CURRICULUM & SYLLABI

B.Tech. CHEMICAL ENGINEERING

Effective from AY: 2024-25



NATIONAL INSTITUTE OF TECHNOLOGY WARANGAL

WARANGAL, TELANGANA

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Vision and Mission of the Institute
National Institute of Technology Warangal

VISION

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

MISSION

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

Vision and Mission of the Department
Chemical Engineering

VISION

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

MISSION

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

Program: B.Tech. Chemical Engineering

Program Educational Objectives

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

Program Articulation Matrix

PEO / Mission Statements	PEO-1	PEO-2	PEO-3	PEO-4	PEO-5
Providing high quality education in tune with changing needs of industry.	3	3	3	3	3
Generating knowledge and developing technology through quality research in frontier areas of chemical and interdisciplinary fields.	3	2	2	-	-
Fostering industry-academia relationship for mutual benefit and growth.	-	2	-	3	2

1 - Slightly; 2 - Moderately; 3 - Substantially

Program: B.Tech. Chemical Engineering

Program Outcomes

PO-1	**Engineering knowledge**: Apply the knowledge of mathematics, science, Engineering fundamentals, and chemical engineering to the solution of complex engineering problems.
PO-2	**Problem analysis:** Identify, formulate, research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
PO-3	**Design/Development of solutions:** Design solutions for complex chemical engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
PO-4	**Conduct investigations of complex problems:** Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
PO-5	**Modern tool usage:** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex chemical engineering activities with an understanding of the limitations.
PO-6	**The engineer and society:** Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
PO-7	**Environment and sustainability:** Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
PO-8	**Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
PO-9	**Individual and team work:** Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
PO-10	**Communication**: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
PO-11	**Project management and Finance**: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
PO-12	**Life-long learning**: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Program Specific Outcomes

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

CURRICULUM
B.Tech. Chemical Engineering

1st Semester

S.No.	Code	Course Title	L-T-P	Credits
1	MA1161	Linear algebra, Calculus and Ordinary Differential Equations	3-0-0	3
2	CY1161	Engineering Chemistry	3-0-2	4
3	EE1161	Basic Electrical & Electronics Engineering	3-0-0	3
4	ME1161	Engineering Drawing	1-0-4	3
5	CH1101	Design Thinking	0-1-4	3
6	ME1165	Engineering Workshop Practice	0-1-2	2
7	IC1101	EAA1 (Games & Sports / Yoga & Wellness)	0-0-0	0
			Total Credits	18

2nd Semester

S.No.	Code	Course Title	L-T-P	Credits
1	MA1162	Integral and Vector Calculus, Laplace Transforms	3-0-0	3
2	PH1161	Engineering Physics	3-0-2	4
3	HS1161	English for Technical Communication	2-0-2	3
4	CS1101	Programming and Data Structures	3-0-0	3
5	BT1161	Biology for Engineers	2-0-0	2
6	CH1102	Chemical Process Calculations	3-0-0	3
7	CS1103	Programming and Data Structures Laboratory	0-1-2	2
8	IC1102	EAA2 (Games & Sports / Yoga & Wellness)	0-0-0	0
			Total Credits	20

3rd Semester

S.No.	Code	Course Title	L-T-P	Credits
1	CY1271	Industrial Organic Chemistry	3-0-0	3
2	CH1201	Fluid and Particle Mechanics	3-1-0	4
3	CH1203	Mechanical Operations	3-0-0	3
4	CH1205	Chemical Engineering Thermodynamics	3-0-0	3
5	CH1207	Heat Transfer	3-0-0	3
6	CH1209	Mechanical Operations Laboratory	0-1-2	2
7	CH1211	Fluid and Particle Mechanics Laboratory	0-1-2	2
			Total Credits	20

4th Semester

S.No.	Code	Course Title	L-T-P	Credits
1	MA1263	Partial differential equations, Statistics and Numerical methods	3-0-0	3
2	MM1262	Material Science and Engineering	3-0-0	3
3	CH1202	Solution thermodynamics and Phase Equilibria	3-1-0	4
4	CH1206	Fundamentals of Mass Transfer	3-0-0	3
5	CH1208	Chemical Reaction Engineering	3-1-0	4
6	CH1210	Heat Transfer Laboratory	0-1-2	2
7	CH1212	Chemical Reaction Engineering Laboratory	0-1-2	2
			Total Credits	21

5th Semester

S.No.	Code	Course Title	L-T-P	Credits
1	MS1262	Business Essentials for Engineers	3-0-0	3
2	CH1301	Mass Transfer Operations	3-1-0	4
3	CH1303	Elements of Transport Phenomena	3-1-0	4
4	CH1305	Heterogeneous Reaction Engineering	3-0-0	3
5	CH13XX	Professional Elective - I	3-0-0	3
6	CH1307	Mass Transfer Laboratory	0-1-2	2
7	CH1309	Computational Methods in Chemical Engineering Laboratory	0-1-2	2
8	CH1381	Fractal Course - I	1-0-0	0.5
			Total Credits	21.5

6th Semester

S.No.	Code	Course Title	L-T-P	Credits
1	CH1302	Instrumentation and Process Control	3-1-0	4
2	CH1304	Chemical Technology	3-0-0	3
3	CH13XX	Professional Elective - II	3-0-0	3
4	CH13XX	Professional Elective - III	3-0-0	3
5	CH1306	Product Development	0-1-4	3
6	CH1308	Design and Simulation Laboratory	0-1-2	2
7	CH1310	Chemical Processing Laboratory	0-1-2	2
8	CH1382	Fractal Course - II	1-0-0	0.5
			Total Credits	20.5

7th Semester

S.No.	Code	Course Title	L-T-P	Credits
1	CH1401	Process Equipment Design and Economics	3-1-0	4
2	CHXXXX	Professional Elective – IV	3-0-0	3
3	CHXXXX	Professional Elective – V	3-0-0	3
4		Open Elective – I	2-0-0	2
5	CH1403	Instrumentation and Process Control Laboratory	0-1-2	2
6	CH1489	Seminar & Technical Writing	0-0-0	2
7	CH1491	Short Term Industrial / EPICS / Research Experience	0-0-0	2
8	CH1495	Minor Project	0-0-0	2
			Total Credits	20

8th Semester

S.No.	Code	Course Title	L-T-P	Credits
1	CHXXXX	Professional Elective – VI	3-0-0	3
2	CHXXXX	Professional Elective – VII	3-0-0	3
3	CHXXXX	Professional Elective – VIII	3-0-0	3
4	CH1498	Major Project	0-0-0	6
			Total Credits	15

Professional Elective Courses:

Professional Electives – I, II & III		
S.No.	**Code**	**Course Title**
1	CH1321	Industrial Safety and Hazard Mitigation
2	CH1322	Pollution Control in Process Industries
3	CH1323	Petroleum Refining Processes
4	CH1324	Pharmaceuticals and Fine Chemicals
5	CH1325	Renewable Energy Sources
6	CH1326	Corrosion Engineering
7	CH1327	Nanotechnology
8	CH1328	Polymer Technology
9	CH1329	Mechanical Design and Drawing
10	CH1330	Fuels and Combustion
11	CH1331	Fertilizer Technology
12	CH1332	Food Technology
13	CH1333	Green Technology
14	CH1334	Pulp and Paper Technology
15	CH1335	Heterogeneous Catalysis
16	CH1336	Analytical Techniques for Chemical Engineers
17	CH1337	Complex Fluids
18	CH1338	Natural Gas Engineering
19	CH1339	Biomass and Biofuels Technology
20	CH1340	Sustainability in Chemical Industries

Professional Elective – IV, V, VI, VII & VIII		
S.No.	**Code**	**Course Title**
1	CH1421	Fuel Cell Engineering
2	CH1422	Process Integration
3	CH1423	Biochemical Engineering
4	CH1424	Interfacial Science
5	CH1425	Process Modelling and Simulation
6	CH1426	Microscale Unit Operations
7	CH1427	Process and Product Design
8	CH1428	Mathematical Methods in Chemical Engineering
9	CH1429	Bioseparation Techniques
10	CH1430	Sustainable Energy Technologies
11	CH1431	Energy Management
12	CH1432	Design of Experiments
13	CH16005	Data Analytics and Machine Learning
14	CH16022	Wastewater Treatment
15	CH16024	Engineering Optimization
16	CH16026	CO_2 Capture, Sequestration and Utilization
17	CH16028	Energy Audit and Conservation
18	CH16029	Chemical Process Synthesis
19	CH16030	Novel Separation Techniques
20	CH16048	Molecular Simulations
21	CH16050	Heat Integration and Process Scheduling
22	CH16052	Statistical Thermodynamics
23	CH16060	Advanced Process Control
24	CH26001	Sustainable Energy Engineering
25	CH26003	Hydrogen Generation and Storage
26	CH26022	Energy Management and Life Cycle Assessment
27	CH26024	Energy, Water and Food Nexus
28	CH26027	Waste to Energy
29	CH26030	Bioenergy and biofuels

Basic Science Courses

S.No.	Code	Course Title	L-T-P	Credits
1	MA1161	Linear algebra, Calculus and Ordinary Differential Equations	3-0-0	3
2	CY1161	Engineering Chemistry	3-0-2	4
3	MA1162	Integral and Vector Calculus, Laplace Transforms	3-0-0	3
4	PH1161	Engineering Physics	3-0-2	4
5	MA1263	Partial differential equations, Statistics and Numerical methods	3-0-0	3

Engineering Science Courses

S.No.	Code	Course Title	L-T-P	Credits
1	EE1161	Basic Electrical & Electronics Engineering	3-0-0	3
2	ME1161	Engineering Drawing	1-0-4	3
3	ME1165	Engineering Workshop Practice	0-1-2	2
4	CS1101	Programming and Data Structures	3-0-0	3
5	BT1161	Biology for Engineers	2-0-0	2
6	CS1103	Programming and Data Structures Laboratory	0-1-2	2
7	CY1271	Industrial Organic Chemistry	3-0-0	3
8	MM1262	Material Science and Engineering	3-0-0	3

Humanities and Social Science Courses

S.No.	Code	Course Title	L-T-P	Credits
1	HS1161	English for Technical Communication	2-0-2	3
2	MS1262	Business Essentials for Engineers	3-0-0	3

Open Elective Course Offered to Other Department Programs

S.No.	Code	Course Title	L-T-P	Credits
1	CH1475	Nanotechnology and Applications	2-0-0	2
2	CH1477	Industrial Pollution Control	2-0-0	2
3	CH1479	Industrial Safety and Management	2-0-0	2

The Overall Credit Structure

Course Category	Credits
Basic Science	17
Engineering Science	21
Humanities and Social Sciences	06
Program Core	86
Professional Elective	24
Open Elective	2
Total Graded Credit Requirement	156

Minor in Chemical Engineering

Code	Course Title	L-T-P	Credits
CH1M01$	Introduction to Unit Operations and Process Calculations	3-0-0	3
CH1M02$	Essentials of Transport Phenomena	3-0-0	3
CH1M03	Chemical Engineering Thermodynamics	3-0-0	3
CH1M04$	Chemical Reaction Engineering	3-0-0	3
CH1M05	Process Dynamics and Control	3-0-0	3
CH1304$	Chemical Technology	3-0-0	3

* Out of the above, five courses (15 credits) should be completed by students for the award of Minor.
$ Mandatory courses.

Honors in Chemical Engineering

Code	Course Title	L-T-P	Credits
CH16001	Advanced Transport Phenomena	3-0-0	3
CH16003	Advanced Reaction Engineering	3-0-0	3
CH16004	Steady State Process Simulation	3-0-0	3
CH16002	Computational Fluid Dynamics	3-0-0	3
CH16060	Advanced Process Control	3-0-0	3
CH16054	Computational Catalysis	3-0-0	3
CH16005	Data Analytics and Machine Learning	3-0-0	3
CH1H01	Project	0-0-0	3

* Out of the above, five courses (15-20 credits) should be completed by students for the award of Honors.

Honors in Sustainable Energy Generation and Storage Technologies (SEG&ST)

Code	Course Title	L-T-P	Credits
CH26001	Sustainable Energy Engineering	3-0-0	3
CH26003	Hydrogen Generation and Storage	3-0-0	3
CH26002	Electrochemical Energy Storage Systems	3-0-0	3
CH16005	Data Analytics and Machine Learning	3-0-0	3
CH26023	Nuclear Power Technology	3-0-0	3
ME16062	Thermal Energy Storage	3-0-0	3
PH18025	Solar Energy Systems	3-0-0	3
CY16061	Electrochemistry and Materials for Energy Systems	3-0-0	3
CH2H01	Project	0-0-0	3

* Out of the above, five courses (15-20 credits) should be completed by students for the award of Honors.

SYLLABI
B.Tech. Chemical Engineering

1st Semester

MA1161 **3-0-0 (3)**

Linear algebra, Calculus and Ordinary Differential Equations

Pre-Requisites: **None**

Course Outcomes:

CO-1	Solve the consistent system of linear equations
CO-2	Apply orthogonal transformations to a quadratic form
CO-3	Determine the series expansion of a given function
CO-4	Explore the properties of functions of several variables
CO-5	Solve arbitrary order linear differential equations

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	3	3	1	2	1	-	-	-	-	-	-	-	-	1	2
CO-2	3	3	1	2	1	-	-	-	-	-	-	-	-	1	2
CO-3	3	3	1	2	1	-	-	-	-	-	-	-	-	1	2
CO-4	3	3	1	2	1	-	-	-	-	-	-	-	-	1	2
CO-5	3	3	1	2	1	-	-	-	-	-	-	-	-	1	2

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

Syllabus:

Linear Algebra: Vector space, Subspace, Examples, Linear span, Linear independence and dependence, Basis, Dimension, Extension of a basis of a subspace, Intersection and sum of two subspace, Examples. Linear transformation, Kernel and Range of a linear map, Rank-Nullity Theorem (without proof). Rank of a matrix, Row, and column spaces, Solvability of the system of linear equations, Inner product spaces, orthogonal basis, Gram-Schmidt orthogonalization process. Eigenvalues, Eigenvectors, and properties, Caley-Hamilton Theorem (without proof) and applications, diagonalization of a matrix, diagonalization by similarity, and orthogonal transformations.

Differential Calculus: Taylor's theorem with remainders; Taylor's and Maclaurin's expansions; Functions of several variables - continuity, differentiability, partial derivatives, Euler's theorem, change of variables, Jacobians, Functional dependence; Maxima and minima of functions of several variables (2 and 3 variables) - Lagrange's method of multipliers.

Ordinary Differential Equations: First order differential equations - Basic definitions, Geometric interpretation of solutions of first order ODE $y' = f(x, y)$, Exact differential equations, Integrating factors, Linear equation, Reducible to linear form: Bernoulli's equations; Orthogonal trajectories; Higher order linear differential equations with constant coefficients - Cauchy-Euler and Legendre's differential equations, Method of variation of parameters - System of linear differential equations; Applications to physical problems.

Learning Resources:

Text Books:

1. Howard Anton and Chris Rorres, Elementary Linear Algebra with Supplementary Applications, John Wiley & Sons, 2014, 11th Edition.

2. George B. Thomas and Ross L. Finney, Calculus and Analytic Geometry, Pearson, 2020, 9th Edition.
3. Erwin Kreyszig, Advanced Engineering Mathematics, John Wiley and Sons, 2015, 8th Edition.

Reference Books:

1. Dennis G. Zill, Advanced Engineering Mathematics, Jones & Bartlett Learning, 2018, 6th Edition.
2. R. K. Jain and S. R. K. Iyengar, Advanced Engineering Mathematics, Narosa Publishing House, 2016, 5th Edition.

CY1161 **3-0-2 (4)**

Engineering Chemistry

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand the basic concepts of chemistry relevant to materials
CO-2	Apply electrochemical concepts for energy harvesting, conversion and storage
CO-3	Analyze the properties of materials for various applications
CO-4	Comprehend the concepts of instrumentation principles, Spectroscopy and procedures involved in characterization of materials
CO-5	Analyze the metal contents from the ores by understanding the redox process
CO-6	Determine the rate of corrosion by a redox reaction and understand the concept of adsorption

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	3	-	-	-	-	-	-	-	-	-	-	2	1	1	-
CO-2	3	-	-	-	-	-	-	-	-	-	2	2	1	1	-
CO-3	3	2	-	-	-	-	-	-	-	-	2	2	1	1	-
CO-4	3	-	-	-	-	-	-	-	-	-	2	2	1	1	-
CO-5	3	3	3	-	2	-	2	-	2	-	-	-	1	1	-
CO-6	3	3	3	-	2	-	2	-	2	-	-	-	1	1	-

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

Syllabus:

Chemical Kinetics and Thermodynamics: Order of a Reaction, Theories of Reaction Rates Homogeneous and Heterogeneous Catalysis. Thermodynamic variables, Laws of Thermodynamics, Thermodynamic Relationships and Applications.

Electrochemistry and Energy Systems: Introduction to Electrochemistry, Nernst's law and its applications. Batteries, fuel cell and photoelectrochemical systems. Corrosion and its prevention.

Transition Metal Chemistry and Organometallic Chemistry: Bonding in transition metal complexes; Crystal field and MO Theories, Jahn-Teller effect. Properties of Coordination complexes; Metal Carbonyls, EAN and 18-electron rule, Ligands and hapticity; Type of reactions: Oxidative addition, Reductive elimination, Migratory insertion, Hydrogenation, Hydro formylation, Monsanto process and Wacker process.

Engineering Materials: Inorganic and Organic Semiconductors, Magnetic materials, Liquid crystals, Super conductors, Photo conducting Materials and conducting polymers.

Spectroscopic Methods: Liquid Chromatographic and Gas Chromatographic methods. UV-VIS spectroscopy, Infrared spectroscopy, NMR spectroscopy.

List of Experiments:

1. Standardization of $KMnO_4$ solution

2. Estimation of metal content in an ore
3. Estimation of Calcium in milk powder by complexometry
4. Extraction and identification of DNA from green peas/onions
5. Estimation of iodine in iodized common salt
6. Blue printing of an object by photochemical reaction
7. Kinetics of acid hydrolysis of methyl acetate
8. Determination of acid strength in citrus fruit
9. Verification of Beer-Lambert Law and estimation of concentration of food color
10. Evaluation of Eo values of $Zn|Zn^{2+}$ and $Cu|Cu^{2+}$ Electrodes and measure the emf by constructing the Daniel cell
11. Estimation of phosphoric acid in soft drinks by pH metry
12. Separation of natural pigments from mixture using paper chromatography
13. Determination of efficiency of a corrosion inhibitor
14. Verification of Freundlich adsorption isotherm
15. Preparation of a polymer and its analysis
16. Estimation of active pharmaceutical ingredient in a drug

Learning Resources:

Text Books:

1. Shashi Chawla, A Text Book of Engineering Chemistry, Dhanpat Rai & Co. Publications, 2007, 6th Edition.
2. Ashutosh Kar, Text Book of Engineering Chemistry, ED-Tech Publications, 2018.
3. William Kemp, Organic Spectroscopy, Macmillan Education, Limited, 2017.
4. Charles Corwin, Introductory Chemistry laboratory manual: Concepts and Critical Thinking, Pearson Education, 2012.
5. David Collins, Investigating Chemistry: Laboratory Manual, Freeman & Co., 2006.

Reference Books:

1. Michael F. Ashby, David R.H. Jones, Engineering Materials, Elsevier Science, 2012.
2. V. Raghava, Material Science and Engineering, PHI Learning, 2015.
3. J. M. Martin, Materials for Engineering, Elsevier Science, 2006.
4. Peter Atkins, Julio de Paula, James Keeler, Physical Chemistry, Oxford University Press, 2018.

EE1161 **3-0-0 (3)**

Basic Electrical & Electronics Engineering

Pre-Requisites: **None**

Course Outcomes:

CO-1	Analyze DC & AC circuits and determine power & power factor
CO-2	Understand the specifications of electrical machines
CO-3	Identify the type of electrical machines for a given application
CO-4	Analyze basic electronic circuits and estimate the illumination requirements

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	3	3	2	2	2	2	1	-	-	-	-	-	-	1	-
CO-2	3	3	2	2	2	2	1	-	-	-	-	-	-	1	-
CO-3	3	3	2	2	2	2	1	-	-	-	-	-	-	1	-
CO-4	3	3	2	2	2	2	1	-	-	-	-	-	-	1	-

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

Syllabus:

DC Circuits: Kirchhoff'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, Determination of Equivalent Circuit Parameters, Calculation of Regulation & Efficiency of a Transformer.

DC Machines: Principle of Operation, Classification, EMF and Torque Equations, Characteristics of Generators and Motors. Speed Control Methods.

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

Illumination: Terminology, Laws of illumination and Luminance, Luminaries, LED Lighting (Qualitative).

Electric Heating: Principles of resistance heating, induction heating and dielectric heating (Qualitative).

Electronic Devices & Circuits: P-type and N-Type semiconductors, P-N junction diode and its I-V characteristics, Single-phase Half-wave and Full wave rectifiers. Bipolar Junction Transistor-operation and CE, CC & CB configurations, Static Characteristics of SCR-MOSFET- IGBT.

Sensors & Transducers: Thermocouple, Thermistor, Resistance Temperature Detector, Hall effect and Piezoelectric Transducers (Qualitative Treatment only).

Electrical Measuring Instruments: Moving Coil & Moving iron ammeters & voltmeters. Wattmeter's (Qualitative).

Electronics Measurements: Principle of Operation of Digital Multi Meter & Cathode Ray Oscilloscope.

Learning Resources:

Text Books:

1. Edward Hughes, Electrical & Electronic Technology, Pearson Education, 2016, 12th Edition.
2. Vincent Del Toro, Electrical Engineering Fundamentals, Pearson Education, 2015, 2nd Edition.
3. V. K Mehtha, Principals of Electrical & Electronics Engineering, S. Chand Publications, 2010, 3rd Edition.
4. V N Mittle and Arvind Mittle, Basic Electrical Engineering, Tata McGraw Hill, 2005, 2nd Edition.

Reference Books:

1. Millman & Halkias, Integrated Electronics - Analog and Digital Circuit and Systems, Tata McGraw-Hill Education, 2017, 2nd Edition.
2. U Bakshi & A. Bakshi, Basic Electrical Engineering, Technical Publications, 2019.
3. A Fitzgerald, Charles Kingsley, Stephen Umans, Electrical Machines, McGraw Hill Education, 2017, 6th Edition.
4. Stephen. J. Chapman, Electric Machinery, McGraw Hill International Edition, 2017, 4th Edition.
5. P.S. Bimhbra, Electrical Machinery - Theory, Performance & Applications, Khanna Publishers 2014, 7th Edition.

Other Suggested Readings:

1. https://nptel.ac.in/courses/108/108/108108076/

ME1161 **1-0-4 (3)**

Engineering Drawing

Pre-Requisites: **None**

Course Outcomes:

CO-1	Apply BIS standards and conventions while drawing Lines, printing Letters and showing Dimensions
CO-2	Classify the systems of projection with respect to the observer, object and the reference planes
CO-3	Construct orthographic views of an object when its position with respect to the reference planes is defined
CO-4	Analyse the internal details of an object through sectional views
CO-5	Develop 3D Isometric View from 2D orthographic views

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	1	1	1	-	-	-	1	1	3	3	-	-	1	-	-
CO-2	1	1	1	-	-	-	1	1	3	3	-	-	-	-	-
CO-3	1	1	1	-	-	-	1	1	3	3	-	-	-	-	-
CO-4	1	1	1	-	-	-	1	1	3	3	-	-	-	-	-
CO-5	1	1	1	-	-	-	1	1	3	3	-	-	-	-	-

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

Syllabus:

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

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

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

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

Fundamentals of AutoCAD: Introduction to Auto-CAD, DRAW tools, modify tools, text, dimension, properties. **(AutoCAD)**

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

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

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

Isometric Views: Isometric axes, Isometric lines, Isometric Planes, Isometric scale, Isometric Views, Isometric projections. **(AutoCAD)**

Learning Resources:

Text Books:

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

Reference Books:

1. B. Agarwal, Engineering Drawing, 2015, McGraw Hill Education, 2015, 2nd Edition.
2. S. Tickoo, Auto CAD 2017 for Engineers & Designers, Dreamtech, 2016, 23rd Edition.

CH1101 **0-1-4 (3)**

Design Thinking

Pre-Requisites: **None**

Course Outcomes:

CO-1	Identify user needs
CO-2	Define problems to stimulate ideation
CO-3	Ideate on problems to propose solutions by working collaboratively
CO-4	Test aspects of proposed solutions and improve solutions by gaining user feedback
CO-5	To understand the role of standardization for sustainable development

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	3	3	1	1	1	3	1	1	3	3	1	3	2	2	2
CO-2	3	3	2	2	3	3	2	2	3	3	2	3	2	2	2
CO-3	3	3	3	3	3	3	2	2	3	3	2	3	2	2	2
CO-4	3	3	2	3	3	3	2	3	3	3	2	3	2	2	2
CO-5	3	3	2	3	3	3	3	3	3	3	3	3	2	2	2

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

Syllabus:

Introduction to Engineering: “Engineering” as a vehicle for social and economic development; the impact of science/engineering on our day-to-day lives; the process of engineering a product; various career options.

Design thinking: Design thinking Process; comprehensive approach to product design; double diamond approach to design thinking.

Product development process: Product development cycle through design thinking and systems mapping, Case studies on ideation, empathy, problem definition, design-develop-prototype-test–product (solution) development.

Problem Formulation: Framing a problem statement neutrally using adequate checks. Creative problem solving, quality circle, brainstorming and decision-making process.

Concept Generation: Generate multiple concepts using various creativity tools and thinking styles.

Prototyping: Select from ideas and make quick prototypes (mock-ups) using available material.

Evaluation: Iterative process of ideation, prototyping and testing-Take the mock-ups to users for feedback and iterate the process till users feel delighted.

Standardisation: Purpose of Standardisation; marking and certification of articles and processes, Importance of Standards to Industry; policy makers; trade; sustainability and innovation; Introduction to Bureau of Indian Standards (BIS); Objectives, roles and functions of BIS; Bureau of Indian Standards Act.; Case discussion through expert lectures.

Activities:

Some of the activities which are undertaken as a part of this course include:

- Field Visits
- Case Studies on innovation, failures, etc.
- Guest lecture
- Group Discussions
- Presentation by student
- Experiential learning workshops

Learning Resources:

Text Books:

1. Andrew Pressman, Design Thinking: A guide to creative problem solving for everyone, Routledge Taylor and Francis group, 2019, 1st Edition.
2. Brown T, Change by Design, Harper Business, 2019, 1st Edition.
3. Micha L, Link P and Leifer L, The Design Thinking Playbook: Mindful Digital Transformation of Teams, Products, Services, Businesses and Ecosystems (Design Thinking Series) Wiley, 2018, 1st Edition.
4. Tim Brown, Change by Design: How Design Thinking Transforms Organizations and Inspires Innovation, Harper Collins, 2009.
5. SO/IEC Guide 59, BIS Standards Formulation Manual, 2022.

Reference Books:

1. Ulrich, K., Eppinger, S. and Yang, M., Product Design and development, 2020, 7th Edition.
2. Cross N, Design Thinking: Understanding How Designers Think and Work, Bloomsbury Visual Arts 2019, 1st Edition.
3. Kumar V, 101 Design Methods: A Structured Approach for Driving Innovation in Your Organization, Wiley, 2012, 1st Edition.

Other Suggested Readings:

1. https://onlinecourses.nptel.ac.in/noc22_mg32/preview

ME1165 **0-1-2 (2)**

Engineering Workshop Practice

Pre-Requisites: **None**

Course Outcomes:

CO-1	Identify workshop tools and their operational capabilities Credits
CO-2	Practice on manufacturing of components using workshop trades including fitting, foundry and welding
CO-3	Apply suitable tools for machining processes including turning, facing, thread cutting and tapping
CO-4	Apply basic electrical engineering knowledge for House Wiring Practice

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	3	3	1	-	-	1	-	-	2	2	-	-	2	-	-
CO-2	3	3	1	-	2	1	-	-	2	2	-	-	2	-	-
CO-3	3	3	1	-	2	1	-	-	2	2	-	-	2	-	-
CO-4	3	3	1	-	2	1	-	-	2	2	-	-	2	-	-

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

Syllabus:

Demonstration: Safety practices and precautions to be observed in workshop.

Fitting Trade: Demonstration and practice of fitting tools, Preparation of T-Shape, Dovetail Joint. Carpentry: Demonstration and practice of carpentry tools, Preparation of Cross Half lap joint and Mortise Tenon Joint.

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

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

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

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

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

Learning Resources:

Text Books:

1. Felix W., Basic Workshop Technology: Manufacturing Process, Independently Published, 2019.
2. Bruce J. Black, Workshop Processes, Practices and Materials, Routledge publishers, 2015, 5th Edition.
3. B.S. Raghuwanshi, A Course in Workshop Technology Vol I. & II, Dhanpat Rai & Co., 2015 & 2017.

Reference Books:

1. S. K. Hajra Choudhury, and Nirjahar Roy, Elements of Workshop Technology, Vol. I, Media Promoters and Publishers, Mumbai, 2007, 14th Edition.
2. S. K. Hajra Choudhury and Nirjahar Roy, Elements of Workshop Technology, Vol. II, Media Promoters and Publishers, Mumbai, 2007, 12th Edition.
3. H. S. Bawa, Workshop Practice, Tata-McGraw Hill, 2004.
4. Steve F. Krar, Arthur R. Gill and Peter Smid, Technology of machine tools, McGraw Hill Education (India) Pt. Ltd., 2013.
5. Ramesh Babu V., Engineering Practices Laboratory Manual, VRB Publishers Private Limited, Chennai, 2013 – 2014.
6. T. Jeyapoovan, Engineering Practices Lab Manual, Vikas Publishers, 2008, 4th Edition.
7. John K.C., Mechanical Workshop Practice, PHI, 2010.
8. Soni P.M. & Upadhyay P.A., Atul Prakashan, Wiring Estimating, Costing and Contracting, 2021-22.

Other Suggested Readings:

1. https://bharatskills.gov.in

2nd Semester

MA1162 **3-0-0 (3)**

Integral and Vector Calculus, Laplace Transforms

Pre-Requisites: **MA1161**

Course Outcomes:

CO-1	Analyze improper integrals for extracting certain properties of beta and gamma integrals
CO-2	Evaluate multiple integrals in various coordinate systems
CO-3	Apply the concepts of gradient, divergence and curl to formulate engineering problems
CO-4	Convert line integrals into area integrals and surface integrals into volume integrals
CO-5	Apply Laplace transforms to solve physical problems arising in engineering

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	3	3	1	2	1	-	-	-	-	-	-	-	-	1	2
CO-2	3	3	1	2	1	-	-	-	-	-	-	-	-	1	2
CO-3	3	3	1	2	1	-	-	-	-	-	-	-	-	1	2
CO-4	3	3	1	2	1	-	-	-	-	-	-	-	-	1	2
CO-5	3	3	1	2	1	-	-	-	-	-	-	-	-	1	2

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

Syllabus:

Integral Calculus: Improper integrals; Beta and Gamma functions, and their properties; Differentiation under integral sign, Evaluation of double and triple integrals; Areas and Volumes, Change of order of integration; Change of variables in double and triple integrals.

Vector Calculus: Scalar and vector fields; Vector differentiation; Level surfaces; Directional derivative; Gradient of a scalar field; Divergence and curl of a vector field; Laplacian operator; Parametrization of curves and surfaces; Line, surface and volume integrals; Green's theorem in a plane; Stoke's theorem; Gauss divergence theorem.

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

Learning Resources:

Text Books:

1. George B. Thomas and Ross L. Finney, Calculus and Analytic Geometry, Pearson, 2020, 9th Edition.
2. Dennis G. Zill, Advanced Engineering Mathematics, Jones & Bartlett Learning, 2018, 6th Edition.

Reference Books:

1. Maurice D. Weir, Joel Hass and Christopher Heil, Thomas' Calculus: Early Transcendentals, Pearson, 2014, 13th Edition.
2. Erwin Kreyszig, Advanced Engineering Mathematics, John Wiley and Sons, 2015, 8th Edition.
3. R. K. Jain and S. R. K. Iyengar, Advanced Engineering Mathematics, Narosa Publishing House, 2016, 5th Edition.

