I Semester:

S. No.	Course Code	Course Title	Category	Type	Credit	L	T	P
1.	22CET101	Engineering Drawing and Sketching	PC	Theory	2	1	0	2
2.	22CYT101	Engineering Chemistry	PC	Theory	3	3	0	0
3.	22HST101	Basic Economics	PC	Theory	2	2	0	0
4.	22HST102	English Communication Skills (Basic)	PC	Theory	2	2	0	0
5.	22MAT101	Mathematics I	PC	Theory	4	3	1	0
6.	22MET101	Introduction to Mechanical Systems	PC	Theory	2	2	0	0
7.	22CHT101	Introduction to Chemical Engineering	PC	Theory	3	3	0	0
8.	22CHT102	Chemical Engineering Thermodynamics-I	PC	Theory	4	3	1	0
9.	22CYP102	Engineering Chemistry Lab	PC	Lab	1	0	0	2
10.	22HSP104	Communication Skills lab (Basic)	PC	Lab	1	0	0	2
11.	22MEP102	Product Realization through Manufacturing	PC	Lab	1	0	0	2
Total					**25**			

SEMESTER – I

1. Subject Code: 22CHT101 **Course Title: Introduction to Chemical Engineering**

2. Contact Hours: L:3 T:0 P:0
3. Credits: 3 Semester: I
4. Pre-requisite: Nil.
5. Objective: To introduce the basic features and concepts of Chemical Engineering to the students.
6. Course Outcomes: Upon completion of this course, the students will be able to:
   i. Understanding the chemical engineering and its future prospects
   ii. To acquire knowledge of chemical process industries
   iii. To acquire knowledge of basic principles of chemical engineering
   iv. Knowledge of new developments in chemical engineering and career prospects
7. Details of Course:

Unit No.	Contents	Contact Hours
1.	**Introduction:**Definition of chemical engineering, historical perspective and contribution; job description and attributes of a chemical engineer, chemical engineering and its seamless integration with other sciences and engineering disciplines; Societal needs and role of chemical engineer for society development; Economic scale of production; Waste utilization and recycle, sustainable technology; Employment opportunities, knowledge resources; Frontiers & future roadmap; Challenges of chemical engineering practice.	8
2.	**Chemical Process Industries**: Framework of chemical industry and its classification, Evolution of chemical industries, Technological developments in major challenges; Chemical industries structure and segments of chemical industry, raw material and production pattern; Petroleum, petrochemical and fertilizer industry integration; Cleaner and greener technologies.	8
3.	**Basic Principles of Chemical Engineering:** Basic principles of chemical processes, unit processes and unit operations and various routes to produce chemicals; Material and Energy balances; Basic concept of mass, energy, and momentum transport; Equilibrium and rate-based processes.	8
4.	Reaction engineering and reactors; Measuring instruments, automation, and control; Concept of equipment design, modelling and simulation.	8
5.	Process Engineering Design Software (Aspen Plus, Hysys, Matlab, etc.), Engineering computation using Microsoft Excel, Process Flow and Instrumentation Diagram, Important developments and milestones in chemical engineering, R&D in chemical engineering; Recent advances in Chemical Engineering	8

8. Books:

(A) Text Books

S.No.	Authors / Name of Book / Publisher	Year of Publication
1	Nnaji, U., "Introduction to Chemical Engineering: For Chemical Engineers and Students", Wiley.	2019
2	Solen, K.A. and Harb, J.N., "Introduction to Chemical Engineering Tools for Today and Tomorrow", 5th edition, John-Wiley.	2011
3	Denn, M.M., "Chemical Engineering: An Introduction", Cambridge University Press.	2012

(B) Reference Books

S.No.	Authors / Name of Book / Publisher	Year of Publication
1	Pushpavanam, S., "Introduction to Chemical Engineering", PHI Learning Pvt. Ltd.	2012
2	Ghosal, S.K., Sanyal, S.K., Datta, S., "Introduction to Chemical Engineering", Tata McGraw Hill.	1997
3	Himmelblau D.M. and Riggs J.B., "Basic Principles and Calculations in Chemical Engineering", 8th Edition, PHI.	2014
4	Austin, G. T., "Shreve's Chemical Process Industries", 5th Edition, McGraw-Hill, Company.	1984

1. Subject Code: 22CHT102   Course Title: Chemical Engineering Thermodynamics-I

2. Contact Hours: L:3 T:1 P:0

3. Credits: 4   Semester: I

4. Pre-requisite: Nil.

5. Objective: To learn the principles of work and energy and understand the laws of thermodynamics to apply in industries.

6. Course Outcomes:Upon completion of this course, the students will be able to:

   i. To understand the basic concepts and first law of thermodynamics
   ii. To understand the PVT behaviour of fluids
   iii. To understand the heat effects
   iv. To understand the second law of thermodynamics
   v. To understand the concepts of statistical thermodynamics

7. Details of Course:

Unit No.	Contents	Contact Hours
1.	**Introduction:** Definitions and Concepts: System, Surroundings, Property, Energy, Work, Thermodynamic equilibrium, stability of equilibrium states. **Zeroth Law of Thermodynamics**: Perfect gas scale. **First Law of Thermodynamics:** First law of Thermodynamics and Its Applications, First law analysis of processes, Control mass and control volume analysis, Steady state, and Transient state flow processes.	8
2.	**Volumetric Properties of Pure Fluids:** PVT behavior of pure substances, virial equation and its applications, cubic equations of state, generalized correlations for gases and liquids.	8
3.	**Heat Effects:** Sensible heat effects, heat effects accompanying phase changes of pure substances, standard heats of reaction, formation and combustion, effect of temperature on the standard heat of reaction.	8
4.	**Second law of Thermodynamics:** Limitation of First Law, Kelvin-Planck and Clausius Statements, Reversible and Irreversible Processes, Carnot cycle, Entropy, Second Law analysis of a control volume. Exergy.	8
5.	**Basic Concepts & Application of Statistical Thermodynamics:** Need of statistical thermodynamics, Macrostates and microstates, Degenerate energy levels, Bose-Einstein statistics, Fermi-Dirac statistics, Entropy, Ideal gas, Maxwell speed distribution, Einstein model of solid, Debye model of solid	8

8. Books:

(A) Text Books

S.No.	Authors / Name of Book / Publisher	Year of Publication
1	Smith, J. M., Van Ness, H. C. and Abbott, M. M., "Introduction to Chemical Engineering Thermodynamics", 8^{th} Ed., McGraw-Hill.	2019
2	Rao, Y. V. C., "An Introduction to Thermodynamics," University Press.	2004

(B) Reference Books

S.No.	Authors / Name of Book / Publisher	Year of Publication
1	Cengel, Y.A., "Thermodynamics: An Engineering Approach," 9^{th} Ed., McGraw-Hill.	2019
2	Nag, P.K., "Engineering Thermodynamics", 6^{th}Ed., McGraw-Hill	2017

II Semester:

S. No.	Course Code	Course Title	Category	Type	Credit	L	T	P
1.	22CET102	Environmental Science	PC	Theory	2	2	0	0
2.	22CST101	Programming with Python	PC	Theory	2	2	0	0
3.	22EET101	Basic Electrical and Electronics Engg	PC	Theory	3	3	0	0
4.	22MAT102	Mathematics II	PC	Theory	4	3	1	0
5.	22PHT101	Classical Physics	PC	Theory	3	3	0	0
6.	22CHT103	Chemical Process Calculations	PC	Theory	4	3	1	0
7.	22CHT104	Process Instrumentation	PC	Theory	3	3	0	0
8.	22CSP102	Programming with Python Lab	PC	Lab	1	0	0	2
9.	22ECP101	Electronics Engineering Lab	PC	Lab	1	0	0	2
10.	22EEP102	Electrical Engineering Lab	PC	Lab	1	0	0	2
11.	22PHP103	Classical Physics Lab	PC	Lab	1	0	0	2
12.	ICP101	CREATIVE ARTS / SPORTS / NSS			1			
13.	ICP102	DISCIPLINE			1			
Total					**27**			

SEMESTER – II

1. Subject Code: 22CHT103 **Course Title: Chemical Process Calculations**

2. Contact Hours: L:3 T:1 P:0

3. Credits: 4 Semester: II

4. Pre-requisite: Nil.

5. Objective: To introduce to the fundamental principles of chemical process analysis.

6. Course Outcomes: Upon completion of this course, the students will be able to:

   i. Correlate between different Unit systems and their conversions for various process variables.
   ii. Learn how to perform materials balance in any chemical processes with or without chemical reactions.
   iii. Apply the gas laws to solve problems related to ideal gases and mixtures.
   iv. Apply the energy balance to solve particular problems with and without chemical reactions
   v. Solve de-coupled and coupled equations of mass and energy balance, numerically and computationally.

7. Details of Course:

Unit No.	Contents	Contact Hours
1.	**Introduction to Chemical Engineering Calculations:** Conversion of Units, dimensional consistency and data analysis, significant figures, precision and accuracy, concepts of molarity, molality, normality, ppm, weight fraction, mole fraction and volume fraction, density and specific gravity, process variables and principles of stoichiometry.	10
2.	**Materials balance with and without chemical reactions:** Flowchart, mole and mass balance for multi-component systems under: steady and unsteady state, single-phase and multiphase, material balances in processes including recycle, bypass and purge, Steady state material balances for reactions: species and elemental balances, combustion reactions, concept of limiting, excess reactants, fractional conversion and percentage of conversion, yield, ultimate and proximate analysis of fuels, excess air, air-fuel ratio calculations.	10
3.	**Thermodynamics of Multi-phase System**: Vapor-liquid equilibrium: Ideal and real gas, equation of state, Bubble point, dew point calculations, Phase diagram, Gibbs phase rule, Antoine equation, phase equilibria of vapour-liquid, solid-liquid and immiscible liquid-liquid systems.	10
4.	**Energy Balance with and without Chemical Reactions**: De-Coupled and coupled mass and energy balances, calculation of enthalpy changes, steady state mass and energy balance with and without reactions, heats of solution and mixing, Use of Psychometric chart, and steam table, thermochemistry, Hess's law of summation- heat of formation, Hess's Law and heats of combustion, Unsteady state material and energy balances, isothermal and adiabatic processes, Numerical and computation approach to solve problems with simultaneous mass and energy balance.	10

8. Books:

(A) Text Books

S.No.	Authors / Name of Book / Publisher	Year of Publication
1	Himmelblau, D., Riggs, J., "Basic Principles and Calculations in Chemical Engineering", 8thEd., Pearson.	2012
2	Hougen, O.A, Watson, K.M and Ragatz R.A, "Chemical Process Principles: Part .1 (Chemical Process Principles: Material and Energy Balances)", 2ndEd., CBS	2004

(B) Reference Books

S.No.	Authors / Name of Book / Publisher	Year of Publication
1	Bhatt B.I, and Vora S.M, "Stoichiometry", 4thEd., McGraw-Hill.	2004
2	Felder, R.M., Rousseau, R.W., and Bullard, L.G., "Elementary Principles of Chemical Processes", 4thEd., John Wiley and Sons.	2016
3	Narayanan, K.V., and Lakshmikutty, B., "Stoichiometry & Process Calculations", 2nd Ed., Prentice Hall Publishing.	2016
4	Chopey, N., Hicks, T., "Handbook of Chemical Engineering Calculations", 4thEd., McGraw-Hill Education.	2012

1. Subject Code: 22CHT104 **Course Title: Process Instrumentation**

2. Contact Hours: L:3 T:0 P:0
3. Credits: 3 Semester: II
4. Pre-requisite: Nil.
5. Objective: To study various types of instruments in terms of fundamental concepts, functional elements, calibration, and characteristics.
6. Course Outcomes: Upon completion of this course, the students will be able to:
   - i. To understand scientific concepts, principles, and theories appropriate to instrumentation.
   - ii. Students developed an understanding of various process instruments, control valves, pressure measurement, temperature measurement, flow measurement devices.
   - iii. Students gained understanding of the performance criteria of instruments (range: precision, accuracy, sensitivity and range ability).
   - iv. To understand scientific concepts, principles, and theories appropriate to instrumentation.
   - v. Students developed an understanding of various process instruments, control valves, pressure measurement, temperature measurement, flow measurement devices.
7. Details of Course:

