and Sprinkler systems.

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

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

Learning Resources:

Text Books:

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

Reference Books:

1. John Metcalf Coulson, John Francis Richardson, R.K. Sinnott, Chemical Engineering Design, Elsevier Butterworth-Heinemann, 2005, 4th Edition
2. Rulph King, Safety in the process Industries, Butterworth-Heinemann, 1990.