PH1161 **3-0-2 (4)**

Engineering Physics

Pre-Requisites: **None**

Course Outcomes:

CO-1	Examine the concepts of Interference, diffraction, polarisation to solve engineering problems
CO-2	Assess the technological applications of lasers and optical fibers
CO-3	Apply the quantum mechanical principles for solving engineering problems
CO-4	Understand the basics of nanomaterials and their engineering applications
CO-5	Demonstrate the production, detection and applications of ultrasonics

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	3	3	1	1	-	-	-	-	-	-	-	-	1	1	-
CO-2	3	3	1	1	-	-	-	-	-	-	-	-	1	1	-
CO-3	3	3	2	1	-	-	-	-	-	-	-	-	1	1	-
CO-4	3	3	2	1	-	-	-	-	-	-	-	-	1	1	-
CO-5	3	3	2	1	-	-	-	-	-	-	-	-	1	1	-

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

Syllabus:

Interference: Principle of Superposition, Coherence and Coherent Sources, Production of Coherent Light, Young's Double Slit Experiment, Concept of interference, Newton's Rings, working of Michelson Interferometer, Fabry-Perot Interferometer, and its application as wavelength filter.

Diffraction: Definition and types of Diffractions, Huygen's Principle and types of wave fronts, types of Diffraction, Single Slit Diffraction, Double Slit Diffraction, Diffraction Grating, Derivation of Resolving Power and Dispersive Power, Rayleigh's Criterion and applications.

Polarization: Introduction to Polarization, Production of Polarized Light by Reflection and Refraction, Phenomenon of Double Refraction, Construction and Working of Nicol's Prism, Half-Wave and Quarter Waveplates, Representation of Different Polarized Lights, Optical Activity, Practical Applications of Polarized Light, Construction and Working of Laurent's Half Shade Polarimeter and Engineering Applications.

Lasers & Optical Fibers: Basic theory of Laser, Fundamentals of lasers, Einstein Coefficients, Characteristics of Laser Pumping Mechanisms; Basic Components of Laser System, 2-Level, 3-Level and 4-Level Systems, Construction and working of He-Ne, Nd-YAG, and semiconductor diode Lasers and Engineering Applications of Lasers. Basic Principle of Optical Fiber, Derivation-Numerical Aperture and Acceptance Angle, Types of Optical Fibers (Step and Graded Index, Single Mode and Multimode), Applications in Communications and Sensors.

Quantum Mechanics: Concepts and experiments that led to the discovery of Quantum Nature, de Broglie hypothesis of matter waves, Heisenberg uncertainty principle, Schrodinger time independent and time dependent wave equations, the free particle problem, Particle in an infinite and finite potential well, Quantum mechanical tunneling and applications.

Nanomaterials: Introduction and importance of Nanomaterials, classification (0D, 1D, 2D and 3D) of nanomaterials, properties of nanomaterials, carbon-based nanomaterials, synthesis of nanomaterials, top-down and bottom-up approaches, characterization of nanomaterials, Engineering Applications of Nanomaterials.

Ultrasonics: Production, detection, and applications of ultrasonics.

List of Experiments:

1. Determination of Wavelength of Sodium light using Newton's Rings
2. Determination of Wavelength of He-Ne laser - Metal Scale
3. Measurement of Width of a narrow slit using He- Ne Laser
4. Determination of Specific rotation of Cane sugar by Laurent Half-shade Polarimeter
5. Determination of Numerical aperture, loss, Acceptance angle of optical fiber
6. Determination of plank constant by photo electric effect
7. Determination of I – V characteristics of photo diode
8. Diffraction grating by normal incidence method
9. Determination of capacitance by using R-C circuit
10. Determination of resonating frequency and bandwidth by LCR circuit
11. Strain Gauge
12. Dielectric constant measurements
13. Determination of carrier concentration, charge by using Hall effect experiment
14. Study of I-V characteristics of Solar Cell
15. Determination of velocity of ultrasonic waves and adiabatic compressibility of liquids using ultrasonic interferometer

Learning Resources:

Text Books:

1. Halliday, Resnic and Walker, Fundamentals of Physics, John Wiley, 2011, 9th Edition.
2. Arthur Beiser, Shobhit Mahajan, S. Rai Choudhury, Concepts of Modern Physics, McGraw Hill Publications, 2009, 6th Edition.
3. Shatendra Sharma, Jyotnsa Sharma, Engineering Physics, Pearson Education, 2018.
4. Sulabha K. Kulkarnl, Nanotechnology: principles and practices, Springer publications, 2018, 3rd Edition.
5. G.L. Squire, Practical Physics, Cambridge University press, 2001, 4th Edition.

Reference Books:

1. Ajoy K. Ghatak, Optics, Tata McGraw Hill, 2017, 6th Edition.
2. Jeff Hecht, Understanding Lasers An Entry-Level Guide, Wiley Publications, 2018, 4th Edition.
3. M.N. Avadhanulu, P.G. Khirsagar, A Textbook of Engineering Physics, S. Chand Publishing, 2011, 9th Edition.
4. Hugh D. Young, Roger A. Freedman, University Physics with modern physics, Pearson Education, 2014.
5. B. Rogers, J Adams and S. Pennathur, Nanotechnology the whole story, CRC Press, 2013.
6. S.K. Gupta Krishna, Engineering Physics Practical, Prakashan Publications, 2010, 9th Edition.

Other Suggested Readings:

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

HS1161 **2-0-2 (3)**

English for Technical Communication

Pre-Requisites: **None**

Course Outcomes:

CO-1	Apply principles of technical communication to interact effectively in diverse environments
CO-2	Analyze complex technical documents to extract and synthesize key information
CO-3	Employ reported speech, active and passive voice in engineering and scientific contexts to compile technical reports
CO-4	Demonstrate use of English speech sounds, stress, and intonation in day-to-day situations, conversations, and interactions
CO-5	Interpret technical data presented in the form of graphs, pie charts, and diagrams
CO-6	Critique and provide constructive feedback on peer communication performances and written works

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	-	-	-	-	-	2	-	-	3	3	-	3	-	-	-
CO-2	-	-	-	-	-	-	-	-	3	3	-	3	-	-	-
CO-3	-	-	-	-	-	-	-	-	3	3	-	3	-	-	-
CO-4	-	-	-	2	-	-	-	-	3	3	-	3	-	-	-
CO-5	-	-	-	-	-	-	-	-	3	3	-	3	-	-	-
CO-6	-	-	-	-	-	-	-	-	3	3	-	3	-	-	-

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

Syllabus:

Grammar Principles & Effective Sentence Construction: Correction of Sentences and Concord, Vocabulary Building, Synonyms and Antonyms, Idioms and Phrasal Verbs: Patterns of Use and Suggestions for Effective Employment in Varied Contexts, Technical Vocabulary (Jargons and Registers), Strategies for Bringing Variety and Clarity in Sentences, Removing Ambiguity, Editing Long Sentences for Brevity and Clarity, Reported Speech, Contexts for Use of Reported Speech, Impact on Audiences and Readers, Active and Passive Voice, Reasons for Preference for Passive Voice in Scientific English.

Writing- Paragraph & Letter: Definition of Paragraph and Types, Features of a Good Paragraph, Unity of Theme, Coherence, Linking Devices, Direction, Patterns of Development. Importance in the Context of Other Channels of Communication, Qualities of Effective Letters, Types of Letters, Official Letters, Letters for Various Purposes, Letters of Application for Jobs, Cover Letter and Resume Types, Letters for Internship/Fellowship, Writing Statements of Purpose (SOPs), Examples and Exercises.

Reading Techniques: Definition and Importance, Skills and Sub-Skills of Reading, Skimming and Scanning: Uses and Purposes, Examples and Exercises, Reading Comprehension, Reading Silently and with Understanding, Process of Comprehension, Types of Comprehension Questions.

Technical Writing: Principles of a Technical Report, Know Your Audience, Purpose, and Length of Report, Understand the Cornerstones of a Presentation, Define Various Purposes of Presentations and Plan the Correct Structure, Writing Clear Sentences and Paragraphs, Removing Jargon, Redundancy, and

Wordiness, Kinds of Graphics and Their Messages, Suitability for Placement in Graphic Representation, Introduction to Basic Concepts in Research, Abstract, Keywords, Methodology, Hypothesis, Plagiarism, Critical Reading, Abstract Writing, How to Read Scientific Articles, Basics of Writing a Research Project Proposal, Preparation and Presentation of Project Reports.

Reviews: Oral and Written Review of a Chosen Novel/Play/Movie, Review of Scientific Articles and Science Fiction, Focus on Appropriate Vocabulary and Structure, Use of Special Vocabulary and Idioms.

Language Laboratory:

1. **English Sound System** -vowels, consonants, Diphthongs, phonetic symbols- using dictionary to decode phonetic transcription-- Received Pronunciation, its value and relevance- transcription.
2. **Stress and Intonation** –word and sentence stress - their role and importance in spoken English- Intonation in spoken English -definition, -use of intonation in daily life-exercises.
3. **Introducing oneself in formal and social contexts**- Role plays. - their uses in developing fluency and communication in general.
4. **Oral presentation** - definition- occasions- structure- qualities of a good presentation with emphasis on body language and use of visual aids.
5. **Listening Comprehension**- Challenges in listening, good listening traits, some standard listening tests- practice and exercises.
6. **Debate/ Group Discussions**-concepts, types, Do's and don'ts- intensive practice, Guided writing practice with examples, Drafting – the mindset to avoid writer's block, Checking your own reports and presentations, Giving and receiving constructive feedback.

Learning Resources:

Text Books:

1. English for Engineers and Technologists, Orient Blackswan, 2010, Combined Edition, Vol. 1 and 2.
2. Ashraf, M Rizvi, Effective Technical Communication, Tata McGraw-Hill, 2006.
3. Meenakshi Raman and Sangeetha Sharma, Technical Communication: Principles and Practice Oxford University Press, 2011, 2nd Edition.
4. Tan, Zhongchao, Academic Writing for Engineering Publications: A Guide for Non-native English Speakers, Springer, 2022.

CS1101 **3-0-0 (3)**

Programming and Data Structures

Pre-Requisites: **None**

Course Outcomes:

CO-1	Design algorithms for solving simple mathematical problems including computing, searching and sorting
CO-2	Compare and contrast algorithms in terms of space and time complexity to solve simple mathematical problems
CO-3	Explore the internals of computing systems to suitably develop efficient algorithms
CO-4	Examine the suitability of data types and structures to solve specific problems
CO-5	Apply control structures to develop modular programs to solve mathematical problems
CO-6	Understand the concept of Abstract Data Types and use in real time applications

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	3	1	1	1	2	1	-	-	-	-	-	3	-	-	3
CO-2	2	1	2	1	2	3	-	-	-	-	-	3	-	-	2
CO-3	1	2	2	2	2	1	-	-	-	-	-	3	-	-	2
CO-4	2	2	2	2	2	2	-	-	-	-	-	2	-	-	1
CO-5	2	2	3	1	2	2	-	-	-	-	-	2	-	-	2
CO-6	2	2	3	2	2	2	-	-	-	-	-	2	-	-	2

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

Syllabus:

Fundamentals of 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, Number systems and data representation.

Elements of C++ programming language: Data types, constants, and variables, expressions and assignment statements, input and output statements, conditional and branch statements: If-else, Switch-case constructs, iteration statements: while, do-while, for, Arrays – Single and Multi-Dimensional Arrays, strings, Bit-wise operations.

Functions and Recursion: Modular approach for solving real time problems, user defined functions, library functions, parameter passing - call by value, call by reference, return values, passing arrays as parameters to functions Recursion.

Structures and Classes: Declaration, member variables, member functions, access modifiers, function overloading, Problems on Complex numbers, Date, Time, Large Numbers.

Pointers and Files: Introduction to pointers and dynamic allocation, String processing, File operations-create, read and write.

Searching and sorting: Linear and binary search, selection sort, bubble sort, insertion sort, merge sort, quick sort.

Data structures: Abstract Data Types (ADTs), Stack ADT, Array-Based Implementation of Stack - Applications, Queue ADT, Array Based Implementation - Applications.

Learning Resources:

Text Books:

1. Walter Savitch, Problem Solving with C++, Pearson, 2018, 10th Edition.
2. Cay Horstmann, Timothy Budd, Big C++, Wiley, 2009, 2nd Edition.
3. R.G. Dromey, How to solve it by Computer, Pearson, 2008.
4. Mark Allen Weiss, Data Structures and Algorithm Analysis in C++, Pearson Education, 2006, 3rd Edition.

BT1161 **2-0-0 (2)**

Biology for Engineers

Pre-Requisites: **None**

Course Outcomes:

CO-1	Realize the significance of biomolecules for sustaining life
CO-2	Identify the difference between unicellular to multi-cellular organisms
CO-3	Understand heredity, variation and central dogma of life
CO-4	Apply the concepts of biology for engineering the cell

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	3	2	2	-	-	2	2	-	-	2	-	3	1	1	-
CO-2	3	2	2	-	-	2	-	-	-	-	-	3	1	1	-
CO-3	3	2	2	-	-	2	-	-	-	-	-	3	1	1	-
CO-4	3	3	2	2	1	2	2	1	-	2	-	3	1	1	-

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

Syllabus:

Molecules of Life: Chemical basis of life, Proteins, Nucleic acids, Carbohydrates, Lipids, Membranes and First cell, Inside the cell, Cell cycle and Division.

Information processing in living system: Central dogma, Concept of Gene, Genetic code, Transcription, Translation, Biological signal transduction, Quorum sensing and Biofilm formation.

Biomolecular machines and motors: Cytoskeletal motor proteins, ATP synthase, Cell motility.

Applied Biotechnology: Biocomputing, Synthetic biology, Biosensors, Biomedical instrumentation in disease diagnosis, Biomimicry, Biomechanics, Biomaterials, Nanobiotechnology, Industrial and Environmental Biotechnology, Biosafety and Bioethics.

Learning Resources:

Text Books:

1. Quillin, Allison Scott Freeman, Kim Quillin and Lizabeth Allison, Biological Science, Pearson Education India, 2016.
2. Reinhard Renneberg, Viola Berkling and Vanya Loroch, Biotechnology for Beginners, Academic Press, 2017.

CH1102 **3-0-0 (3)**

Chemical Process Calculations

Pre-Requisites: **None**

Course Outcomes:

CO-1	Convert physicochemical quantities from one system of units to another
CO-2	Calculate mass balances on non-reactive systems
CO-3	Carry out mass balances on reactive systems
CO-4	Perform mass and energy balances in processes involving phase changes
CO-5	Analyse the mass and energy balances for combustion and reactive processes

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	3	2	3	3	2	-	-	-	2	2	1	1	3	3	2
CO-2	3	2	3	3	2	-	-	-	2	2	1	1	3	3	2
CO-3	3	2	3	3	3	-	-	-	2	2	1	1	3	3	2
CO-4	3	2	3	3	3	-	-	-	2	2	1	1	3	3	2
CO-5	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/

CS1103 **0-1-2 (2)**

Programming and Data Structures Laboratory

Pre-Requisites: **None**

Course Outcomes:

CO-1	Design and test programs to solve mathematical and scientific problems
CO-2	Develop and test programs using control structures
CO-3	Implement modular programs using functions
CO-4	Develop programs using classes
CO-5	Develop ADT for stack and queue applications

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	3	2	2	1	2	1	-	-	-	-	-	-	-	-	2
CO-2	1	1	2	1	2	2	-	-	-	-	-	-	-	-	2
CO-3	1	2	3	2	2	1	-	-	-	-	-	-	-	-	2
CO-4	2	2	2	2	2	3	-	-	-	-	-	-	-	-	2
CO-5	2	2	2	2	2	3	-	-	-	-	-	-	-	-	2

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

Syllabus:

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

Learning Resources:

Text Books:

1. Walter Savitch, Problem Solving with C++, Pearson, 2014, 9th Edition.
2. Cay Horstmann, Timothy Budd, Big C++, Wiley, 2009, 2nd Edition.
3. R.G. Dromey, How to solve it by Computer, Pearson, 2008.
4. Mark Allen Weiss, Data Structures and Algorithm Analysis in C++, Pearson Education, 2006, 3rd Edition.

3rd Semester

CY1271 **3-0-0 (3)**

Industrial Organic Chemistry

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand the concepts of organic chemistry to synthesize small organic molecules
CO-2	Apply the knowledge to purify organic compounds
CO-3	Analyse approaches of drug discovery process
CO-4	Design the synthetic process using sustainable approach
CO-5	Predict the structure of organic molecule using spectroscopic methods
CO-6	Develop a synthetic process for an organic compound at larger scale

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	3	-	3	-	-	2	3	-	-	-	-	3	1	2	-
CO-2	3	-	3	-	-	2	3	-	-	-	-	3	1	2	-
CO-3	3	-	3	-	-	2	3	-	-	-	-	3	1	2	-
CO-4	3	-	3	-	-	2	3	-	-	-	-	3	3	2	-
CO-5	3	-	3	-	-	2	3	-	-	-	-	3	1	2	-
CO-6	3	-	3	-	-	2	3	-	-	-	-	3	3	2	-

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

Syllabus:

Current approaches to organic synthesis: Functional group inter conversions, synthesis of value-added chemicals based on functional group inter conversions (synthon approach), alternative reaction media (water, ionic liquids, and deep eutectic solvents), and alternative energy sources (microwave, sonication) for organic reactions. Homogeneous and heterogeneous catalysis.

Purification of organic compounds: Chromatography (Thin-layer, Column, Gas and high-performance liquid chromatography), Bulk separation.

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

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

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

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

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

Learning Resources:

Text Books:

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

Reference Books:

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

Other Suggested Readings:

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

CH1201 **3-1-0 (4)**

Fluid and Particle Mechanics

Pre-Requisites: None

Course Outcomes:

CO-1	Derive dimensionless groups using dimensional analysis
CO-2	Determine pressure differential using the principles of hydrostatic equilibrium
CO-3	Determine the pipe size / flow rate / power requirements under laminar and turbulent flow conditions
CO-4	Solve problems involving motion of particles in fluid, fluid–solid operations in packed beds and fluidized beds
CO-5	Select machinery and measuring devices for fluid flow

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	3	1	1	1	-	-	-	-	-	-	-	-	3	-	3
CO-2	3	2	2	2	-	-	-	-	-	-	-	-	3	1	-
CO-3	3	1	3	3	1	2	-	-	-	-	-	-	3	1	2
CO-4	3	3	3	3	1	2	-	-	-	-	-	-	3	1	2
CO-5	3	3	2	3	1	-	-	-	-	-	-	-	3	1	-

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

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

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

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

Basic Equations of Fluid Flow: Mass balance in a flowing fluid; Continuity, Differential momentum balance; Equations of motion; macroscopic momentum balances; Mechanical energy equation - Bernoulli Equation.

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

Flow of Compressible Fluids: Definitions and basic equations.

Flow past immersed objects: Drag and Drag Coefficients, Friction in flow through beds of solids; Motion of particles through fluids; Fluidization.

Transportation and Metering of Fluids: Pipes, Fittings and valves; Pumps - positive displacement pumps and centrifugal pumps; Fans, blowers, and compressors; Flow measuring devices for pipes and open channels – variable head and variable area meters; Other invasive and noninvasive devices.

Learning Resources:

Text Books:

1. McCabe W. L., Jullian Smith C. and Peter Harriott, Unit operations of Chemical Engineering, McGraw-Hill international Edition, 2017, 7th Edition.
2. Munson, Bruce R., Donald F. Young, and Theodore H. Okiishi, Fundamentals of Fluid Mechanics, John Wiley & Sons, Inc. 2013, 8th Edition.

Reference Books:

1. Coulson J.M, Richardson. J.F, Chemical Engineering Volume I and II, Elsevier India, 2006, 5th Edition.
2. De Nevers N H, Fluid Mechanics for Chemical Engineers, McGraw Hill, NY, 2004, 3rd Edition.
3. Fox, Robert W., Introduction to Fluid Mechanics, John Wiley & Sons, Inc., 2019, 9th Edition.
4. Wilkes James O., Fluid Mechanics for Chemical Engineers, Prentice Hall, 2017, 3rd Edition.

Other Suggested Readings:

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

CH1203 **3-0-0 (3)**

Mechanical Operations

Pre-Requisites: **None**

Course Outcomes:

CO-1	Identify the role of mechanical unit operations in chemical industries
CO-2	Select suitable size reduction equipment based on performance and power Requirement
CO-3	Analyze particle size distribution of solids
CO-4	Evaluate solid-solid and solid-fluid separation equipment
CO-5	Demonstrate agitation and mixing processes

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	3	2	1	2	1	1	1	2	1	1	1	2	3	-	3
CO-2	3	2	2	3	1	1	1	2	1	1	1	2	3	1	-
CO-3	3	2	2	3	1	1	1	2	1	1	1	2	3	1	2
CO-4	3	2	3	3	1	1	1	2	1	1	1	2	3	1	2
CO-5	3	2	2	2	1	1	1	2	1	1	1	2	3	1	-

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 and mixing of solids; mixing equipment.

Size reduction: Laws of comminution; Size reduction equipment.

Screening: Screening equipment; Standard Screens; Screen effectiveness; Differential and cumulative analysis.

Filtration: Principles of cake filtration; Plate and frame filter press; Rotatory vacuum drum filter; Centrifugal filters; Clarifying filters; Liquid clarification; Gas cleaning; Cyclone separators.

Sedimentation: Gravity sedimentation processes; Centrifugal sedimentation processes.

Agitation and mixing: Introduction to agitation and mixing process.

Learning Resources:

Text Books:

1. McCabe W. L., Jullian Smith C and Peter Harriott, Unit Operations of Chemical Engineering, McGraw-Hill international Edition, 2017, 7th Edition.

Reference Books:

1. Coulson J.M., Richardson J.F, Chemical Engineering, Vol. II, Elsevier India, 2006, 4th Edition.

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

CH1205 **3-0-0 (3)**

Chemical Engineering Thermodynamics

Pre-Requisites: **None**

Course Outcomes:

CO-1	Apply the first and second laws of thermodynamics to chemical processes
CO-2	Compute the properties of ideal and real gas mixtures
CO-3	Evaluate the efficiency of expansion and compression flow processes
CO-4	Estimate heat and work requirements for industrial processes
CO-5	Analyze refrigeration and liquefaction processes

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	2	2	1	-	-	-	-	-	-	-	-	-	1	3	3
CO-2	2	3	2	2	1	-	-	-	-	-	-	-	2	2	3
CO-3	2	2	3	3	2	-	-	-	-	-	-	-	2	1	1
CO-4	2	2	2	3	2	-	-	-	-	-	-	-	3	1	2
CO-5	2	2	3	2	1	-	-	-	-	-	-	-	3	2	2

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

Syllabus:

First Law of Thermodynamics and Volumetric Properties of Pure Fluids: First Law of Thermodynamics; Mass and Energy balances for Open Systems; General P-V-T Behavior of Pure Substances; Virial Equations of State; The Ideal Gas; Application of the Virial Equations; Cubic Equations of State; Generalized Correlations for Gases; Generalized Correlations for Liquids.

The Second Law of Thermodynamics: Statements of the Second Law; Heat Engines; Entropy; Entropy Balance for Open Systems; Calculation of Ideal Work; Lost Work; The Third Law of Thermodynamics.

Thermodynamic Properties of Fluids: Thermodynamic Property Relations for Single Phase Systems; Residual Property Relations; Residual Property Calculation by Equations of State; Two-Phase Systems; Thermodynamic Diagrams; Tables of Thermodynamic Properties; Generalized Property Correlations for Gases.

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

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

Learning Resources:

Text Books:

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

Reference Books:

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

Other Suggested Readings:

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

CH1207 **3-0-0 (3)**

Heat Transfer

Pre-Requisites: None

Course Outcomes:

CO-1	Calculate steady and unsteady conduction heat transfer rate and temperature distributions
CO-2	Calculate heat transfer coefficients for forced and natural convection
CO-3	Perform heat transfer calculations involving phase changes
CO-4	Calculate net radiant heat loss from a surface
CO-5	Carryout preliminary design calculations for heat exchange equipment

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	3	2	3	1	1	2	3	–	2	3	1	1	3	3	2
CO-2	3	2	3	1	1	2	3	–	2	3	1	1	3	3	2
CO-3	3	2	3	1	1	2	3	–	2	3	1	1	3	3	2
CO-4	3	2	3	1	1	2	3	–	2	3	1	1	3	3	2
CO-5	3	2	3	1	1	2	3	–	2	3	1	1	3	3	2

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

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

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

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

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

Learning Resources:

Text Books:

1. McCabe W. L., Smith J. C., Harriott P., Unit Operations of Chemical Engineering, McGraw Hill, 2017, 7th Edition.

2. Holman J. P, Heat Transfer, McGraw Hill, 2017, 10th Edition.

Reference Books:

1. Cengel Y., Heat Transfer: A Practical Approach, McGraw Hill, 2002, 2nd Edition.
2. Kern D. Q., Process Heat Transfer, Tata McGraw Hill Education Pvt. Ltd., 2017.
3. Theodore L. Bergman, Adrienne S. Lavine, Frank P. Incropera, David P. DeWitt, Introduction to heat transfer, John Wiley and Sons Inc, 2011, 6th Edition.

Other Suggested Readings:

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

CH1209 **0-1-2 (2)**

Mechanical Operations Laboratory

Pre-Requisites: **None**

Course Outcomes:

CO-1	Apply and validate comminution laws for size reduction using various size reduction equipment
CO-2	Evaluate the performance of screening equipment
CO-3	Determine the crushing efficiency and reduction ratios of different size reduction equipment
CO-4	Evaluate the performance of various separation equipment for gas-solid, liquid- solid and solid-solid separation
CO-5	Conduct filtration experiments and determine key parameters

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	3	1	1	1	-	-	-	-	2	-	-	-	3	2	1
CO-2	3	1	1	1	-	-	-	-	2	-	-	-	3	2	1
CO-3	3	1	1	1	-	-	-	-	2	-	-	-	3	2	1
CO-4	3	1	1	1	-	-	-	-	2	-	-	-	3	2	1
CO-5	3	1	1	1	-	-	-	-	2	-	-	-	3	2	1

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

List of experiments

1. Evaluate the screen effectiveness of a specific screen within a stack of sieves
2. Determine the specific cake resistance and filter medium resistance of a slurry in plate and frame filter press
3. Batch sedimentation data collection and minimum thickener area calculation
4. Verification of comminution laws using jaw crusher
5. Verification of bond's law for size reduction using ball mill
6. Estimating particle separation efficiency using cyclone separator
7. Ore crushing with roll crusher and average size determination by sieving
8. Ore beneficiation using froth flotation technique
9. Separation of a particle mixture using the Jigging method
10. Analyze the influence of inlet pressure and feed concentration on separation efficiency of hydrocyclone

Learning Resources:

Reference Books:

1. Laboratory Manuals.
2. McCabe W. L., Smith J. C., Harriott P., Unit Operations of Chemical Engineering, McGraw Hill, 2017, 7th Edition.

CH1211 **0-1-2 (2)**

Fluid and Particle Mechanics Laboratory

Pre-Requisites: **None**

Course Outcomes:

CO-1	Determine viscosity of liquids using Cannon Fenske viscometer and terminal settling velocity
CO-2	Distinguish laminar and turbulent flows
CO-3	Determine the characteristics of flow meters, packed & fluidized beds and centrifugal pumps
CO-4	Verify Bernoulli's theorem
CO-5	Calculate pressure drop across pipes, valves and fittings

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	2	1	2	3	-	-	-	2	3	3	2	1	1	3	1
CO-2	2	1	2	3	-	-	-	2	3	3	2	1	2	3	1
CO-3	2	1	2	3	-	-	-	2	3	3	2	1	2	3	1
CO-4	2	1	2	3	-	-	-	2	3	3	2	1	2	3	1
CO-5	2	1	2	3	-	-	-	2	3	3	2	1	2	3	1

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

Syllabus:

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

Learning Resources:

Reference Books:

1. Laboratory Manuals.
2. McCabe W. L., Smith J. C., Harriott P., Unit Operations of Chemical Engineering, McGraw Hill, 2017, 7th Edition.

4th Semester

MA1263 **3-0-0 (3)**

Partial differential equations, Statistics and Numerical methods

Pre-Requisites: **None**

Course Outcomes:

CO-1	Determine the solution of a PDE by variable separable method
CO-2	Interpret an experimental data using interpolation / curve fitting
CO-3	Solve algebraic/transcendental equations and ordinary differential equations
CO-4	Understand the concepts of probability and statistics
CO-5	Perform testing of hypothesis

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	3	3	1	2	1	-	-	-	-	-	-	-	-	1	2
CO-2	3	3	1	2	1	-	-	-	-	-	-	-	-	1	2
CO-3	3	3	1	2	1	-	-	-	-	-	-	-	-	1	2
CO-4	3	3	1	2	1	-	-	-	-	-	-	-	-	1	2
CO-5	3	3	1	2	1	-	-	-	-	-	-	-	-	1	2

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

Syllabus:

Partial Differential Equations: Introduction to Fourier series (including half range), Method of separation of variables - Solution of one-dimensional wave equation, one dimensional heat conduction equation.

Numerical Methods: Gauss-Seidal iteration method to solve a system of equations - Numerical solution of algebraic and transcendental equations by Regula-Falsi method and Newton-Raphson's method - Lagrange interpolation, Forward and backward differences, Newton's forward and backward interpolation formulae - Numerical differentiation with forward and backward differences - Numerical Integration with Trapezoidal rule, Simpson's 1/3 rule and Simpson's 3/8 rule - Taylor series method, Euler's method, 4th order Runge-Kutta method for solving first order ordinary differential equations.

Probability and Statistics: Random variables, discrete and continuous random variables, Mean and variance of Binomial, Poisson and Normal distributions and applications. Testing of Hypothesis – Null and alternate hypothesis, level of significance and critical region - Z-test for single mean and difference of means, t-test for single mean and difference of means - F-test for comparison of variances.

Learning Resources:

Text Books:

1. R. K. Jain, S. R. K. Iyengar, Advanced Engineering Mathematics, Narosa Publishing House, 2016, 5th Edition.
2. Erwin Kreyszig, Advanced Engineering Mathematics, John Wiley and Sons, 2015, 10th Edition.

Reference Books:

1. Richard A. Johnson, Miller & Freund's Probability and Statistics for Engineers, Pearson, 2018,
2. NinthEditionDennis G. Zill, Advanced Engineering Mathematics, Jones & Bartlett Learning, 2018, 6th Edition.
3. B. S. Grewal, Higher Engineering Mathematics, Khanna Publishers, 2012, 42nd Edition.

MM1262 **3-0-0 (3)**

Material Science and Engineering

Pre-Requisites: None

Course Outcomes:

CO-1	Classify the materials and discuss their applications
CO-2	Describe the crystal structure, constitution and microstructure of materials
CO-3	Suggest ferrous and non-ferrous alloys for different applications based on their properties
CO-4	Differentiate the properties and applications of ceramics, polymers and composites
CO-5	Select suitable advanced materials for electronic and thermochemical applications

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	-	1	-	1	-	2	-	-	-	-	-	1	-	-	-
CO-2	-	1	3	3	-	-	-	2	-	-	-	1	-	-	-
CO-3	-	1	3	3	-	2	-	-	-	-	-	1	-	-	-
CO-4	-	1	3	3	-	2	-	-	-	-	-	1	-	-	-
CO-5	-	1	2	2	-	2	-	-	-	-	-	1	-	-	-

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

Syllabus:

Introduction: Historical materials, Introduction and classification of materials.

Crystal Geometry and Constitution of Alloys: Crystal structure, Crystal directions and planes, Crystal imperfections; Substitutional and interstitial solid solutions; Hume-Rothery rules, Construction and interpretation of binary equilibrium diagrams.

Plain Carbon Steels, Cast Irons and Alloy Steels: Iron-carbon phase diagram, Low, medium and high carbon steels, Cast irons, Stainless steels and their applications in chemical industries; Heat treatment.

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

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

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

Learning Resources:

Text Books:

1. Callister, W. D. (Adapted by R. Balasubramaniam), Materials Science and Engineering, Wiley Publications, 2014, 2nd Edition.
2. Raghavan, V., Materials Science and Engineering: A First Course, Prentice Hall of India Learning Pvt. Ltd., 2015, 6th Edition.

Reference Books:

1. Avner, S. H., Introduction to Physical Metallurgy, McGraw- Hill Education Publishers, 1997, 2nd Edition.
2. Clark, D.S., Varney, W., Physical Metallurgy for Engineers, CBS Publishers and Distributors, 2004, 2nd Edition.
3. Raghavan, V., Physical Metallurgy: Principles and Practice, Prentice Hall of India Learning Pvt. Ltd., 2012, 2nd Edition.