Unit No.	Contents	Contact Hours
1.	**Introduction:** Application of instrument systems, functional elements of a measurement system, classification of instruments, standards and calibration, instrument symbols & tag numbering system.	6
2.	**Temperature Measurement:** Temperature scales, temperature measuring instruments, liquid in glass thermometer, bimetallic thermometer, resistance temperature detectors (RTD), thermocouples, pyrometry.	4
3.	**Pressure Measurement:** Measurement of moderate pressure, high pressure and low pressure (vacuum), calibration and standardization.	3
4.	**Flow Measurement:** Positive displacement meters, variable head meters, variable area meters (rotameters), Weirs and notches, pitot tube, electromagnetic flow meter, hot wire anemometer, ultrasonic flow meters, laser Doppler anemometer.	5
5.	**Acoustics Measurement:** Characteristics of sound, Sound pressure, Power and intensity levels, Loudness, Typical Sound Measuring systems & Microphones.	3
6.	**Static characteristics of instruments:** Liquid level, pH, viscosity, conductivity, humidity, gas composition, and nuclear radiation, Errors and uncertainties in performance parameters, propagation of uncertainties in compound quantities, static performance parameters.	6
7.	**Dynamic characteristics of instruments:** Formulation of system	5

	equations, dynamic response, compensation, Transducers, building blocks of an instrument, Control centre, Instrumentation diagram, online instrumentation in modern plants.	
8.	**Control Valves:** Valve terminology, Valve capacity, Valve rangeability, Valve type based on body Design: Globe bodies, Angle, Needle, Ball, Eccentric rotating, Plug, Butterfly, Diaphragm, Pinch, Drag flow characteristic, Trim design, Mechanical feature, Actuator, Pneumatic types, Electric types, Electro-hydraulic types. Positioner-Pneumatic, Electro pneumatic, Positioner features & accessories, Control Valve Accessories-Testing procedure of control valve: CV and Rangeability (Valve sizing- initial level), Pressure Relieving Devices: Relief valve, Safety valves and Rupture discs.	6
9.	**Signal Converting Elements:** Pneumatic to electrical convertors, Electric to Pneumatic convertors, Voltage to Current convertor, Current to Voltage convertor, Frequency to voltage & voltage to Frequency convertor, Transmitter and Transducer signals.	4

8. Books:

(A) Text Books

S. No.	Authors / Name of Book / Publisher	Year of Publication
1	Eckman, D. P., "Industrial Instrumentation," Wiley Eastern	2004
2	Nakra, B.C. and Chaudhry, K.K., "Instrumentation, Measurement and Analysis," 2nd Ed., Tata McGraw Hill, New Delhi.	2006

(B) Reference Books

S. No.	Authors / Name of Book / Publisher	Year of Publication
1	Patranabis, D., "Principles of Industrial Instrumentation," Tata McGraw Hill, New Delhi.	2007
2	E.O. Doebelin, "Measurement Systems", McGraw Hill, 4th Ed.	1990
3	Lipták, B.G., "Instrument Engineers' Handbook: Process Measurement and Analysis," Vol 1 & 2, CRC Press.	2003

III Semester:

S. No.	Course Code	Course Title	Category	Type	Credit	L	T	P
1.	22CHT202	Computer Aided Numerical Methods	PC	Theory	4	2	2	0
2.	22CHT204	Fluid Mechanics	PC	Theory	4	3	1	0
3.	22CHT205	Mechanical Operations	PC	Theory	4	3	1	0
4.	22CHT201	Chemical Engineering Thermodynamics-II	PC	Theory	4	3	1	0
5.	22CHT203	Conventional &Alternate Energy Resources	PC	Theory	3	3	0	0
6.	22MST241	Fundamentals of Materials Science and Engineering#	PL/EAS	Theory	3	3	0	0
7.	22CHP206	Fluid Mechanics Lab	PC	Lab	1	0	0	2
8.	22CHP207	Mechanical Operations Lab	PC	Lab	1	0	0	2
Total					**24**	**17**	**5**	**4**

#To be taught by the Material Research Centre

SEMESTER – III

1. Subject Code: 22CHT202 Course Title: Computer Aided Numerical Methods

2. Contact Hours: L:2 T:2 P:0

3. Credits: 4 Semester: III

4. Pre-requisite: Nil

5. Course objective:To learn the different numerical techniques for solving algebraic, ordinary differential, partial differential equations and curve fitting of experimental data.

6. Course outcome:Upon completion of this course, the students will be able to:

i. Apply numerical techniques for solving linear and nonlinear problems, including polynomials, single equation problems, and systems of linear and nonlinear equations

ii. Use the regression techniques for linear and nonlinear parameter estimation

iii. Able to apply the different techniques of numerical differentiation and integration

iv. Use the numerical techniques for solving all the different types of ordinary and partial differential equations

7. Details of Course:

Unit No.	Contents	Contact Hours
1.	**Linear Algebraic Equations:** Introduction, Gauss-Elimination, Gauss-Siedel and LU Decomposition methods, Thomas' algorithm.	8
2.	**Nonlinear Algebraic Equations:** Single variable and multivariable successive substitution method, single variable and multivariable Newton-Raphsontechnique,Polynomial root finding methods.	6
3.	**Function Approximation:** Least squares curve fit, Newton's interpolation formulae, Lagrangian interpolation, Pade approximation, Cubic spline approximation.Numerical differentiation& Integration.	8
4.	**Ordinary Differential Equations - Initial Value Problems:** Explicit Adams Bashforth technique, Implicit Adams-Moulton technique, Predictor-corrector technique, Runge-Kutta methods, Stability of algorithms. **Ordinary Differential Equations - Boundary Value Problems:** Finite difference technique, Orthogonal Collocation (OC), Shooting Techniques.	10
5.	**Partial Differential Equations:** Partial Differential Equations (PDE) – Classification of PDE, Finite difference technique (Method of lines), Case Studies. Use of spreadsheets.	6

8. Books:

(A) Text **Books:**

S.No.	Authors / Name of Book / Publisher	Year of Publication
1	Sastry, S. S., Introductory Methods of Numerical Analysis, 5^{th}Ed., PHI, New Delhi.	2012
2	Gupta, S. K., Numerical Methods for Engineers, 4^{th} Ed. New Age International Ltd., New Delhi.	2019

(B) Reference **Books:**

S.No.	Authors / Name of Book / Publisher	Year of Publication
1	Constantinides, A., and Mostoufi, N., Numerical Methods for Chemical Engineers with MATLAB Applications, Prentice Hall.	1999
2	Hanna, O.T. and Sandall, O. C., Computational Methods in Chemical Engineering,Prentice-Hall.	1995
3	Davis, M. E., Numerical Methods & Modeling for Chemical Engineers,JohnWiley.	1984
4.	Finlayson Bruce A., Introduction to Chemical Engineering Computing, Wiley.	2012

1. Subject Code: 22CHT204 **Course Title: Fluid Mechanics**

2. Contact Hours: L:3 T: 1 P: 0
3. Credits: 4 Semester: III
4. Pre-requisite: Nil
5. Course Objective:

To understand the basic principles of fluid mechanics and acquiring the ability to analyze fluid flow problems with the application of the momentum and energy equations. The studentare also to be made familiar with understanding of pipe flows as well as fluid machinery.

6. Course Outcomes: Upon completion of this course, the students will be able to:

i. To understand types of flows, various laws related to fluid flow and concept of fluid friction and its determination
ii. To understand principles and working of various fluid moving devices.
iii. To illustrate the principles of fluid flow on some real systems such as piping, porous beds, fluidized beds, metering devices and fluid machinery.
iv. To understand and apply the concept of Boundary layer

7. Details of Course:

Unit No.	Contents	Contact Hours
1.	**Introduction:** Overview**,** Properties of fluids, Pressure measurement, Types of flows, Method of describing fluid motion	3
2.	**Fluid Flow Equations:** Continuity equation for compressible and incompressible fluids. Bernoulli's equation, Euler's equation, introduction to Navier-Stokes equation.	12
3.	**Flow Measuring Devices:** Venturimeter, Orificemeter, Rotameter, Pitot tube, etc.	4
4.	**Flow of Incompressible Fluids:** Relationship between shear stress and pressure gradient, laminar and turbulent flow, Hagen-Poiseuille equation, friction loss in flow, velocity profile and boundary layer calculations for turbulent flow	8
5.	**Flow through Packed and Fluidized Beds**	4
6.	**Transportation of Fluids**: Valves, pipe fittings and their standards, equivalent length of pipe fittings, Pumps (positive displacement and centrifugal), compressors fans and blowers	9

8. Books:

(A) Text Books

S.No.	Authors / Name of Book / Publisher	Year of Publication
1.	Streeter, V. L. and Wylie, "Fluid Mechanics," 8thEd., McGraw-Hill, New York.	1985
2.	McCabe, W.L., Smith, J.C., and Harriott, P., "Unit Operations of Chemical Engineering", 7thEd., McGraw Hill.	2017

(B) Reference Books

S.No.	Authors / Name of Book / Publisher	Year of Publication
1.	Gupta, S. K., "Momentum Transfer Operations," 2ndEd. Tata McGraw-Hill.	1982
2.	Coulson, J. M. and Richardson, J. F., "Chemical Engineering," Vol. 1, Asian books, New Delhi.	2017

1. Subject Code: 22CHT205 **Course Title: Mechanical Operations**

2. Contact Hours: L:3 T:1 P:0

3. Credits: 4 Semester: III

4. Pre-requisite: NIL

5. Course Objective: To understand basic principles of various mechanical operations, construction, and working of the equipment

6. Course Outcomes:Upon completion of this course, the students will be able to:

i. Understand fluid particle systems and equipment
ii. Select suitable size reduction equipment, solid-solid separation method, conveying systemand analyze mixing processes
iii. Understand the fluid flow and design of filtration and sedimentation processes

7. Details of Course:

Unit No.	Contents	Contact Hours
1	**Size Reduction:** Principles of crushing and grinding, Determination of mean particle size and size distribution, Laws of crushing and grinding, Energy required for size reduction, crushing and grinding equipment, closed and open circuit grinding.	10
2	**Screen Analysis and Size Separation:** Types of screens, mesh number and size distribution, different types of screening, effectiveness of screen, Particle size analysis, separation efficiency and screening equipment.	8
3	**Solid-Liquid-Gas Separation:** Theory of Filtration, Filtration equipment, equations for compressible and incompressible cakes, Constant volume and Constant Pressure Filtration, Press Filter, Rotary drum and vacuum filter. Fiber and fabric filters, sedimentation, classifiers and thickeners, Centrifuges- Principles and applications, Cyclone separators and electrostatic precipitator- Principles and applications.	10
4	**Fluidization:** Fluidization of solids and its applications, Hydraulic and Pneumatic transport of solids.	6
5	**Mixing:** Mixing of liquids and solids, Power requirement in mixing. **Storage and Handling of Materials:** Hoppers and bins, Mechanical and pneumatic conveying systems.	6

8. Books:

(A) Text Books

S.No.	Authors / Name of Book / Publisher	Year of Publication
1	McCabe, W.L., Smith, J.C., and Harriott, P., "Unit Operations of Chemical Engineering", 7thEd., McGraw Hill.	2017
2	Brown, G. G., "Unit Operations," CBS Publishers & Distributors, New Delhi.	2005
3	Coulson, J. H. and Richardson, J. F., Backhurst, J. R., and Harker, J.H., "Coulson & Richardson's Chemical Engineering," Vol. 2, 4thEd., Asian Books Private Ltd., New Delhi.	1998

(B) Reference Books

S.No.	Authors / Name of Book / Publisher	Year of Publication
1	Perry, R. H. and Green, D.W., "Perry's Chemical Engineers' Handbook," 9thEd., McGraw-Hill.	2018
2	Foust, A.S., et al., "Principles of Unit Operations", 2ndEd., John Wiley, Singapore.	1980
3	Chattopadhyay, P. "Unit Operations of Chemical Engineering", Vol. I., Khanna Publishers, Delhi.	1998
4	Anup Swain, Hemlata Patra, G K Roy, "Mechanical Operations", McGraw Hill Education	2017

1. Subject Code: 22CHT201 Course Title: Chemical Engineering Thermodynamics-II

2. Contact Hours: L:3 T:1 P:0

3. Credits: 4 Semester: III

4. Pre-requisite: Chemical Engineering Thermodynamics-I

5. Course Objective: To learn and apply the principles of phase equilibrium and chemical equilibrium to analyze the problems.