Other Suggested Readings:

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

CH1202 **3-1-0 (4)**

Solution Thermodynamics and Phase Equilibria

Pre-Requisites: **CH1205**

Course Outcomes:

CO-1	Evaluate heat effects involved in industrial chemical processes
CO-2	Determine thermodynamic properties of gaseous mixtures and solutions
CO-3	Estimate Bubble-P & T, Dew-P & T for binary and multi-component systems
CO-4	Calculate vapor-liquid equilibrium (VLE) composition for ideal and non-ideal systems
CO-5	Determine equilibrium constant and composition of product mixture for single and multiple reactions

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	2	1	1	2	2	-	-	-	-	-	-	-	2	3	1
CO-2	1	2	1	2	2	-	-	-	-	-	-	-	1	2	2
CO-3	2	2	1	1	2	-	-	-	-	-	-	-	1	2	2
CO-4	2	1	1	`2	2	-	-	-	-	-	-	-	2	2	2
CO-5	1	1	1	1	2	-	-	-	-	-	-	-	1	2	1

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

Syllabus:

Heat Effects: Sensible heat effects; Temperature dependency of heat capacity; Latent Heat of pure substance; Standard heats of reaction; Formation and combustion; Heat effects of industrial reactions.

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

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

Applications of Solution Thermodynamics: Liquid phase properties from VLE data; Activity coefficient; Excess Gibbs Energy; Models for the excess Gibbs energy; Property changes of mixing; Heat effects of mixing process.

Chemical Reaction Equilibria: The reaction coordinate; Equilibrium criteria to chemical reactions; Gibbs free energy change; Equilibrium constant; Effect of temperature on equilibrium constant; Evaluation of equilibrium constants; Relation of equilibrium constant to composition; Equilibrium conversions for single reactions; Phase rule and Duhem's theorem for reacting systems; Multi-reaction equilibria.

Learning Resources:

Text Books:

1. Smith J. M, H. C. Van Ness and M. M. Abbott, Introduction to Chemical Engineering Thermodynamics, McGraw-Hill, 2018, 8th Edition.

2. K. V. Narayanan, Chemical Engineering Thermodynamics, Prentice Hall of India Pvt. Ltd., 2013, 2nd Edition.

Reference Books:

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

Other Suggested Readings:

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

CH1206 **3-0-0 (3)**

Fundamentals of Mass Transfer

Pre-Requisites: **CH1205**

Course Outcomes:

CO-1	Identify diffusion phenomena in various chemical processes
CO-2	Determine diffusivity coefficient in gases, liquids and solids
CO-3	Calculate mass transfer coefficients at interfaces of multiphase mass transfer systems
CO-4	Design equipment for gas-liquid mass transfer operations

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	2	2	2	2	2	–	–	–	–	–	–	2	2	2	1
CO-2	3	3	2	2	2	–	–	–	–	–	–	2	2	2	2
CO-3	3	3	2	2	2	–	–	–	–	–	–	2	2	2	2
CO-4	3	3	3	2	2	–	–	–	–	–	–	2	3	2	2

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

Syllabus:

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

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

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

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

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

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/103/103/103103035/

CH1208 **3-1-0 (4)**

Chemical Reaction Engineering

Pre-Requisites: **CH1201**

Course Outcomes:

CO-1	Derive the rate law for non-elementary chemical reactions
CO-2	Determine the kinetics of chemical reaction using integral, differential, fractional-life methods and method of initial rates
CO-3	Design reactors for homogenous reactions under isothermal conditions
CO-4	Select optimal sequence in multiple reactor systems
CO-5	Design adiabatic plug flow reactor
CO-6	Analyze the performance of non-ideal reactors using segregation model, tanks-in series model and dispersion model

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	3	3	3	3	1	-	-	-	-	-	-	-	3	3	1
CO-2	3	3	3	3	-	-	-	-	-	-	-	-	3	3	2
CO-3	3	3	3	3	-	-	-	-	-	-	-	-	3	3	3
CO-4	3	3	3	3	-	-	-	-	-	-	-	-	3	3	3
CO-5	3	3	3	3	-	-	-	-	-	-	-	-	3	3	1
CO-6	3	3	3	3	1	-	3	-	-	-	-	-	3	3	3

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

Syllabus:

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

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

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

Isothermal Reactor Design: Mole Balances in Terms of Conversion- Design Structure for Isothermal Reactors; Scale-Up of Liquid-Phase Batch Reactor Data to the Design of a CSTR; Design of Continuous Stirred Tank Reactors (CSTRs); Tubular Reactors. Mole Balances Written in Terms of Concentration and Molar Flow Rate- Mole Balances on CSTRs; PFRs; and Batch Reactors; recycle reactor.

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

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 of Multiple Reactors.

Analysis of non-ideal reactors: One- parameter models; two-parameter models; Tanks-in- Series (T-I-S) Model; Dispersion Model; Two-Parameter Models-Modelling Real Reactors with Combinations of Ideal Reactors; Other Models of Non-ideal Reactors Using CSTRs and PFRs.

Learning Resources:

Text Books:

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

Reference Books:

1. E. Bruce Nauman, Chemical Reactor Design, Optimization and Scaleup, Wiley, 2008.
2. Mark E. Davis & Robert J. Davis, Fundamentals of Chemical Reaction Engineering, McGraw Hill, 2002.
3. Martin Schmal, Chemical Reaction Engineering: Essentials, Exercises and Examples, CRC Press, 2014, 1st Edition.
4. Smith J. M., Chemical Engineering Kinetics, McGraw Hill India, 1981, 3rd Edition.

Other Suggested Readings:

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

CH1210 **0-1-2 (2)**

Heat Transfer Laboratory

Pre-Requisites: **CH1207**

Course Outcomes:

CO-1	Determine thermal conductivity of solids and fluids
CO-2	Calculate efficiency of fins
CO-3	Verify Newton's law of cooling of hot objects
CO-4	Determine rate of heat transfer in heat exchangers
CO-5	Analyze the heat transfer by radiation

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	3	2	3	1	1	2	3	-	2	3	1	1	3	3	2
CO-2	3	2	3	1	1	2	3	-	2	3	1	1	3	3	2
CO-3	3	2	3	1	1	2	3	-	2	3	1	1	3	3	2
CO-4	3	2	3	`1	1	2	3	-	2	3	1	1	3	3	2
CO-5	3	2	3	1	1	2	3	-	2	3	1	1	3	3	2

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

Syllabus:

List of experiments:

1. Determination of thermal conductivity for a composite wall
2. Determination of heat transfer coefficient for natural convection from a heated vertical cylinder
3. Determination of thermal conductivity of metal rod
4. Determination of heat transfer coefficient for natural convection and radiation
5. Determination of Emissivity of Non-Black Body
6. Determination of heat transfer in parallel flow and counter flow heat exchanger
7. Determination of heat transfer in forced convection
8. Determination of heat transfer in heat pipe
9. Determination of heat transfer coefficient in dropwise and film wise condensation
10. Determination of heat transfer from a pin fin apparatus

Learning Resources:

Reference Books:

1. Lab Manual

Other Suggested Readings:

1. http://htv-au.vlabs.ac.in/

CH1212 **0-1-2 (2)**

Chemical Reaction Engineering Laboratory

Pre-Requisites: **None**

Course Outcomes:

CO-1	Determine the kinetics of a reaction in a batch reactor, semi-batch reactor, CSTR, & PFR
CO-2	Determine the kinetics of a variable volume reaction
CO-3	Determine the kinetics by fractional life method
CO-4	Determine the temperature dependency of a reaction
CO-5	Evaluate the performance of reactors through RTD studies
CO-6	Compare the performance of single reactor with combination of reactors

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	3	2	1	1	1	-	1	-	2	-	-	-	2	3	1
CO-2	3	2	1	1	1	-	1	-	2	-	-	-	2	3	1
CO-3	3	2	1	1	1	-	1	-	2	-	-	-	2	3	1
CO-4	3	2	1	1	1	-	1	-	2	-	-	-	2	3	1
CO-5	3	2	1	1	1	-	1	-	2	-	-	-	2	3	1
CO-6	3	2	1	1	1	-	1	-	2	-	-	-	2	3	1

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

Syllabus:

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

5th Semester

MS1262 **3-0-0 (3)**

Business Essentials for Engineers

Pre-Requisites: None

Course Outcomes:

CO-1	Understand the basic concepts of management and its functions
CO-2	Apply the functions of management for taking effective decisions
CO-3	Analyze factors influencing management in competitive business environment
CO-4	Identify business opportunities and challenges
CO-5	Integrate functions of management for building a better organization

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	-	-	-	-	-	-	-	-	3	2	3	1	-	-	-
CO-2	-	-	-	-	-	-	-	-	2	-	3	1	-	-	-
CO-3	-	-	-	-	-	-	-	-	-	-	3	3	-	-	-
CO-4	-	-	-	-	-	-	-	-	1	2	3	3	-	-	-
CO-5	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-

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

Syllabus:

Introduction: The evolution of management theory, Business functions and their roles, Organizations and types, Levels of management, Types of markets and pillars of management- planning, organizing, leading and controlling.

People Management: Catalysts for organizational performance – Motivation & Leadership, Organization culture & Change, Human resource functions in a dynamic business environment and evolving dynamics in Industrial Relations.

Marketing Management: Nature and scope of marketing, Company's orientation towards marketplace, Importance of marketing concept, Marketing environment, 4p's of marketing, market segmentation, target market selection and positioning.

Financial Management: Financial accounting, Financial statements and analysis for decisions, Financial planning, Capital, Working capital, Capital structure and Sources of corporate finance, Investment decisions.

Project Management: Project screening and Selection, Techniques, Structuring concepts and Tools (WBS, OBS, and LRC, RACE). Project life cycle analysis. Appraisal of a project, Project Planning: Techniques, CPM, PERT- GAN - Time Cost Trade-off and Crashing Procedure, Project Monitoring: Monitoring Techniques and time control System, EVA Analysis.

Quality & Strategy: Quality, Principles, Quality Awards, Standards of Quality culture, Quality metrics programs, Strategy, Vision and Mission, Porter's 5–forces, McKinsey's 7S Model, BCG Matrix, Competitive advantage - Value chain analysis & Resource-based view.

Learning Resources:

Text Books:

1. Ronald J. Ebert, Ricky W. Griffin, Business Essentials, Global Edition, Pearson, 2019, 12th Edition.
2. Harold Koontz, Heinz Weihrich, Mark V. Cannice, Essentials of Management, McGraw Hill, 2020, 11th Edition.

Reference Books:

1. G. Shainesh Philip Kotler, Kevin lane Keller, Alexander Chernev, Jagdish N. Sheth, Marketing Management, Pearson, 2022, 16th Edition.
2. Dessler, G., & Varkkey, B, Human Resource Management, Pearson Education, 2018.
3. Prasanna Chandra, Financial Management: Theory & Practice, Mc Graw Hill, 2022, 11th Edition.
4. Poornima M Charantimath, Total Quality Management, Pearson, 2022, 4th Edition.
5. IM Pandey, Financial Management, Vikas Publications, 2021, 12th Edition.
6. Jack R. Meredith, Mantel, Project Management - A Managerial Approach, John Wiley, 2021,11th Edition.

Other Suggested Readings:

1. https://nptel.ac.in/courses/110106050
2. https://nptel.ac.in/courses/110105146
3. https://nptel.ac.in/courses/110105069
4. https://nptel.ac.in/courses/110104068
5. https://ocw.mit.edu/courses/15-535-business-analysis-using-financial-statements-spring-2003/
6. https://ocw.mit.edu/courses/15-810-marketing-management-fall-2010/

CH1301 **3-1-0 (4)**

Mass Transfer Operations

Pre-Requisites: **CH1206**

Course Outcomes:

CO-1	Analyze VLE, LLE, and SLE data
CO-2	Select a suitable mass transfer operation for a given separation
CO-3	Determine number of stages in absorption, distillation, extraction and adsorption operations
CO-4	Design packed column for absorption, distillation, extraction and adsorption operations
CO-5	Calculate drying rates and moisture content for batch and continuous drying operations

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	3	2	2	2	2	-	-	-	-	-	-	2	2	2	1
CO-2	3	2	2	2	2	-	-	-	-	-	-	2	2	2	1
CO-3	3	2	3	2	2	-	-	-	-	-	-	2	3	2	1
CO-4	3	2	3	2	2	-	-	-	-	-	-	2	3	2	1
CO-5	3	2	2	2	2	-	-	-	-	-	-	2	2	3	1

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

Syllabus:

Gas Absorption: Equilibrium solubility of gases in liquids; One component transferred - material balances; one component transferred counter-current multistage operation; Stage efficiency; Continuous contact equipment.

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

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

Drying: Equilibrium; Drying operations - batch drying; Mechanism of batch drying and continuous drying; Drying equipment.

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

Learning Resources:

Text Books:

1. 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/

CH1303 **3-1-0 (4)**

Elements of Transport Phenomena

Pre-Requisites: **None**

Course Outcomes:

CO-1	Estimate the transport properties of solids, liquids and gases
CO-2	Formulate mathematical representation of momentum/energy/mass transport phenomena
CO-3	Solve flow/ heat/ mass transfer problems either individually or coupled for simple geometries analytically
CO-4	Apply analogy between momentum, energy and mass transport

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	1	2	2	1	2	-	1	-	1	-	-	2	1	3	1
CO-2	3	2	2	2	1	-	1	-	1	1	-	2	2	3	2
CO-3	3	3	3	2	1	-	1	-	1	1	-	2	2	3	2
CO-4	3	2	2	2	1	-	1	-	1	1	-	2	2	3	2

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

Syllabus:

Introduction: Need to study Transport phenomena; Levels of transport phenomena.

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

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

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

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

Learning Resources:

Text Books:

1. 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/

CH1305 **3-0-0 (3)**

Heterogeneous Reaction Engineering

Pre-Requisites: **CH1208**

Course Outcomes:

CO-1	Select reactor type and operating conditions for conducting multiple reactions
CO-2	Design reactors under non-isothermal conditions
CO-3	Derive the rate law for heterogeneous catalytic reactions
CO-4	Design packed bed reactor in the absence and presence of mass transfer effects
CO-5	Analyze the effect of velocity, particle size and fluid properties on rate of reactions controlled by mass transfer

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	3	2	2	1	-	-	-	-	-	-	-	-	3	2	1
CO-2	3	2	3	-	-	-	-	-	-	-	-	-	3	3	1
CO-3	3	2	2	-	1	-	-	-	-	-	-	-	3	2	1
CO-4	3	2	3	-	-	-	-	-	-	-	-	-	3	2	2
CO-5	3	2	2	-	-	-	-	-	-	-	-	-	3	2	1

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

Syllabus:

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

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

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

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

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/

CH1307 **0-1-2 (2)**

Mass Transfer Laboratory

Pre-Requisites: **CH1206**

Course Outcomes:

CO-1	Determine separation performance of batch distillation, steam distillation and sieve plate distillation
CO-2	Determine the efficiency of liquid-liquid extraction
CO-3	Determine the critical moisture content in drying
CO-4	Determine the effect of mass transfer with and without chemical reaction
CO-5	Estimate the diffusion coefficient of vapour in gas

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	2	2	1	1	1	2	1	-	-	-	2	1	2	3	-
CO-2	2	2	2	1	1	2	1	-	-	-	2	1	2	3	-
CO-3	3	2	2	2	1	2	1	-	-	-	2	1	2	2	-
CO-4	2	2	2	1	2	2	1	-	-	-	2	1	2	3	-
CO-5	2	2	3	1	1	2	1	-	-	-	2	1	2	3	-

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

Syllabus:

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

Learning Resources:

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.

CH1309 **0-1-2 (2)**

Computational Methods in Chemical Engineering Lab

Pre-Requisites: **None**

Course Outcomes:

CO-1	Find roots of algebraic equations and solution of simultaneous equations
CO-2	Apply regression analysis, interpolation, extrapolation, numerical differentiation and numerical integration
CO-3	Write program for solving a given chemical engineering problem
CO-4	Solve initial value problems, boundary value problems, & Initial and boundary value problems

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	3	3	-	-	2	3	3	-	-	-	-	-	3	3	3
CO-2	3	3	-	-	3	1	3	-	-	-	-	-	3	3	3
CO-3	3	3	-	-	-	1	3	-	-	-	-	-	3	3	3
CO-4	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.

Learning Resources:

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/

CH1381 **1-0-0 (0.5)**

Fractal Course - I

Pre-Requisites: None

Course Outcomes:

CO-1	Acquire an in-depth understanding of the specific topic covered in the course, which could range from a particular technology, method, or recent advancement in Chemical Engineering
CO-2	Develop hands-on skills relevant to the course topic, such as using specific tools, software, or techniques
CO-3	Apply learned concepts to solve focused and practical engineering problems related to the course content
CO-4	Understand the interdisciplinary aspects and applications of the course to solve real-world industrial problems

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	3	3	3	-	-	-	-	-	-	-	-	-	1	2	2
CO-2	-	-	-	2	2	3	3	-	-	-	-	-	3	2	1
CO-3	-	-	3	2	2	-	-	-	-	-	-	-	3	1	1
CO-4	-	-	-	-	1	-	-	-	1	-	-	2	-	1	-

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

This one-week course aims to bridge the gap between academic learning and industry application / latest research developments, providing students with a comprehensive understanding of the chemical engineering field and enhancing their readiness for professional careers.

a. **Structure:** Lectures delivered by an expert from the Chemical Engineering Industry / R&D Organization / Academic Institution (SPARK Collaborators / Foreign Subject Experts in GIAN program / Adjunct Professors from Foreign Universities @ NITW).

b. **Content:** Topics covering current practices, case studies, technological advancements, and future trends.

c. **Interactive Sessions:** Q&A sessions, discussions, and case study analyses to foster interaction between students and the subject expert.

d. **Assessment:** the mode of assessment (Participation, a short reflective report / a presentation summarizing key takeaways from the lectures / Objective or descriptive type exam, etc.) will be decided by the subject expert.

Learning Resources:

1. Course material and any learning resources suggested by the experts.

6th Semester

CH1302 **3-1-0 (4)**

Instrumentation and Process Control

Pre-Requisites: None

Course Outcomes:

CO-1	Characterize the performance of instruments and Identify the instrument for pressure and temperature measurements
CO-2	Understand the dynamic behavior of processes
CO-3	Evaluate the stability of feedback control system
CO-4	Design controllers for first and second order processes
CO-5	Determine the frequency response for controllers and processes

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	1	-	2	3	2	-	-	-	-	-	-	1	-	3	1
CO-2	3	3	3	3	2	-	-	-	-	-	-	1	2	3	3
CO-3	3	3	3	3	2	-	-	-	-	-	-	1	2	3	3
CO-4	3	3	3	3	2	-	-	-	-	-	-	1	1	3	3
CO-5	3	3	3	3	2	-	-	-	-	-	-	1	2	3	3

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

Syllabus:

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

Measurement Instruments: Industrial thermocouples, thermocouple wires, thermal wells, pressure, vacuum and head manometers, open channel meters, flow of dry materials, level measurement in pressure vessels, interface measurements, control valves and characteristics, valve positioner.

Motivation and Introduction to the course: Open and closed loop control, Review of Laplace transforms. Transfer Functions, Linearization, Forcing Functions and Responses. Physical examples of First and Second order systems.

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

Stability and Controller Design: Routh Test, Root Locus, Direct substitution method, Ziegler-Nichols and Cohen-Coon Controller Settings. Direct synthesis method.

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

Advanced Regulatory Control Strategies: Cascade Control, Feed-forward Control, Ratio Control, Split-range control, Override control and inferential control.

Learning Resources:

Text Books:

1. Coughanowr D.R., Process System analysis and Control, McGraw Hill, 2012, 3rd Edition.
2. Seborg D.E., Edgar T. E, Millichamp D.A, Process Dynamics and Control, John Wiley & Sons, 2016, 4th Edition.
3. Raghunathan Rengaswamy, Babji Srinivasan, Nirav Pravinbhai Bhatt, Process Control Fundamentals: Analysis, Design, Assessment, and Diagnosis, CRC Press, 2020.
4. Patranabis D., Principles of Industrial instrumentation, McGraw Hill education, 2017, 3rd Edition.

Reference Books:

1. Eckman Donald P., Industrial instrumentation, Wiley Eastern Ltd., 2004.
2. Stephanopolis G., Chemical Process Control, Prentice Hall India, 2008.
3. Bequette, B.W., Process Control: Modeling, Design and Simulation, 2007.
4. William C. Dunn, Fundamentals of industrial instrumentation and process control, McGraw Hill Education, 2017.

Other Suggested Readings:

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

CH1304 **3-0-0 (3)**

Chemical Technology

Pre-Requisites: **None**

Course Outcomes:

CO-1	Selection of a process for the manufacture of chemicals
CO-2	Draw process flow diagrams
CO-3	Identify the engineering problems in chemical processes
CO-4	List chemical reactions and their mechanism involved

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	1	1	3	1	2	3	3	-	-	-	-	-	3	2	-
CO-2	2	2	2	2	2	-	-	-	-	-	-	-	3	2	-
CO-3	3	3	2	1	2	-	-	-	-	-	-	-	3	2	-
CO-4	2	2	2	2	-	-	-	-	-	-	-	-	3	2	-

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

Syllabus:

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

Chloro-alkali industries: soda ash, Solvay process, dual process, Natural soda ash from deposits, Electrolytic process, and Caustic soda.

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

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

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

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

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

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

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

Learning Resources:

Text Books:

1. Austin G.T., Shreve's Chemical Process Industries - International Student Edition, McGraw Hill Inc., 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/

CH1306 **0-1-4 (3)**

Product Development

Pre-Requisites: **None**

Course Outcomes:

CO-1	Express Product Design Ideas using 2D or 3D sketches, diagrams etc.
CO-2	Model the components with geometric (engineering) specifications and appropriate materials
CO-3	Develop a prototype of the product
CO-4	Evaluate the entire product
CO-5	Improve the product based on testing with user feedback

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	-	-	2	3	3	3	2	2	3	3	2	3	1	2	1
CO-2	-	-	2	3	3	3	2	2	3	3	2	3	1	2	1
CO-3	-	-	2	3	3	3	2	2	3	3	2	3	1	2	1
CO-4	-	-	2	3	3	3	2	2	3	3	2	3	1	2	1
CO-5	-	-	2	3	3	3	2	2	3	3	2	3	1	2	1

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

Syllabus:

Design Thinking Process for Product Development: Review of five step design thinking process of Empathize- Define- Ideate- Prototype- Test.

Project Selection: Identification of the problem through empathy, formulate and ideate to solve the problem.

Chemical Product Design: Chemical Product design and its importance, Product design procedure, categories of chemical products; Needs: Customer needs, consumer products, converting needs to specifications, revising product specifications; Ideas: Human ideas, chemical ideas, sorting and screening the ideas; Selection: Selection using thermodynamics, selection using kinetics, less objective criteria, risk in product selection.

Product Manufacture: Preparations for manufacture, final specification, scale-up/scale-down, economic considerations. Commodity products: Characteristics of chemical commodities, getting started, The commodity toolbox: reactors and separations, using the commodity toolbox; Devices: Properties of devices, getting started, The device toolbox: Chemical reactors, and separations, using the design toolbox. Molecular products: Characteristics of molecular products, getting started, The molecular toolbox: Chemical reactors, and separations, using the molecular toolbox. Microstructures: Properties of microstructures, getting started, The microstructure toolbox: Reactions and unit operations, using the microstructure toolbox.

Iterative improvement of the product and Report writing: Development of assemblies/mock-up models/ working models/ prototypes/functional models/products, Testing and design review, Report writing.

Learning Resources:

Text Books:

1. E. L. Cussler, G. D. Moggridge, Chemical Product Design, Cambridge University Press, 2011, 2nd Edition.
2. Sullivan, Brian, The design studio method: creative problem solving with UX sketching, Focal Press, 2016.
3. Verma G., Autodesk Fusion 360 Black Book, CADACAMCAE Works, 2021, 2nd Edition.

Reference Books:

1. Ka M. Ng, Rafiqul Gani and Kim Dam-Johansen, Chemical Product design: Towards a perspective through case studies, Elsevier Science, 2007.
2. Mario R. Eden, Mariano Martin, Nishanth G. C., Tools for Chemical Product Design from Consumer Products to Biomedicine, Elsevier Science, 2016.

Other Suggested Readings:

1. Self-Paced Tutorials: https://help.autodesk.com/view/fusion360/ENU/courses/
2. Product Documentation: https://help.autodesk.com/view/fusion360/ENU/?guid=GUID1C665B4D-7BF7-4FDF-98B0-AA7EE12B5AC2
3. https://onlinecourses.nptel.ac.in/noc20_mg03/preview

CH1308 **0-1-2 (2)**

Design and Simulation Laboratory

Pre-Requisites: **None**

Course Outcomes:

CO-1	Carry out thermodynamic property estimations
CO-2	Simulate Mixer, splitter, pumps, compressors and flash units
CO-3	Apply sensitivity, design specification and case study tools
CO-4	Design heat exchangers, reactors and distillation columns
CO-5	Optimize process flowsheets using sequential modular and equation-oriented approaches

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	3	3	3	3	3	3	-	-	-	-	-	-	3	3	3
CO-2	3	3	3	3	3	1	-	-	-	-	-	-	3	3	3
CO-3	3	3	3	3	3	3	-	-	-	-	-	-	3	3	3
CO-4	3	3	3	3	3	2	-	-	-	-	-	-	3	3	3
CO-5	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
10. Simulation using equation-oriented approach
11. Design the MER heat exchange network for the given process

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.

CH1310 **0-1-2 (2)**

Chemical Processing Laboratory

Pre-Requisites: None

Course Outcomes:

CO-1	Analyze samples such as water, soap, urea, and petroleum products
CO-2	Synthesize products such as soap, formaldehyde, and silica colloids
CO-3	Evaluate thermodynamic properties such as specific heat capacity, volume of mixing, and heat of mixing of binary liquids
CO-4	Calculate the Energy content of coal, oil, and natural gas

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	2	2	2	2	1	1	1	2	3	3	1	1	-	1	-
CO-2	3	2	2	2	1	1	1	2	3	3	1	1	2	1	1
CO-3	3	2	1	2	1	1	1	2	3	3	1	1	3	3	2
CO-4	3	2	1	2	1	1	1	2	3	3	1	1	3	3	2

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Analysis

1. To determine the total alkalinity of a given water sample using the methyl orange indicator
2. To determine the total alkalinity of a given water sample using methyl orange & phenolphthalein indicator
3. To determine the alkali content in the given soap sample
4. To determine the Fatty acid content present in the given sample of soap
5. To determine the percentage of nitrogen content present in the given sample of urea fertilizer

Product Synthesis

6. Preparation of soap
7. Preparation of formaldehyde resin
8. Synthesis of silica colloids

Testing Methods of Fuels

9. To determine the Flash and Fire point of petroleum products
10. To determine the Smoke point and Aniline point of petroleum products
11. To determine the viscosity of petroleum products

Thermodynamics

12. To determine the thermodynamic properties of a given binary mixture
13. To obtain the VLE data for a given binary mixture
14. To determine the Calorific value of a given fuels by using a Bomb Calorimeter

Learning Resources:

Reference Books:

1. Lab manuals.
2. McCabe W. L., Smith J. C., Harriott P., Unit Operations of Chemical Engineering, McGraw Hill, 2017, 7th Edition.
3. Smith J. M, H. C. Van Ness, and M. Abbott, Introduction to Chemical Engineering Thermodynamics, McGraw-Hill, 2018, 8th Edition.

CH1382 **1-0-0 (0.5)**

Fractal Course - II

Pre-Requisites: None

Course Outcomes:

CO-1	Acquire an in-depth understanding of the specific topic covered in the course, which could range from a particular technology, method, or recent advancement in Chemical Engineering
CO-2	Develop hands-on skills relevant to the course topic, such as using specific tools, software, or techniques
CO-3	Apply learned concepts to solve focused and practical engineering problems related to the course content
CO-4	Understand the interdisciplinary aspects and applications of the course to solve real-world industrial problems

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	3	3	3	-	-	-	-	-	-	-	-	-	1	2	2
CO-2	-	-	-	2	2	3	3	-	-	-	-	-	3	2	1
CO-3	-	-	3	2	2	-	-	-	-	-	-	-	3	1	1
CO-4	-	-	-	-	1	-	-	-	1	-	-	2	-	1	-

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

This one-week course aims to bridge the gap between academic learning and industry application / latest research developments, providing students with a comprehensive understanding of the chemical engineering field and enhancing their readiness for professional careers.

a. **Structure:** Lectures delivered by an expert from the Chemical Engineering Industry / R&D Organization / Academic Institution (SPARK Collaborators / Foreign Subject Experts in GIAN program / Adjunct Professors from Foreign Universities @ NITW).

b. **Content:** Topics covering current practices, case studies, technological advancements, and future trends.

c. **Interactive Sessions:** Q&A sessions, discussions, and case study analyses to foster interaction between students and the subject expert.

d. **Assessment:** the mode of assessment (Participation, a short reflective report / a presentation summarizing key takeaways from the lectures / Objective or descriptive type exam, etc.) will be decided by the subject expert.

Learning Resources:

1. Course material and any learning resources suggested by the experts.

7th Semester

CH1401 **3-1-0 (4)**

Process Equipment Design and Economics

Pre-Requisites: **None**

Course Outcomes:

CO-1	Design heat exchangers, evaporators and distillation column
CO-2	Apply mechanical design concepts to process equipment
CO-3	Determine costs involved in process plants
CO-4	Perform economic analysis and Evaluate project profitability

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	3	3	3	3	2	1	-	-	-	-	2	3	3	3	2
CO-2	3	3	3	3	2	1	-	-	-	-	2	3	3	3	2
CO-3	2	2	3	2	1	2	-	-	-	-	-	-	3	1	1
CO-4	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.

Mechanical Design: Design of cylindrical and spherical vessels under internal pressure, external pressure and combined loading, Design of tall vessels.

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

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

CH1403 **0-1-2 (2)**

Instrumentation and Process Control Laboratory

Pre-Requisites: **CH1302**

Course Outcomes:

CO-1	Identify the dynamics of first order, second order, interacting and non-interacting Processes
CO-2	Implementing the PID controller for temperature control in a mixing heating process
CO-3	Evaluate the characteristics of I-P and P-I converters
CO-4	Study the cascade control scheme using simulation
CO-5	Determine control valve characteristics

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	3	1	2	3	1	–	–	–	2	1	3	2	3	3	2
CO-2	3	1	2	3	3	–	–	–	2	1	3	2	1	3	2
CO-3	3	1	1	3	1	–	–	–	2	1	3	2	1	3	2
CO-4	3	1	2	3	3	–	–	–	2	1	3	2	1	3	2
CO-5	3	1	2	3	2	–	–	–	2	1	3	2	1	3	2

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

Syllabus:

The list of experiments include:

1. Dynamics of non-interacting process
2. Dynamics of interacting process
3. Dynamics of first and second order processes
4. Flapper nozzle system & Characteristics of I&P and P&I converters
5. Measurement of liquid level using air-purge method & DPT method
6. Control valve characteristics
7. Flow measurement
8. Temperature measurement
9. Cascade control simulation
10. Design of PID controller for mixing heating tank using simulation

Learning Resources:

Reference Books:

1. Lab manuals.
2. Jean-Pierre Corriou, Process Control: Theory and Applications, 2nd Edition, Springer, 2018.
3. Seborg, D. E., Edgar, T. F., Millechamp, D. A., Doyle III, F. J., Process Dynamics and Control, Wiley, 2014, 3rd Edition.

Other Suggested Readings:

1. https://techteach.no/simview/cascade_control_temperature/index.php
2. https://techteach.no/simview/temp_control_pid_onoff/index.php

CH1489 **0-0-0 (2)**

Seminar and Technical Writing

Pre-Requisites: None

Course Outcomes:

CO-1	Consolidate ideas based on expert talks attended
CO-2	Prepare a well-organized report employing elements of critical thinking and technical writing
CO-3	Demonstrate the ability to describe, interpret and analyze the subject matter and develop competence in presenting

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	-	-	-	2	-	-	3	3	2	3	-	3	-	-	-
CO-2	-	-	-	2	-	-	3	3	2	3	-	3	-	-	-
CO-3	2	3	-	2	-	-	3	3	2	3	-	3	-	2	2

1 - Slightly; 2 - Moderately; 3 - Substantially

Description:

In Seminar and Technical Writing, every student is expected to prepare a well-organized report based on one / all of the following:

- by attending at least 5 expert lectures/ invited talks/ Seminar/ Popular lectures etc. organized by the institute/any of the departments, ideally in a specific domain or with the same theme.
- prepare a business or marketing plan based on patent search.

The student is expected to consolidate the ideas from these lectures/patent searches and may even include material from other sources to strengthen the content of the report. The student should prepare a well-organized report based on the above and present it to the panel constituted by the department, for evaluation.

Evaluation Criteria:

The student will be evaluated by the panel based on the below criteria.