6. Course Outcomes: Upon completion of this course, the students will be able to:

   i. Understand the concepts of multi-component systems
   ii. To apply phase equilibria using various thermodynamic models
   iii. To grasp the calculation of chemical reaction equilibria

7. Details of Course:

Unit No.	Contents	Contact Hours
1.	**Multi-component Systems:** Chemical potential, ideal-gas mixture, ideal solution, Raoult's Law. Partial properties, fugacity and fugacity coefficient, generalized correlations for the fugacity coefficient, excess Gibbs' energy, activity coefficient.	10
2.	**Phase Equilibria at Low to Moderate Pressures:** Phase rule, phase behavior for vapor liquid systems, Margules equation, Van Laar equation, Wilson equation, NRTL equation, UNIQUAC, UNIFAC. Dew point, bubble point and flash calculations.	10
3.	**Solution Thermodynamics:** Ideal solution, fundamental residual-property relation, fundamental excess-property relation. Evaluation of partial properties. Heat effects of mixing processes. Partially miscible systems.	10
4.	**Chemical Reaction Equilibria:** Reaction coordinate, equilibrium criteria to chemical reactions, standard Gibbs' energy change and the equilibrium constant. Effect of temperature on the equilibrium constant, evaluation of equilibrium constants. Relations between equilibrium constants and compositions: gas-phase reactions, liquid-phase reactions, heterogeneous reaction mixtures. Calculation of equilibrium compositions for single-phase reactions. Multi-reaction equilibria.	10

8. Books:

(A) Text Books

S.No.	Authors / Name of Book / Publisher	Year of Publication
1	Smith, J. M., Van Ness, H. C. and Abbott, M. M., "Introduction to Chemical Engineering Thermodynamics", 7th Ed., McGraw-Hill.	2009
2	Rao, Y. V. C., "Chemical Engineering Thermodynamics," University Press.	1997

(B) Reference Books

S.No.	Authors / Name of Book / Publisher	Year of Publication
1	Sandler, S.I., "Chemical and Engineering Thermodynamics", 3rd Ed., John-Wiley & Sons.	1998

1. **Subject Code: 22CHT203 Course Title: Conventional and Alternate Energy Resources**
2. Contact Hours: L: 3 T: 0 P: 0
3. Credits: 3 Semester: VII
4. Pre-requisite: Nil.
5. Objective: To study various types of conventional and non-conventional energy resources including solid, liquid and gaseous fuels.
6. Course Outcomes: Upon completion of this course, the students will be able to:
   i. Work in energy-related fields by providing an overview of the challenges related to energy production
   ii. Understand environmental and economic issues related to energy production
   iii. Carry out a comparative analysis of different types of coal, including their treatment, liquefaction and gasification
   iv. Compare the liquid and gaseous fuels sourced from petroleum including their characterization
   v. Analyse the potential of alternate energy sources and their scope and limitations
7. Details of Course:

Unit No.	Contents	Contact Hours
1.	**Energy Scenario:** Energy resources spectrum, Classification of various energy sources, Renewable and non-renewable energy sources, Present and future energy demands, Energy crisis, Pattern of energy consumption, Efficiency of energy resources	2
2.	**Solid Fuels:** Coal: Origin, formation, Properties, proximate and ultimate analyses, heating value, classification, washing and carbonization, Treatment of coal gas, Recovery of chemicals from coal tar, Coal gasification, Liquid fuel synthesis from coal, Carbonization of coal, Briquetting of fines, electricity generation from coal.	8
3.	**Liquid and Gaseous Fuels:**Petroleum origin and processing, various types of fuels, Properties and handling. Natural and liquefied petroleum gases, CNG, Gas hydrates, Gasification of liquid fuels, Hydrogen as a fuel, fuel cell	8
4.	**Biomass Energy**: Biomass types, characterization, pyrolysis, gasification, biochemical conversion routes, biogas, fuel alcohol, biodiesel.	8
5.	**Alternate Energy Sources**: Wind power, Geothermal energy,Tidal energy, Nuclear power **Solar Energy:** Solar insolation, flat plate and focusing collectors, solar space heating and cooling, solar pond, solar cells and storage.	14

8. **Books:**

(A) Text Books

S.No.	Authors / Name of Book / Publisher	Year of Publication
1	Gupta, O.P., Elements of Fuel, Furnaces and Refractories, Khanna Publishers.	1996
2	Brame J.S.S. and King J.G., Edward Arnold "Fuel Solid, Liquid and Gases" Edward Arnold.	1967
3	Rai, G.D., Non-Conventional Energy Sources, Khanna Publishers.	2001

(B) Reference Books

S.No.	Authors / Name of Book / Publisher	Year of Publication
1	Twiddle, J. Weir, T. "Renewable Energy Resources," Cambridge University Press.	1986
2	Sorenson, B, "Renewable Energy", 3rd Ed., Elsevier Science.	2004
3	Sukhatme S.P, Solar Energy - Principles of Thermal Collection and Storage, Tata McGraw- Hill.	1996

1. Subject Code: 22MST241

Course Title: Fundamentals of Materials Science and Engineering
(To be taught by Material Research Centre)

2. Contact Hours: L: 3 T: 0 P: 0

3. Credits: 3 Semester: III

4. Pre-requisite: Nil

5. Course Objective:

The objective of this course is to provide basic understanding of the structure, properties and applications of materials to the undergraduate students. The course will also introduce the students to phases and enable them to understand the phenomenon pf phase transformations in materials.

6. Course Outcome:Upon completion of this course, the students will be able to:

i. Classify various classes of materials and explain their structures and imperfections.
ii. Construct the phase diagrams of some systems and interpret the phase transformations
iii. Explain the types and applications of ceramics and polymers
iv. Understand and appreciate the distinctive properties of materials.
v.

7. Details of Course:

Unit No.	Course content	Contact Hours
1.	**Introduction:**Why study materials science and engineering? Review of basic types of interatomic bonds, Classification of materials, Processing/structure/properties/ performance correlations.	3
2.	**Structure and Imperfections**:Lattices, Unit cells, Miller indices of directions and planes for cubic and hexagonal systems, Close packing in solids, Common metallic structures, Voids in close-packed structures, Common ceramics structures – NaCl, CsCl, Diamond Cubic, Zinc Blende, Wurtzite, Rutile, Fluorite, Fullerenes, Spinel, Perovskite, etc., Polycrystalline materials, X-Ray diffraction for determination of crystal structures, Solid state diffusion – Ficks laws of diffusion, Diffusion mechanisms, Temperature dependence of diffusivity, Defects in crystals - Point defects, Dislocations, Grain boundaries and Surfaces	10
3.	**Phase Diagrams and Phase Transformations:** Phase rule, Solid solutions, Hume-Rothery rules, Intermediate phases and compounds, Unary and binary phase diagrams, Isomorphous and eutectic systems, Lever rule, Typical phase diagrams: Fe-C, Cu-Ni, Cu-Zn etc. Classification of phase transformations, Liquid to solid transformation, Homogeneous and heterogeneous Nucleation, Nucleation growth and	8

	overall transformations, Kinetic considerations in solid state transformations, Microstructure evolution during solidification in isomorphous system.	
4.	**Ceramics and polymers:** Types and applications of Glasses, Glass-Ceramics, Clay products, Abrasives, Cements. Introduction to polymers, Types of polymerizations, Molecular weight, shape, structure and configuration, Thermoplastic and Thermosetting polymers. Glass transition, melting and glass transition temperature, factors affecting melting and glass transition temperatures. Plastics, elastomers, fibres, Advanced polymeric materials, Some applications of polymers	7
5.	**Properties of Materials** **Mechanical Properties**: Stress-strain response of metallic, ceramic and polymer materials, yield strength, tensile strength and modulus of elasticity, toughness, plastic deformation, fatigue, creep and fracture; **Electronic Properties**: Free electron theory, Fermi energy, density of states, elements of band theory, semiconductors, Hall effect, dielectric behaviour, piezo, ferro, pyroelectric materials; **Magnetic Properties:** Origin of magnetism in metallic and ceramic materials, paramagnetism, diamagnetism, ferro and ferrimagnetism; **Thermal Properties:** Specific heat, thermal conductivity and thermal expansion, thermoelectricity. **Optical Properties:** Refractive index, absorption and transmission of electromagnetic radiation in solids, electrooptic and magneto-optic materials, spontaneous and stimulated emission, gas and solid state lasers.	11

8. Books:

(A) Text Books

S.No.	Authors / Name of Book / Publisher	Year of Publication
1.	V. Raghavan, "Materials Science and Engineering- A First Course", 5th Edition, PHI Learning Pvt. Ltd., New Delhi	2004
2.	W. D. Callister, Jr. and D. G. Rethwisch, "Materials Science and Engineering- An Introduction", 10th edition, John Wiley and Sons, Inc.	2018

1. Subject Code: 22CHP206 **Course Title: Fluid Mechanics Lab**

2. Contact Hours: L: 0 T: 0 P: 2

3. Credits: 1 Semester: III

4. Pre-requisite: Studying/completed Fluid Mechanics course

5. Course Objective:

To provide hands on practice in estimating friction losses in pipe line flow, estimating equivalent length for fittings, understanding of pressure drop and flow in packed and fluidized bed. To impart training to use various flow measuring devices for making engineering judgments.

6. Course Outcome: Upon completion of this course, the students will be able to:

vi. Estimate the friction and measure the frictional losses in fluid flow.
vii. Experiment with flow measurement devices like venture meter and orifice meter.
viii. Predict the coefficient of discharge for flow through pipes
ix. Understand Bernoulli's theorem and its applications
x. Predict pressure drop in packed and fluidized bed.

7. Details of Course:

Experiment No.	Objectives	Contact Hours
1.	Determination of head losses in the pipe fitting and valves at various flow rates by determining the loss coefficient for pipe fittings and valves.	3
2.	Experimental verification of Bernoulli's equation and graphically justifying the observations on total energy vs. distance line.	3
3.	Measurement of flow discharge through Venturimeter and Orificemeter by determiningthe coefficient of discharge.	3
4.	Determining the friction factor and friction losses in circular and non-circular pipes.	3
5.	Studying the flow through a fluidized bed and determining the pressure drop and minimum fluidization velocity.	3
6.	Studying the characteristics of a packed bed and determining the pressure drop.	3
7.	Studying the Reynolds Apparatus to identify the nature of fluid flow.	3
8.	Determining the friction factor and losses due to pipes.	3
9.	Centrifugal Pump Test Rig	3
10.	Reciprocating Pump Test Rig	3

8. Books:

(A) Text Books

S.No.	Authors / Name of Book / Publisher	Year of Publication
1.	Streeter, V. L. and Wylie, "Fluid Mechanics,"8thEd., McGraw-Hill, New York.	1985
2.	McCabe, W.L., Smith, J.C., and Harriott, P., "Unit Operations of Chemical Engineering", 7thEd., McGraw Hill.	2017

(B) Reference Books

S.No.	Authors / Name of Book / Publisher	Year of Publication
1.	Gupta, S. K., "Momentum Transfer Operations," 2nd Ed. Tata McGraw-Hill.	1982
2.	Coulson, J. M. and Richardson, J. F., "Chemical Engineering," Vol. 1, Asian books, New Delhi.	1998

1. Subject Code: 22CHP207 **Course Title: Mechanical Operations Lab**

2. Contact Hours: L: 0 T: 0 P: 2

3. Credits: 1 Semester: III

4. Pre-requisite: Studying/completed Mechanical Operations course

5. Course Objective:

To understand the importance of various mechanical operations used in process industry. To apply principles of basic sciences and chemical engineering for designing various size reduction, size separation and conveying equipment.