Criteria	Description	Weightages
I	Clarity on the topic	15 marks
II	List of lectures attended	15 marks
III	Report	15 marks
IV	Presentation	30 marks
V	Response to questions	25 marks

Evaluation Criteria-CO Mapping

CO / Criteria	CO-1	CO-2	CO-3
I	X		
II	X		
III		X	
IV			X
V			X

CH1491 **0-0-0 (2)**

Short Term Industrial / EPICS / Research Experience

Pre-Requisites: **None**

Course Outcomes:

CO-1	Apply engineering principles to real-world problems, gaining practical experience
CO-2	Plan, manage and execute the work with ethical consideration
CO-3	Review the social and environmental impact of the work
CO-4	Communicate the learnings through report and presentation

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	3	3	3	3	3	-	-	-	-	-	-	3	3	3	3
CO-2	2	2	2	2	2	-	-	3	3	-	3	3	2	2	2
CO-3	-	-	-	-	-	3	3	-	-	-	-	3	-	-	-
CO-4	-	-	-	-	-	-	-	-	-	3	-	3	-	-	-

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

Description:

Every student has to undergo either a Summer Internship / EPICS / Research project. The summer internship may be undergone in an Industry/Research organization or any premier academic Institution, including NIT Warangal for 6-8 weeks. The EPICS/research project shall be registered under the guidance of any faculty member in the institute. The student is required to submit a report and present the work before an evaluation committee, nominated by the Head of the Department.

Evaluation Criteria:

The student will be evaluated by the panel based on the below criteria.

Criteria	Description	Weightages
I	Relevance of the area of work	25 marks
II	Performance of the Task	20 marks
III	Crucial learnings from the work	20 marks
IV	Report Preparation	15 marks
V	Presentation and Response to questions	20 marks

Evaluation Criteria-CO Mapping

CO / Criteria	CO-1	CO-2	CO-3	CO-4
I	X			
II		X		
III			X	
IV				X
V				X

CH1495 **0-0-0 (2)**

Minor Project

Pre-Requisites: **None**

Course Outcomes:

CO-1	Apply engineering principles to real-world projects
CO-2	Plan and monitor project tasks individually or as a team
CO-3	Demonstrate practical experience in project execution
CO-4	Communicate project findings clearly through reports and presentations

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	3	3	3	3	3	3	3	3	2	-	-	3	3	3	3
CO-2	-	-	-	-	-	-	-	-	3	2	3	-	-	-	-
CO-3	2	2	2	2	2	3	-	-	3	2	2	3	2	2	2
CO-4	-	-	-	-	-	-	-	-	3	3	-	-	-	-	-

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

Description:

Students are expected to choose real world or relevant problems and apply the engineering principles learned, to solve the problem through building prototypes or simulations or writing codes or establishing processes/synthesis/correlations etc. The department constituted panel can decide the suitability and worthiness of the project.

Evaluation Criteria:

The student will be evaluated by the panel based on the below criteria.

Criteria	Description	Weightages
I	Identification of Problem Domain	20 marks
II	Study of Existing Systems and establishing clear objectives	20 marks
III	Planning of project and work distribution within the team	10 marks
IV	Proper Documentation and Technical Writing	20 marks
V	Presentation and Response to questions	30 marks

Evaluation Criteria-CO Mapping

CO / Criteria	CO-1	CO-2	CO-3	CO-4
I	X			
II	X			
III		X	X	
IV				X
V				X

8th Semester

CH1498 **0-0-0 (6)**

Major Project

Pre-Requisites: **None**

Course Outcomes:

CO-1	Identify a domain specific and contemporary topic
CO-2	Review literature to identify gaps and define objectives & scope of the work
CO-3	Develop a prototype/model, experimental set-up or software systems to meet the objectives
CO-4	Analyze the results to draw valid conclusions

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	3	2	-	-	-	-	2	-	3	2	-	2	1	1	2
CO-2	3	-	-	2	-	-	-	3	3	3	-	3	1	1	2
CO-3	1	2	3	3	3	2	2	3	3	2	3	2	2	2	3
CO-4	1	3	-	3	3	-	-	3	3	3	-	3	2	2	2

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

Description:

Students are expected to choose real-world contemporary problem and apply the engineering principles learned, to solve the problem through building prototypes or simulations or writing codes or establishing processes/synthesis/correlations etc. The department constituted panel will decide the suitability and worthiness of the project.

The method of evaluation should be as per the guidelines stipulated for the B.Tech. Project evaluation. The template for preparation of the project report may be downloaded from (**https://www.nitw.ac.in/path/?dept=/nitwForms**) under UG Forms. The students are required to submit a report showing that plagiarism is within 30%. The B.Tech. Project work will be evaluated for 100 marks, with the following weightages:

Component	**Weightage**
Periodic evaluation by Guide	40 marks
Mid-term review	20 marks
End Semester viva-voce examination	40 marks
Total	100 marks

The midterm review and the end semester viva-voce examination will be conducted by a committee constituted by the Head of the Department. If the performance of a student is not satisfactory, he/ she can be awarded ‘F’ grade. Such a student will be given a maximum time of three months to improve his/her performance. If the performance of such a student is not satisfactory even after the extended time period, he/ she will have to repeat the project work in the next academic year.

Evaluation Criteria:

The student will be evaluated by the panel based on the below criteria.

Criteria	Description	Weightages (%)
I	Selection of Topic	05
II	Literature Review	10
III	Objectives and Solution Methodology	15
IV	Performance of the Task and clarity on the work	20
V	Report Preparation	20
VI	Presentation and Response to questions	30

Evaluation Criteria-CO Mapping

CO / Criteria	CO-1	CO-2	CO-3	CO-4
I	X			
II		X		
III		X		
IV			X	
V				X
VI				X

Refer to B.Tech. – Regulations for any further information regarding Mid-term review, End Sem evaluation, Template for report preparation and plagiarism.

Professional Electives – I, II & III

CH1321 **3-0-0 (3)**

Industrial Safety and Hazard Mitigation

Pre-Requisites: None

Course Outcomes:

CO-1	Analyze the effects of toxic releases
CO-2	Select the methods for the prevention of fires and explosions
CO-3	Identify the hazards and preventive measures
CO-4	Assess the risks using a fault tree diagram

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	2	2	3	–	–	3	3	2	–	–	–	–	2	3	1
CO-2	2	2	3	–	–	3	3	2	–	–	–	–	2	3	1
CO-3	2	2	3	–	–	3	3	2	–	–	–	–	2	3	1
CO-4	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.

CH1322 **3-0-0 (3)**

Pollution Control in Process Industries

Pre-Requisites: None

Course Outcomes:

CO-1	Analyze the effects of pollutants on the environment
CO-2	Distinguish air pollution control methods
CO-3	Design gas equipment for pollution control
CO-4	Assess treatment technologies for wastewater
CO-5	Identify solid waste treatment technologies

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	3	1	2	2	–	1	2	1	1	1	1	1	1	–	–
CO-2	3	1	2	2	–	1	2	1	1	1	1	1	1	–	–
CO-3	2	2	3	2	1	1	1	–	–	–	–	1	1	2	1
CO-4	3	2	3	2	2	3	3	1	1	1	1	1	3	3	–
CO-5	3	2	3	2	2	3	3	1	1	1	1	1	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 & equipment: Control methods, Source correction methods, Cleaning of gaseous effluents, Particulate emission control, Selection of a particulate collector, Control of gaseous emissions, Design methods for control equipment.

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

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

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

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

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

Learning Resources:

Text Books:

1. Rao C.S., Environmental Pollution Control Engineering, 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, Prentice Hall of India, 2004, 2nd Edition.
4. Rao M.N, Rao H.V.N, Air Pollution, Tata McGraw Hill Education, 2017, 1st Edition.

Reference Books:

1. De A.K, Environmental Chemistry, New Age International Publishers, 2007, 7th Edition.
2. George Tchobanoglous, Franklin Louis Burton, H. David Stensel, Metcalf & Eddy, Wastewater engineering: treatment and reuse, McGraw Hill Education, 2003, 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, CRC Press, 2001,1st Edition.

Other Suggested Readings:

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

CH1323 **3-0-0 (3)**

Petroleum Refining Processes

Pre-Requisites: None

Course Outcomes:

CO-1	Characterize the petroleum and petroleum products
CO-2	Design the fractionating column for crude
CO-3	Differentiate the treatment techniques involved in post processing of crude
CO-4	Apply the process flow technologies for crude conversion to fuels

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	3	3	-	-	2	3	3	-	-	-	-	-	3	3	3
CO-2	3	3	-	-	3	1	3	-	-	-	-	-	3	3	3
CO-3	3	3	-	-	-	1	3	-	-	-	-	-	3	3	3
CO-4	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/

CH1324 **3-0-0 (3)**

Pharmaceuticals and Fine Chemicals

Pre-Requisites: None

Course Outcomes:

CO-1	Understand the grades of chemicals
CO-2	State properties, uses and testing of pharmaceuticals and fine chemicals
CO-3	Draw flow sheets for manufacture of pharmaceuticals and fine chemicals
CO-4	Understand tablet making and coating, preparation of capsules and extraction of crude drugs
CO-5	Understand sterilization

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	3	2	3	2	–	2	2	2	–	–	–	–	–	2	2
CO-2	3	2	3	2	–	2	2	2	–	–	–	–	–	2	2
CO-3	3	2	3	2	–	2	2	2	–	–	–	–	–	2	2
CO-4	3	2	3	2	–	2	2	2	–	–	–	–	–	2	2
CO-5	3	2	3	2	–	2	2	2	–	–	–	–	–	2	2

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

Syllabus:

Different grades of chemicals: Reagent grade and Laboratory grade.

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

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

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

Compressed tablet making and coating: Types of tablets and Methods of compressed tablet making and coating.

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

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

Learning Resources:

Text Books:

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

CH1325 **3-0-0 (3)**

Renewable Energy Sources

Pre-Requisites: **None**

Course Outcomes:

CO-1	Identify the challenges and problems associated with the use of energy sources
CO-2	Illustrate the renewable energy technologies
CO-3	Distinguish conversion technologies for solar, wind, biomass and hydrogen energies
CO-4	Evaluate the performance of energy conversion technologies

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	2	3	1	–	–	1	3	–	–	–	–	–	1	2	–
CO-2	2	3	1	2	–	2	3	–	–	–	–	–	3	1	–
CO-3	1	2	2	–	–	2	2	–	–	–	–	–	3	2	–
CO-4	2	3	2	1	1	2	3	–	–	–	–	–	2	3	–

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

Syllabus:

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

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

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

Geothermal Energy: Introduction, Origin and distribution of geothermal energy, types of geothermal resources, Hybrid geothermal power plant, Application of geothermal energy.

Hydrogen energy: Introduction, Hydrogen production, Hydrogen storage, Hydrogen transportation.

Energy from the Oceans: Introduction, Ocean Thermal Electric Conversion (OTEC).

Tidal Power: Energy from Tides, Ocean Waves, Chemical Energy Sources.

Green Energy: Introduction to Fuel cells, and Batteries.

Learning Resources:

Text Books:

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

Reference Books:

1. A.W. Culp Jr, Principles of energy conversion, Mc Graw Hill, 1996.
2. Sobha Nath Singh, Non -Conventional Energy Resources, Pearson, 2018.

Other Suggested Readings:

1. https://nptel.ac.in/courses/103103206

CH1326 **3-0-0 (0)**

Corrosion Engineering

Pre-Requisites: **None**

Course Outcomes:

CO-1	Identify various forms of corrosion
CO-2	Determine corrosion rates for metals from their polarization curves
CO-3	Analyze corrosion rate characteristics from electrochemical impedance spectroscopy
CO-4	Select suitable corrosion resistant coatings, oxide layers for various applications

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	1	2	1	2	2	1	2	-	1	-	-	2	1	3	1
CO-2	2	2	1	2	2	1	2	-	1	-	-	2	1	3	1
CO-3	2	2	1	2	2	1	2	-	1	-	-	2	1	3	1
CO-4	1	2	3	2	2	1	2	-	1	-	-	2	1	3	1

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

Syllabus:

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

Forms of Corrosion: Galvanic corrosion, Crevice corrosion, Pitting, Intergranular corrosion, Erosion corrosion, Stress corrosion, Hydrogen damage.

Corrosion testing: Specimen preparation, Exposure tests, Open corrosion potential, Linear polarization, Tafel slopes, Corrosion current, Stress corrosion cracking, AC impedance/EIS.

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

Modern Theory-Principles & Applications: Alloy evaluation, Nobel metal alloying, Flow accelerated corrosion, Galvanic corrosion as a moving boundary problem.

Learning Resources:

Text Books:

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

Reference Books:

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

CH1327 **3-0-0 (3)**

Nanotechnology

Pre-Requisites: None

Course Outcomes:

CO-1	Understand the properties of nanomaterials and their applications
CO-2	Apply chemical engineering principles to nanoparticles production and scale-up
CO-3	Analyze the nanomaterials characterization
CO-4	Identify the applications of nanotechnology in electronics and chemical industries

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	3	1	1	1	-	-	-	-	-	-	-	-	3	-	-
CO-2	3	2	2	2	-	-	-	-	-	-	-	-	3	1	-
CO-3	3	3	3	3	1	2	-	-	-	-	-	-	3	1	-
CO-4	3	1	1	1	-	-	-	-	-	-	-	-	3	-	-

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Nanomaterials and their Properties: Introduction to nanotechnology and nanomaterials, Clusters, Semiconductor nanoparticles, Plasmonic materials, Nanomagnetism, Mechanical & Structural properties.

Synthesis of Nanomaterials: Physical methods: Mechanical methods, Methods based on Evaporation, Sputter deposition and Chemical vapour deposition; Chemical methods: Nucleation and growth, Colloidal route, Langmuir-Blodgett method, Microemulsions, Sol-gel method, Hydrothermal synthesis, Sonochemical synthesis and Microwave synthesis; Biological methods: Synthesis using microorganisms, plant extracts, protein and templates.

Special Nanomaterials: Carbon Nanomaterials: Fullerenes, Graphene, Carbon nanotubes: Types of carbon nanotubes, Synthesis of carbon nanotubes, Growth mechanism; Porous materials; Aerogels; Zeolites; Core-shell particles; Bio-inspired materials.

Analysis Techniques: Microscopes: Optical, Confocal, Scanning electron, Transmission electron, Scanning tunneling and Atomic force microscopes; Diffraction techniques: X-ray diffraction, Dynamic light scattering; Spectroscopies: Optical, UV-Vis-NIR, Infrared, Dispersive infrared, Fourier transform infrared and Raman spectroscopy.

Applications: Energy: Solar cells, Fuel cells, Hybrid energy cells, Hydrogen generation and storage; Automobiles; Textiles; Cosmetics; Medical field; Agriculture & Food; Space; Defense and Engineering.

Nanotechnology and Environment: Environmental pollution and role of nanotechnology; Effect of nanotechnology on human health.

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.

Reference Books:

1. Robert Kelsall, Ian Hamley, Mark Geoghegan, Nanoscale Science and Technology, John Wiley & Sons, 2005, 1st Edition.
2. Stuart M. Lindsay, Introduction to Nanoscience, Oxford University Press, 2009, 1st Edition.
3. Davies, J.H. The Physics of Low Dimensional Semiconductors: An Introduction, Cambridge University Press, 1998, 1st Edition.
4. B. Viswanathan, Nano Materials, Alpha Science 2009. 1st Edition.
5. T. Pradeep, Nano - The essentials of understanding nanoscience and nanotechnology, The McGraw Hill, 2007, 1st Edition.

Other Suggested Readings:

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

CH1328 **3-0-0 (3)**

Polymer Technology

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand the polymerization reaction mechanism & kinetics
CO-2	Identify suitable processing method for a given polymer
CO-3	Choose additives for polymers, blends
CO-4	Characterize polymers using different techniques

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	3	1	1	1	-	-	-	-	-	-	-	-	3	2	1
CO-2	2	1	-	-	-	-	-	-	-	-	-	-	2	-	-
CO-3	2	-	-	-	-	-	-	-	-	-	-	-	1	-	-
CO-4	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.

Reference Books:

1. R. Sinha, Outlines of Polymer Technology: Manufacture of Polymers, Prentice Hall of India Pvt. Ltd., 2002.
2. George Odian, Principles of Polymerization, John Wiley & Sons, Inc., 2004.
3. V. R. Gowariker, Polymer science, New Age International Publishers, 2019, 3rd Edition.

Other Suggested Readings:

1. https://nptel.ac.in/courses/103/106/105106205/
2. https://nptel.ac.in/courses/103/107/103107139/

CH1329 **3-0-0 (3)**

Mechanical Design and Drawing

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand mechanical aspects involved in process equipment design
CO-2	Design pressure vessels of varying shapes and pressure conditions
CO-3	Select suitable components for the process equipment
CO-4	Evaluate the mechanical aspects for designing chemical process equipment
CO-5	Draw piping and instrumentation diagram for chemical processes

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	2	2	2	1	-	1	-	-	-	-	-	-	-	-	-
CO-2	3	3	3	1	1	-	-	-	-	-	-	-	1	1	1
CO-3	3	3	3	1	1	-	-	-	-	-	-	-	1	1	-
CO-4	3	3	3	1	1	-	-	-	-	-	-	-	2	2	-
CO-5	1	2	1	1	3	-	-	-	-	-	-	-	-	-	-

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

Syllabus:

Introduction to design procedure: General design procedure. Material of construction, Material properties, Corrosion and mechanical strength criteria, Design consideration, Stress analysis, Yield/Ultimate/Proof/Code Stresses, Elastic and plastic deformation, Strain hardening, Safety measures in equipment design, Economic considerations.

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

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

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

Learning Resources:

Text Books:

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

Reference Books:

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

Other Suggested Readings:

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

CH1330 **3-0-0 (3)**

Fuels and Combustion

Pre-Requisites: None

Course Outcomes:

CO-1	Differentiate between various fuels
CO-2	Analyse exhaust and flue gases
CO-3	Understand design considerations of burners
CO-4	Preparation of Rocket propellants and Explosives

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	2	3	-	-	-	-	3	-	-	-	-	-	3	2	-
CO-2	1	3	2	3	-	-	3	-	-	-	-	-	3	3	-
CO-3	1	3	2	2	-	-	3	-	-	-	-	-	3	3	-
CO-4	1	3	-	3	-	1	3	-	-	-	-	-	3	3	-

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

Syllabus:

Solid fuels: Classification of coal, analysis and properties of coal, oxidation of coal, hydrogenation of coal, agrofuels, solid fuel handling.

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

Combustion Principles: Stoichiometry relations, theoretical and minimum air required for complete combustion, calculation of dry flue gases, exhaust gas analysis, flue gas analysis, rapid methods of combustion, flame propagation, various methods of flame stabilization. Basic features of burner, types of solid, liquid and gaseous fuel burners, design consideration of different types of burners, recuperative and regenerative burners, Pulverised fuel furnaces–fixed, entrained, and fluidized bed systems. Emissions, Emission index, corrected concentrations, control of emissions for premixed and non-premixed combustion.

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

Learning Resources:

Text Books:

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

Reference Books:

1. H. Joshua Phillips, Fuels, solid, liquid and gaseous – Their analysis and valuation, General Books, 2010.
2. K. Kanneth, Principles of combustion, Wiley and Sons, 2005.
3. S.P. Sharma and C. Mohan, Fuels and combustion, Tata McGraw-Hill, 1987.
4. A.I. Levorsen, Geology of Petroleum, CBS, 2004.

CH1331 **3-0-0 (3)**

Fertilizer Technology

Pre-Requisites: **None**

Course Outcomes:

CO-1	Classify Fertilizers
CO-2	Explain manufacturing processes for production of fertilizers
CO-3	Identify the effect of technologies on the health, safety and environment
CO-4	Explain the mechanism of chemical reactions

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	1	3	–	–	–	–	3	–	–	–	–	–	3	1	–
CO-2	2	3	–	–	–	2	3	–	–	–	–	–	3	1	–
CO-3	1	3	–	–	–	3	3	–	–	–	–	–	3	3	–
CO-4	2	3	–	–	–	1	3	–	–	–	–	–	3	1	–

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

Syllabus:

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

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

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

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

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

Learning Resources:

Text Books:

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

Reference Books:

1. K. K. Pant, Shailendra Bajpai, Fertilizer Technology I: Synthesis, Studium Press LLC, 2015.
2. Vasant Gowariker, V.N. Krishnamurthy, Sudha Gowariker, Manik Dhanorkar, Kalyani Paranjape, The Fertilizer Encyclopedia, Wiley, 2008.

CH1332 **3-0-0 (3)**

Food Technology

Pre-Requisites: **None**

Course Outcomes:

CO-1	Explain techniques in food processing
CO-2	Design process equipment to achieve the desired quality of food
CO-3	Develop novel food processes that have a minimal effect on food quality
CO-4	Select control strategies to maintain food quality

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	2	3	-	-	-	-	3	-	-	-	-	-	3	2	-
CO-2	1	3	2	3	-	-	3		-	-	-	-	3	3	-
CO-3	1	3	2	2	-	-	3	-	-	-	-	-	3	3	-
CO-4	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 micro-organisms; Basic Food Biochemistry and Microbiology; Food Constituents; Food fortification; Water activity; Effects of processing on sensory characteristics of foods; Effects of processing on nutritional properties; Food safety; Good manufacturing practice and quality process control in food processing.

Ambient Temperature Processing: Raw material preparation; Size reduction; Mixing and forming; Separation and concentration of food components; Centrifugation; Membrane concentration; Fermentation and enzyme technology; Irradiation; Effect on micro-organisms; Processing using electric fields, high hydrostatic pressure, light or ultrasound.

Heat processing using steam, water and air: Blanching; 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.

Learning Resources:

Text Books:

1. Fellows P., Food Processing Technology: Principles and Practice, Woodhead Publishing, 2016, 4th Edition.

2. Toledo R, Fundamentals of Food Process Engineering, Springer, 2010, 3rd Edition.
3. Singh R.P., Heldman D.R., Introduction to Food Engineering, Academic Press, 2001, 3rd Edition.

Other Suggested Readings:

1. https://nptel.ac.in/courses/103107088

CH1333 **3-0-0 (3)**

Green Technology

Pre-Requisites: None

Course Outcomes:

CO-1	Understand principles and concepts of green chemistry
CO-2	Develop manufacturing processes to reduce wastage and energy consumption
CO-3	Design the technologies to reduce the level of emissions from buildings and core infrastructure
CO-4	Analyze the effects of pollutants on the environment

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	3	3	1	1	1	2	3	1	–	–	–	–	3	2	1
CO-2	3	3	3	1	1	2	3	–	–	–	–	–	3	2	2
CO-3	3	3	3	1	1	2	3	–	–	–	–	–	3	2	2
CO-4	3	3	2	2	2	2	3	1	–	–	–	–	3	2	3

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Principles and concepts of Green Chemistry: Introduction, Sustainable Development and Green Chemistry, Rearrangement Reactions, Addition Reactions, Atom Un-economic Reactions, Substitution Reactions, Elimination Reactions, Wittig Reactions, Toxicity, Waste- Production.

Problems and Prevention: Introduction, Some Problems Caused by Waste, Sources of Waste from the Chemical Industry, The Cost of Waste, Waste Minimization Techniques.

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

Catalysis and green chemistry: Introduction to Catalysis, Comparison of Catalyst Types, Heterogeneous Catalysts, Basics of Heterogeneous Catalysis and Homogeneous Catalysis. Organic solvents, Environmentally benign solutions: Organic Solvents and Volatile Organic Compounds, Solvent-free Systems, Supercritical Fluids, Supercritical Carbon Dioxide, Supercritical Water, Water as a Reaction Solvent, Water-based Coatings, Ionic Liquids, Ionic Liquids as Catalysts, Ionic Liquids as Solvents, Fluorous Biphase Solvents. Renewable Energy as a means of Green energy: Role of Renewable energy sources in promoting Green Technology.

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

Designing greener processes: Conventional Reactors, Batch Reactors, Continuous Reactors, Inherently Safer Design, Minimization, Simplification, Substitution, Moderation, Limitation, Process Intensification,

Some PI Equipment, Examples of Intensified Processes, In-process Monitoring, Near-infrared Spectroscopy. Inherent safety-safety in design, case studies of major accidents.

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

Learning Resources:

Text Books:

1. Mike Lancaster, Green Chemistry, Royal Society of Chemistry, 2010.
2. John C. Warner, Paul T. Anastas, Green Chemistry: Theory and Practice, Oxford University Press, 2000.

Reference Books:

1. Annie Warmke, Jay Warmke, Green Technology, Educational Technologies Group, 2009.
2. James Clark, Duncan Macquarrie, Handbook of Green Chemistry & Technology, Blackwell Publishing, 2002.
3. S. Suresh, S. Sundaramoorthy, Green Chemical Engineering: An introduction to Catalysis, Kinetics, and Chemical Processes, CRC Press, 2015.

CH1334 **3-0-0 (3)**

Pulp and Paper Technology

Pre-Requisites: **None**

Course Outcomes:

CO-1	Explain process for manufacturing paper
CO-2	Identify harmful impacts of paper and pulp industries on environment
CO-3	Describe mechanical-chemical pulping processes
CO-4	Distinguish methods for pulp treatment

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	2	3	2	2	2	2	2	-	-	2	-	1	3	2	1
CO-2	2	3	3	2	2	2	3	-	2	2	-	2	2	2	1
CO-3	2	3	2	2	2	2	2	-	-	2	-	1	3	2	1
CO-4	2	3	2	-	-	2	2	-	-	2	-	1	3	3	2

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

Syllabus:

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

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

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

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

Learning Resources:

Text books:

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

4. K. P. Rao, Pulp and paper Technology: Technology, Testing & Applications, CBS Publishers & Distributors, 2003, 1st Edition.

Reference Books:

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

CH1335 **3-0-0 (3)**

Heterogeneous Catalysis

Pre-Requisites: None

Course Outcomes:

CO-1	Describe the methods of preparation and characterization of catalysts
CO-2	Analyze the role of heat and mass transfer in the catalytic reactor design
CO-3	Determine the deactivation kinetic parameters and selectivity
CO-4	Distinguish the performance of catalytic reactors
CO-5	Identify the role of industrial catalysts in the environmental protection

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	3	3	2	1	-	-	-	-	-	-	-	-	3	2	-
CO-2	2	3	2	1	-	-	-	-	-	-	-	-	3	1	-
CO-3	2	1	2	1	-	-	-	-	-	-	-	-	1	1	-
CO-4	2	3	1	1	-	-	-	-	-	-	-	-	1	1	-
CO-5	-	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.

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/

CH1336 **3-0-0 (3)**

Analytical Techniques for Chemical Engineers

Pre-Requisites: **None**

Course Outcomes:

CO-1	Develop a comprehensive understanding of various microscopy techniques
CO-2	Use appropriate spectroscopy method for specific analytical problems
CO-3	Select the electro-analytical techniques for analyzing electrochemical reactions
CO-4	Understand the principles and applications of chromatography

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	3	3	-	3	2	-	-	-	-	3	-	1	-	-	-
CO-2	3	3	-	3	2	-	-	-	-	3	-	1	-	-	-
CO-3	3	3	-	3	2	-	-	-	-	3	-	1	-	-	-
CO-4	3	3	-	3	2	-	-	-	-	3	-	1	-	-	-

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

Syllabus:

Microscopy Techniques: Optical microscopy**;** Scanning electron microscopy; Scanning probe microscopy; Scanning tunneling microscopy; Atomic force microscopy; Transmission electron microscopy.

Spectroscopy Methods: Fourier Transform Infrared Spectroscopy; Raman spectroscopy; UV-VIS spectroscopy; Energy dispersive X-ray spectroscopy; X-ray photoelectron spectroscopy; Mass spectroscopy; X-ray diffraction; Atomic absorption spectroscopy; Atomic emission spectroscopy; Inductively coupled plasma optical emission spectroscopy.

Electro-Analytical Techniques: Voltammetry; Coulometry; Amperometry; Potentiometry; Polarography; Electrolytic conductivity; Impedance spectroscopy.

Separation Methods: Normal and reversed phase liquid chromatography; Gas chromatography; High performance liquid chromatography; Size- exclusion chromatography; Ion chromatography.

Learning Resources:

Text Books:

1. Douglas B. Murphy, Fundamentals of Light Microscopy and Electronic Imaging, John Wiley & Sons, Inc., Publication, 2001.
2. C.N. Banwell, Fundamentals of Molecular Spectroscopy, McGraw-Hill, 2001.
3. R. Wiesendanger, Scanning Probe Microscopy and Spectroscopy, Cambridge University Press, 1994.
4. Frank A. Settle, Handbook of instrumental techniques for analytical chemistry, Prince Hall, 997.
5. D. A. Skoog, D. M. West, F. J. Holler and S. R. Couch, Fundamentals of analytical chemistry. Belmont: Brooks/Cole: Cengage Learning, 2014, 9th Edition.

6. P. Atkins and J. de Paula, Atkins' physical chemistry, Oxford University Press, 2008, 8th Edition.

Reference Books:

1. Gregory S. Patience, Experimental Methods and Instrumentation for Chemical Engineers, Elsevier, 2018, 2nd Edition.

CH1337 **3-0-0 (3)**

Complex Fluids

Pre-Requisites: **None**

Course Outcomes:

CO-1	Distinguish the complex fluids from classical fluids
CO-2	Understand the macroscopic behavior of the complex fluids
CO-3	Identify forces involved in complex fluids
CO-4	Analyze rheology of polymers, glassy liquids and gels
CO-5	Understand rheology of suspensions, surfactant solutions and block copolymers

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	2	2	1	2	1	-	-	-	2	2	-	1	2	1	2
CO-2	2	2	1	2	1	-	-	-	2	2	-	1	2	1	2
CO-3	2	2	1	2	1	-	-	-	2	2	-	1	2	1	2
CO-4	2	2	1		1	-	-	-	2	2	-	1	2	1	2
CO-5	2	2	1	2	1	-	-	-	2	2	-	1	2	1	2

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

Syllabus:

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

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

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

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

Surfactant solutions and block copolymers: Theory and rheology of surfactants and block polymers.

Learning Resources:

Text Books:

1. R.G. Larson, The Structure and Rheology of Complex Fluids, Oxford University Press, 1999.
2. R.P. Chhabra, J.F. Richardson, Non-Newtonian Flow and Applied Rheology: Engineering Applications, Butterworth-Heinemann, 2008, 2nd Edition.
3. P.D. Abhijit, J. Murali Krishna, P.B. Sunil Kumar, Rheology of Complex Fluids, Springer, 2010.

Reference Books:

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

Other Suggested Readings:

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

CH1338 **3-0-0 (0)**

Natural Gas Engineering

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand the properties, phase behavior of natural gas
CO-2	Evaluate oil and gas reserves, and bottom hole pressure
CO-3	Design the compressors used in the natural gas industry
CO-4	Illustrate the production economics and production trends of natural gas

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	3	2	3	1	2	3	3	-	2	2	-	1	2	2	1
CO-2	3	2	3	1	2	3	3	-	2	2	-	1	2	2	1
CO-3	3	2	3	1	2	3	3	-	2	2	-	1	2	2	1
CO-4	3	2	3	1	2	3	3	-	2	2	-	1	2	2	1

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

Syllabus:

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

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

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

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

Natural Gas conversion technologies: Natural Gas Conversion to Liquids (GTL), Fischer-Tropsch Synthesis: Methanol and Dimethyl Ether (DME) Production- Syngas Production and Uses, Natural Gas Conversion to Hydrogen: Steam Methane Reforming (SMR)- Partial Oxidation and Autothermal Reforming-Carbon Capture and Storage (CCS).

Natural Gas Conversion to Electricity: Combined Cycle Gas Turbines (CCGT), Direct Methane Fuel Cells (DMFC), Microturbines and Other Distributed Generation Technologies, Introduction to Emerging technologies Biogas and Renewable Natural Gas (RNG), Methane Pyrolysis and Plasma Reforming, Novel Catalytic and Non-Catalytic Processes.

Learning Resources:

Text Books:

1. Mohan Kelkar, Natural Gas Production Engineering, Pennwell Books, 2008
2. Sanjay Kumar, Gas Production Engineering, Volume 4, Gulf Publishing Company, Houston, Texas, 1960.

Reference Books:

1. Katz D., Robert Lee, Natural Gas Engineering - Production and Storage, McGraw Hill, 1990.
2. Katz D., Hand Book of Natural Gas engineering, McGraw Hill, 1959.

Other Suggested Readings:

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

CH1339 **3-0-0 (0)**

Biomass and Biofuels Technology

Pre-Requisites: None

Course Outcomes:

CO-1	Identify potential biomass sources for renewable energy generation
CO-2	Understand the production process for liquid biofuels
CO-3	Design the compressors used in the natural gas industry
CO-4	Understand the concept of strain improvement for biofuels production
CO-5	Forecast the entrepreneurial opportunities in Bioenergy

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	1	3	-	-	-	-	3	-	-	-	-	-	2	2	3
CO-2	1	3	-	-	-	-	3	-	-	-	-	-	2	2	3
CO-3	1	-	3	-	-	-	3	-	-	-	-	-	2	2	3
CO-4	3	-	-	-	-	-	3	-	-	-	-	-	2	2	3
CO-5	1	-	3	-	-	-	3	-	-	-	-	-	2	2	3

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

Syllabus:

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

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

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

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

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

Entrepreneurial Opportunities in Bioenergy: Market trends, economic potential, and growth opportunities; Business Models and Value Chains in Bioenergy; Financing and Investment Strategies; Regulatory, Environmental, and Social Considerations in Bioenergy.

Learning Resources:

Text Books:

1. Vijai K. Gupta.,Maria Tuohy, Christian Kubicek, Jack Saddler, Feng Xu, Bioenergy Research: Advances and Applications, Elsevier, 2014.
2. Dahiya, A., Bioenergy: biomass to biofuels, Elsevier, 2015.

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

Reference Books:

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

CH1340 **3-0-0 (0)**

Sustainability in Chemical Industries

Pre-Requisites: None

Course Outcomes:

CO-1	Understand the basic concepts of sustainability
CO-2	To learn the fundamental philosophy and the latest developments in sustainable chemistry.
CO-3	To understand how waste can be converted to wealth and apply chemical engineering principles for value added products
CO-4	To understand importance of recycling and its application in circular economy

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	1	1	1	1	-	2	3	1	-	-	-	-	1	2	-
CO-2	1	-	1	2	-	2	3	1	-	-	-	-	1	2	-
CO-3	1	1	1	2	-	2	3	1	-	-	-	-	1	2	1
CO-4	1	-	1	3	-	2	3	1	-	-	-	-	1	2	1

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Chemical Industries current Scenario: The nature of production, concepts, tasks, production resources, processes and approaches to sustainability.

Sustainability concepts: Sustainable Development Goals for Clean Energy (SDGs), Emerging issues in energy access, technologies, economics. Sustainability Concepts of Energy Generation Technologies, Energy and resource utilization.

Sustainable Energy: The Engine of Sustainable Development: Aspects of energy production, nations and global patterns of energy supply and utilisation, environmental effects of energy.

Estimation and evaluation of Energy Resources: Comparison of different forms of energy, energy life cycle, estimation and validation of energy resources.

Green Processes: Designing safer compounds, predicting their characteristics and environmental aspects prior to synthesis; Use catalysts to reduce time and energy demands, and minimise waste. Design for energy efficiency, using the least energy-intensive approach for synthesis.

Biomass feedstock, value added products, biofuel: Characterisation, Biomass relevance to energy production, bioconversion, economics.

Circular Economy and CO_2 sequestration and Utilization: Life-Cycle Analysis and design for sustainability, Chemical industries, cement and lime industries, sustainability issues.

Synergistic complex systems: The complex systems view, Some case studies, Transitional pathways, The challenge to Society.CO_2 sequestration utilization, circular economy.

Learning Resources:

Text Books:

1. Purohit S. S., Green Technology - An approach for sustainable environment, Agrobios, 2008
2. Bhavik R. Bakshi, Sustainable Engineering: Principles and Practice, Cambridge University Press, 2019.
3. Jeffery Perl, Sustainability Engineering: A Design Guide for the Chemical Process Industry, Springer International, 2016.
4. Ibrahim Dincer, Azzam Abu-Rayash, Energy Sustainability, Elsevier, 2019.

Reference Books:

1. Catherine N. Mulligan, Sustainable Engineering: Principles and Implementation, CRC Press, 2019.
2. Allen D. T., Shonnard D. R., Sustainability Engineering: Concepts, Design and Case Studies, Prentice Hall, 2015.
3. Hazra Somnath, Bhukta Anindya, Sustainable Development Goals An Indian Perspective, Springer International, 2020.

Professional Electives – IV, V, VI, VII & VIII

CH1421 **3-0-0 (3)**

Fuel Cell Engineering

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand the working principle of fuel cells
CO-2	Analyze the performance of fuel cell systems
CO-3	Identify the intricacies in the operation of fuel cells
CO-4	Apply fuel processing techniques

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	2	2	3	2	1	1	2	-	2	2	-	1	1	3	1
CO-2	2	2	3	2	1	1	2	-	2	2	-	1	1	3	1
CO-3	2	2	3	2	1	1	2	-	2	2	-	1	1	3	1
CO-4	2	2	3	2	1	1	2	-	2	2	-	1	1	3	1

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

Syllabus:

Introduction to Fuel Cells: Fuel Cells as Electrochemical Engines; Generic Fuel Cell and Stack; Classification of Fuel Cells; Potential Applications; History of Fuel Cell Development.

Thermodynamics and Basic Electrochemical Principles: Heat; Work Potentials; Prediction of Reversible Voltage, Fuel Cell Efficiency; Polarization curve; Electrode Kinetics; Butler-Volmer Equation; Overpotentials; Tafel Equation; Theoretical fuel cell efficiency.

Fuel Cell Components and Their Impact on Performance: Fuel Cell Performance Characteristics – Current/Voltage; Voltage Efficiency and Power Density; Ohmic Resistance; Kinetic Performance; Membrane Electrode Assembly Components; Fuel Cell Stack; Bi-Polar Plate; Humidifiers and Cooling Plates.

Principles and technology of different types of fuel cell systems: Alkaline Fuel Cells; Molten Carbonate Fuel Cells; PEM Fuel Cells; Solid Oxide Fuel Cells; Phosphoric acid Fuel Cells; Microbial Fuel Cells; Regenerative Fuel Cells.

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

Learning Resources:

Text Books:

1. Hoogers G., Fuel Cell Technology Hand Book, CRC Press, 2003, 1st Edition.
2. Mathew M. Mench, Fuel Cell Engines, Wiley, 2008, 1st Edition.
3. O'Hayre, R. P., Cha, S., Colella, W., Prinz, F. B., Fuel Cell Fundamentals, Wiley, 2016, 3rd Edition.
4. Barbir, F., PEM Fuel Cells: Theory and Practice, Elsevier/Academic Press, 2013, 2nd Edition.

Reference Books:

1. Detlef Stolten, Bernd Emonts, Fuel Cell Science and Engineering – Materials, Processes, Systems and Technology, Vol-1, Wiley-VCH, 2012, 1st Edition.
2. Subhash C. Singal, Kevin Kendall, High Temperature Fuel Cells: Fundamentals, Design and Applications, Elsevier Science, 1985, 1st Edition.
3. Laminie, J., Dicks, A., John Wiley, Fuel Cell Systems Explained, New York, 2003, 2nd Edition.

Other Suggested Readings:

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

CH1422 **3-0-0 (3)**

Process Integration

Pre-Requisites: **None**

Course Outcomes:

CO-1	Synthesize mas-exchange networks
CO-2	Synthesize reactive and recycle mass-exchange networks
CO-3	Integrate heat, and reactive mass-exchange networks
CO-4	Optimize mass, heat and recycle networks

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	3	3	3	3	3	3	3	-	-	-	3	2	3	3	3
CO-2	3	3	3	3	3	3	3	-	-	-	3	2	3	3	3
CO-3	3	3	3	3	3	3	3	-	-	-	3	2	3	3	3
CO-4	3	3	3	3	3	3	3	-	-	-	3	2	3	3	3

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

Syllabus:

Introduction to Sustainability, Sustainable Design, and Process Integration. Benchmarking Process Performance through Overall Mass Targeting.

Synthesis of mass-exchange networks: Graphical, algebraic and mathematical programming approach. Synthesis of reactive mass-exchange networks.

Direct recycle networks: Algebraic approach.

Heat integration: Integration of combined heat and power systems, Property Integration.

Overview of Optimization, Combining mass integration strategies, Mathematical optimization techniques for mass integration, An optimization approach to direct recycle.

Mathematical techniques for synthesis of heat-exchange networks, Synthesis of combined heat and reactive mass-exchange networks.

Launching successful process-integration initiatives and applications.

Learning Resources:

Text Books:

1. Mahmoud M. El-Halwagi, Sustainable design through Process Integration Fundamental applications to Industrial pollution prevention, resource conservation, and profitability enhancement, Butterworth-Heinemann (Imprint of Elsevier), 2012, 2nd Edition.
2. Mahmoud M. El-Halwagi, Process Integration, Academic press, 2006.

Reference Books:

1. Jiri J Klemes, Handbook of Process Integration: Minimisation of energy and water use, waste and emissions, Woodhead Publishing Limited, 2013.
2. Dominic C Y Foo, Process Integration for resource conservation, CRC Press, 2013.

CH1423 **3-0-0 (3)**

Biochemical Engineering

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand cell and enzyme kinetics
CO-2	Explain cell disruption Techniques
CO-3	Select the methods of enzyme immobilization
CO-4	Compare the performance of aeration and bioreactor systems
CO-5	Select sterilization methods for a given system

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	3	3	2	1	-	1	2	1	-	-	-	-	3	3	-
CO-2	3	3	2	1	-	1	2	1	-	-	-	-	3	3	-
CO-3	3	3	2	1	-	1	2	1	-	-	-	-	3	3	-
CO-4	3	3	2	1	-	1	2	1	-	-	-	-	3	3	-
CO-5	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.

CH1424 **3-0-0 (3)**

Interfacial Science

Pre-Requisites: None

Course Outcomes:

CO-1	Understand concepts such as surfaces, interfaces and their properties
CO-2	Apply inter-molecular and inter-particle forces to model interfaces
CO-3	Quantify interfacial properties at macro scale
CO-4	Evaluate surface excess properties using thermodynamic description of surfaces
CO-5	Design processes that utilize interfacial phenomena

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	1	2	1	2	-	-	-	-	-	-	-	-	-	1	2
CO-2	2	2	1	2	-	-	-	-	-	-	-	-	-	1	2
CO-3	3	2	1	2	-	-	-	-	-	-	-	-	-	1	2
CO-4	3	2	1	3	-	-	-	-	-	-	-	-	-	1	2
CO-5	3	2	1	3	-	-	-	-	-	-	-	-	-	1	2

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

Syllabus:

Introduction: The importance of interfaces, Surfaces and interfaces, Stable interfaces.

Inter-molecular forces: Introduction, Charge-charge interaction, Ion-dipole interaction, Dipole-dipole interaction, Ion/dipole-polarisable molecule interaction, Dispersion interaction, van der Waals interaction.

Inter-particle forces: Introduction, Hamaker's additivity approach, Deryaguin's approximation, Retardation effect.

Capillarity and surface tension: Surface tension and work, Measurement of surface tension, The Laplace equation, The Kelvin equation, The surface tension of pure liquids, Surfactants and micelles, Application of surfactants, Adsorption of surfactants, Films and foams, Aerosols.

Adsorption and thermodynamics of surfaces: Models of the interface, Adsorption, Adsorption isotherms, Thermodynamic properties of interfaces, Surface excess quantities, Measurement of Adsorption, Adsorption form solution, Kinetics of Adsorption.

Liquid/Solid interfaces: Surfaces of solids, Colloidal dispersions, The properties of colloidal dispersions, Coagulation of lyophobic colloids by electrolytes, Solvation effects in colloidal interactions, Stability of colloids, Nanoparticles, Emulsions, Emulsion stability and selection of the emulsifier, Micro-emulsion, Emulsion polymerization.

Nucleation and Growth: Classical Nucleation theory, Homogeneous nucleation, Heterogeneous nucleation, Spinodal decomposition.

Learning Resources:

Text Books:

1. 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.

CH1425 **3-0-0 (3)**

Process Modelling and Simulation

Pre-Requisites: None

Course Outcomes:

CO-1	Understand model building techniques and simulation approaches
CO-2	Solve model equations using numerical method
CO-3	Develop model for simple systems based on first principles, stochastic and empirical
CO-4	Model and simulate chemical process using Artificial Neural Networks

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
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, classification of models, tools of simulation, approaches of simulation, Numerical methods for model equations. Application of simulation.

Models: Models, need of models and their classification, models based on transport phenomena principles, population balance, stochastic, and empirical models, unit models. Artificial Neural Network. Model development for simple system.

Models of Reactors: Model for batch and semi-batch reactor, Model for Continuous stirred tank reactor, Classification of fixed bed reactor models, fluidized bed reactor models.

Models of Separation Processes: Model for distillation column, compartmental distillation model, ideal binary distillation, binary batch distillation, binary continuous distillation, multicomponent distillation column, flash calculation under isothermal and adiabatic conditions.

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

Learning Resources:

Text Books:

1. W.L. Luyben, Process Modeling, Simulation and Control for Chemical Engineers, 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.
3. Ashok Kumar Verma, Process Modeling and Simulation in Chemical, Biochemical and Environmental Engineering, CRC Press, 2014.

4. K. M. Hangos and I. T. Cameron, Process Modelling and Model Analysis, Academic Press, 2001.
5. M. Chidambaram, Mathematical Modelling and Simulation in Chemical Engineering, Cambridge University Press, 2018.

Other Suggested Readings:

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

CH1426 **3-0-0 (3)**

Microscale Unit Operations

Pre-Requisites: None

Course Outcomes:

CO-1	Identify the microscale phenomena in various miniaturized equipment like MEMS
CO-2	Solve fluid flow phenomena for single and two immiscible liquids in microchannels
CO-3	Design architectures of microfluidic devices for chemical & medical applications
CO-4	Integrate theoretically the modular components for assembling of Lab-on-a-chip devices
CO-5	Understand applications of micro devices for chemical and biomedical applications

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	3	1	1	1	-	-	-	-	-	-	-	-	3	-	-
CO-2	3	2	2	2	-	-	-	-	-	-	-	-	3	1	-
CO-3	3	1	3	3	1	2	-	-	-	-	-	-	3	1	-
CO-4	3	3	3	3	1	2	-	-	-	-	-	-	3	1	-
CO-5	3	1	1	1	-	-	-	-	-	-	-	-	3	-	-

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

Syllabus:

Physics and Chemistry at microscale: Introduction, Introduction to forces of microscopic origin; Physics of miniaturization of mechanical, thermal and chemical systems ranges of forces of microscopic origin, Microscopic length scales intervening in liquids and gases, Micromanipulation of molecules.

Fluid dynamics in micro channels: Introduction, hypotheses of hydrodynamics, Hydrodynamics of gases in Micro channels, Flow of liquids with slip at the surface, Micro hydrodynamics, Microfluidics. Fluid dynamics in micro channels: flow of liquids with and without slip, capillarity, two phase flow, preparation of micro emulsions, Micro reactor, Mixing and separation at microscale, cells in Microsystems, The physics of miniaturization, miniaturization of electrostatic systems.

Reaction Diffusion at microscopic level: The microscopic origin of diffusion process, Advection-diffusion equation and its properties, Analysis of dispersion phenomena, chaotic mixing, mixing in Microsystems, Adsorption phenomena, Dispersion with chemical kinetics, Chromatography.

Miniaturization: Miniaturization of electromagnetic systems, miniaturization of mechanical systems, miniaturization of thermal systems, miniaturization of systems for chemical analysis. Interfacial phenomena: a few ideas about capillarity, Microfluidics of drops and bubbles,

Applications: Application to chromatography; Examples of microfluidic structures, connectors, valves and pumps; Fabrication methods and applications of micro devices, Mixing at microscale: Gas - Gas, Liquid-Liquid. Fundamentals and Applications of Microfluidics, featuring new material on nanoparticle suspensions through microdevices, carbon nanotubes application in microfluidics devices, performance benefits of microfluidics.

Learning Resources:

Text Books:

1. Nguyen N T, Wereley S and Shaegh S A M, Fundamentals and Applications of Microfluidics, Artech House, 2018, 3rd Edition.
2. Tabeling P, Introduction to Microfluidics, Oxford University Press, 2006, 1st Edition.
3. Gad-el-HukM, MEMS: Applications, CRC Press, 2005,1st Edition.

Reference Books:

1. McGuire F, Microfluidics Handbook, NY Research Press, 2015, 1st Edition.
2. Seiffert S, Microfluidics: Theory and Practice for Beginners, De Gruyter, 2019, 1st Edition.
3. Wirth T, Microreactors in Organic Chemistry and Catalysis, Wiley-VCH, 2013, 2nd Edition.

Other Suggested Readings:

1. https://nptel.ac.in/courses/103/105/103105057/

CH1427 **3-0-0 (3)**

Process and Product Design

Pre-Requisites: None

Course Outcomes:

CO-1	Understand Chemical product design principles
CO-2	Select processes and flowsheets
CO-3	Assess energy requirements and safety/sustainability indicators of processes
CO-4	Execute computer aided molecular and mixture design
CO-5	Design chemical devices

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	3	2	2	1	2	-	-	-	-	-	-	-	1	1	2
CO-2	3	3	3	2	1	-	-	-	-	-	-	-	2	2	2
CO-3	2	3	3	2	1	2	2	-	-	-	-	-	3	3	3
CO-4	3	3	3	2	3	-	-	-	-	-	-	-	2	3	3
CO-5	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.

CH1428 **3-0-0 (3)**

Mathematical Methods in Chemical Engineering

Pre-Requisites: **None**

Course Outcomes:

CO-1	Formulate lumped and distributed parameter mathematical models for chemical processes
CO-2	Evaluate degrees of freedom for the developed mathematical models
CO-3	Solve the model equations describing chemical processes and equipment
CO-4	Analyze the results of the solution methods
CO-5	Perform nonlinear analysis

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	3	1	3	3	–	3	–	–	–	–	–	–	3	3	3
CO-2	3	2	3	3	–	–	–	–	–	–	–	–	3	3	3
CO-3	3	3	3	3	–	–	–	–	–	–	–	–	3	3	3
CO-4	3	3	3	3	–	–	–	–	–	–	–	–	3	3	3
CO-5	3	–	–	3	3	–	–	–	–	–	–	–	3	–	3

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

Syllabus:

Mathematical Formulation of the Physical Problems: Introduction, Representation of the problem, blending process, continuous stirred tank reactor, Unsteady state operation, heat exchangers, distillation columns, biochemical reactors.

Analytical (explicit) Solution of Ordinary Differential Equations encountered in Chemical Engineering Problems: Introduction, Order and degree, first order differential equations, second order differential equations, Linear differential equations, Simultaneous differential equations. Differential algebraic equations.

Non-linear analysis: Phase plane analysis, Bifurcation behavior.

Formulation of partial differential equations: Introduction, Interpretation of partial derivatives, Formulation partial differential equations, particular solutions of partial differential equations, Orthogonal functions, Method of separation of variables, The Laplace Transform method, Other transforms.

Unsteady state heat conduction in one dimension: Mass transfer with axial symmetry, Continuity equations, Boundary conditions, Iterative solution of algebraic equations, The difference operator, Properties of the difference operator, Linear finite difference equations, Non-linear finite difference equations, Simultaneous linear differential equations, analytical solutions, Application of Statistical Methods.

Learning Resources:

Text Books:

1. V.G. Jenson, G.V. Jeffrys, Mathematical methods in chemical engineering, Academic Press, 2000, 2nd Edition.

2. B.W. Bequette, Process Dynamics- Modelling, Analysis and Simulation, Prentice Hall India, 1998.

Reference Books:

1. B. A. Finlayson, Introduction to Chemical Engineering Computing, Wiley India, 2010.
2. Norman W. Loney, Applied Mathematical Methods for Chemical Engineers, 2015, 3rd Edition.

CH1429 **3-0-0 (0)**

Bioseparation Techniques

Pre-Requisites: None

Course Outcomes:

CO-1	Explain the fundamental concepts of Bioseparation processes, including the RIPP scheme
CO-2	Evaluate the properties of biological materials relevant to separation processes & Compare various techniques
CO-3	Demonstrate the principles and techniques of liquid-liquid extraction and liquid chromatographic methods
CO-4	Analyze the chemistry of extraction processes (batch, staged, differential extractions) and design experiments
CO-5	Develop strategies for product purification using elution chromatography, precipitation, affinity ultrafiltration, and electrophoresis, and optimize final product quality

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	1	3	-	-	-	-	3	-	-	-	-	-	2	2	3
CO-2	1	3	-	-	-	-	3	-	-	-	-	-	2	2	3
CO-3	1	-	3	-	-	-	3	-	-	-	-	-	2	2	3
CO-4	3	-	-	-	-	-	3	-	-	-	-	-	2	2	3
CO-5	1	-	3	-	-	-	3	-	-	-	-	-	2	2	3

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

Syllabus:

Introduction to Bioseparations: Range and characteristics of fermentation broth and microorganisms. Economic significance of bioseparation processes; The RIPP scheme: Recovery, isolation, purification and polishing. Examples and current trends in bioseparations.

Removal of insolubles: Properties of biological materials Size, molecular weight, diffusivity, sedimentation coefficient, osmotic pressure, solubility, partition coefficient, light absorbance, Filtration, pretreatment of fermentation broth, continuous filtration equipment, microfiltration. Centrifugation, settling of solids, scaleup of centrifugation, centrifugal filtration.

Cell disruption: Intracellular products, cell wall, cell disruption using bead mill, French press, ultrasonic vibrations, detergents, enzymes, solvents, and osmotic shock, Liquid- liquid extractions, Liquid chromatographic methods- Medium Pressure Liquid Chromatography, HPLC (different principles: ion exchange; affinity, gel permeation).

Isolation: Extraction, the chemistry of extraction, batch, staged and differential extractions, fractional extraction with stationary and moving phases, Adsorption in Continuous stirred tank reactors and fixed beds.

Product purification: Elution chromatography, adsorbents, yield and purity, HPLC (different principles: ion exchange; affinity, gel permeation). Kinetic analysis, Precipitation using organic solvents, non-solvents, anti-chaotropic salts, temperature, Largescale precipitation. Affinity ultrafiltration, field flow fractionation and Electrophoresis, Polishing using Crystallization and Drying.

Learning Resources:

Text Books:

1. Harrison, R. G., Todd, P., Rudge, S. R., & Petrides, D. P., Bioseparations science and engineering. Oxford University Press, 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. Product Recovery in Bioprocess technology, BIOTOL series, Butterworth–Heinemann, 2006.
2. M. Moo–young, Comprehensive Biotechnology, 1985, 2nd Edition.
3. Ronald, J. Lee, Principles of Downstream processing, Wiley Publications, 2007.
4. Satinder Ahuja, Handbook of Bioseparations, Academic Press, Volume 2, 2000.
5. Robert K. Scopes. Protein Purification: Principles and Practice, Springer, 1994.

CH1430 **3-0-0 (3)**

Sustainable Energy Technologies

Pre-Requisites: **None**

Course Outcomes:

CO-1	Identify the Energy sources and its exploration
CO-2	Design process equipment for alternative energy sources
CO-3	Explain the principles of solar cells and fuel cells
CO-4	Analysis for energy accounting & auditing

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	2	3	-	-	-	-	3	-	-	-	-	-	3	2	-
CO-2	1	3	2	3	-	-	3	-	-	-	-	-	3	3	-
CO-3	1	3	2	2	-	-	3	-	-	-	-	-	3	3	-
CO-4	1	3	-	3	-	1	3	-	-	-	-	-	3	3	-

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

Syllabus:

Fundamental Concepts: Work, energy and heat; Units and unit conversions; Thermal efficiency and other figures of merit; Practical cycles for power production and refrigeration; Exergy: Availability.

Energy Demand and Supply: Demand for energy: Whither does it go? Energy supply: Whence does it come? Energy for transportation; Production of electricity; Future TPES demand; Energy resources and reserves; Finite life of a resource; Sustainable energy supply and limitations.

Environmental Effects of Energy Production and Utilization: Energy, ecology, and the environment; Recent successes in environmental stewardship; Global climate change; Nuclear waste; Thermal pollution; Energy sustainability and carbon footprint.

Conventional Energy Sources: Formation of fossil fuels & resources. Energy sources: Coal, oil, natural gas, hydropower; Coal gasification & liquefaction; Synthetic fuels; Hydrogen; Methods & applications of cogeneration; Fluidized-bed combustion; combined cycle plants; Role of coal in energy crisis.

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

Energy Conservation and Higher Efficiency: Desired actions; Energy consumption; conservation; and higher efficiency; Use of the exergy concept to reduce energy resource consumption; Improved efficiency in electric power generation; Waste heat utilization; Conservation and efficiency improvement in buildings; Conservation and improved efficiency in transportation.

Learning Resources:

Text Books:

1. Michaelides Efstathios E., Energy, the environment, and sustainability, CRC press, 2018.
2. S. Rao, B. B. Parulekar, Energy Technology – Nonconventional, Renewable & conventional, Khanna Publications, 2012, 3rd Edition.

Reference Books:

1. Eduardo Rincón-Mejía, Alejandro de las Heras, Sustainable Energy Technologies, CRC Press, 2020, 1st Edition.
2. K. Hanjalić, R. Krol, A. Lekić, Sustainable Energy Technologies - Options and Prospects, Springer, 2008.

Other Suggested Readings:

1. https://onlinecourses.nptel.ac.in/noc23_me138/preview

CH1431 **3-0-0 (3)**

Energy Management

Pre-Requisites: None

Course Outcomes:

CO-1	Understand energy management policies, methods and planning
CO-2	Carry out energy audit and economic analysis
CO-3	Assess energy management control schemes
CO-4	Design energy utilization systems for heat recovery
CO-5	Select energy security and reliability methods

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	-	-	3	-	-	3	3	-	-	1	2	1	1	-	-
CO-2	1	1	2	1	1	3	3	-	-	1	2	1	1	2	2
CO-3	1	1	2	1	1	3	3	-	-	1	2	1	1	2	-
CO-4	2	3	2	1	1	3	3	-	-	1	2	1	1	2	2
CO-5	-	-	3	1	1	3	3	-	-	1	2	1	1	2	2

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Introduction: The value of energy management, Suggested principles of energy management.

Effective Energy Management: Energy Policy and planning.

Energy Auditing and Economic Analysis: Energy auditing services, Basic components of an energy audit, Industrial, Commercial and residential audits, General characteristics of capital investments, Project measures of worth.

Energy Systems: Boilers and fired systems, Steam and condensate systems, Cogeneration, Waste heat recovery, Energy management control systems, Energy systems maintenance.

Thermal Energy Storage: Storage system, Storage mediums.

Energy Security and Reliability: Risk analysis methods, Economics of energy security and reliability, Links to energy management.

Learning Resources:

Text Books:

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

Reference Books:

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

CH1432 **3-0-0 (3)**

Design of Experiments

Pre-Requisites: None

Course Outcomes:

CO-1	Design experiments for a critical comparison of outputs
CO-2	Propose hypothesis from experimental data
CO-3	Implement factorial and randomized sampling from experiments
CO-4	Estimate parameters by multi-dimensional optimization

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	3	2	3	3	3	3	3	3	-	-	-	-	-	3	3
CO-2	3	3	-	3	-	-	-	3	-	-	-	-	-	3	-
CO-3	-	-	-	-	-	-	-	3	-	-	-	-	-	-	3
CO-4	3	3	3	3	3	-	-	-	-	-	-	-	-	-	3

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

Syllabus:

Introduction: Strategy of experimentation, basic principles, guidelines for designing experiments. Simple Comparative Experiments: Basic statistical concepts, sampling and sampling distribution, inferences about the differences in means: Hypothesis testing, Choice of samples size, Confidence intervals, Randomized and paired comparison design.

Experiments with Single Factor: An example, the analysis of variance, Analysis of the fixed effect model, Model adequacy checking, Practical interpretation of results, Sample computer output, Determining sample size, Discovering dispersion effect, The regression approach to the analysis of variance, Non-parametric methods in the analysis of variance, Problems.

Design of Experiments: Introduction, Basic principles: Randomization, Replication, Blocking, Degrees of freedom, Confounding, Design resolution, Metrology considerations for industrial designed experiments, Selection of quality characteristics for industrial experiments. Parameter Estimation.

Response Surface Methods: Introduction, the methods of steepest ascent, Analysis of a second- order response surface, Experimental designs for fitting response surfaces: Designs for fitting the first-order model, Designs for fitting the second-order model, Blocking in response surface designs, Computer-generated (Optimal) designs, Mixture experiments, Evolutionary operation, Robust design, Problems.

Design and Analysis: Introduction, Preliminary examination of subject of research, Screening experiments: Preliminary ranking of the factors, active screening experiment- method of random balance, active screening experiment Plackett-Burman designs, Completely randomized block design, Latin squares, Graeco-Latin Square, Youdens Squares, Basic experiment-mathematical modelling, Statistical Analysis, Experimental optimization of research subject: Problem of optimization, Gradient optimization methods, Nongradient methods of optimization, Simplex sum rotatable design, Canonical analysis of the response surface, Examples of complex optimizations.

Learning Resources:

Text Books:

1. Lazic Z. R., Design of Experiments in Chemical Engineering, A Practical Guide, Wiley, 2005.
2. Antony J., Design of Experiments for Engineers and Scientists, Butterworth Heinemann, 2004.
3. Montgomery D. C., Design and Analysis of Experiments, Wiley, 2010, 5th Edition.
4. Doebelin E. O., Engineering Experimentation: Planning, Execution, Reporting, McGraw- Hill, 1995.

CH16005 **3-0-0 (3)**

Data Analytics and Machine learning

Pre-Requisites: None

Course Outcomes:

CO-1	Demonstrate proficiency with statistical analysis of data
CO-2	Use inferential statistics for decision making
CO-3	Apply supervised learning for classification and regression problems
CO-4	Apply unsupervised learning for clustering

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	1	1	-	1	2	-	-	-	-	-	-	-	-	1	1
CO-2	1	1	-	1	1	-	-	-	-	-	-	-	-	1	1
CO-3	1	1	-	1	1	-	-	-	-	-	-	-	-	-	2
CO-4	-	1	-	1	1	-	-	-	-	-	-	-	-	-	2

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Data Quality and Pre-processing: Distance measures, dimensionality reduction, principal component analysis (PCA).

Descriptive Statistics: Graphical approach - Frequency tables, relative frequency tables, grouped data, pie chart, barchart, histograms, ogives, stem and leaf plots, box plots, dot diagram, scatter plots, Pareto diagram.

Measure of Central Tendency and Dispersion - Arithmetic mean, median and mode, variance,standard deviation, quartiles, range, mean absolute deviation, coefficient of variation, Z scores,normal distribution, confidence interval estimation.

Probability Distribution and Inferential Statistics: Random variables, probability distributions, hypothesis testing, single sample test, two sample test, Type I error, Type II error,Analysis of Variance (ANOVA).

Supervised learning: Linear regression, ridge regression, Lasso regression, logistic regression, multiple linear regression, goodness of fit, bias–variance trade off, k-nearest neighbors algorithm, linear discriminant analysis, classification and regression trees andpruning, support vector machines, random forest, Naive Bayes, Introduction to Neural networksand deep learning.

Unsupervised learning: Cluster analysis – K Means, hierarchical, DBSCAN.

Time series analysis: Auto-Regressive (AR), Moving Average (MA), Auto Regressive Moving Average (ARMA), Auto-Regressive Integrated Moving Average (ARIMA).

Practical applications to different engineering systems.

Learning Resources:

Text Books:

1. Douglas C. Montgomery, George C. Runger, Applied Statistics and Probability for Engineers, John Wiley & Sons Inc., 2016, 6th Edition.
2. Trevor Hastie, Robert Tibshirani, Jerome Friedman, The Elements of Statistical Learning, Springer, 2009, 2nd Edition.
3. Ethem Alpaydın, Introduction to Machine Learning, MIT Press, 2014, 3rd Edition.

Reference Books:

1. João Mendes Moreira, André C. P. L. F. deCarvalho, Tomáš Horváth, A General Introduction to Data Analytics, Wiley, 2019.
2. Pang-Ning Tan, Michael Steinbach, Anuj Karpatne, Vipin Kumar, Introduction to Data Mining, Pearson, 2019, 2nd Edition.

Other Suggested Readings:

1. https://nptel.ac.in/courses/106107220
2. https://nptel.ac.in/courses/110106072

CH16022 **3-0-0 (3)**

Wastewater Treatment

Pre-Requisites: None

Course Outcomes:

CO-1	Understand the principles and operation of wastewater treatment systems
CO-2	Identify suitable treatment processes
CO-3	Evaluate process operations and performance
CO-4	Differentiate coagulation, flocculation, sedimentation, filtration and disinfection

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	3	2	1	-	-	1	1	-	-	-	-	-	2	1	-
CO-2	3	2	1	1	1		1	-	-	-	--	-	2	1	-
CO-3	3	3	3	3	2	1	2	1	1	-	-	1	3	3	1
CO-4	3	3	3	3	-	1	2	1	1	-	-	1	3	3	1

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Introduction: Sources of wastewater; Necessity of treatment; Critical wastewater quality parameters; Water quality guidelines and standards for various water uses; Wastewater flowrates and constituent loadings.

Wastewater microbiology: Bacteria; Cell composition and structure; Bacterial growth curve; Classification by carbon and energy requirement; Classification by oxygen requirement; Classification by temperature; Bacteria of significance – Archaea, Protozoa, Algae, Fungi, Virus.