6. Course Outcome: Upon completion of this course, the students will be able to:

i. To apply the principles of various fluid particle mechanics unit operations through experimentation

ii. To demonstrate the ability to understand the various equipment used in chemical and allied process industry

7. Details of Course:

Experiment No.	Objective	Contact Hours
1.	Determining the efficiency of the Jaw crusher for crushing a material of known weight of feed.	3
2.	Calculating the efficiency of a ball mill for grinding a material of known work index by using variable speed ball mill. Determination of critical speed of ball mill	3
3.	Studying the motion of solid particle moving through a liquid to determine its drag coefficient and to obtain the relation between drag coefficient vs. particle Reynolds number.	3
4.	Studying the operation of Elutriator and to determine the water velocity at varying condition.	3
5.	Separation of different particle sizes using screen analysis and estimating the efficiency of the screen used.	3
6.	Studying the Power number vs. Reynolds number for the given set of impellers in agitated vessels.	3
7.	Understanding working principle of continuous type thickener and to determine the concentration of product obtained at the different heights of sampling points.	3
8.	Understanding the performance of a vacuum rotary drum filter by determining the specific cake resistance for given slurry of $CaCO_3$.	3
9.	Understanding the operation of cyclone separator and determining is collection efficiency.	3
10.	Understanding of the operation of Plate and Frame Filter Press by calculating the medium resistance and the specific cake resistance.	3

8. Books:

(A) Text Books

S.No.	Authors / Name of Book / Publisher	Year of Publication
1	McCabe, W.L., Smith, J.C., and Harriott, P., "Unit Operations of Chemical Engineering", 7th Ed., McGraw Hill.	2017
2	Brown, G. G., et al, "Unit Operations," CBS Publishers & Distributors, New Delhi.	1995
3	Coulson, J. H. and Richardson, J. F., Backhurst, J. R., and Harker, J.H., "Coulson & Richardson's Chemical Engineering," Vol. 2, 4th Ed., Asian Books Private Ltd., New Delhi.	1998

(B) Reference Books

S.No.	Authors / Name of Book / Publisher	Year of Publication
1	Perry, R. H. and Green, D.W., "Perry's Chemical Engineers' Handbook," 9th Ed., McGraw-Hill.	2018
2	Foust, A.S., et al., "Principles of Unit Operations", 2nd Ed., John Wiley, Singapore.	1980
3	Chattopadhyay, P. "Unit Operations of Chemical Engineering", Vol. I., Khanna Publishers, Delhi.	1998

IV Semester:

S. No.	Course Code	Course Title	Category	Type	Credit	L	T	P
1.	22CHT251	Chemical Reaction Engineering-I	PC	Theory	4	3	1	0
2.	22CHT253	Heat Transfer Operations	PC	Theory	4	3	1	0
3.	22CHT255	Mass Transfer-I	PC	Theory	4	3	1	0
4.	22CHT254	Industrial Pollution Abatement	PC	Theory	4	3	1	0
5.	22CHT252	Chemical Technology	PC	Theory	4	3	1	0
6.	22RET291	Energy Storage*	PL/EAS	Theory	3	3	0	0
7.	22CHP256	Chemical Reaction Engineering Lab	PC	Lab	1	0	0	2
8.	22CHT257	Heat Transfer Operations Lab	PC	Lab	1	0	0	2
9.	22CHP258	Industrial Pollution Abatement Lab	PC	Lab	1	0	0	2
Total					**26**	**18**	**5**	**6**

***To be taught by Centre for Energy and Environment**

SEMESTER – IV

1. Subject Code: 22CHT251 **Course Title: Chemical Reaction Engineering-I**

2. Contact Hours: L: 3 T: 1 P: 0

3. Credits: 4 Semester: IV

4. Pre-requisite: Nil.

5. Course Objective: To understand the kinetics of single and multiple reactions and the effect of temperature on reaction systems along with the RTD and reactor model.

6. Course Outcomes: Upon completion of this course, the students will be able to:

   i. Develop rate laws for homogeneous reactions.
   ii. Analyze batch reactor data by integral and differential methods.
   iii. Design ideal reactors for homogeneous single and multiple reactions.
   iv. Understand the RTD flow behaviour model
   v. Demonstrate the temperature effect on reaction rate and design non-isothermal reactors.

7. Details of Course:

Unit No.	Contents	Contact Hours
1.	**Introduction and Kinetics of Homogeneous Reaction**: Rate of Reaction, Elementary and non-elementary homogeneous reactions, Molecularity and order of reaction, Mechanism of reaction, temperature dependency from thermodynamics, collision and activated complex theories.	8
2.	**Interpretation of Batch Reactor Data:** Integral and differential methods for analyzing kinetic data., constant volume reactor for zero, first, second and third order reactions, half-life period, irreversible reaction in parallel and series, catalytic reaction, auto catalytic reaction, reversible reactions, Variable volume batch Reactor for zero, first and second order reactions. Temperature and Reaction Rate.	8
3.	**Introduction to Reactor Design:** Ideal reactors for single reaction: Ideal batch reactor, steady state Mixed Flow Reactor, steady state PFR, Holding time and space time for flow systems. Design equation for batch, continuous stirred tank, plug flow reactors for isothermal reaction. Design for single reactions: Optimum reactor size, Size comparison, multiple reactor systems, recycle reactor, auto catalytic reactions. Design for multiple reactions: Reactions in parallel, reactions in series, series- parallel reactions.	8
4.	**Residence Time Distribution**: Residence time distribution of fluids in vessels, E, F and C curves, Dispersion model, Tank in series model. Non Isothermal PFR and CSTR, Safety issues in Non Isothermal Reactors.	8
5.	**Temperature and pressure effects on reaction:** Single reactions: Heat of reaction, equilibrium constants, graphical design procedure, optimum temperature progression, adiabatic operations. Multiple reactions: Product distribution and temperature.	6

8. Books:

(A) Text Books

S.No.	Authors / Name of Book / Publisher	Year of Publication
1	Levenspiel, O., “Chemical Reaction Engineering”, 3rd Ed., John Wiley & Sons, Singapore.	2006
2	Fogler, H. S., “Elements of Chemical Reaction Engineering,” 5th Ed., Prentice Hall of India.	2016

(B) Reference Books

S.No.	Authors / Name of Book / Publisher	Year of Publication
1	Keith J. Laidler, “Chemical Kinetics” 3rd Edition, Pearson.	2003
2	Smith, J. M., “Chemical Engineering Kinetics”, 3rd Ed. McGraw Hill.	1981
3	Richardson, J.F., and Peacock D.G., “Coulson and Richardson’s Chemical Engineering,” vol. 3, 3rd Ed., Asian Books Pvt. Ltd., New Delhi.	1998

1. Subject Code: 22CHT253 **Course Title: Heat Transfer Operations**

2. Contact Hours: L:3 T:1 P:0
3. Credits: 4 Semester: IV
4. Pre-requisite: Nil.
5. Course Objective: To understand the fundamentals of heat transfer mechanisms in fluids and solids and their applications in various heat transfer equipment in process industries
6. Course Outcomes: Upon completion of this course the students will be able to:
   i. Understood the basic fundamentals of heat transfer and also various mode of heat transfer along with governing laws and for extended surfaces.
   ii. Understood the concept of heat transfer coefficient and its calculation for natural and forced convection using various empirical correlations.
   iii. Understood concept of boiling and condensation phenomenon and correlation for the various heat transfer coefficient.
   iv. Design heat exchanger for different applications in a chemical process plant.
7. Details of Course:

Unit No.	Contents	Contact Hours
1.	**Introduction:** Modes of heat transfer: conduction, convection, radiation. **Steady-State Conduction in One Dimension:** Fourier's Law, thermal conductivity, steady-state conduction of heat through a composite solid, cylinder and sphere. Steady-state heat conduction in bodies with heat sources: plane wall, cylinder and sphere. **Unsteady-State Heat Conduction:** Mathematical formulations and initial and boundary conditions. Analytical solution, numerical solution.	8
2.	**Heat Transfer Coefficient:** Convective heat transfer and the concept of heat transfer coefficient, overall heat transfer coefficient, heat transfer from extended surfaces, thermal contact resistance, critical insulation thickness, optimum insulation thickness. **Forced Convection:** Flow over a flat plate, thermal boundary layer, flow across a cylinder. Dimensional analysis: Buckingham Pi theorem, Dimensional groups in heat transfer. Correlations for the heat transfer coefficient: Laminar flow through a circular pipe, turbulent flow through a circular pipe, flow through a non-circular duct, flow over flat plate, flow across a cylinder, flow past a sphere, flow across a bank of tubes, heat transfer coefficient in a packed and fluidized bed. Double-pipe heat exchanger in parallel and counter-current flow.	8
3.	**Free Convection:** Introduction, heat transfer correlations for free convection: flat surface, cylinder, sphere, enclosure. Combined free and forced convection. **Boiling and Condensation:** Boiling phenomenon, nucleate boiling, Correlations for pool boiling heat transfer: Nucleate boiling, critical heat flux, stable film boiling. Forced convection boiling, condensation phenomena, film condensation on a vertical surface, turbulent film	6

	condensation, condensation outside a horizontal tube and tube bank. Condensation inside a horizontal tube, effect of non-condensable gases. Dropwise condensation.	
4.	**Radiation Heat Transfer:** Basic concepts of radiation from a surface: black body radiation, Planck's Law, Wien's Displacement Law, Stefan-Boltzmann Law, Kirchoff's Law, Gray body. Radiation intensity of a black body, spectral emissive power of a black body over a hemisphere. Radiation heat exchange between surfaces – the view factor. Radiation exchange between black bodies and between diffuse gray surfaces.	6
5.	**Evaporators:** Types of evaporators: Natural-circulation evaporators, forcedcirculation evaporators, falling film evaporators, climbing-film evaporators, agitated thin-film evaporators and plate evaporators. Principles of evaporation and evaporators; Single and multiple effect evaporators, Capacity and economy, Boiling point rise, heat transfer coefficient enthalpy of a solution. Calculations of a single effect evaporator.	6
6.	**Heat Exchangers:** Construction of a shell-and-tube heat exchanger, fouling of a heat exchanger, LMTD, temperature distribution in multi-pass heat exchangers, individual heat transfer coefficients.Types of shell-and-tube heat exchanger. Design of different type of heat exchangers.	8

8. Books:

(A) Text Books

S.No.	Authors / Name of Book / Publisher	Year of Publication
1	Dutta, B. K. "Heat transfer: Principles and Applications", PHI, New Delhi	2001
2	Kern, D. Q., "Process Heat Transfer", Tata- McGraw Hill	1950

(B) Reference Books

S.No.	Authors / Name of Book / Publisher	Year of Publication
1	Holman, J. P., "Heat Transfer", McGraw Hill, 10^{th} Ed. New York	2017
2	Chapman, A. J., "Heat Transfer", Maxwell Macmillan	1984

1. Subject Code: 22CHT255 **Course Title: Mass Transfer I**

2. Contact Hours: L:3 T:1 P:0

3. Credits: 4 Semester: IV

4. Pre-requisite: NIL

5.Course Objective: To introduce the undergraduate students with the most important separation equipment in the process industry, and provide proper understanding of various mass transfer operations.