Classification of wastewater treatment methods: Physical treatment; Chemical treatment; Biological treatment. Levels of wastewater treatment: Preliminary treatment; Primary treatment; Enhanced primary treatment; Conventional secondary treatment; Secondary treatment with nutrient removal; Tertiary treatment; Advanced treatment.

Preliminary treatment: Screens; Shredder/grinder; Grit chambers; Primary treatment - Types of settling/sedimentation; Primary sedimentation; Chemically enhanced primary treatment.

Secondary treatment (Suspended growth processes): Microbial growth kinetics; Activated sludge process; Aeration requirements; Types of aerators, Types of suspended growth processes, Staged activated sludge process; Extended aeration process; Oxidation ditch; Sequencing batch reactor (SBR); Membrane biological reactor (MBR); Stabilization ponds and lagoons.

Secondary treatment (Attached growth and combined processes): System microbiology and biofilms; Stone media trickling filter; Rotating biological contactor; Hybrid processes; Moving bed biofilm reactor (MBBR); Integrated fixed-film activated sludge (IFAS); Fluidized bed bioreactor (FBBR); Combined processes.

Secondary Clarification: Secondary clarifier for attached growth processes and suspended growth processes.

Anaerobic wastewater treatment: Anaerobic growth kinetics; Anaerobic attached and suspended growth processes.

Solids processing and disposal: Characteristics of municipal sludge; Sludge thickening and stabilization; Biosolids dewatering.

Introduction to advanced treatment processes: membrane processes; ceramic and polymeric membrane processes; microfiltration; ultrafiltration; reverse osmosis.

Learning Resources:

Text Books:

1. MetCalf, Eddy, Wastewater engineering, Treatment and Reuse, Tata McGraw Hill, 2003, 3rd Edition.
2. Rumana Riffat, Fundamentals of wastewater treatment and engineering, CRC Press, 2013.

Reference Books:

1. S.J. Arceivala, S.R. Asolekar, Wastewater Treatment for Pollution Control and Reuse, Tata McGraw-Hill, 2007, 3rd Edition.
2. Fair, G.M., Geyer J.C, Okun, Water and Wastewater Engineering, John Wiley Publications, 2010, 3rd Edition.
3. Tchobanoglous G., Burton F. L., Stensel H.D., Wastewater Engineering: Treatment and Reuse, Tata McGraw Hill, 2002, 4th Edition.

Other Suggested Readings:

1. https://onlinecourses.nptel.ac.in/noc19_ce32/preview

CH16024 **3-0-0 (3)**

Engineering Optimization

Pre-Requisites: None

Course Outcomes:

CO-1	Formulate objective function for a given problem
CO-2	Solve unconstrained single and multi-variable optimization problems
CO-3	Apply linear programming and nonlinear programming techniques
CO-4	Use dynamic programming for optimization

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	-	-	3	-	-	3	3	-	-	1	2	1	1	-	-
CO-2	1	1	2	1	1	3	3	-	-	1	2	1	1	2	2
CO-3	1	1	2	1	1	3	3	-	-	1	2	1	1	2	-
CO-4	2	3	2	1	1	3	3	-	-	1	2	1	1	2	2

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

Syllabus:

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

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

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

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

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

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

Optimization of Staged and Discrete Processes: Dynamic programming, Introduction tointeger and mixed integer programming, Assignment problem (Hungarian method).

Learning Resources:

Text Books:

1. Edgar T.F., D. M. Himmelblau, Optimization of Chemical Processes, McGraw Hill, 2001, 2nd Edition.
2. Stoecker W. F., Design of Thermal Systems, McGraw-Hill, 2011, 3rd Edition.

Reference Books:

1. Singiresu S Rao, Engineering Optimization: Theory and Practice, John Wiley & Sons Ltd., 2019, 5th Edition.
2. Stephen Boyd, Lieven Vandenberghe, Convex optimization, Cambridge University Press, 2004.
3. P. Venkataraman, Applied Optimization with MATLAB Programming, Wiley, 2009, 2nd Edition

Other Suggested Readings:

1. https://nptel.ac.in/courses/103105139

CH16026 **3-0-0 (3)**

CO_2 Capture, Sequestration and Utilization

Pre-Requisites: **None**

Course Outcomes:

CO-1	Identify the necessity of CO_2 capture, storage and utilization
CO-2	Distinguish the CO_2 capture techniques
CO-3	Evaluate CO_2 storage and sequestration methods
CO-4	Assess environmental impact of CO_2 capture and utilization

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	3	2	3	1	2	3	3	-	2	2	-	1	2	2	-
CO-2	3	2	3	1	2	3	3	-	2	2	-	1	2	2	-
CO-3	3	2	3	1	2	3	3	-	2	2	-	1	2	2	-
CO-4	3	2	3	1	2	3	3	-	2	2	-	1	2	2	-

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

Syllabus:

Introduction: Global Status of CO_2 Emission Trends; Policy and Regulatory Interventions in Abatement of Carbon Footprint; Carbon Capture, Storage and Utilization (CCS&U).

CO_2 Capture Technologies from Power Plants: Post-Combustion Capture; Pre-Combustion Capture; Oxy-Fuel Combustion; Chemical Looping Combustion; Calcium Looping Combustion.

CO_2 Capture Agents and Processes: Capture Processes; CO_2 Capture Agents; Adsorption; Ionic Liquids; Metal Organic Frameworks.

CO_2 Storage and Sequestration: Geological Sequestration Methods; Biomimetic Carbon Sequestration.

CO_2 Utilization: CO_2 Derived Fuels for Energy Storage; Polymers from CO_2; CO_2 Based Solvents; CO_2 to Oxygenated Organics; Conversion into Higher Carbon Fuels; High Temperature Catalysis.

Environmental Assessment of CO_2 Capture and Utilization: Need for Assessment; Green Chemistry and Environmental Assessment Tools; Life Cycle Assessment (LCA); ISO Standardization of LCA; Method of Conducting an LCA for CO_2 Capture and Utilization.

Learning Resources:

Text Books:

1. Peter Styring, Elsje Alessandra Quadrelli, Katy Armstrong, Carbon dioxide utilization: Closing the Carbon Cycle, Elsevier, 2015.
2. Goel, M., Sudhakar, M., Shahi, R. V., 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.

Reference Books:

1. Fennell, P., Anthony, B., Calcium and Chemical Looping Technology for Power Generation and Carbon Dioxide (CO_2) Capture, Woodhead Publishing Series in Energy: No. 82, 2015.
2. Mercedes Maroto-Valer M., Developments in Innovation in Carbon Dioxide Capture and Storage Technology: Carbon Dioxide Storage and Utilization, Woodhead Publishing Series in Energy, 2014, Vol 2.
3. Alireza Bahadori, Fundamentals of Enhanced Oil and Gas Recovery from Conventional and Unconventional Reservoirs, Elsevier, 2018.

Other Suggested Readings:

1. https://nptel.ac.in/courses/103/107/103107157/
2. https://climate.mit.edu/explainers/carbon-capture

CH16028 **3-0-0 (3)**

Energy Audit and Conservation

Pre-Requisites: **None**

Course Outcomes:

CO-1	Implement energy audit for a process plant
CO-2	Plan energy conservation strategies
CO-3	Evaluate the suitability of renewable energy resources
CO-4	Analyze the energy utilization of a process equipment

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	-	-	3	-	-	3	3	-	-	1	2	1	1	-	-
CO-2	1	1	2	1	1	3	3	-	-	1	2	1	1	2	2
CO-3	1	1	2	1	1	3	3	-	-	1	2	1	1	2	-
CO-4	2	3	2	1	1	3	3	-	-	1	2	1	1	2	2

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

Syllabus:

Energy Scenario: Energy Use Patterns, Energy Resources, Oil - A Critical Resource, Economic and Environmental Consideration, Future Scenario.

Heat & Work: First & Second Law of Thermodynamics, Heat Engines.

Energy Audit: Energy Conversion, Energy Index, Energy Consumption Representation - PieChart, Sankey Diagram & Load Profile, General Audit, Detailed Audit, Waste Heat Recovery.

Targeting and Conservation: Energy Utilization and Conversion – Thermal Efficiency, HeatExchangers – Heat Recovery, Air Conditioners – Supply and Removal of Heat.

Use of Alternate Energy: Solar Energy, Wind Energy, Nuclear Energy, Biomass, GeothermalEnergy, Future Energy Alternatives.

Energy Integration: Pinch Analysis and Process Heat Integration, Energy Management, KeyPerformance Indicators and Energy Dashboards.

Case Studies: Energy Conservation in Alcohol Industry, Fertilizer Industry, and Pulp and PaperIndustry, Energy Conservation in Different Units of Refinery Like FCCU, HCU and ADU.

Learning Resources:

Text Books:

1. Murphy, W. R., Mckay, G., Energy Management, Elsevier, 2007.
2. Hinrichs, R. A., Kleinbach, M. H., Energy: Its Use and the Environment, Cengage Learning, 2012.
3. Capehart, B. L., Turner, W. C., Kennedy, W. J., Guide to Energy Management, KeinneduFairmant press, 2011, 7th Edition.

Reference Books:

1. Rai, G. D., Non-conventional Energy Sources, Khanna Publishers, New Delhi, 2010.
2. Rossiter, A. P., Jones, B.P., Energy Management and Efficiency for the Process Industries, AIChE, Wiley, 2015.

Other Suggested Readings:

1. https://nptel.ac.in/courses/112/105/112105221/

CH16029 **3-0-0 (3)**

Chemical Process Synthesis

Pre-Requisites: None

Course Outcomes:

CO-1	Identify the steps and information required for process synthesis
CO-2	Recognize the role of energy, environment, sustainability, safety and engineering ethics in process synthesis
CO-3	Develop preliminary process flow sheet using heuristics
CO-4	Synthesize heat exchanger networks and separation trains
CO-5	Perform economic analysis related to process design

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	1	1	3	2	2	3	3	-	-	1	2	1	1	-	-
CO-2	1	1	2	1	1	3	3	-	-	1	2	1	1	2	2
CO-3	1	1	2	1	1	3	3	-	-	1	2	1	1	2	-
CO-4	2	3	2	1	1	3	3	-	-	1	2	1	1	2	2
CO-5	1	1	3	1	1	3	3	-	-	1	2	1	1	2	2

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Introduction to Process design: Preliminary Process Synthesis, Synthesis Steps, Process Design Tasks, Preliminary Flowsheet Mass Balances.

Energy, Environment, Sustainability, Safety, Engineering Ethics: Environmental Protection, Sustainability, Safety Considerations, Engineering Ethics.

Synthesis of steady state flow sheet: Introduction, Flow sheets, the problem of steady stateflow sheeting, general semantic equation of equipment, Generalization of the method of synthesis of process flow sheet, Recycle structure of the flow sheet, separation systems.

Heuristics for process synthesis: Raw materials and Chemical reactions, Distribution of chemicals, Separations, Heat exchangers and furnaces, pumping pressure reduction and conveying of solids.

Algorithmic methods for process synthesis: Synthesis of separation trains, sequencing of ordinary distillation columns, Optimization of flow sheet with respect to heat exchanger network, Network of heat exchanger, Some necessary conditions for the existence of an optimal exchanger network, Condition of optimality for the minimum area network, Rules of adjustment of the minimum heat exchanger network to find the optimal solution.

Cost Accounting and Capital Cost Estimation: Estimation of the Total Capital Investment, Purchase Costs of the Most Widely Used Process Equipment, Purchase Costs of Other Chemical Processing Equipment.

Annual Costs, Earnings, and Profitability Analysis: Annual Sales Revenues, Production Costs, and the Cost Sheet, Working Capital and Total Capital Investment, Approximate Profitability Measures, Time Value of Money, Cash Flow and Depreciation.

Learning Resources:

Text Books:

1. Seider W. D., Seader J. D., Lewin, D. R., Product and Process Design Principles: Synthesis, Wiley, 2016.
2. Bieglar L.T, Grossman E.I. , Westerberg A.W., Systematic Methods of Chemical Process Design, Prentice Hall Inc., 1997.
3. Douglas J. M., Conceptual Design of Chemical Processes, McGraw Hill.

CH16030 **3-0-0 (3)**

Novel Separation Techniques

Pre-Requisites: **None**

Course Outcomes:

CO-1	Select a membrane and membrane process for a given application
CO-2	Evaluate the flux of solvent and solute through membrane
CO-3	Differentiate surfactant based separation
CO-4	Design centrifugal separation processes

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	3	3	3	3	-	-	-	-	-	-	-	-	3	3	1
CO-2	3	3	3	3	1	-	3	-	-	-	-	-	3	2	1
CO-3	3	3	3	3	-	-	-	-	-	-	-	-	3	1	1
CO-4	3	3	3	3	-	-	-	-	-	-	-	-	3	3	1

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

Syllabus:

Introduction: Fundamentals of separation processes, basic definitions of relevant terms.

Membrane separation process: Definition of Membrane, Membrane types, Advantages and limitations of membrane technology compared to other separation processes, Membrane materials and properties.

Preparation of synthetic membranes: Phase inversion membranes, Preparation techniques for immersion precipitation, Synthesis of asymmetric and composite membranes and Synthesis of inorganic membranes.

Transport in membranes: Introduction, Driving forces, Non-equilibrium thermodynamics, Transport through porous membranes, transport through non- porous membranes, Transport through ion-exchange membranes.

Membrane processes: Pressure driven membrane processes, Concentration as driving force, electrically driven membrane processes.

Polarization phenomena and fouling: Concentration polarization, Pressure drop, Membrane fouling, methods to reduce fouling.

Modules: Introduction, membrane modules, Comparison of the module configurations.

Gas separation: Basic Principles, Membranes for gas separations, membrane modules, gas transport mechanisms, factors affecting gas permeation, complete mixing model, cross flow model, counter current model.

Surfactant based separation processes: Liquid membranes, Fundamentals and modelling, Micellar enhanced separation processes, Cloud point extraction.

Other separation processes: Centrifugal Separation processes and their calculations, Ion exchange and chromatographic separation processes, Supercritical fluid extraction.

Learning Resources:

Text Books:

1. Mulder M, Basic Principles of Membrane Technology, Kluwer Academic Publishers,1996.
2. Baker R. W., Membrane Technology and Research, Inc. (MTR), 2004.
3. Nath K., Membrane Separation Processes, Prentice-Hall Publications, 2008.
4. R. W. Rousseau, Handbook of Separation Process Technology, John Wiley & Sons, 1987.
5. McHugh, M.A. and Krukonis, V.J., Supercritical Fluid Extraction: Principles and Practice, Butterworth-Heinemann, 2013, 2nd Edition.

Other Suggested Readings:

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

CH16048 **3-0-0 (3)**

Molecular Simulations

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand the concepts of ensembles and interatomic potentials
CO-2	Simulate different ensembles using Monte Carlo and molecular dynamics techniques
CO-3	Compute thermodynamic properties
CO-4	Simulate a real life problem using molecular dynamics and Monte Carlo methods

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	3	2	2	2	2	1	2	-	1	-	-	1	1	1	2
CO-2	3	2	2	2	2	-	-	-	1	-	-	1	1	2	1
CO-3	3	2	2	2	1	1	2	-	2	-	-	2	1	2	1
CO-4	3	2	1	2	1	1	1	-	1	-	-	2	1	2	2

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

Syllabus:

Thermodynamics and statistical mechanics: Classical thermodynamics; Statistical thermodynamics; Ensembles; Ergodicity.

Monte Carlo simulations: Monte Carlo method; a basic Monte Carlo method; Trial Moves.

Molecular dynamics simulations: Molecular dynamics initialization; Solving equations of motion.

Properties computation: Static properties; Dynamical properties.

Ensemble simulations: Monte Carlo simulations in various ensembles; Molecular dynamics simulation in various ensembles.

Learning Resources:

Text Books:

1. Daan Frenkel, Berend Smit, Understanding Molecular Simulation: From Algorithms to Applications, Academic Press, 2023, 3rd Edition.
2. M. P. Allen, D. J. Tildesley, Computer Simulations of Liquids, Oxford University Press, 2017,2nd Edition.

Reference Books:

1. Andrew Leach, Molecular Modelling: Principles and Applications, Prentice Hall, 2001, 2nd Edition.
2. D. C. Rapapport, The art of Molecular Dynamics Simulation, Cambridge university press, 2004, 2nd Edition.

Other Suggested Readings:

1. https://nptel.ac.in/courses/103103036

CH16050 **3-0-0 (3)**

Heat Integration and Process Scheduling

Pre-Requisites: None

Course Outcomes:

CO-1	Identify the objectives of heat integration and process scheduling
CO-2	Apply the concepts of pinch technology and retrofitting
CO-3	Develop models for batch process scheduling
CO-4	Analyze heat exchanger networks and process scheduling models

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	3	1	-	1	-	-	1	1	-	-	-	-	1	-	2
CO-2	3	1	-	2	-	-	2	1	-	-	-	-	1	1	2
CO-3	3	2	1	2	3	1	3	1	1	1	1	1	2	2	3
CO-4	3	2	1	3	3	1	3	1	1	1	1	1	2	2	3

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

Syllabus:

Heat Integration:

Introduction: Heat integration fundamentals; History and industrial experience; Why does pinch analysis work; The concept of process synthesis; The role of thermodynamics in process design.

Key concepts of Pinch analysis: Heat recovery and heat exchange; The pinch and its significance; Heat exchanger network design; Choosing ΔT_{min}; Methodology of pinch analysis.

Data extraction and energy targeting: Data extraction; Case study: Organics distillation plant, Energy targeting, Multiple utilities, Targeting heat exchanger units, Area and shells, Super targeting, Targeting organics distillation plant case study.

HEN Design Utilities: Heat exchange equipment; Stream splitting and cyclic matching; Network relaxation; More complex designs; Multiple pinches and near pinches; Retrofit design.

Process Scheduling:

Short-Term Scheduling: Effective technique for scheduling of multipurpose and multi product batch plants; Different storage policies for intermediate and final products; Evolution of multiple time grid models in batch process scheduling; Short-term scheduling of multipurpose plants; Planning and scheduling in chemical and biopharmaceutical industry.

Heat integration in multipurpose batch plants: Direct and indirect heat integration; Simultaneous optimization of energy and water use in multipurpose batch plants.

Design and Synthesis: Design and synthesis of multipurpose batch plants; Process synthesis approaches for enhancing sustainability of batch process plants; Scheduling and design of multipurpose batch facilities.

Learning Resources:

Text Books:

1. Ian C Kemp, Pinch Analysis and Process Integration, Elsevier Publication, 2007, 2nd Edition.
2. Thokozani Majozi, Esmael Reshid Seid, Jui-Yuan Lee, Synthesis, Design, and Resource Optimization in Batch Chemical Plants, CRC Press Taylor & Francis, 2015.

Reference Books:

1. Thokozani Majozi, Batch Chemical Process Integration - Analysis, Synthesis and Optimization, Spinger, 2010.
2. Mohmoud Bahy Noureddin, Pinch Technology and Beyond Pinch, New Vistas on Energy Efficiency Optimization, Booktopia, 2011.
3. Gintaras V. Reklaitis, Aydin K. Sunol, David W. T. Rippin, Oner Hortacsu, Batch Processing Systems Engineering, Spinger, 1996.
4. Mariano Martin, Introduction to Software for Chemical Engineers, CRC Press, 2015.

CH16052 **3-0-0 (3)**

Statistical Thermodynamics

Pre-Requisites: None

Course Outcomes:

CO-1	Identify the molecular level properties influencing the macroscopic thermodynamic properties
CO-2	Develop models to estimate thermodynamic properties of real gases, liquids and solids
CO-3	Design molecular level architecture to enhance macroscopic properties
CO-4	Estimate macroscopic properties based on molecular level interactions

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	1	2	1	2	2	1	2	–	1	–	–	2	1	3	1
CO-2	2	2	2	2	3	–	–	–	1	–	–	2	1	3	2
CO-3	1	2	1	2	2	1	2	–	1	–	–	2	1	3	1
CO-4	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.

Reference Books:

1. Leonard K. Nash, Elements of Statistical Thermodynamics, Dover Publications, 2006, 2nd Edition.
2. Stanley I. Sandler, An Introduction to Applied Statistical Thermodynamics, John Wiley & Sons, 2010.
3. Herbert B. Callen, Thermodynamics and Introduction to Thermo-statistics, Wiley, 1985, 2nd Edition.

Other Suggested Readings:

1. https://nptel.ac.in/courses/103103355
2. https://nptel.ac.in/courses/115106126

CH16060 **3-0-0 (3)**

Advanced Process Control

Pre-Requisites: **None**

Course Outcomes:

CO-1	Identify controlled and manipulated variables
CO-2	Design regulatory control schemes for a given process
CO-3	Analyse the multivariable process control schemes
CO-4	Evaluate linear and nonlinear model predictive control strategies

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	3	2	2	2	2	1	2	-	1	-	-	1	1	1	2
CO-2	3	2	2	2	2	-	-	-	1	-	-	1	1	2	1
CO-3	3	2	2	2	1	1	2	-	2	-	-	2	1	2	1
CO-4	3	2	1	2	1	1	1	-	1	-	-	2	1	2	2

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

Syllabus:

Introduction: Hierarchy of control layers, review of basics, system linearization, state space and transfer function models.

Advanced regulatory control schemes: Cascade control, feed-forward control, ratio control, split-range control, time delay compensator, and inverse response compensator.

Multivariable control: Challenges, Control pairing; Interactions in closed-loop systems; Relative Gain Array (RGA) and variants. Centralized, decentralized, decoupled control schemes.

Model Predictive Control (MPC): MPC control formulation: simple unconstrained optimal control formulation, general characteristics of MPC formulation, translation of MPC problem into quadratic programming optimization problem, Practical MPC implementation considerations: empirical model development, usage of design/tuning parameters, design of MPC control for typical systems.

Extensions of MPC: Theory: Economic MPC, Nonlinear Model Predictive Control (NMPC), Robust MPC, Data-driven MPC.

Learning Resources:

Text Books:

1. Seborg, D. E., Edgar, T. F., Millechamp, D. A., Doyle III, F. J., Process Dynamics and Control, Wiley, 2014, 3rd Edition.
2. Raghunathan Rengaswamy, Babji Srinivasan, Nirav Pravinbhai Bhatt, Process Control Fundamentals: Analysis, Design, Assessment, and Diagnosis, CRC Press, 2020.
3. Liuping Wang, Model Predictive Control System Design and Implementation using MATLAB, Springer, 2009.

Reference Books:

1. Francesco Borelli, Alberto Bemporad, Manfred Morari, Predictive Control for Linear and Hybrid Systems, Cambridge University Press, 2017.
2. Jean-Pierre Corriou, Process Control: Theory and Applications, Springer, 2018, 2nd Edition.
3. B. Roffel and B. Betlem, Process Dynamics and Control, Wiley, 2006.
4. Cecil L. Smith, Advanced Process Control, Wiley, 2010.
5. Surekha Bhanot, Process Control: Principles and Applications, Oxford, 2008.

Other Suggested Readings:

1. https://onlinecourses.nptel.ac.in/noc21_ge01/preview

CH26001 **3-0-0 (3)**

Sustainable Energy Engineering

Pre-Requisites: **None**

Course Outcomes:

CO-1	Quantify the variety of energy resources
CO-2	Perform project economics evaluation
CO-3	Evaluate sustainability metrics
CO-4	Select suitable sustainable energy technologies

Course Articulation Matrix:

	PO-1	PO-2		PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	-	-		1	-	-	-	2	-	-	-	-	-	-	-	-
CO-2	-	1		1	-	1	1	2	-	-	-	-	-	-	-	1
CO-3	-	1		2	1	1	1	3	1	-	-	1	-	-	-	1
CO-4	-	-		1	-	-	1	3	1	-	-	-	-	-	-	2

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

Syllabus:

Sustainability Concepts: Sustainable Development Goals for Clean Energy (SDGS), Emerging Issues in Energy Access, Technologies, Economics. Sustainability Concepts of Energy Generation Technologies, Energy and Resource Utilization.

Sustainable Energy: The Engine of Sustainable Development: Aspects of Energy Production,Nations and Global Patterns of Energy Supply and Utilisation, Environmental Effects of Energy.

Estimation and Evaluation of Energy Resources: Comparison of Different Forms of Energy,Energy Life Cycle, Estimation and Validation of Energy Resources.

Technical Performance: Allowability, Efficiency, Production Rates, Relation of Technical Performance to Sustainability, Thermodynamic Analysis, Chemical Rate Processes, Use and Abuse of Time Scales.

Local, Regional, and Global Environmental Effects of Energy: Adverse Environmental Effects, Attribution of Environmental Damage, Methods of Environmental Protection.

Project Economic Evaluation: Time Value of Money Mechanics, Economy of Scale and Learning Curve, Energy Accounting.

Energy Systems and Sustainability Metrics: System Analysis Approach, Measures, GeneralPrinciples for Sustainable Development.

Energy, Water and Land Use: Major Planetary Cycles, Land-Use Issues, Ocean-Use Issues, Implications for Sustainable Energy, Charting Pathways for Energy Democracy, Building an Energy Democracy Movement.

Biomass Energy, Biofuel: Characterization, Biomass Relevance to Energy Production, Properties Relevant to Energy Production, Thermal Conversion, Bioconversion, Economics.

Solar Energy: Resource Assessment, Concentrating Solar Power, Solar Photovoltaic Systems.

Ocean Wave, Tide, Current, and Thermal Energy Conversion: Energy from the Tides and Currents, Energy from Waves, Economic Prospects, Environmental and Sustainability Considerations.

Wind Energy: Wind Resources, Wind Machinery and Generating Systems, Wind Power Economics, Measure of Sustainability.

Energy Carriers: Electric Power, Hydrogen Fuel: Electricity as an Energy Carrier, Hydrogen as an Energy Carrier, Sustainability Issues.

Industrial Energy Usage: Life-Cycle Analysis and Design for Sustainability, Chemical Industries, Cement and Lime Industries, Sustainability Issues.

Synergistic Complex Systems: Complex Systems View, Some Case Studies, Transitional Pathways, Challenge to Society.

Learning Resources:

Text Books:

1. Tester, J. W., Drake, E. M., Driscoll, M. J.,Golay, M. W., Peters, W. A., Sustainable Energy: Choosing Among Options, MIT Press, 2012, 2nd Edition.
2. Martin A. Abraham, Encyclopedia of Sustainable Technologies, Elsevier Publication, 2024, 2nd Edition.
3. Eduardo Rincon-Mejia, Alejandro de las Heras, Sustainable Energy Technologies, CRC Press, Taylor & Francis Group, 2018.
4. Denise Fairchild, A.I. Weinrub, Energy democracy: Advancing equity in clean energy solutions, Island press, 2017.

Reference Books:

1. Mulligan, C. N., Sustainable Engineering: Principles and Implementation, CRC Press,Taylor and Francis Group, 2019.
2. Bakshi, B. R., Sustainable Engineering: Principles and Practice, Cambridge UniversityPress, 2019.
3. David Allen, David Shonnard, Sustainable Engineering: Concepts, Design, and Case studies, Prentice Hall, 2011.
4. Hazra Somnath, Bhukta Anindya, Sustainable Development Goals an Indian Perspective, Springer International Publishing, Switzerland, 2020.

CH26003 **3-0-0 (3)**

Hydrogen Generation and Storage

Pre-Requisites: None

Course Outcomes:

CO-1	Understand the basic properties of hydrogen, including its chemical and physical characteristics, and its role as an energy carrier
CO-2	Select a suitable hydrogen generation and storage technique based on the mechanisms, performance characteristics, and applicability
CO-3	Understand the safety considerations and regulations related to hydrogen handling
CO-4	Analyze the economic viability and environmental impact of hydrogen generation and storage systems

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	1	2	1	2	2	1	2	–	1	–	–	2	1	3	1
CO-2	2	2	2	2	3	–	–	–	1	–	–	2	1	3	2
CO-3	1	2	1	2	2	1	2	–	1	–	–	2	1	3	1
CO-4	1	2	1	2	2	1	2	–	1	–	–	2	1	3	1

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

Syllabus:

Introduction: Basic Properties of Hydrogen; Engineering Thermodynamics; Hydrogen and Environment; Hydrogen and Sustainability; Hydrogen Production Methods; Green Hydrogen Sources; Hydrogen as an Energy Carrier; Historical Background and Current Applications.

Hydrogen Generation Methods: Steam methane reforming; Electrolysis (alkaline; PEM, and solid oxide electrolysis); Coal/Biomass Gasification; Solar and Wind-based Hydrogen Production; Emerging Hydrogen Generation Technologies.

Hydrogen Storage Techniques: Compressed Gas Storage; Liquid Hydrogen Storage; Chemical Storage (hydrogenation, metal hydrides); Physical Storage Using Nanostructured and Porous Materials; Underground Hydrogen Storage; Emerging Hydrogen Storage Technologies.

Performance and Efficiency: Efficiency Considerations in Hydrogen Generation; Energy Losses and Efficiency of Different Storage Methods; Performance Assessment of Hydrogen Production and Storage Systems.

Safety and Regulations: Safety Considerations in Hydrogen Handling and Storage; Codes and Standards for Hydrogen Storage Systems; Risk Assessment and Mitigation Strategies; Case Studies of Hydrogen-related Incidents.

Learning Resources:

Text Books:

1. Gupta, R. B., Hydrogen Fuel: Production, Transport, and Storage, CRC press, 2008.
2. Zhang, J. Z., Li, J., Li, Y., Zhao, Y., Hydrogen Generation, Storage and Utilization, John Wiley & Sons, 2014.

3. Dinçer, I., Zamfirescu, C., Sustainable Hydrogen Production, Elsevier, 2016.

Reference Books:

1. Altalhi, T. A., Adnan, S. M., Amin, M. A., Materials for Hydrogen Production, Conversion, and Storage, John Wiley & Sons, 2023.
2. Winter, C. J., Nitsch, J., Hydrogen as an Energy Carrier: Technologies, Systems, Economy, Springer Science & Business Media, 2012.
3. Sherif, S. A., Goswami, D. Y., Stefanakos, E. L., Steinfeld, A., Handbook of Hydrogen Energy, CRC press, 2014.

Other Suggested Readings:

1. https://onlinecourses.nptel.ac.in/noc22_ch66/preview

CH26022 **3-0-0 (3)**

Energy Management and Life Cycle Assessment

Pre-Requisites: **None**

Course Outcomes:

CO-1	Demonstrate the goals, scope and industrial standards of LCA & energy
CO-2	Interpret the results of inventory analysis and life cycle impact assessment
CO-3	Compare the environmental performance of different renewable energy options
CO-4	Apply various approaches to optimize energy use and reduce energy consumption
CO-5	Apply LCA as a decision-making tool to create sustainable and environmentally friendly energy systems

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	1	2	1	2	2	1	2	–	1	–	–	2	1	3	1
CO-2	2	2	2	2	3	–	–	–	1	–	–	2	1	3	2
CO-3	1	2	1	2	2	1	2	–	1	–	–	2	1	3	1
CO-4	1	2	1	2	2	1	2	–	1	–	–	2	1	3	1
CO-5	1	2	1	2	2	1	2	–	1	–	–	2	1	3	1

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

Syllabus:

Introduction to Life Cycle Assessment (LCA) and Energy Management: Definition and Principles of Life Cycle Assessment, Overview of Energy Management Concepts, Importance and Benefits of LCA and Energy Management, Regulatory and Industry Standards Related to LCA and Energy Management.

Life Cycle Assessment Methodology: Life Cycle Inventory (LCI) Analysis, Life Cycle ImpactAssessment (LCIA), Interpretation and Reporting of LCA Results.

Energy Management: Energy Auditing and Energy Management Systems (ENMS), Energy Efficiency Measures in Buildings, Energy Efficiency Measures in Industrial Processes.

Life Cycle Assessment Applications: Integration of Renewable Energy Sources, LCA of Solar Photovoltaic (PV) Systems, LCA of Wind Energy Systems, LCA of Biomass Energy Conversion, LCA of Hydropower Systems, LCA of Geothermal Energy Systems, Comparative LCA of Renewable Energy Technologies.

Eco-Design and LCA Principles: Life Cycle Assessment (LCA) as a Tool for Eco-Design andProduct Development, Eco-Design, Strategies and Techniques for Sustainable Product Development, Communicating LCA Results and Findings Effectively.

Integrating LCA and Energy Management: Synergies Between LCA and Energy Management, Energy Performance Indicators and Metrics in LCA, Incorporating LCA in Energy Management Plans and Strategies, Life Cycle Assessment of Energy Management Strategies, Life Cycle Assessment of Energy Storage Systems, Life Cycle Assessment of Energy Generation Technologies, LCA-Based Decision Support Tools for Energy Management, Life Cycle Assessment of Energy Efficiency Measures in Buildings, Life Cycle Assessment of Energy Management in Industrial Processes, Life Cycle Assessment of Energy

Management in Transportation (EVs), LCA of Sustainable Transportation Policies and Infrastructure Development.