6. Course Outcome: Upon completion of this course, the students will be able to:

i. Solve problems related to diffusion and inter-phase mass transfer, mass transfer theories and mass transfer equipment.

ii. Perform design calculation related to absorption (plate and packed column)

iii. Solve problems related to binary and multi-component distillation

7. Details of Course:

Unit No.	Contents	Contact Hours
1.	**Basics of Mass Transfer:**Physico-chemical basis of separation processes-thermodynamic considerations, Chemical Potential, stage and continuous contacting operations, concepts of equilibrium stage, operating line and tie line. Liver Rule. Introduction to Membrane Separation Processes.	4
2.	**Diffusion:** Molecular and turbulent diffusion, diffusion coefficient, Fick's Law of diffusion, dependence of diffusion coefficient on temperature, pressure and composition; measurement and estimation of diffusivity. Diffusion in multi-component gas mixtures. Diffusion in Solids: Molecular, Knudsen &surface diffusion; Inter- phase mass transfer: Mass transfer coefficients, Laminar and turbulent flow situations and Correlations, Diffusion between phases, Equilibrium solubility of gases in liquids, Various Mass transfer theories, Mass transfer in fluidized beds, Flow past solids and boundary layers, Simultaneous heat and mass transfer.	10
3.	**Absorption and Stripping:**Equipment, Gas-liquid equilibria, Henry's law, Selection of solvent, Absorption in tray column, Graphical and analytical methods, Absorption in packed columns, HTU, NTU & HETP concepts, Design equations for packed column, Absorption with chemical reaction and mass transfer.	8
4.	**Distillation:** Basic fundamentals of distillation, Ideal and non- ideal stages; definitions of point, stage and column efficiencies Pressure-composition, Temperature-concentration, Enthalpy-concentration diagrams for ideal and non-ideal solutions, Raoult's law and its application, Maximum and minimum boiling mixtures, concept of relative volatility, Single Stage Distillation Differential distillation, Flash vaporization, Vacuum, molecular and steam distillation. McCabe-Thiele method;Plate calculations, simple and complex fractionators. Ponchon-Savarit method, Multi-component distillation (short-cut and MESH method), Azeotropic and extractive	18

	distillation.	

8. Books:

(A) Text Books

S.No.	Authors / Name of Book / Publisher	Year of Publication
1	Treybal, R "Mass Transfer Operations", 3rd Ed.NewYork: McGraw-Hill.	1981
2	Sherwood T. K., Pigford R. L. and Wilke P. "Mass Transfer" McGraw-Hill.	1975
3	Geankoplis, CJ, "Transport Processes and Unit Operations", 4th Ed. Prentice Hall.	2013
4	B K Dutta, Principles of Mass Transfer and Separation Processes, PHI Learning.	2007

(B) Reference Books

S.No.	Authors / Name of Book / Publisher	Year of Publication
1	Foust A.S., Wenzel, L.A., Clump, C.W., Maus,L., Anderseny, L.B., "Principles of Unit Operations" 2nd Ed., John Wiley.	2008
2	King, C. J.," Separation Processes", 2nd Ed. McGraw-Hill, NY.	2013
3	Smith, B. D., "Design of Equilibrium Stage Processes", McGraw-Hill, NY.	1963
4	McCabe, W. L., Smith, J. C. and Harriot, P., "Unit Operations of Chemical Engineering", 7th Ed., McGraw-Hill, NY.	2017
5	Coulson, J. M. and Richardson, J. F., "Chemical Engineering", Vol. I and II, 6th Ed., Elsevier.	1999

1. Subject Code: 22CHT254 **Course Title: Industrial Pollution Abatement**

2. Contact Hours: L:3 T:1 P:0

3. Credits: 4 Semester: IV

4. Pre-requisite: Nil.

5. Course Objective: To provide concepts of water and air pollution, related legislation, pollution abatement and solid waste management

6. Course Outcomes: Upon completion of this course, the students will be able to:

i. Quantify and analyze the pollution load
ii. Analyze/design of suitable treatment operation for wastewater
iii. Model the atmospheric dispersion of air pollutants and design of air pollution control devices
iv. Analyze the characteristics of solid waste, its handling &management
v. Gained knowledge of the Environmental legislation and standards

7. Details of Course:

Unit No.	Contents	Contact Hours
1.	**Wastewater Treatment:** Characterization of Industrial wastewater, primary, secondary and tertiary treatment, segregation, screening, equalization, Disinfection, coagulation, flocculation, precipitation, flotation, sedimentation, aerobic and anaerobic treatment, Design of activated sludge system, absorption, ion exchange, membrane filtration, electrodialysis, sludge dewatering and disposal methods.	16
2.	**Air Pollution Control:** Sources and classification of air pollutants, nature and characteristics of gaseous and particulate pollutants, pollutants from automobiles. Air pollution meteorology, plume and its behavior and atmospheric dispersion, control of particulate emissions by gravity settling chamber, cyclones, wet scrubbers, bag filters and electrostatic precipitators. Control of gaseous emissions by absorption, adsorption, chemical transformation and combustion.	12
3.	**Solid Waste Management:** Hazardous and non-hazardous waste, methods of treatment and disposal, land filling, leachate treatment and incineration of solid wastes.	8
4.	Legislation, standards for water and air,Environmental regulatory legislations and standards	4

8. Books:

(A) Text Books

S.No.	Authors / Name of Book / Publisher	Year of Publication
1	Peavy, H. S., Rowe, D. R.,Tchobanoglous, G., "Environmental Engineering"; McGraw Hill.	1985
2	Masters, G.M., "Introduction to Environmental Engineering and Science", 3rdEd. Prentice Hall.	1991
3	Metcalf & Eddy, Inc., "Wastewater Engineering: Treatment and Reuse", 4thEd., Tata McGraw Hill, New Delhi.	2003

(B) Reference Books

S.No.	Authors / Name of Book / Publisher	Year of Publication
1	De Nevers, N., "Air Pollution Control Engineering", 2ndEd., McGraw-Hill.	1999
2	Mahajan, S. P., "Pollution Control in Process Industries," Tata McGraw-Hill, New Delhi.	1985
3	Modi, P. N., "Sewage Treatment and Disposal and Waste Water Engineering," Vol. II, 17th Ed. Standard Book House, Delhi.	2020

1. Subject Code: 22CHT252 **Course Title: Chemical Technology**

2. Contact Hours: L:3 T: 1 P: 0

3. Credits: 4 Semester: IV

4. Pre-requisite: Studied unit processes and unit operations courses prescribed in Chemical Engineering syllabus

5. Course objective: To study process technologies of various organic and inorganic process industries

6. Course Outcome: Upon completion of this course, the students will be able to:

i. Understand the processes involved in manufacturing of various inorganic and organic chemicals

ii. Prepare the process flow diagrams

iii. Analyze important process parameters and engineering problems during production

7. Details of Course:

Unit No.	Contents	Contact Hours
1.	**Introduction to Chemical Engineering**: Unit operations and unit processes,functions of a Chemical Engineer, new emerging areas. Study of the following chemical industries/processes involving process details, production trends, thermodynamic considerations, material and energy balances, flow sheets, engineering problems pertaining to materials of construction, waste regeneration/recycling, and safety, environmental and energy conservation measures.	2
2.	**Industrial Gases:** Hydrogen, producer gas and water gas. **Nitrogen Industries:** Ammonia, nitric acid, nitrogenous and mixed fertilizers. **Coal Conversion technologies**	9
3.	**Chlor-Alkali Industries:** Common salt, caustic soda, chlorine, hydrochloric acid, sodaash.	7
4.	**Sulphur Industries:** Sulphuric acid, oleum. **Cement Industries:** Portland cement.	6
5.	**Agrochemicals:** Important pesticides, BHC, DDT, Malathion. **Alcohol Industries:** Industrial alcohol, Absolute alcohol.	7
6	**Oils and Fats:** Oils, Fats and Waxes, Soaps and Detergents. **Pulp and Paper Industry** **Sugar Industry**	9

8. Books:

(A) Text Books:

S.No.	**Authors / Name of Book / Publisher**	**Year of Publication**
1	Rao, M.G. and Sittig, M., Dryden's Outlines of Chemical Technology, Affiliated East West Press.	1997
2	Austin, G.T., Shreve's Chemical Process Industries, 5th Ed., McGraw-Hill.	2017

(B) Reference Books:

S.No.	**Authors / Name of Book / Publisher**	**Year of Publication**
1	Faith, W.L., Keyes, D.B. and Clark, R.L., Industrial Chemicals, 4thEd., John Wiley.	1975
2	Kirk-Othmer Encyclopedia of Chemical Technology, John Wiley and Sons, Inc.	2001

1. Subject Code: 22RET291 Course Title: Energy Storage

(To be taught by Centre for Energy and Environment)

2. Contact Hours: L: 3 T: 0 P: 0

3. Credits: 3 Semester: IV

4. Pre-requisite: Nil

5. Course Objective:

CO1: To understand different aspects and parameters of energy storage.

CO2: To determine utilization, sizing, and operation of energy storage systems.

CO3: To solve energy storage system design problems.

6. Course Outcome: Upon completion of this course, the students will be able to:

i. Select and size suitable energy storage systems for any application.

ii. Compare and evaluate different energy storage systems.

7. Details of Course:

S. No.	Objectives	Contact Hours
1.	Introduction of energy storage technology, requirement for energy storage, Current status, storage services and benefits, cost performance and maturity of storage technology, methods and tools for evaluation of storage, future prospect of storage, policy and regulatory framework.	7
2.	Introduction to Electrochemical energy storage. Comparison, Ragone plot and state-of-art application, their function and deployments. Technical characteristics, introduction to battery states and their estimation methods, Performance characteristics, testing, safety, standards and system sizing, different electrochemical energy storage methods, flow battery, lead acid battery, characteristics of battery.	10
3.	Thermal energy storage (TES) methods Sensible TES, Latent TES, Thermochemical TES, Selection depending on the application. Types of storage systems Design and operation of thermal storage systems	8
4.	Hydrogen energy: hydrogen economy, Hydrogen based energy storage, hydrogen storage and transportation safety	6
5.	Mechanical energy storage systems, flywheel energy storage (FES), pumped hydropower storage (PHS), and compressed air energy storage (CAES). Comparison and application state of art including principle, function and deployments.	8

8. Books:

(A) Text Books

S.No.	Authors / Name of Book / Publisher	Year of Publication
1.	Large Energy Storage Systems Handbook Edited by Frank S. Barnes Jonah G. Levine. Publisher CRC Press Taylor & Francis Group ISBN 9781138071964	2011
2.	Energy Storage Fundamentals, Materials and Applications Edited by Robert Huggins. Publisher Springer ISBN: 978-3-319-21239-5	2016
3	Grid-Scale Energy Storage Systems and Applications Edited by Fu-Bao Wu, Ji-Lei Ye, Bo Yang ISBN:9780128152935	2019

(B) Reference Books

S.No.	Authors / Name of Book / Publisher	Year of Publication
1.	Compressed Hydrogen in Fuel Cell Vehicles: On-board Storage and Refueling Analysis Edited by Shitanshu Sapre, Kapil Pareek, Rupesh Rohan. CRC Press Taylor & Francis Group ISBN 9781032154893	2022
2.	US DOE Energy storage handbook (https://www.sandia.gov/ess/publications/doe-oe-resources/eshb/doe-epri-nreca)	2013
3	Advances in Batteries for Medium and Large-Scale Energy Storage Edited by Maria Skyllas-Kazacos, Chris Menictas, T. M. LimISBN:9781782420224	2014

1. Subject Code: 22CHP256 Course Title: Chemical Reaction Engineering Lab
2. Contact Hours: L:0 T:0 P:2
3. Credits: 1 Semester: IV
4. Pre-requisite: CHT XXX Chemical Reaction Engineering- I
5. Course Objective: Hands on practice on the study of kinetics of homogeneous and heterogeneous reactions using different reactors and RTD studies in different reactors
6. Course outcome: Upon completion of this course, the students will be able to:

i. Run various homogeneous and heterogeneous laboratory size reactors and to determine different kinetic parameters in Batch reactor, CSTR, CSTRs in series, Spinning basket reactor, Packed bed recycle reactor etc.
ii. Development of practical skills leading to research initiatives