Recovery, Recycle of Energy Materials: Analysis of Effective Recycling Initiatives in the Energy Sector, Advancements in Recycling Technologies and Processes.

Learning Resources:

Text Books:

1. Curran, M. A., Life Cycle Assessment Student Handbook, John Wiley & Sons, 2015.
2. David Allen, David R. Shonnar, Sustainable Engineering: Concepts, Design, and Case Studies, Prentice Hall, 2011.
3. Stephen A. Roosa, Steve Doty, Wayne C. Turner, Energy Management Handbook, River Publishers, 2000, 9th Edition.

Reference Books:

1. Michael, Z. H., Ralph, K. R., Stig, I. O., Life Cycle Assessment: Theory and Practice, Springer, 2018.
2. Mirjana Radovanovic, Stevan Popov, Sinisa Dodic, Sustainable Energy Management, Academic Press, 2015.

CH26024 **3-0-0 (3)**

Energy, Water and Food Nexus

Pre-Requisites: None

Course Outcomes:

CO-1	Understand the concept of the Energy-Water-Food Nexus and its importance
CO-2	Analyse the interactions within the Energy-Water-Food Nexus and investigate the emerging paradigm
CO-3	Evaluate the energy and water use in agriculture for food production and security
CO-4	Explore the models and tools used to operationalize the Energy-Water-Food nexus
CO-5	Assess water, energy, and carbon footprints using relevant case studies

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	1	1	3	2	2	3	3	-	-	1	2	1	1	-	-
CO-2	1	1	2	1	1	3	3	-	-	1	2	1	1	2	2
CO-3	1	1	2	1	1	3	3	-	-	1	2	1	1	2	-
CO-4	2	3	2	1	1	3	3	-	-	1	2	1	1	2	2
CO-5	1	1	3	1	1	3	3	-	-	1	2	1	1	2	2

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Introduction to the Energy-Water-Food Nexus: The Need for the Nexus Approach, Evolutionof the Nexus as a Policy and Development Discourse, The Nexus Contribution to Better WaterManagement and Its Limitations, Dynamic and Cross Sectoral Analyses of the Water-Energy-Food Nexus, Investigating an Emerging Paradigm, Importance and Relevance of the Nexus in Addressing Global Challenges, Key Principles and Concepts Related to the Nexus.

Energy-Water Interactions: Energy Production and Its Impact on Water Resources, Water Use in Energy Production, The Role of Water in Unconventional in Situ Energy Resource Extraction Technologies, Water Management in Unconventional Oil and Gas Development, Coal Use as a Cause of Water Quality, Water-Energy Efficiency and Conservation Measures.

Water-Food Interactions: Water Use in Agriculture, Water Scarcity and Its Impact on Food Production and Security, Sustainable Water Management Practices in Agriculture.

Energy-Food Interactions: Energy Requirements in the Food Supply Chain, Renewable Energy Applications in the Food Sector, Energy-Efficient Technologies for Food Production.

Operationalizing the Nexus: Modelling the Water Energy Food Nexus, Water Energy Food Nexus: Selected Tools and Models in Practice, Governing for the Nexus: Empirical, Theoretical, and Normative Dimensions, the Role of International Cooperation in Operationalizing the Nexus in Developing Countries, Emerging Lessons of the Nexus Observatory.

Nexus in Practice – Case Studies: The Water, Energy and Food Nexus from a South AfricanPerspective, Water, Energy and Food Nexus: Examples from the USA, Water, Energy, and Food Security Nexus in the West Asian Region; Assessment of Water, Energy, and Carbon Footprints of Crop Production: Case Studies.

Learning Resources:

Text Books:

1. Salam, P. A., Shrestha, S.,Pandey, V. P., Anal, A. K., Water-Energy-Food nexus: Principles and Practices, John Wiley & Sons, 2017.
2. Ahuja, S., Food, Energy, and Water: The Chemistry Connection, Elsevier, 2015.
3. Allouche, J., Middleton,C., Gyawali, D., Routledge, The Water–Food–Energy Nexus: Power, Politics, and Justice, Taylor & Francis Group, 2019.

Reference Books:

1. Mujtaba, I. M., Srinivasan, R., Elbashir, N. O., The Water-Food-Energy Nexus: Processes, Technologies, and Challenges, CRC Press, 2017.
2. Dodds, F., Bartram, J., Routledge, The Water, Food, Energy and Climate Nexus: Challenges and an Agenda for Action, 2016.
3. Ray, C., Muddu, S., Sharma, S., Unfolding Food, Energy, and Water Nexus, Springer International Publishing, 2022.

CH26027 **3-0-0 (3)**

Waste to Energy

Pre-Requisites: **None**

Course Outcomes:

CO-1	Demonstrate technologies for generation of energy from solid waste
CO-2	Select thermochemical conversion methods
CO-3	Identify sources of energy from biochemical conversion
CO-4	Analyse the environmental and health impact of waste to energy conversion

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	-	-	1	-	-	1	3	-	-	-	-	-	-	1	-
CO-2	1	-	1	-	-	-	1	-	-	-	-	-	-	-	-
CO-3	1	1	1	-	-	1	3	-	-	-	-	-	-	1	-
CO-4	1	-	1	-	1	1	3	1	-	-	-	-	-	1	-

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

Syllabus:

Introduction: Characterization of Wastes, Agricultural Residues and Wastes Including AnimalWastes, Industrial Wastes, Municipal Solid Wastes. Waste Processing Types and Compositionof Various Types of Wastes, Characterization of Municipal Solid Waste, Industrial Waste and Biomedical Waste, Waste Collection and Transportation, Waste Processing-Size Reduction, Separation, Waste Management Hierarchy, Waste Minimization and Recycling of Municipal Solid Waste.

Thermochemical Conversion: Incineration, Pyrolysis, Gasification of Waste Using Gasifiers, Environmental and Health Impacts of Incineration; Strategies for Reducing Environmental Impacts. Energy Production from Wastes Through Incineration, Energy Production Through Gasification of Wastes. Energy Production Through Pyrolysis and Gasification of Wastes, Syngas Utilization.

Biochemical Conversion: Anaerobic Digestion of Sewage and Municipal Wastes, Direct Combustion of MSW-Refuse Derived Solid Fuel, Industrial Waste, Agro Residues, Anaerobic Digestion Biogas Production, and Present Status of Technologies for Conversion of Waste intoEnergy, Design of Waste to Energy Plants for Cities, Small Townships and Villages, Energy Production from Wastes Through Fermentation and Trans Esterification, Cultivation of Algal Biomass from Wastewater and Energy Production from Algae, Energy Production from OrganicWastes Through Anaerobic Digestion and Fermentation, Introduction to Microbial Fuel Cells, Process Analysis and Reactor Configurations for Methane Production, Energy Assessment, Bio-Methanation from Sludge Digestion.

Energy Production from Waste Plastics, Gas Cleanup Waste, Heat Recovery: Concept ofConversion Efficiency, Energy Waste, Waste Heat Recovery Classification, Advantages and Applications, Commercially Viable Waste Heat Recovery Devices.

Environmental and Health Impacts-Case Studies: Environmental and Health Impacts of Waste to Energy Conversion, Case Studies of Commercial Waste to Energy Plants, Waste to Energy- Potentials and Constraints in India, Eco-Technological Alternatives for Waste to Energy Conversions.

Learning Resources:

Text Books:

1. Robert C. Brown, Thermo-chemical Processing of Biomass: Conversion into Fuels, Chemicals and Power, John Wiley and Sons, 2019.
2. Sergio Capareda, Introduction to Biomass Energy Conversions, CRC Press, 2013.
3. Krzysztof J Ptasinski, Efficiency of Biomass Energy: An Exergy Approach to Biofuels, Power, and Biorefineries, John Wiley & Sons, 2016.
4. Vesilind, P. A., Worrell W. A., Solid Waste Engineering, Cengage India, 2016, 2nd Edition.

Other Suggested Readings:

1. https://nptel.ac.in/courses/103/107/103107125/

CH26030 **3-0-0 (3)**

Bioenergy and Biofuels

Pre-Requisites: None

Course Outcomes:

CO-1	Describe the nature and principle of different biomass energy extraction systems
CO-2	Choose suitable biomass fuels for different energy applications
CO-3	Address the desirable features of biomass energy sources and their advantages over traditional fuels such as petroleum and coal
CO-4	Identify suitable bioenergy sources in terms of suitable sites, composition and cost-effectiveness

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	-	-	1	-	-	1	3	-	-	-	-	-	-	1	-
CO-2	-	-	1	-	-	-	2	-	-	-	-	-	-	-	-
CO-3	-	-	1	1	-	1	3	-	-	-	-	-	-	1	-
CO-4	1	1	1	-	1	1	3	1	-	-	-	-	-	1	-

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

Syllabus:

Introduction to Bioenergy: Global Energy Outlook, Importance of Bioenergy in Solving the Energy Crisis and Global Warming, Sustainability, Introduction to Various Biomass Feedstocks-Constituents and Characterization.

Introduction to Biofuels: Seed-Based Biodiesel, Bioethanol, Conversion of Waste VegetableOil to Biodiesel, Advanced Biofuels Including Algae-Biofuel, Microbial Biofuel and Advanced Innovations in the Enzymatic Conversion of Non-Food Feedstocks; Biohydrogen, Biobutanol and Other Green Fuels.

Biomass Feedstock Preparation and Pre-Treatment: Drying, Devolatilization, SizeReduction, Particle Size Classification, Torrefaction, Pelletizing and Mixing; Physical, Chemical, Physiochemical and Mechanical Pre-Treatments.

Biomass Conversion Technologies for Biofuel: Thermochemical Processes, Combustion, Gasification, Pyrolysis, Hydrothermal Liquefaction, Hydropyrolysis, Torrefaction and Choice ofThermal Process Based on Biomass Type and Product Requirement.

Bioenergy & Biofuels Related Environmental, Economic and Social Issues: Source, Processing and Social Impacts of Biofuel Utilization.

Learning Resources:

Text Books:

1. Filemon A. Uriarte Jr., Biofuels from Plant Oils, ASIAN Foundation, 2010.
2. Anuj Dahiya, Bioenergy: Biomass to Biofuels, Elsevier 2015.
3. Sunggyu Lee, Y. T. Shah, Biofuels and Bioenergy Processes and Technology, CRC Press,

Tailor and Francis Group, 2013.
4. Pandey, A., Larroche, C.,Ricke, S. C., Dussap, C. G., Gnansounou, E., Biofuels: Alternative Feedstocks and Conversion Processes, Academic Press, 2011.
5. Brown, R. C. Wiley, Thermochemical Processing of Biomass into Fuels, Chemicals and Power, 2011.

Reference Books:

1. Clark, J., Deswarte, F., Introduction to Chemicals from Biomass, John Wiley and Sons, 2008.
2. Mukunda, H. S., Understanding Clean Energy and Fuels from Biomass, Wiley India, 2011.

Open Electives

CH1475 **2-0-0 (2)**

Nanotechnology and Applications

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand the properties of nanomaterials
CO-2	Synthesize nanoparticles
CO-3	Evaluate safety and health-related issues of nanoparticles
CO-4	Characterize nanoparticles
CO-5	Identify the applications of nanotechnology in Industries

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/

CH1477 **2-0-0 (2)**

Industrial Pollution Control

Pre-Requisites: **None**

Course Outcomes:

CO-1	Analyze the effects of pollutants on the environment
CO-2	Distinguish air pollution control methods
CO-3	Design gas equipment for pollution control
CO-4	Assess treatment technologies for wastewater
CO-5	Identify solid waste treatment technologies

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.

Learning Resources:

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/103/107/103107084/

CH1479 **2-0-0 (2)**

Industrial Safety and Management

Pre-Requisites: **None**

Course Outcomes:

CO-1	Analyze the effects of toxic releases
CO-2	Select the methods for the prevention of fires and explosions
CO-3	Identify the hazards and preventive measures
CO-4	Assess the risks using a fault tree diagram

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.

SYLLABI

Minor: Chemical Engineering

CH1M01 **3-0-0 (3)**

Introduction to Unit Operations and Process Calculations

Pre-Requisites: **None**

Course Outcomes:

CO-1	Convert physicochemical quantities from one system of units to another
CO-2	Calculate mass and energy balances on non-reactive systems
CO-3	Selection of a process for manufacture of chemicals
CO-4	List chemical reactions and their mechanism involved

Syllabus:

Introduction: Unit operation and unit process concept, Chemical processing and role of chemical engineers.

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, Absorption, Distillation, etc.; Balances on multiple unit processes – Recycle and bypass.

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.

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

Phosphorus Industries: Phosphoric acid, Wet process, Electric furnace process, Nitrogen Industries: Ammonia, Nitric acid, Urea from ammonium carbonate. Sulfur and Sulfuric Acid Industries: Elemental sulfur mining by Frasch process, Sulfuric acid. Contact process, Chamber process. Sugar and Starch Industries. Pulp and Paper Industries.

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.

Learning Resources:

Text Books:

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

3. Sittig M., Gopala Rao M., Dryden's Outlines of Chemical Technology for the 21st Century, WEP East West Press, 2010, 3rd Edition.

Reference Books:

1. Austin G.T., Shreve's Chemical Process Industries - International Student Edition, McGraw Hill Inc., 1998, 5th Edition.
2. Nayef Ghasem, Henda R., Principles of Chemical Engineering Processes: Material and Energy Balances, CRC Press, 2015, 2nd Edition.
3. Narayanan K.V., Lakshmikutty B., Stoichiometry and Process Calculations, PHI Learning Pvt. Ltd., 2015, 7th Edition.
4. Hougen O.A., Watson K.M., Ragatz R.A., Chemical Process Principles (Part-I): Material and Energy Balances, CBS Publishers, 2004, 2nd Edition.
5. Bhatt B.I., Thakore S.M., Stoichiometry, Tata McGraw-Hill Publishing Company Ltd., 2010, 5th Edition.

Other Suggested Readings:

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

CH1M02 **3-0-0 (3)**

Essentials of Transport Phenomena

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand the principles of transport phenomena and basic properties
CO-2	Analyze fluid flow phenomena in pipes
CO-3	Evaluate modes of heat transfer and heat transfer equipment
CO-4	Understand mass transfer mechanism and various mass transfer operation

Syllabus:

Introduction: Need to study Transport phenomena; Levels of transport phenomena.

Momentum Transfer: Fluid Flow Phenomena - Nature of Fluids, Boundary layer, Laminar flow, Shear rate, Shear stress, Rheological properties of fluids, Turbulence; Basic Equations of Fluid Flow - Equations of continuity and motion, Bernoulli equation; Incompressible Flow in Pipes and Channels: skin friction in pipes, laminar and turbulent flow in pipes and channels, form friction. Friction in flow through beds of solids, Fluidization; Transportation and Metering of Fluids - Pipes, fittings and valves, Pumps, Flow measuring devices.

Heat Transfer: Modes of heat transfer, thermal conductivity; Conduction in Solids - Steady state heat conduction, Conduction through bodies in series; Unsteady state heat conduction - lumped capacity method; Principles of heat flow in fluids - Concept of heat transfer coefficient, Individual and overall heat transfer coefficient, Forced convection in laminar and turbulent flows, Natural convection; Radiation- Concepts of radiation, Laws of radiation; Heat Exchange equipment - Double pipe and Shell and Tube Heat Exchangers.

Mass Transfer: Diffusivity & mechanisms of mass transport – Fick's law of binary diffusion; Convective Mass transfer coefficients; Equilibrium staged operations (basics); Overview of various mass transfer operations.

Learning Resources:

Text Books:

1. W.L. McCabe, J.C. Smith, P. Harriott, Unit Operations of Chemical Engineering, McGraw Hill, 2017, 7th Edition.
2. C.J. Geankoplis, Transport Processes and Separation Process Principles, Prentice Hall Inc., 2009, 4th Edition.
3. Richard G. Griskey, Transport Phenomena and Unit operations – A combined approach, John Wiley & Sons, 2002, 1st Edition.

Reference Books:

1. S.K. Ghosal, S.K. Sanyal, S. Datta, Introduction to Chemical Engineering, Mc Graw Hill, 2004, 1st Edition.
2. R.B. Bird, W.E. Stewart, E.N. Lightfoot, Transport Phenomena, John Wiley & Sons, 2007, 2nd Edition.
3. Bodh Raj, Introduction to Transport Phenomena: Momentum, Heat, and Mass, Prentice Hall India Learning Private Limited, 2012.

CH1M03 **3-0-0 (3)**

Chemical Engineering Thermodynamics

Pre-Requisites: **None**

Course Outcomes:

CO-1	Apply the first and second laws of thermodynamics to chemical processes
CO-2	Estimate heat and work requirements for industrial processes
CO-3	Evaluate heat effects involved in industrial chemical processes
CO-4	Calculate Bubble-P & T, Dew-P & T for binary systems
CO-5	Evaluate the efficiency of expansion and compression flow processes

Syllabus:

Introduction and First Law of Thermodynamics: First Law of Thermodynamics, Energy Balance for Closed Systems, Equilibrium, The Phase Rule, General P-V-T Behavior of Pure Substances, Virial Equations of State, The Ideal Gas, Application of the Virial Equations.

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

Thermodynamic Properties of Fluids: Thermodynamic Property Relations for Single Phase Systems, Residual Property Relations, Residual Property Calculation by Equations of State, Two-Phase Systems, Thermodynamic Diagrams, Tables of Thermodynamic Properties, Generalized Property Correlations for Gases.

Heat Effects: Sensible heat effects, Temperature dependency of heat capacity, Latent Heat of pure substance, Standard heats of reaction, formation and combustion, Heat effects of industrial reactions.

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

Applications of Thermodynamics to Flow Processes: Duct Flow of Compressible Fluids, Turbines (Expanders), Compression Processes. Refrigeration and Liquefaction: Carnot Refrigerator, Vapor-Compression Cycle, Choice of Refrigerant, Absorption Refrigeration, Heat Pump.

Learning Resources:

Text Books:

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

Reference Books:

1. J.W. Tester, M. Modell, Thermodynamics and its Applications, Prentice Hall, 1999, 3rd Edition.

2. Stanley I. Sandler, Chemical, Biochemical, and Engineering Thermodynamics, Wiley, 2020, 5th Edition.

Other Suggested Readings:

1. https://nptel.ac.in/courses/103/101/103101004/#
2. https://nptel.ac.in/courses/103/104/103104151/
3. https://nptel.ac.in/courses/103/103/103103144/

CH1M04 **3-0-0 (3)**

Chemical Reaction Engineering

Pre-Requisites: **None**

Course Outcomes:

CO-1	Derive the rate law for non-elementary chemical reactions
CO-2	Determine the kinetics of chemical reaction using integral, differential, fractional life methods and method of initial rates
CO-3	Design reactors for homogenous reactions under isothermal conditions
CO-4	Select optimal sequence in multiple reactor systems
CO-5	Analyze the performance of non-ideal reactors using segregation model, tanks-in series model and dispersion model

Syllabus:

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

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

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

Isothermal Reactor Design: Mole Balances in Terms of Conversion- Design Structure for Isothermal Reactors, Scale-Up of Liquid-Phase Batch Reactor Data to the Design of a CSTR, Design of Continuous Stirred Tank Reactors (CSTRs), Tubular Reactors. Mole Balances Written in Terms of Concentration and Molar Flow Rate- Mole Balances on CSTRs, PFRs, and Batch Reactors, recycle reactor.

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

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

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

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

Learning Resources:

Text Books:

1. Levenspiel O., Chemical Reaction Engineering, Wiley India, 2006, 3rd Edition.

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

Reference Books:

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

Other Suggested Readings:

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

CH1M05 **3-0-0 (3)**

Process Dynamics and Control

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand the dynamic behavior of processes
CO-2	Analyze components of a control loop
CO-3	Evaluate the stability of feedback control system
CO-4	Design controllers for first and second order processes
CO-5	Determine the frequency response for controllers and processes

Syllabus:

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

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

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

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

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

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

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

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

Introduction to model predictive control.

Learning Resources:

Text Books:

1. Coughanowr D.R., Process System analysis and Control, McGraw Hill, 2012, 3rd Edition.
2. Seborg D.E., Edgar T. E, Millichamp D.A, Process Dynamics and Control, John Wiley & Sons, 2016, 4th Edition.
3. Raghunathan Rengaswamy, Babji Srinivasan, Nirav Pravinbhai Bhatt, Process Control Fundamentals: Analysis, Design, Assessment, and Diagnosis, CRC Press, 2020.

Reference Books:

1. Stephanopolis G., Chemical Process Control, Prentice Hall India, 2008.
2. Bequette, B.W., Process Control: Modeling, Design and Simulation, 2007.

CH1304 **3-0-0 (3)**

Chemical Technology

Pre-Requisites: **None**

Course Outcomes:

CO-1	Selection of a process for the manufacture of chemicals
CO-2	Draw process flow diagrams
CO-3	Identify the engineering problems in chemical processes
CO-4	List chemical reactions and their mechanism involved

Syllabus:

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

Chloro-alkali industries: soda ash, Solvay process, dual process, Natural soda ash from deposits, Electrolytic process, and Caustic soda.

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

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

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

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

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

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

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

Learning Resources:

Text Books:

1. Austin G.T., Shreve's Chemical Process Industries - International Student Edition, McGraw Hill Inc., 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, 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/

SYLLABI

Honors-1: Chemical Engineering

CH16001 **3-0-0 (3)**

Advanced Transport Phenomena

Pre-Requisites: **None**

Course Outcomes:

CO-1	Perform momentum, energy and mass balances for a given system at macroscopic and microscopic scale
CO-2	Solve the governing equations to obtain velocity, temperature and concentration profiles
CO-3	Model the momentum, heat and mass transport under turbulent conditions
CO-4	Develop analogies among momentum, energy and mass transport

Syllabus:

Equations of Change for Isothermal Systems: Equation of Continuity, Equation of Motion, Equation of Mechanical Energy, Equations of Change in terms of the Substantial Derivative, Use of the Equations to solve Flow Problems, Dimensional Analysis of the Equations of Change.

Velocity Distributions with more than one Independent Variable: Time Dependent Flow ofNewtonian Fluids. Velocity Distributions in Turbulent Flow -Comparisons of Laminar and Turbulent Flows, Time Smoothed Equations of Change for Incompressible Fluids, Time Smoothed Velocity Profile near a wall, Empirical Expressions for the Turbulent Momentum Flux,Turbulent Flow in Ducts.

Macroscopic Balances for Isothermal Systems: The Macroscopic Mass Balance, The Macroscopic Momentum Balance, The Macroscopic Mechanical Energy Balance, Estimation of the Viscous loss, Use of the Macroscopic Balances for Steady-State Problems, Derivation ofthe Macroscopic Mechanical Energy Balance.

Equations of Change for Non-Isothermal Systems: The Energy Equation, Special forms of the Energy Equation, The Boussinesq Equation of Motion for Forced and Free Convection, Useof the Equations of change to Solve Steady-State Problems, Dimensional Analysis of the Equations of Change for Non-Isothermal Systems.

Temperature Distributions in Solids and in Laminar Flow: Heat Conduction with anElectrical Heat Source, Heat Conduction with a Viscous Heat Source. Temperature Distributions with more than One Independent Variable - Unsteady Heat Conduction in Solids,Temperature Distributions in Turbulent Flow - Time-Smoothed Equations of Change for Incompressible Non-Isothermal Flow, Time-Smoothed Temperature Profile near a Wall, Empirical Expressions for the Turbulent Heat Flux Temperature Distribution for Turbulent Flowin Tubes.

Macroscopic Balances for Non-Isothermal Systems: Macroscopic Energy Balance, Macroscopic Mechanical Energy Balance, Use of The Macroscopic Balances to Solve SteadyState Problems With Flat Velocity Profiles.

Concentration Distributions in Solids and in Laminar Flow: Shell Mass Balances BoundaryConditions, Diffusion through a Stagnant Gas Film, Diffusion with a Heterogeneous Chemical Reaction. Concentration Distributions with more than One Independent Variable: Time- Dependent Diffusion. Concentration Distributions in Turbulent Flow - Concentration Fluctuations and the Time-Smoothed Concentration, Time-Smoothing of the Equation of Continuity, Semi-Empirical Expressions for the Turbulent Mass Flux.

Interphase Transport in Multi-Component Systems: Definition of Transfer Coefficients in One Phase, Analytical Expressions for Mass Transfer Coefficients, Correlation of Binary Transfer Coefficients in One Phase, Definition of Transfer Coefficients in Two Phases, Mass Transfer and Chemical Reactions.

Macroscopic Balances for Multi-Component Systems: Macroscopic Mass Balances, Macroscopic Momentum, Use of the Macroscopic Balances to solve Steady-State Problems.

Learning Resources:

Text Books:

1. Bird R. B., Stewart W. E. and Light Foot E. N., Transport Phenomena, John Wiley & Sons,2007, Revised 2nd Edition.
2. Geankopolis C. J., Transport Processes and Unit Operations, Prentice Hall (India) Pvt. Ltd., 2004, 4th Edition.
3. Mauri Robert., Transport Phenomena in Multiphase Flows, Springer International Publishing, Switzerland, 2015.

Reference Books:

1. Koichi Asano, Mass Transfer: From Fundamentals to Modern Industrial Applications, Wiley-VCH, 2006.
2. Thomson W. J., Transport Phenomena, Pearson Education, 2001.
3. W.M. Deen, Analysis of Transport Phenomena, Oxford University Press, 2013, 2nd Edition.

Other Suggested Readings:

1. NPTEL lectures: https://nptel.ac.in/courses/103106068
2. https://ocw.tudelft.nl/courses/advanced-transport-phenomena/?view=lectures&paging=1

CH16003 **3-0-0 (3)**

Advanced Reaction Engineering

Pre-Requisites: None.

Course Outcomes:

CO-1	Evaluate heterogeneous reactor performance considering mass transfer
CO-2	Determine the concentration profiles in multiphase reactors
CO-3	Estimate the performance of multiphase reactors under non-isothermal conditions
CO-4	Evaluate the role of modern reactor technologies for mitigation of global warming

Syllabus:

Non-Isothermal reaction modelling in CSTR & Batch, Semi-Batch reactor: Energy Balance equations for CSTR, PFR and Batch reactors. Unsteady state non-isothermal reactor design, adiabatic operation in batch, Heat effects in semi-batch. Auto thermal reactors.

Catalyst preparation and characterization: Catalysis - Nature of catalysis, methods of evaluation of catalysis, factors affecting the choice of catalysts, promoters, inhibitors, and supports, catalyst specifications, preparation and characterization of catalysts, surface area measurement by BET method, pore size distribution, catalyst, poison, mechanism and kineticsof catalyst, deactivation.

Heterogeneous Reactors: Catalytic wall reactor, monolithic reactors, limiting steps reactions and mass transfer limiting Porous catalyst on tube wall reactors Design of packed bed porous catalytic reactors: Mass transfer limited reactions in Packed bed packed beds: Transport and Reactions, Gradients in the reactors: temperature. Fluidized bed reactor modelling: Class III Modelling the Bubbling Fluidized Bed Reactor, BFB, The Kunii-Levenspiel bubbling bed model,Gas Flow Around and Within a Rising Gas Bubble in a Fine particle BFB, Reactor performanceof BFB.CVD, trickle bed reactors. Polymerization techniques and reactors.

Application of Population Balance Equations for reactor modelling: Particle size distribution, Distribution Functions in Particle Measuring Techniques, Particle distribution model in colloidal particle synthesis in batch reactor, Moments of Distribution, Nucleation rate based on volumetric holdup versus crystal growth rate.

Reaction engineering and mitigation of Global warming: CO_2 absorption, different techniques of mitigation of CO_2, Recent advancements, automotive monolith catalytic converter example, removal and utilization of CO_2 for thermal power plants.

Learning Resources:

Text Books:

1. Fogler H.S., Elements of Chemical Reaction Engineering, Prentice Hall of India, 2008.
2. Levenspiel O., Chemical Reaction Engineering, John Wiley & Sons, 1999, 3rd Edition.
3. Fromment G.F., Bischoff K.B, Chemical Reactor Analysis and Design, John Wiley, 2010.

Reference Books:

1. Schmidt L.D., The Engineering of Chemical Reactions, Oxford, 2007.
2. Harriott P., Chemical Reactor Design, CRC Press, 2002.
3. James J. Carberry, Chemical and catalytic reaction engineering, Dover Publications, 2001.

Other Suggested Readings:

1. https://nptel.ac.in/courses/103101001

CH16004 **3-0-0 (3)**

Steady State Process Simulation

Pre-Requisites: **None**

Course Outcomes:

CO-1	Analyse the role and importance of property estimation methods in process simulation
CO-2	Determine the degrees of freedom for a given stream, process unit and flowsheet
CO-3	Apply suitable mathematical methods for solving sparse sets of equations, partitioning & precedence ordering and tear stream sets
CO-4	Carry out steady state process simulation using sequential modular approach and equation-oriented approach
CO-5	Apply convergence promotion techniques for both sequential and simultaneous convergence loops

Syllabus:

Introduction: Steady-state flowsheeting and the design process, the total design project.

Flowsheeting on the computer: Motivation for development, Developing a simulation model, Approaches to flowsheeting systems-examples.

Solving linear and nonlinear algebraic equations: Solving one equation in one unknown, Solution methods for linear equations, General approaches to solving sets of nonlinearequations, Solving sets of sparse nonlinear equations.

Physical property service facilities: The data cycle, Computerized physical property systems, Physical property calculations.

Degrees of freedom in a flowsheet: Degrees of freedom, Independent stream variables, Degrees of freedom for a stream and a unit, Degrees of freedom for a flowsheet.

The sequential modular approach to flowsheeting: The solution of an example flowsheeting problem, Other features: Handling design specifications, information streams and control blocks.

Convergence of tear streams: Sequential convergence and simultaneous convergence, Partitioning and precedence ordering set of equations and a flowsheet, tearing a flowsheet, Finding the best tear set family or tear set with minimum number of tears.

Flowsheeting by equation solving methods based on tearing: An example system based on equation solving, A complex example of selecting decision and tear variables for a flowsheet, Handling the iterated variables.

Simulation by linear methods: Introduction to linear simulation, Application to staged operations, Application to management problem.

Learning Resources:

Text Books:

1. Westerberg A. W., Hutchison H. P., Motard R. L. and Winter P., Process Flowsheeting, Cambridge University Press, 2011.

Reference Books:

1. Ivan Dano Gill Chaves, Javier Ricardo Guevara Lopez, Jpose Luis Garcia Zapata, Alexander Leguizamon Robayo, Gerardo Rodrigue Nino, Process Analysis and Simulation in Chemical Engineering, Springer, 2016.
2. Babu B. V., Process Plant Simulation, Oxford University Press, 2004.
3. Mariano Martin Martin, Introduction to Software for Chemical Engineers, CRC Press, 2015.

CH16002 **3-0-0 (3)**

Computational Fluid Dynamics

Pre-Requisites: **None.**

Course Outcomes:

CO-1	Develop governing equations of fluid flow and heat transfer
CO-2	Discretize the equations using finite difference and finite volume formulation
CO-3	Solve the discretized equations
CO-4	Implement pressure velocity coupling algorithms
CO-5	Generate grid for a given geometry

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 discretisation 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; Iterative methods.

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

CH16060 **3-0-0 (3)**

Advanced Process Control

Pre-Requisites: **None**

Course Outcomes:

CO-1	Identify controlled and manipulated variables
CO-2	Design regulatory control schemes for a given process
CO-3	Analyse the multivariable process control schemes
CO-4	Evaluate linear and nonlinear model predictive control strategies

Syllabus:

Introduction: Hierarchy of control layers, review of basics, system linearization, state space and transfer function models.

Advanced regulatory control schemes: Cascade control, feed-forward control, ratio control, split-range control, time delay compensator, and inverse response compensator.

Multivariable control: Challenges, Control pairing; Interactions in closed-loop systems; Relative Gain Array (RGA) and variants. Centralized, decentralized, decoupled control schemes.

Model Predictive Control (MPC): MPC control formulation: simple unconstrained optimal control formulation, general characteristics of MPC formulation, translation of MPC problem into quadratic programming optimization problem, Practical MPC implementation considerations: empirical model development, usage of design/tuning parameters, design of MPC control for typical systems.

Extensions of MPC: Theory: Economic MPC, Nonlinear Model Predictive Control (NMPC), Robust MPC, Data-driven MPC.

Learning Resources:

Text Books:

1. Seborg, D. E., Edgar, T. F., Millechamp, D. A., Doyle III, F. J., Process Dynamics and Control, Wiley, 2014, 3rd Edition.
2. Raghunathan Rengaswamy, Babji Srinivasan, Nirav Pravinbhai Bhatt, Process Control Fundamentals: Analysis, Design, Assessment, and Diagnosis, CRC Press, 2020.
3. Liuping Wang, Model Predictive Control System Design and Implementation using MATLAB, Springer, 2009.

Reference Books:

1. Francesco Borrelli, Alberto Bemporad, Manfred Morari, Predictive Control for Linear and Hybrid Systems, Cambridge University Press, 2017.
2. Jean-Pierre Corriou, Process Control: Theory and Applications, Springer, 2018, 2nd Edition.
3. B. Roffel, B. Betlem, Process Dynamics and Control, Wiley, 2006.
4. Cecil L. Smith, Advanced Process Control, Wiley, 2010.
5. Surekha Bhanot, Process Control: Principles and Applications, Oxford, 2008.

Other Suggested Readings:

1. https://onlinecourses.nptel.ac.in/noc21_ge01/preview

CH16054 **3-0-0 (3)**

Computational Catalysis

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand the basic concepts & methods in computational catalysis
CO-2	Acquire basic knowledge about Density Functional theory (DFT)
CO-3	Describe different computational methods of catalysts in macroscopic level size
CO-4	Apply computational methods to find different properties of the catalysts

Syllabus:

Introduction: Behavior of materials, Design of catalysts electronic level to industrial application, Methods and applications of computational catalysis**,** Sabatier principle, Volcano plots, BrΦnsted Evans-Polanyi (BEP) scaling relations, Industrial requirements for efficient catalysts, Tools for computational catalysis, Limitations.

Density Functional Theory (DFT): The Schrödinger Equation, Hohenberg - Kohn (HK) theorems, Kohn-Sham (KS) equations, Wave Functions to Electron Density, Exchange-Correlation Functional, Pseudopotentials (PP), Ground state properties, Electron density approximations, minimizing of total energy, Self-consistent filed (SCF), Gaussian functions (Cluster models) & Periodic functions (crystal models), Basis set, Algorithm of DFT, Practical examples, Challenges in DFT calculations.

Molecular dynamics: Ab Initio molecular dynamics- Born-Oppenheimer molecular dynamics (BOMD), Car-Parrinello molecular dynamics (CPMD), Error estimation in CPMD, Classical molecular dynamics-Force Field Methods, Making reactive Force Field (ReaxFF), Transferability &Training of ReaxFF, Difficulties in ReaxFF.

Statistical methods: Rare event dynamics, mapping to lattice, mean filled approximation, Kinetic Monte Carlo (KMC) simulations, CO oxidation with Pt surface.

Properties: Adsorption of small molecules on solid surfaces and clusters, Solvation model environment, Vibrational properties (Infrared spectroscopy), Reaction mechanism (energy barriers), interaction between reacting species in a reaction.

Learning Resources:

Text Books:

1. Rutger A. van Santen, Philippe Sautet, Computational Methods in Catalysis and Materials Science: An Introduction for Scientists and Engineers, Wiley-VCH, 2009.
2. Asthagiri A, Janik MJ, editors. Computational catalysis, Royal Society of Chemistry, 2023, 2nd Edition.

Reference Books:

1. F. Giustino, Materials Modelling using Density Functional Theory, Oxford University Press, 2014, 1st Edition.
2. J. G. Lee, Computational materials science: an introduction, CRC press, 2011, 2nd Edition.

CH16005 **3-0-0 (3)**

Data Analytics and Machine learning

Pre-Requisites: **None**

Course Outcomes:

CO-1	Demonstrate proficiency with statistical analysis of data
CO-2	Use inferential statistics for decision making
CO-3	Apply supervised learning for classification and regression problems
CO-4	Apply unsupervised learning for clustering

Syllabus:

Data Quality and Pre-processing: Distance measures, dimensionality reduction, principal component analysis (PCA).

Descriptive Statistics: Graphical approach - Frequency tables, relative frequency tables, grouped data, pie chart, barchart, histograms, ogives, stem and leaf plots, box plots, dot diagram, scatter plots, Pareto diagram.

Measure of Central Tendency and Dispersion - Arithmetic mean, median and mode, variance,standard deviation, quartiles, range, mean absolute deviation, coefficient of variation, Z scores,normal distribution, confidence interval estimation.

Probability Distribution and Inferential Statistics: Random variables, probability distributions, hypothesis testing, single sample test, two sample test, Type I error, Type II error,Analysis of Variance (ANOVA).

Supervised learning: Linear regression, ridge regression, Lasso regression, logistic regression, multiple linear regression, goodness of fit, bias–variance trade off, k-nearest neighbors algorithm, linear discriminant analysis, classification and regression trees andpruning, support vector machines, random forest, Naive Bayes, Introduction to Neural networksand deep learning.

Unsupervised learning: Cluster analysis – K Means, hierarchical, DBSCAN.

Time series analysis: Auto-Regressive (AR), Moving Average (MA), Auto Regressive Moving Average (ARMA), Auto-Regressive Integrated Moving Average (ARIMA).

Practical applications to different engineering systems**.**

Learning Resources:

Text Books:

1. Douglas C. Montgomery, George C. Runger, Applied Statistics and Probability for Engineers, John Wiley & Sons Inc., 2016, 6th Edition.
2. Trevor Hastie, Robert Tibshirani, Jerome Friedman, The Elements of Statistical Learning, Springer, 2009, 2nd Edition.
3. Ethem Alpaydın, Introduction to Machine Learning, MIT Press, 2014, 3rd Edition.

Reference Books:

1. João Mendes Moreira, André C. P. L. F. deCarvalho, Tomáš Horváth, A General Introduction to Data Analytics, Wiley, 2019.

2. Pang-Ning Tan, Michael Steinbach, Anuj Karpatne, Vipin Kumar, Introduction to Data Mining, Pearson, 2019, 2nd Edition.

Other Suggested Readings:

1. https://nptel.ac.in/courses/106107220
2. https://nptel.ac.in/courses/110106072

CH1H01 **0-0-0 (3)**

Project

Pre-Requisites: None

Course Outcomes:

CO-1	Apply engineering knowledge/principles and use practical experience to real-world projects
CO-2	Identify the gaps in literature to define objectives and research methodology for chemical processes
CO-3	Analyze, and draw valid conclusions by using modern tool usage
CO-4	Communicate project results clearly through reports and presentations adhering with professional ethics in engineering

Description:

Students are expected to choose real world or relevant problems and apply the engineering principles learned, to solve the problem through building prototypes or simulations or writing codes or establishing processes/synthesis/correlations etc. The department constituted panel will decide the suitability and worthiness of the project.

Evaluation Criteria:

The student will be evaluated by the panel based on the below criteria.

Criteria	Description	Weightages
I	Identification of Problem Domain	15 marks
II	Study of Existing Systems and establishing clear objectives	20 marks
III	Proper Documentation and Technical Writing	25 marks
IV	Presentation and Response to questions	40 marks

Evaluation Criteria-CO Mapping

CO / Criteria	CO-1	CO-2	CO-3	CO-4
I	X			
II	X	X		
III		X	X	
IV				X

SYLLABI

Honors-2: Sustainable Energy Generation and Storage Technologies (SEG&ST)

CH26001 **3-0-0 (3)**

Sustainable Energy Engineering

Pre-Requisites: **None**

Course Outcomes:

CO-1	Quantify the variety of energy resources
CO-2	Perform project economics evaluation
CO-3	Evaluate sustainability metrics
CO-4	Select suitable sustainable energy technologies

Syllabus:

Sustainability Concepts: Sustainable Development Goals for Clean Energy (SDGS), Emerging Issues in Energy Access, Technologies, Economics. Sustainability Concepts of Energy Generation Technologies, Energy and Resource Utilization.

Sustainable Energy: The Engine of Sustainable Development: Aspects of Energy Production, Nations and Global Patterns of Energy Supply and Utilization, Environmental Effects of Energy.

Estimation and Evaluation of Energy Resources: Comparison of Different Forms of Energy, Energy Life Cycle, Estimation and Validation of Energy Resources.

Technical Performance: Allowability, Efficiency, Production Rates, Relation of Technical Performance to Sustainability, Thermodynamic Analysis, Chemical Rate Processes, Use and Abuse of Time Scales.

Local, Regional, and Global Environmental Effects of Energy: Adverse Environmental Effects, Attribution of Environmental Damage, Methods of Environmental Protection.

Project Economic Evaluation: Time Value of Money Mechanics, Economy of Scale and Learning Curve, Energy Accounting.

Energy Systems and Sustainability Metrics: System Analysis Approach, Measures, General Principles for Sustainable Development.

Energy, Water and Land Use: Major Planetary Cycles, Land-Use Issues, Ocean-Use Issues, Implications for Sustainable Energy, Charting Pathways for Energy Democracy, Building an Energy Democracy Movement.

Biomass Energy, Biofuel: Characterization, Biomass Relevance to Energy Production, Properties Relevant to Energy Production, Thermal Conversion, Bioconversion, Economics.

Solar Energy: Resource Assessment, Concentrating Solar Power, Solar Photovoltaic Systems.

Ocean Wave, Tide, Current, and Thermal Energy Conversion: Energy from the Tides and Currents, Energy from Waves, Economic Prospects, Environmental and Sustainability Considerations.

Wind Energy: Wind Resources, Wind Machinery and Generating Systems, Wind Power Economics, Measure of Sustainability.

Energy Carriers: Electric Power, Hydrogen Fuel: Electricity as an Energy Carrier, Hydrogen as an Energy Carrier, Sustainability Issues.

Industrial Energy Usage: Life-Cycle Analysis and Design for Sustainability, Chemical Industries, Cement and Lime Industries, Sustainability Issues.

Synergistic Complex Systems: Complex Systems View, Some Case Studies, Transitional Pathways, Challenge to Society.

Learning Resources:

Text Books:

1. Tester, J. W., Drake, E. M., Driscoll, M. J.,Golay, M. W., Peters, W. A., Sustainable Energy: Choosing Among Options, MIT Press, 2012, 2nd Edition.
2. Martin A. Abraham, Vladimir Strezov, Joseph Zoeller, Encyclopedia of Sustainable Technologies, Volume 3: Sustainable Energy Technologies & Sustainable Chemical Processes, Elsevier Science, 2017.
3. Eduardo Rincon-Mejia, Alejandro de las Heras, Sustainable Energy Technologies, CRC Press, Taylor & Francis Group, 2018.
4. Denise Fairchild, Al Weinrub, Energy democracy: Advancing equity in clean energy solutions, Island press, 2017.

Reference Books:

1. Mulligan, C. N., Sustainable Engineering: Principles and Implementation, CRC Press,Taylor and Francis Group, 2019.
2. Bakshi, B. R., Sustainable Engineering: Principles and Practice, Cambridge UniversityPress, 2019.
3. David Allen, DavidShonnard, Sustainable Engineering: Concepts, Design, and Case studies, Prentice Hall, 2011.
4. Hazra Somnath, Bhukta Anindya, Sustainable Development Goals an Indian Perspective, Springer International Publishing Switzerland, 2020.

CH26003 **3-0-0 (3)**

Hydrogen Generation and Storage

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand the basic properties of hydrogen, including its chemical and physical characteristics, and its role as an energy carrier
CO-2	Select a suitable hydrogen generation and storage technique based on the mechanisms, performance characteristics, and applicability
CO-3	List the safety considerations and regulations related to hydrogen handling
CO-4	Analyze the economic viability and environmental impact of hydrogen generation and storage systems

Syllabus:

Introduction: Basic Properties of Hydrogen; Engineering Thermodynamics; Hydrogen and Environment; Hydrogen and Sustainability; Hydrogen Production Methods; Green Hydrogen Sources; Hydrogen as an Energy Carrier; Historical Background and Current Applications.

Hydrogen Generation Methods: Steam methane reforming; Electrolysis (alkaline; PEM, and solid oxide electrolysis); Coal/Biomass Gasification; Solar and Wind-based Hydrogen Production; Emerging Hydrogen Generation Technologies.

Hydrogen Storage Techniques: Compressed Gas Storage; Liquid Hydrogen Storage; Chemical Storage (hydrogenation, metal hydrides); Physical Storage Using Nanostructured and Porous Materials; Underground Hydrogen Storage; Emerging Hydrogen Storage Technologies.

Performance and Efficiency: Efficiency Considerations in Hydrogen Generation; Energy Losses and Efficiency of Different Storage Methods; Performance Assessment of Hydrogen Production and Storage Systems.

Safety and Regulations: Safety Considerations in Hydrogen Handling and Storage; Codes and Standards for Hydrogen Storage Systems; Risk Assessment and Mitigation Strategies; Case Studies of Hydrogen-related Incidents.

Learning Resources:

Text Books:

1. Gupta, R. B., Hydrogen Fuel: Production, Transport, and Storage, CRC press, 2008.
2. Zhang, J. Z., Li, J., Li, Y., Zhao, Y., Hydrogen Generation, Storage and Utilization, John Wiley & Sons, 2014.
3. Dinçer, I., Zamfirescu, C., Sustainable Hydrogen Production, Elsevier, 2016.

Reference Books:

1. Altalhi, T. A., Adnan, S. M., Amin, M. A., Materials for Hydrogen Production, Conversion, and Storage, John Wiley & Sons, 2023.
2. Winter, C. J., Nitsch, J., Hydrogen as an Energy Carrier: Technologies, Systems, Economy, Springer Science & Business Media, 2012.
3. Sherif, S. A., Goswami, D. Y., Stefanakos, E. L., Steinfeld, A., Handbook of Hydrogen Energy, CRC press, 2014.

Other Suggested Readings:

1. NPTEL lectures: https://onlinecourses.nptel.ac.in/noc22_ch66/preview

CH26002 **3-0-0 (3)**

Electrochemical Energy Storage Systems

Pre-Requisites: None

Course Outcomes:

CO-1	Explain fundamental electrochemical principles such as redox reactions, cell potentials, and ionic conductivity of electrolytes
CO-2	Apply electrochemical techniques like cyclic voltammetry and galvanostatic charge-discharge to characterize electrochemical systems
CO-3	Analyze various battery technologies and their components, focusing on performance and key characteristics
CO-4	Describe the design and functionality of flow batteries, including the roles of electrodes, electrolytes, membranes, and stack design
CO-5	Evaluate the principles, materials, and applications of supercapacitors, comparing them with batteries and identifying challenges and future directions
CO-6	Analyze various recycling processes for energy storage systems and their impact on sustainability and environmental challenges

Syllabus:

Battery Fundamentals and Technologies: Electrochemical energy storage mechanisms. cell vs. battery. History of battery development. Battery Classification: Primary and secondary batteries; Based on electrode materials and electrolytes (aqueous vs. non-aqueous).

Existing Battery Systems: Basic operation and key characteristics (Lead-Acid, Nickel Cadmium, Nickel Hydrogen, Nickel Metal Hydride). Lead acid batteries: Effect of Temperature- Peukert's Law, Discharge Rate, Sulfation, Overcharging, Plate Thickness; Nickel cadmium: components, advantages and limitations.

Lithium-Ion Batteries: Classification: Based on cathode and anode materials (LFP, LCO). Working Principle: Charge/discharge cycles, role of the electrolyte. Critical Components and Materials: Anode Materials: Graphite, silicon, lithium titanate; Cathode Materials: Layered oxides, spinel oxides, olivine phosphates. Electrolytes: Organic solvents with lithium salts, ionic conductivity, safety. Separators: Microporous polymer membranes. Advantages and Limitations: Capacity, cycling stability, safety.

Advanced Battery Technologies: Lithium-Air Batteries: Ultra-high energy density potential, working principle, challenges (electrode stability, electrolyte decomposition). **Sodium-Ion Batteries:** History, working mechanism, components and materials (anodes: hard carbon, sodium titanate; cathodes: layered oxides, polyanionic compounds), advantages and limitations. **Aluminum-Ion Batteries:** Introduction, historical development, rechargeable types (chloroaluminate, aluminum-sulfur), specific requirements for electrolytes, challenges, and future prospects. **Dual-Ion Batteries**: Working mechanism, cathode and anode materials, advantages and limitations.

Flow Batteries: Concept and Working Principle. Electrolytes: Different redox couples and performance properties; Electrodes: Porous carbon materials; Membranes and Stack Design: Flow field design, materials selection.

Supercapacitors: Introduction and Comparison with Batteries: Basic principles (electric charge, electric field, potential, capacitance), charging/discharging, energy storage mechanisms. Materials for Supercapacitors: Electrolytes: Aqueous, organic, ionic liquids. Energy Storage Mechanisms: Electrostatic

vs. pseudocapacitive. Electrode materials: Carbon materials (activated carbon, CNTs, graphene), metal oxides/sulfides, conducting polymers.

Recycling Processes: Recycling Methods: Hydrometallurgy, pyrometallurgy, chemical, biological, direct recycling. Future Prospects: Innovations and sustainability in recycling technologies.

Learning Resources:

Text Books:

1. Allen J. Bard, Larry R. Faulkner, Electrochemical Methods: Fundamentals and Applications, Wiley, 2000, 2nd Edition.
2. Beard, K.W., Linden's handbook of batteries. McGraw Hill Education, 2019.
3. Brian E. Conway, Electrochemical Supercapacitors: Scientific Fundamentals and Technological Applications, Volume: 1, Springer, 1999.

Reference Books:

1. Vladimir S. Bagotsky, Alexander M. Skundin, Yurij M. Volfkovich, Electrochemical Power Sources: Batteries, Fuel Cells, and Supercapacitors, Wiley, 2015.
2. Aiping Yu, Victor Chabot, Jiujun Zhang, Electrochemical Supercapacitors for Energy Storage and Delivery: Fundamentals and Applications, CRC Press, 2017, 1st Edition.
3. François Béguin, Elżbieta Frąckowiak, Supercapacitors: Materials, Systems and Applications, Wiley, 2013.
4. Warner, J. T., The Handbook of Lithium-Ion Battery Pack Design: Chemistry, Components, Types and Terminology, Elsevier, 2015.

CH16005 **3-0-0 (3)**

Data Analytics and Machine Learning

Pre-Requisites: **None**

Course Outcomes:

CO-1	Demonstrate proficiency with statistical analysis of data
CO-2	Use inferential statistics for decision making
CO-3	Apply supervised learning for classification and regression problems
CO-4	Apply unsupervised learning for clustering

Syllabus:

Data Quality and Pre-processing: Distance measures, dimensionality reduction, principal component analysis (PCA).

Descriptive Statistics: Graphical approach - Frequency tables, relative frequency tables, grouped data, pie chart, barchart, histograms, ogives, stem and leaf plots, box plots, dot diagram, scatter plots, Pareto diagram.

Measure of Central Tendency and Dispersion - Arithmetic mean, median and mode, variance,standard deviation, quartiles, range, mean absolute deviation, coefficient of variation, Z scores,normal distribution, confidence interval estimation.

Probability Distribution and Inferential Statistics: Random variables, probability distributions, hypothesis testing, single sample test, two sample test, Type I error, Type II error,Analysis of Variance (ANOVA).

Supervised learning: Linear regression, ridge regression, Lasso regression, logistic regression, multiple linear regression, goodness of fit, bias–variance trade off, k-nearest neighbors algorithm, linear discriminant analysis, classification and regression trees andpruning, support vector machines, random forest, Naive Bayes, Introduction to Neural networksand deep learning.

Unsupervised learning: Cluster analysis – K Means, hierarchical, DBSCAN.

Time series analysis: Auto-Regressive (AR), Moving Average (MA), Auto Regressive Moving Average (ARMA), Auto-Regressive Integrated Moving Average (ARIMA).

Practical applications to different engineering systems.

Learning Resources:

Text Books:

1. Douglas C. Montgomery, George C. Runger, Applied Statistics and Probability for Engineers, John Wiley & Sons Inc., 2016, 6th Edition.
2. Trevor Hastie, Robert Tibshirani, Jerome Friedman, The Elements of Statistical Learning, Springer, 2009, 2nd Edition.
3. Ethem Alpaydın, Introduction to Machine Learning, MIT Press, 2014, 3rd Edition

Reference Books:

1. João Mendes Moreira, André C. P. L. F. deCarvalho, Tomáš Horváth, A General Introduction to Data Analytics, Wiley, 2019.

2. Pang-Ning Tan, Michael Steinbach, Anuj Karpatne, Vipin Kumar, Introduction to Data Mining, Pearson, 2019, 2nd Edition.

Other Suggested Readings:

1. NPTEL lectures: https://nptel.ac.in/courses/106/107/106107220/
2. NPTEL lectures: https://nptel.ac.in/courses/110/106/110106072/

CH26023 **3-0-0 (3)**

Nuclear Power Technology

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand nuclear fission and nuclear fusion techniques
CO-2	Analyse the interaction of alpha, beta particles and neutrons with matter
CO-3	Evaluate the neutron diffusion theory, fuel depletion, and neutron transport equations
CO-4	Apply engineering aspects to reactor kinetics and control, radiation shielding, and reactor material selection

Syllabus:

Chemical Engineering Aspects of Nuclear Power: Introduction, Nuclear Fission, Nuclear Fuels, Nuclear Reactor Types, Fuel Processing Flow Sheets, Fuel-Cycle Operations, Fuel Reprocessing, Isotope Separation, Nuclear Fusion.

Nuclear Reactions and Radiations: Introduction, Radioactivity, Interaction of Alpha and BetaParticles with Matter, Interaction of Gamma Rays with Matter, Interaction of Neutrons with Matter, Cross Sections for Neutron Reactions, Variation of Cross Sections with Neutron Energy,The Fission Process.

Neutron Transport Behavior: Neutron Transport Concepts, Neutron Diffusion Theory, Diffusion in Multiplying Systems, Slowing Down of Neutrons, Slowing Down in Infinite Media, Spatial Distribution of Slowed-Down Neutrons, Critical Equations Based on Diffusion Theory, Criticality Measurements.

Nuclear Design Basics: Introduction, Multigroup Diffusion Theory, Fuel Depletion Calculations, Neutron Transport Equation and Its Approximation.

Nuclear Reactor Kinetics and Control: Introduction, Reactor Kinetics, Fission-Product Poisoning, Effect of Temperature on Reactivity, Reactor Stability Analysis, General Features ofReactor Control, Reactivity Control Instrumentation, Reactor Operations.

Radiation Protection and Shielding: Introduction, Health Physics Activities, Radiation Units,Biological Effects of Radiation, Radiation Protection Standards, Radiation Shielding Principles, Radiation Attenuation Calculations, Reactor Shield Analysis, Heating in Shields.

Reactor Materials: Introduction, Mechanical Properties of Materials, Stress Analysis, Radiation Effects in Materials, Corrosion of Metals, Structural and Cladding Materials, Moderator and Reflector Materials, Fuel Materials.

Learning Resources:

Text Books:

1. Glasstone Samuel, Sesonske Alexander, Nuclear Reactor Engineering Reactor Systems Engineering, Springer, 1994, 4th Edition.
2. Manson Benedict, Thomas H. Pigford, Hans Wolfgang Levi, Nuclear Chemical Engineering, McGraw-Hill, 1981, 2nd Edition.
3. Lamarsh, J. R., Baratta, A. J., Introduction to Nuclear Engineering, Pearson, 2001, 3rd Edition.

Reference Books:

1. Vaidyanathan G., Nuclear Reactor Engineering (principles and Concepts), S Chand &Company, 2013,

ME16062 **3-0-0 (3)**

Thermal Energy Storage

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand the principles, concepts, and operation of thermal energy storage systems
CO-2	Select the suitable energy storage materials
CO-3	Design thermal energy storage systems
CO-4	Evaluate the performance of thermal energy storage systems for different applications

Syllabus:

Introduction: Classification of Energy Resources, Energy Scenario in the World and India,Need for Energy Efficiency, Energy Conservation and Management.

Introduction to Thermal Energy Storage Systems: Introduction, Thermodynamics of EnergyStorage, System Types, Environmental Impact.

Sensible Heat Storage Systems: Introduction, Types, Principles of Sensible Heat StorageSystems, Limitations, Advantages and Future Trend.

Latent Heat Storage Systems (Phase Change Materials): Introduction, Types, Selection Criteria, Thermophysical Properties, Thermal Stability, Corrosion, Phase Segregation, Sub Cooling, Applications.

Microencapsulation and Nanoencapsulation of Phase Change Materials: Introduction, Microencapsulation and Nanoencapsulation of Phase Change Materials, Methods, Shape Stabilized Phase Change Materials, Applications.

Design of Latent Heat Storage System: Introduction, Requirements and Considerations for the Design, Design Methodologies, Applications of Latent Heat Storage Systems .incorporating PCMS, Future Trends.

Modelling of Heat Transfer in Phase Change Materials (PCMS): Introduction, Inherent Physical Phenomena in Phase Change Materials, Modelling Methods and Approaches for the Simulation of Heat Transfer in PCMS for Thermal Energy Storage, Examples of Modelling Applications, Future Trends.

Phase Change Materials for Energy Conservation in Buildings: Introduction, Integration of PCMS into Building Envelop, PCM Containment, Measurement of Thermal Properties of PCM Integrated in Buildings, Experimental and Numerical Studies.

Thermochemical Heat Storage: Introduction, Phenomena and Principles, Thermochemical Energy Storage Systems, Applications, Remarks.

Thermal Energy Storage Systems Applications: Introduction, Solar Air Heating, Solar WaterHeating, District Heating, Heat to Waste, Cogeneration and Trigeneration Systems, Concentrated Solar Power, Cooling.

Learning Resources:

Text Books:

1. Kalaiselvam, S., Parameshwaran, R., Thermal Energy Storage Technologies for Sustainability Systems Design, Assessment and Applications, Elsevier, 2014.
2. Luisa F.Cabeza, Advances in Thermal Energy Storage Systems - Methods and Applications, Elsevier, 2015.

Reference Books:

1. Ibrahim Dinçer, Marc A. Rosen, Thermal Energy Storage: Systems and Applications, John Wiley & Sons Ltd., 2010.

PH18025 **3-0-0 (3)**

Solar Energy Systems

Pre-Requisites: None

Course Outcomes:

CO-1	Outline the technologies that are used to harness the power of solar energy
CO-2	Understanding of the available solar energy and the current solar energy conversion and utilization processes
CO-3	Comprehend the challenges in sustainable energy processes, perform cost analysis, design photovoltaic systems for different applications meeting residential and industrial needs, predict and test performance
CO-4	Understand the manufacturing processes involved, environmental challenges that need to be solved, economic aspects, and future potentials
CO-5	Illustrate the concepts of direct energy conversion systems & their applications

Syllabus:

Introduction to Solar Energy: Fundamentals of Solar Energy-Spectral Irradiance, Terrestrial Solar Radiation, Atmospheric Effects, Air Mass, Sun's Position, Solar Radiation on a Tilted Surface, Solar Insolation, Measurement and Analysis of Solar Irradiance.

Solar Photovoltaics: Solar Cell and Its Operation, Solar Technologies, Silicon Solar Structure and Parameters, Efficiency of Solar and Spectral Response, Solar Cell Design Principles-Light Trapping, Optical Losses, Anti-Reflection Coatings, Top Contact Design, Metal Grid Pattern. Environmental and Safety Issues, Cell Passivation.

Solar PV Modules and PV Systems: PV Module Circuit Design, Module Structure, Packing Density, Interconnections, Mismatch and Temperature Effects, Electrical and Mechanical Insulation, Lifetime of PV Modules, Degradation and Failure, PV Module Parameters, Efficiency of PV Module, Solar PV Systems-Design of Off Grid Solar Power Plant. Installation and Maintenance.

Storage in PV Systems: Battery Operation, Types of Batteries, Battery Parameters, Application and Selection of Batteries for Solar PV System, Battery Maintenance and Measurements, Battery Installation for PV System.

Solar Thermal Systems: Design of Solar Thermal Systems-Solar Concentrators, Storage of Solar Generated Heat, Hybrid Systems-Combinations of Solar Thermal and Solar Cell Systems.

Learning Resources:

Text Books:

1. Martin A. Green, Solar Cells: Operating Principles, Technology and System Applications, Published by the University of New South Wales, 1998, 1st Edition.
2. D. Yogi Goswami, Principles of Solar Engineering, Taylor and Francis, 2000, 1st Edition.

Reference Books:

1. Lasnier, F., Ang, T. G., Photovoltaic Engineering Handbook, IOP Publishing UK, 1990,1st Edition.
2. Sze, S. M., Semiconductor Devices, Physics, and Technology, Wiley, 2001, 2nd Edition.

Other Suggested Readings:

1. Energy Education (Link:https://energyeducation.ca/encyclopedia/Photovoltaic_system)

CY16061 **3-0-0 (3)**

Electrochemistry and Materials for Energy Systems

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand the principles of electrochemistry and electrochemical techniques
CO-2	Apply electrochemical techniques to investigate and analyze the performance of electrochemical systems
CO-3	Analyze the data obtained from various electrochemical techniques
CO-4	Evaluate different materials and mechanisms to determine their effectiveness and potential for optimization in various applications
CO-5	Create and design new electrochemical devices and systems and improvements in the synthesis and application of materials

Syllabus:

Introduction: Galvanic Cells and Electrolytic Cells, Nomenclature, Potential Representation, Cathodic and Anodic Currents and Potentials, Electrolytic Cells, Electrodes, Working Potential Window, Supporting Electrolyte, Open Circuit Potential, Reference Electrodes, Cell Setup. Introduction to Electrochemical Capacitors, Batteries, Fuel Cells and Sensors.

Voltammetry: Cyclic Voltammetry and Linear Sweep Voltammetry: Principles and Applications in Supercapacitors, Fuel Cells and Sensors. Diffusion Controlled Reactions. Stern Layer Thickness, Reversible, Irreversible and Quasi-Reversible Electrochemical Reactions. Electrochemistry of Modified Electrodes and Self-Assembly Electrodes. Microelectrodes, Hydrodynamic Measurements, Rotating Disk and Ring Disk Electrodes, Koutechky Plot Analysis, Mass-Transport Condition, Koutechky-Levich Plot Analysis, Kinetic Controlled Current, and Flow-Cell Analysis.

Chronopotentiometry and Chronoamperometry: Principles and Applications of Chronopotentiometry and Chronoamperometry in Electrocatalysis, Supercapacitors, Batteries, Fuel cells and Sensors. Electrochemical Sensors: Principles, Instrumentation, Performance Factors and Applications.

Electrochemical Impedance Spectroscopy: Principles Instrumentation and Applications. Equivalent circuit models in electrochemistry, Nyquist and Bode Plot Analysis.

Pulse Methods: Normal Pulse Voltammetry, Differential Pulse Voltammetry, Principles and Applications in Molecular Sensors.

Electrocatalysis: Mechanism of Electrocatalytic Reactions, Role of electrocatalysts in various electrocatalytic reactions.

Materials for Different Types of Fuel Cells, Batteries and Electrochemical Capacitors: Synthesis, Properties, Performance Metrics and Electrochemical Analysis.

Electrochemical Quartz Crystal Nanobalance: Principle, Thin Layer Coatings, Electropolymerization and Electrodeposition of Metals, Adlayer Formations, Automobile Exhaust Analysis, Applications.

Learning Resources:

Text Books:

1. Fritz Scholz, Electroanalytical Methods: Guide to Experiments and Applications, Springer, 2014, 2nd Edition.

2. Monk, P. M. S., Fundamentals of Electroanalytical Chemistry, John Wiley, 2003.
3. Conway, B. E., Electrochemical Supercapacitors- Scientific Fundamentals and Technological Applications, Springer, 2014.

Reference Books:

1. Joseph Wang, Analytical Electrochemistry, John Wiley, 2006, 3rd Edition.
2. Paola Ceroni, Alberto Credi and Margherita Venturi (Ed.), Electrochemistry of Functional Supramolecular Systems, John Wiley, 2010.

CH2H01 **0-0-0 (3)**

Project

Pre-Requisites: None

Course Outcomes:

CO-1	Apply engineering knowledge/principles and use practical experience to real-world projects
CO-2	Identify the gaps in literature to define objectives and research methodology for chemical processes
CO-3	Analyze, and draw valid conclusions by using modern tool usage
CO-4	Communicate project results clearly through reports and presentations adhering with professional ethics in engineering

Description:

Students are expected to choose real world or relevant problems and apply the engineering principles learned, to solve the problem through building prototypes or simulations or writing codes or establishing processes/synthesis/correlations etc. The department constituted panel will decide the suitability and worthiness of the project.

Evaluation Criteria:

The student will be evaluated by the panel based on the below criteria.

Criteria	Description	Weightages
I	Identification of Problem Domain	15 marks
II	Study of Existing Systems and establishing clear objectives	20 marks
III	Proper Documentation and Technical Writing	25 marks
IV	Presentation and Response to questions	40 marks

Evaluation Criteria-CO Mapping

CO / Criteria	CO-1	CO-2	CO-3	CO-4
I	X			
II	X	X		
III		X	X	
IV				X