7. Details of Course:

Experiment No.	Objective	Contact Hours
1.	Study of a non-catalytic homogeneous reaction between sodium hydroxide and ethyl acetate in a BatchReactor and to determine: (i) Order of reaction, (ii) Rate constant k, and (iii) Effect of temperature on k and determineactivation energy E.	3
2.	Study of a non-catalytic homogeneous reaction between sodium hydroxide and ethyl acetate ina Plug Flow Reactor between and to determine: (i) Order of reaction and (ii) Rate constant k	3
3.	Study of a non-catalytic homogeneous reaction between sodium hydroxide and ethyl acetate ina series of three CSTRs and to draw the performance chart for the reactor system and evaluate the rateconstant at ambient temperature.	3
4.	Study of a non-catalytic gas solid reaction for the decomposition of $CaCO_3$ in air in a MuffleFurnace and to record the decomposition-time data for calcination of $CaCO_3$ particles and find out a suitablemodel for the reaction.	3
5.	Characterization of the given sample of Adsorbent/Catalyst and to determine its (i) Bulkdensity and (ii) Pore volume	3
6.	Study of the behaviour of a given CSTR/ Packed Bed Reactor/ CSTRs in series by using pulseinput and step input of a tracer and determine (i) Mean resistance time, (ii) Variance, (iii) Dispersion no.,and (iv) Dispersion coefficient.	3
7.	Study of the kinetics of hydrolysis of ethyl acetate in a Packed Bed Recycle Reactor filled withion exchange resin and to determine the effect of recycle ratio on the conversion.	3
8.	Study heterogeneous catalytic hydrolysis of ethyl acetate using ion exchange resin in a SpinningBasket Reactor and determine (i) Reaction rate constant (ii) Study the effect of Mass Transfer.	3

9.	Study of the kinetics of photo-catalytic oxidation of formic acid in a UV Reactor and to determine the rate constant of reaction.	3
10.	Propose an experiment based on any of the existing experimental set up ofCRE Lab. or a combination of the same. Or Propose an experimental set up (with as much details as possible) along with a suitable experiment, which is not presently existing in CRE Lab.	3

8. Books

A) Text Books

S. No.	Authors / Name of Book / Publisher	Year of Publication
1	Levenspiel, O., "Chemical Reaction Engineering," 3rd Ed., John Wiley.	2006
2	Fogler, H. S., "Elements of Chemical Reaction Engineering," 5th Ed., Prentice-Hall of India, Delhi.	2016
3	Smith, J. M., "Chemical Engineering Kinetics," 3rd Ed., McGraw-Hill.	1981

(B) Reference Books

S. No.	Authors / Name of Book / Publisher	Year of Publication
1	Carberry, J. J., "Catalytic Reaction Engineering," McGraw-Hill.	1976
2	Levenspiel, O., "The Chemical Reactor Omnibook," OSU Bookstores, Corvallis, Oregon.	1996

1. Subject Code: 22CHT257 **Course Title: Heat Transfer Operations Lab**

2. Contact Hours: L:0 T:0 P:2
3. Credits: 1 Semester: IV
4. Pre-requisite: Principles of Heat Transfer
5. Course Objective: To provide hands on experience on heat transfer operations and equipment
6. Course Outcome: Upon completion of this course, the students will be able to:
   i. Understand the principles of heat transfer
   ii. Understand the operations of various heat transfer equipments
   iii. Measure physical properties and heat transfer coefficient
7. Details of Course:

Experiment No.	**Objective**	**Contact Hours**
1.	Study of Heat transfer by conduction in a metal bar	3
2.	Study of Heat transfer by conduction in a Composite metal wall	3
3.	Study of unsteady state heat transfer	3
4.	Determination of Thermal conductivity of Insulated Powder	3
5.	Study of Heat transfer by Natural convection	3
6.	Study of Heat transfer by Forced convection	3
7.	Study of Heat transfer in Agitated Vessel	3
8.	Determination of Emissivity of given material	3
9.	Study of Heat transfer in double pipe heat exchanger	3
10.	Study of Heat transfer in Shell and Tube heat exchanger	3
11.	Determination of heat transfer coefficient in boiling phenomenon	3
12.	Determination of heat transfer coefficient for Dropwise Condensation	3
13.	Determination of heat transfer coefficient for Film wise Condensation	3
14	Determination of thermal conductivity of liquids	3
15	Determination of critical heat flux from pool boiling apparatus	3

8.Books:

(A) Text **Books:**

S.No.	**Authors / Name of Book / Publisher**	**Year of Publication**
1	Dutta, B. K. "Heat transfer: Principles and Applications", PHI, New Delhi, "Transport Phenomena", 2nd Ed., Wiley.	2001
2	Kern, D. Q., "Process Heat Transfer", Tata- McGraw Hill,	1950

(B) Reference	**Authors / Name of Book / Publisher**	**Year of Publication**

Books**S.No.**		
1	Holman, J. P., "Heat Transfer", 10th Ed. McGraw Hill, New York.	2017
2	Chapman, A. J., "Heat Transfer", Maxwell Macmillan.	1984

1. Subject Code: 22CHP258 **Course Title: Industrial Pollution Abatement Lab**

2. Contact Hours: L:0 T:0 P:2

3. Credits: 1 Semester: IV

4. Pre-requisite: Nil.

5. Course Objective: Hands on practice to analysis the water and wastewater for some of their key parameters by standard methods and impart the practical skills leading to research initiatives.

6. Course outcome: Upon completion of this course, the students will be able to:

i. Students got hands on practice of analyzing water and wastewater for some of their key parameters by standard methods.
ii. Development of practical skills leading to research initiatives.

7. Details of Course:

Experiment No.	Objective	Contact Hours
1.	Determination of Total Solids (TS), Total Suspended Solids (TSS), and Total Dissolved Solids(TDS) of a given wastewater sample.	3
2.	Determination of Volatile Suspended Solids (VSS) and Fixed Suspended Solids (FSS) of a given water sample	3
3.	Determination of pH, Electrical Conductivity (EC), and Turbidity of a given water sample.	3
4.	Determination of Dissolved Oxygen (DO) of a given water sample byWinkler's method.	3
5.	Determination of Chemical Oxygen Demand (COD) of a given water sample.	3
6.	Determination of Oil and Grease in a given wastewater sample.	3
7.	Determination of Biological Oxygen Demand (BOD) of a given water/ wastewater sample.	3
8.	Determination of Available Chlorine in a given sample of Bleaching Powder	3
9.	Propose an experiment consistent with the theory subject of IPA and for which infrastructureis available in IPA Lab. giving complete details (as given in IPA Lab practical instructionsheet).	3
10.	Some real lifeproblem based on the course content of Industrial Pollution Abatement. Theproblem should have application of Numerical methods and/or statistics. Select a problemfrom journal research paper/ text book of the subject. The project must have somecontribution of the team commensurate with the level of the Class.	3
11.	Propose an experiment consistent with the theory subject of IPA and for which infrastructureneeds to be arranged in IPA Lab. giving complete details (as given in IPA Lab	3

	practicalinstruction sheet)	
12.	Estimation of Settling Property using Jar Test	3
13.	Estimation Water Turbidity	3

8. Books:

(A) Text Books

S.No.	Authors / Name of Book / Publisher	Year of Publication
1	Clesceri, L. S., Greenberg, A. E., Eaton, A. D. (Eds.),“Standard Methods forWater and Wastewater Analysis”, 20thEd., American Public Health Association(APHA),Washington.	1998

(B) Reference Books

S.No.	Authors / Name of Book / Publisher	Year of Publication
1	Maiti, S. K., “Handbook of Methods in Environmental Studies”, Vol. I, ABD Publishers, Jaipur.	2001
2	Mathur, R. P., “Water andWastewater Testing (Laboratory Manual)”, 4thEd., Nemchand and Brothers, Roorkee.	2005

V Semester:

S.No.	Course Code	Course Title	Category	Type	Credit	L	T	P
1.	22CHT305	Mass Transfer-II	PC	Theory	4	3	1	0
2.	22CHT301	AI & ML in Chemical Engineering	PC	Theory	4	3	1	0
3.	22CHT306	Process Dynamics and Control	PC	Theory	4	3	1	0
4.	22CHT307	Process Safety and Hazards Management	PC	Theory	4	3	1	0
5.	22CHT302	Chemical Reaction Engineering-II	PC	Theory	4	3	1	0
6.	22CHP311	Process Instrumentation and Control Lab	PC	Lab	1	0	0	2
7.	22CHP310	Mass Transfer Lab	PC	Lab	1	0	0	2
Total					**22**	**15**	**5**	**4**

SEMESTER – V

1. Subject Code: 22CHT305 **Course Title: Mass Transfer II**

2. Contact Hours: L:3 T:1 P:0
3. Credits: 4 Semester: V
4. Pre-requisite: Mass Transfer-I
5. Course Objective:To learn the different separation techniques and analysis of mass transfer equipment
6. Course Outcomes: Upon completion of this course, the students will be able to:
   i. Develop the ability to develop analytical and graphical solution of separation by liquid-liquid Extraction and leaching.
   ii. Solve problem based on separation by adsorption and understood the design of adsorber for stage calculation,
   iii. Understand the operation of cooling tower, Dryer and mechanism of crystallization.
7. Details of Course:

Unit No.	Contents	Contact Hours
1.	**Liquid-Liquid& Solid/Liquid Extraction:** Ternary liquid equilibria, Triangular graphical representation concept of theoretical or ideal stage, Equipment used for single stage and multistage continuous operation; Analytical and graphical solution of single and multistage operation, Super critical fluid extraction. Leaching, Solid liquid equilibrium, Equipment used in solid – liquid extraction, Single and multistage cross current contact and counter current operations. Concept of an ideal stage, Overall stage efficiency, Determination of number of stages.	12
2.	**Adsorption:** Description of adsorption processes and their application, Types of adsorption, Nature of adsorbents, adsorption equilibria and adsorption hysteresis, Stage wise and continuous contact adsorption operations, Determination of number of stages.	10
3.	**Crystallization:** Equilibrium yield of crystallization, Heat and mass transfer rates in crystallization, Theories of crystallization, Factors governing nucleation and crystal growth rates, Controlled growth of crystal, Classification and design of crystallizers	6
4.	**Humidification and Dehumidification:**Vapour liquid equilibrium and enthalpy for a pure substance, vapour pressure temperature curve, Vapour gas mixtures, Definition and derivations of relationships related with humidity Fundamental concept of humidification, Dehumidification and water cooling,Wet bulb temperature, Adiabatic and non-adiabatic operations, Evaporative cooling,Classification and design of cooling towers.	6
5.	**Drying:** Solid-gas equilibria, Different modes of drying operations, Definitions of moisture contents, Types of batch and continuous dryers, Rate of batch drying, Time of drying, Mechanism of batch drying, Continuous drying, Design of continuous dryers.	6

8. Books:

(A) Text Books

S.No.	Authors / Name of Book / Publisher	Year of Publication
1	Treybal, R "Mass Transfer Operations", 3rd Ed. NewYork: McGraw-Hill.	2017
2	Sherwood T. K., Pigford R. L. and Wilke P. "Mass Transfer" McGraw-Hill.	1975
3	Geankoplis, CJ, "Transport Processes and Unit Operations", 3rd Ed. Prentice Hall.	1993
4	B K Dutta, Principles of Mass Transfer and Separation Processes, PHI Learning.	2007

(B) Reference Books

S.No.	Authors / Name of Book / Publisher	Year of Publication
1	Foust A.S., Wenzel, L.A., Clump, C.W., Maus,L., Anderseny, L.B., "Principles of Unit Operations" 2nd Ed., John Wiley.	2008
2	King, C. J.," Separation Processes", 2nd Ed., McGraw-Hill, NY.	1980
3	Smith, B. D., "Design of Equilibrium Stage Processes", McGraw-Hill, NY.	1963
4	McCabe, W. L., Smith, J. C. and Harriot, P., "Unit Operations of Chemical Engineering", 7th Ed., McGraw-Hill, NY.	2017
5	Coulson, J. M. and Richardson, J. F., " ChemicalEngineering",7th Ed. Vol. I and II, Elsevier.	2017

1. **Subject Code: 22CHT301** **Course Title: AI & ML in Chemical Engineering**
2. Contact Hours: L: 3 T: 1 P: 0
3. Credits: 4 Semester: V
4. Pre-requisite: Nil.
5. Course Objective:To provide comprehensive knowledge of various AI and ML tools and their applications in solving Chemical Engineering Problems.
6. Course Outcomes: Upon completion of this course, the students will be able to:
   i. Understand the fundamentals of AI and ML, tools used in Al & ML.
   ii. Integrate chemical engineering domain knowledge into AI/ML solutions whereby making students equipped for in-demand careers.
7. Details of Course:

Unit No.	Contents	Contact Hours
1.	Introduction to Artificial Intelligence (AI) and Machine Learning (ML); Types of learning problems: Supervised, Unsupervised, Semi-supervised; Overview of optimization techniques.	10
2.	Introduction to software tools used in AI & ML; Solving problems in Chemical Engineering (like decision support system, process control, modeling and simulation) applying rule-based AI & ML tools and lifecycle: (i) Data preprocessing: Data visualization, Outlier detection, & Smoothing techniques, Data scaling (Need for Scaling – Scale invariance, Standardization, Normalization), Dimensionality reduction, Feature extraction, selection (ii) Model Evaluation & identification: Performance metrics, analysis, Model selection, Hybrid cross-Validation methods (iii) Model development: (a) Classification – (Logistic regression, Naïve Bayes classifier, K-nearest neighbors, Support vector machines, Decision trees, Random forests, Boosting), (b) Regression - (Linear regression – simple, multiple, Kernel, Regression analysis, Box-Jenkins models (ARMA, ARIMA), Neural Network).	30

8. Books:

S. No.	**Authors / Name of Book / Publisher**	**Year of Publication**
1	Hastie, T., Tibshirani, R., Friedman, J.H., The Elements of Statistical Learning Data Mining, Inference, and Prediction, Second Edition, Springer.	2009
2	Abu-Mostafa, Y.S., Magdon-Ismail, M., Hsuan-Tein, L., Learning from Data. AMLBook.	2012
3	Bishop, C., Pattern Recognition and Machine Learning. Springer-Verlag.	2006
4	Gareth, J., Witten, D., Hastie. T., Tibshirani, R., An Introduction to Statistical Learning with Applications in R, Springer-Verlag.	2013
5	Müller, A. C., Gudio, S., Introduction to Machine Learning with Python, O'Reilly Media, Inc.	2016
6	Shalev-Shwartz, S. and Ben-David, S., Understanding Machine Learning: From Theory to Algorithms, Cambridge University Press.	2014

1. Subject Code: 22CHT306 **Course Title: Process Dynamics and Control**

2. Contact Hours: L:3 T:1 P:0
3. Credits: 4 Semester: V
4. Pre-requisite: Nil.
5. Course Objective: To learn the fundamentals of developing dynamic models of processes and control strategies for linear time-invariant systems
6. Course Outcomes: Upon completion of this course, the students will be able to:
   i. Develop transfer function models for linear dynamical processes
   ii. Characterize the dynamics and stability of processes based on mathematical analysis
   iii. Understand the principles of feedback controllers
   iv. Design PID controllers using different tuning rules
   v. Carry out a frequency-response analysis of control loop systems
7. Details of Course:

Unit No.	Contents	Contact Hours
1.	Introduction to process control and review of Laplace transforms. **Linear Open-Loop Systems** First-Order Systems: Transfer function, transient response (step response, impulse response, sinusoidal response),	8
2	**Examples of first-order systems, response of first-order systems in series**: non-interacting systems and interacting systems. Second-Order Systems: Transfer function, step response, impulse response, sinusoidal response, transportation lag.	8
3	**Linear Closed-Loop Systems** Control system: Components of a control system, block diagram, negative feedback and positive feedback, servo problem and regulator problem. Controller and final control element: Mechanism of control valve and controller, transfer functions of control valve and controllers (P, PI, PD, PID) Example of a chemical-reactor control systemClosed-Loop Transfer Functions: Overall transfer function for single-loop systems, overall transfer function for set-point change and load change, multi-loop control systems.	8
4	**Transient Response of Simple Control Systems:** P and PI control for set-point change and for load change. **Stability:** Concept of Stability; Stability criteria; Routh test for stability; Root Locus.	8
5	**Frequency Response:** Introduction to Frequency Response, Bode Diagrams for first- and second-order systems, Bode Stability Criteria, Ziegler-Nichols and Cohen-Coon Tuning Rules. Introduction to cascade, ratio and feed-forward controllers	8

8. Books:

(A) Text Books

S.No.	Authors / Name of Book / Publisher	Year of Publication
1	Coughanowr, D. R., LeBlanc, S.E., "Process Systems Analysis and Control", 3rd Ed., McGraw Hill.	2017
2	Stephanopoulos, G., "Chemical Process Control", PHI, New Delhi.	2015

(B) Reference Books

S.No.	Authors / Name of Book / Publisher	Year of Publication
1	Luyben, W. L., "Process Modeling, Simulation and Control for Chemical Engineers," 2nd Ed., McGraw Hill.	2013
2	Bequette, B.W., "Process Control - Modeling, Design and Simulation," Pretice Hall.	2003
3	Seborg, D.E., Edgar, T.F., Mellichamp, D.A., Doyle III, F.A., "Process Dynamics and Control," 4th Ed., Wiley.	2016

1. Subject Code: 22CHT307 Course Title: Process Safety and Hazards Management

2. Contact Hours: L: 3 T: 1 P: 0

3. Credits: 4 Semester: V

4. Pre-requisite: Nil.

5. Course Objective: To deliver a broad level of risk identification and management in process plant integrity management. Student will be able to recognize and evaluate occupational safety and health hazards in the workplace

6. Course Outcomes: Upon completion of this course, the students will be able to:

   i. Understand the fundamental principles underlying safety and risk management
   ii. Understandthetoxicology, fire & explosion hazards
   iii. Establish expertise relevant to the practice of safety and risk management
   iv. Undertake a Hazard and Operability Study (HAZOP)

7. Details of Course:

Unit No.	**Contents**	**Contact Hours**
1.	Origin of process hazards, Laws Codes, Standards, Case Histories, Properties of Chemicals, Health hazards of industrial substances, Personal Protective equipment.	8
2.	**Toxicology:** Toxic materials and their properties, effect of dose and exposure time, relationship and predictive models for response, Threshold value and its definitions, material safety data sheets, industrial hygiene evaluation.	5
3	**Industrial Hygiene:** Government Regulations, Industrial Hygiene identification, evaluating worker exposure to dust, noise, toxic vapor and volatile toxicants. Industrial hygiene control techniques.	7
4	**Fire and explosion**: Fire and explosion hazards causes of fire and preventive methods. Flammability characteristics of chemical, fire and explosion hazard, rating of process plant. Propagation of fire and effect of environmental factors, ventilation, dispersion, purifying and sprinkling, safety and relief valves.	7
5	**Hazards Identification:** Process Hazards checklists, Hazards surveys, hazards and operability studies, safety reviews.	6
6	**Hazard Assessment:** Failure distribution, failure data analysis, modeling for safety, safety training, emergency planning ad disaster management, case studies	8

8. Books:

(A) Text Books

S.No.	Authors / Name of Book / Publisher	Year of Publication
1.	Crawl D.A. and Louvar J.A., "Chemical Process Safety Fundamentals with Applications," 4thEd.,Prentice Hall.	2020

(B) Reference Books

S.No.	Authors / Name of Book / Publisher	Year of Publication
1.	Lees, F. P., "Loss Prevention in Process Industries", Vol.1 and 2, 4th Ed., Butterworth.	2012
2.	Wentz, C.A., "Safety Health and Environmental Protection," McGraw Hill.	1998

1. Subject Code: 22CHT302 Course Title: Chemical Reaction Engineering-II
2. Contact Hours: L:3 T:1 P:0
3. Credits: 4 Semester: V
4. Pre-requisite: Chemical Reaction Engineering-I
5. Course Objective: To understand the effect of non-ideal flow on reactor performance and to design reactors for heterogeneous reaction systems.
6. Course outcome: Upon completion of this course, the students will be able to:

i. Diagnose non ideal flow in process vessels using concepts of RTD studies
ii. Understand the fundamentals of Catalyst manufacture and its characterization
iii. Understand the fundamentals of non-catalytic and catalytic heterogeneous reactions
iv. Understand the fundamentals of gas-liquid reactions
v. Design of heterogeneous reactors

7. Details of Course:

Unit No.	Contents	Contact Hours
1.	**Non-catalytic Gas-Solid Reactions:** Progressive conversion model, Shrinking core model; various controlling regimes, design of gas-solid reactors.	8
2.	**Catalyst synthesis & characterization**: Description, methods of catalyst preparation and manufacture; impregnation, sol-gel, catalyst characterization – BET surface area, pore volume, pore size distribution, catalyst promoters and inhibitors, catalyst poisoning, types of catalyst deactivation, kinetics of catalytic deactivation.	8
3.	**Catalyst Reaction Kinetic Models:** Physical and chemical adsorption; Determination of rate expressions using adsorption, surface reaction and desorption as rate-controlling steps. **Determination of Global Rate of Reaction**: Heterogeneous laboratory reactors; Determination of rate expressions from experimental data.	8
4.	**Effect of Intra-pellet Diffusion on Reaction Rates in Isothermal Pellets:** concept of effectiveness factor, Thiele modulus, experimental determination of effectiveness factor, falsified kinetics, Weisz-Prater criterion for internal diffusion, Mears criterion for external diffusion, Non-isothermal effectiveness factor; Prater number, maximum temperature rise in a pellet, multiple steady-states in heterogeneous reactors.	8
5.	**Gas-Liquid Reactions:** Effect of diffusion on rate of reaction, enhancement factor. **Introduction to Design of Heterogeneous Reactors:** One-dimensional model for fixed-bed reactors, parametric sensitivity; design of fluidized bed reactors.	8

8. Books:

(A) Text Books

S. No.	Authors / Name of Book / Publisher	Year of Publication
1	Levenspiel, O., “Chemical Reaction Engineering,” 3rd Ed., John Wiley.	2006
2	Fogler, H. S., “Elements of Chemical Reaction Engineering,” 5th Ed., Prentice-Hall of India, Delhi	2016
3	Smith, J. M., “Chemical Engineering Kinetics,” 3rd Ed., McGraw-Hill	1981

(B) Reference Books

S. No.	Authors / Name of Book / Publisher	Year of Publication
1	Carberry, J. J., “Catalytic Reaction Engineering,” McGraw-Hill.	1976
2	Levenspiel, O., “The Chemical Reactor Omnibook,” OSU Bookstores, Corvallis, Oregon.	1996

1. Subject Code:22CHP311 Course Title: Process Instrumentation and Control Lab

2. Contact Hours: L:0 T:0 P:2

3. Credits: 1 Semester: V

4. Pre-requisite: Nil.

5. Course Objective: To make the students understand basic applications of process control for controlling various processes used in industries

6. Course Outcomes: Upon completion of this course, the students will be able to:

   i. Understand the dynamics of various processes
   ii. Understand the applications of feedback controllers
   iii. Design and tune P, PI, PID controllers

7. Details of Course:

Experiment No.	Objective	Contact Hours
1.	Study of First order Tank level Dynamics	2
2.	Study of Control Valve Characteristics, to obtain Control value Flow Co-efficient (Cv) and hysteresis	2
3.	Study of First-order dynamics of mercury thermometer	2
4.	Study of dynamic response of mercury thermometer to sinusoidal/on-off change in surroundings temperature	2
5.	Study of second order Process Dynamics of U-Tube Manometers	2
6.	Study of second order Process Dynamics of U-Tube Manometers for different manometric fluids	2
7.	Study of Flow Control trainer to study the on-off, P,PI, PID control	2
8.	Study of Process Dynamics of a Two-Tank Noninteracting System	2
9.	Study of Process Dynamics of a Two Tank Interacting System	2
10.	Study of temperature Control trainer to study the P,PI,PID control	2
11.	Study of Ziegler–Nichols Tuning Technique to identify the best value of Kc, τ_I, τ_D for a PID controller.	2
12.	Study of Cohen Coon tuning technique to identify the best value of Kc, τ_I, τ_D for a PID controller	2
13	Cascade Control Trainer	2
14	Flow Control Trainer	2
15	Pressure Control Trainer	2

8. Books:

(A) Text Books

S.No.	Authors / Name of Book / Publisher	Year of Publication
1	Coughanowr, D. R., LeBlanc, S.E., "Process Systems Analysis and Control", 3rd Ed., McGraw Hill.	2009

(B) Reference Books

S.No.	Authors / Name of Book / Publisher	Year of Publication
1	Stephanopoulos, G., "Chemical Process Control", PHI, New Delhi.	1984
2	Luyben, W. L., "Process Modeling, Simulation and Control for Chemical Engineers," 2nd Ed., McGraw Hill.	2013
3	Bequette, B.W., "Process Control - Modeling, Design and Simulation," Pretice Hall	2003
4	Seborg, D.E., Edgar, T.F., Mellichamp, D.A., Doyle III, F.A., "Process Dynamics and Control," 3rd Ed., Wiley.	2010

1. Subject Code: 22CHP310 **Course Title: Mass Transfer Lab**

2. Contact Hours: L: 0 T: 0 P: 2

3. Credits: 1 Semester: V

4. Pre-requisite: Nil.

5. Course Objective: Student get hands on practice of conducting various mass transfer operation such as distillation, absorption, liquid-liquid extraction, adsorption, determine the efficiency of separation process and analyze the ratio results.

6. Course outcome: Upon completion of this course, the students will be able to:

   i. Conduct mass transfer experiments-distillation, absorption, extraction, drying, mass transfer coefficient etc.

   ii. Development practical skills to collect data, calculate mass transfer efficiency and analyze the results.

7. Details of Course:

Experiment No.	Objective	Contact Hours
1.	To study the operation of a batch cooling crystallizer experimentally, find the yield of sodium thiosulphate crystal in the batch crystallizer and to verify the material balance.	3
2.	Determination of loss of cooling water due to the evaporation in a cooling tower under given operating conditions.	3
3.	Determination of stage efficiency of the flash vaporization unit for separation of a liquid mixture under given operating conditions.	3
4.	To study the hydrodynamic characteristics of a given packed column operated with counter current flow of gas and liquid (a) to plot log ΔP vs log G', and locate the loading and flooding region.	3
5.	Determination of gas phase mass transfer coefficient under given operating condition in a wetted wall column.	3
6.	Separation of methanol water mixture by bubble cap distillation column and estimate the composition of the low boiling component in the distillate and the bottom product, determine the column efficiency using McCabe-Thiele method.	3
7.	To plot the rate of batch drying curve for a given material under constant drying conditions in a tray dryer	3
8.	Determination of gas-phase convective mass-transfer coefficient by sublimation of a spherical naphthalene ball	3
9.	Determination of solid-liquid mass transfer coefficient for dissolution of a cylindrical rod shaped benzoic acid in water.	3
10.	To determine the efficiency of solid liquid extraction(leaching) in a packed bed extraction column.	3
11.	Packed bed distillation column for separation of MVC from	3

	binary mixture.	
12.	Study of hydrodynamics in packed bed column	3
13.	Study of vapor-liquid equilibrium	3
14.	Estimation of mass transfer coefficient in wetted wall column	3

8. Books:

(A) Text Books

S.No.	Authors / Name of Book / Publisher	Year of Publication
1	Treybal, R. E., "Mass Transfer Operations," 3rd Ed., McGraw Hill, Singapore.	1980
2	McCabe, W.L., Smith, J.C. and Harriott, P. Unit Operations of Chemical Engineering. McGraw-Hill, New York.	1993

(B) Reference Books

S.No.	Authors / Name of Book / Publisher	Year of Publication
1	King, C. J., "Separation Processes," 2ndEd., Tata McGraw Hill, New Delhi.	1982

VI Semester:

S.No.	Course Code	Course Title	Category	Type	Credit	L	T	P
1.	22CHT354	Plant Design & Process Economics	PC	Theory	4	3	1	0
2.	22CHT358	Transport Phenomena	PC	Theory	4	3	1	0
3.	22CHT353	Petroleum Refining and Petrochemicals	PC	Theory	3	3	0	0
4.	22CHT356	Process Equipment Design	PC	Theory	4	3	1	0
5.	22BMT922	Management Principles for Engineers	IC	Theory	3	3	0	0
6.	22CHP359	Petroleum Lab	PC	Lab	1	0	0	2
7.	22CHP360	Process Equipment Design Lab	PC	Lab	1	0	0	2
Total					**20**	**15**	**3**	**4**

SEMESTER – VI

1. Subject Code: 22CHT354 **Course Title: Plant Design and Process Economics**

2. Contact Hours: L: 3 T: 1 P: 0

3. Credits: 4 Semester: VI

4. Pre-requisite: Nil.

5. Course Objective: To provide comprehensive knowledge of various process parameters and economics involved in the development of process and plant design.

6. Course Outcomes: Upon completion of this course, the students will be able to:

    i. Understand the concepts of engineering and economics for chemical plant design and optimization
    ii. Synthesize a process flow sheet for recycle structure
    iii. Calculate different costs involved in a process plant
    iv. Perform breakeven analysis and optimum design of a process

7. Details of Course:

Unit No.	Contents	Contact Hours
1.	**Process Design and Development:** General design considerations, hierarchy of chemical process design, nature of process synthesis and analysis, Developing a conceptual design and finding the best flowsheet, input information and batch versus continuous, Input/output structure of the flowsheet, Recycle structure of the flowsheet, Separation system, Heat Exchanger Networks, Site selection and feasibility analysis.	10
2.	**Project Concept to Commissioning:**Milestones, project execution as conglomeration of technical and non-technical activities, contractual details. Contract:meaning, contents, types of contract. Lump-sum Turnkey (LSTK), Eng, Procurement and Construction (EPC), Eng, Procurement and Construction Management (EPCM). Mergers and Acquisitions	4
3.	**Estimation of Project Cost:**Introduction to various components of project cost and their estimation. Introduction to concept of Inflation, location index and their use in estimating plant and machinery cost. Various cost indices, Relationship between cost and capacity.Relationship between price of a product and project cost and cost of production	8
4.	**Project Financing:**Debt, Equity ratio, Promoter's contribution, Shareholder's contribution, source of finance, time value of money, annuity. Concept of interest, time value of money, selection of various alternative equipment or system based on this concept. Indian norms, EMI calculations. Depreciation concept, Indian norms and their utility in estimate of working results of project.	6
5.	**Estimate of Profitability Analysis of Project:** Capacity utilization, Gross profit, operating profit, profit before tax, Corporate tax, dividend, Net cash accruals. Project evaluation: Cumulative cash flow analysis	8

	Break-Even analysis, incremental analysis, various ratios analysis, Discounted cash flow analysis	
6.	**Techno-commercial Analysis**: Reading of Balance Sheets and evaluation of Techno-commercial Project Reports, PERT, CPM, bar charts and network diagrams	4

8. Books:

(A) Text Books

S.No.	Authors / Name of Book / Publisher	Year of Publication
1	Douglas, James M., "Conceptual Design of Chemical Processes", McGraw-Hill, International Editions (Chemical Engineering Series), New York, USA.	1988
2	Peters, Max S., K.D. Timmerhaus and R.E. West, "Plant Design and Economics for Chemical Engineers", (5^{th} Ed.,), McGraw-Hill International Editions (Chemical Engineering Series), New York, USA.	2017
3	Mahajani, V.V., "Chemical Project Economics", Macmillan Indian Ltd., New Delhi, India.	2005

(B) Reference Books

S.No.	Authors / Name of Book / Publisher	Year of Publication
1	Biegler, L.T., I.E. Grossmann and A.W. Westerberg, Systematic Methods of Chemical Process Design, Prentice Hall (Pearson Education), New Jersey, USA	1997
2	Smith, R. Chemical Process Design and Integration. John Wiley & Sons, West Sussex, England.	2005

1. Subject Code: 22CHT358 **Course Title: Transport Phenomena**

2. Contact Hours: L:3 T:1 P:0

3. Credits: 4 Semester: VI

4. Pre-requisite:Momentum Transfer Operations, Heat Transfer, Mass Transfer.

5. Course Objective: To impart knowledge about individual and simultaneous momentum, heat and mass transfer, model development along with appropriate boundary conditions.

6. Course Outcome: Upon completion of this course, the students will be able to:

i. Understand the chemical and physical transport processes and their mechanism

ii. Do heat, mass and momentum transfer analysis

iii. Analyze industrial problems along with appropriate approximations and boundary conditions

iv. Develop steady and time dependent solutions along with their limitations

7. Details of Course:

Unit No.	Contents	Contact Hours
1.	Continuum fluids, Newton's law of viscosity, Introduction to non-Newtonian fluids, pressure and temperature dependency of viscosity, viscosity of gases at low density.	4
2.	Laminar flow, shell momentum balance, boundary conditions, selected applications. Equations of change for isothermal systems–Navier-Stokes equation, use of equations of change to set up steady state flow problems with Newtonian fluids.	9
3.	Friction factor, similarity and dimensionless parameters, Buckingham pi-theorem, Microscopic mass, momentum and energy balance for isothermal systems, Bernoulli's equation, compressible flow, pipe flow.	7
4.	Shell energy balances, Fourier's Law of heat conduction, boundary conditions. Application to steady and unsteady problems, convective heat transfer, heat transfer coefficients for forced convection around submerged objects, for free convection for condensation of pure vapours on solid surface.	7
5.	Macroscopic energy balance, Bernoulli's Equation, parallel/counter flow heat exchanger – concepts, heating of a liquid in an agitated tank, similarity parameter.	5
6.	Fick's Law of diffusion, analogy with heat transfer, shell mass balances, boundary conditions, applications, species continuity equation, conductive mass transfer, mass transfer coefficients, applications, correlations, macroscopic balances and application to solve steady state problems.	8

8. Books:

(A)Text Books

S.No.	Authors / Name of Book / Publisher	Year of Publication
1	Bird, R. B., Stewart, W. E. and Lightfoot, E. N., Transport Phenomena, 2nd Ed., Wiley.	2006

(B) Reference books

S.No.	Authors / Name of Book / Publisher	Year of Publication
1	Batchelor, G. K., An Introduction to Fluid Dynamics, 2ndEd., Cambridge University Press, Cambridge.	2000
2	Slattery, J. C., Momentum, Energy and Mass Transfer in Continua, Robert E. Krieger Publishing Company, New York.	1981
3	Geankoplis, C. J., Transport Processes and Separation Process Principles, 4th Ed., Pearson Education India, New Delhi.	2013

1. Subject Code: 22CHT353 Course Title: Petroleum Refining and Petrochemicals

2. Contact Hours: L: 3 T: 0 P: 0

3. Credits: 3 Semester: VI

4. Pre-requisite: Nil.

5. Course Objective: To impart knowledge of petroleum refining, hydrocarbon processing, and derived petrochemicals

6. Course Outcomes:Upon completion of this course, the students will be able to:

   i. Select the appropriate characterization parameters
   ii. Specify the properties of petroleum products
   iii. Attain knowledge of various separation & conversion processes involved in petroleum refining
   iv. Attain knowledge of manufacturing of various petrochemical products

7. Details of Course:

Unit No.	Contents	Contact Hours
1.	**Introduction:** World petroleum resources, Petroleum industries in India, Chemistry and composition of crude oil, Transportation and pretreatment of crude oil, **New trends in refinery**	8
2.	**Classification&Characterization and Crude Oil Distillation:** Classification of petroleum, Characterization of petroleum fractions, Impurities in crude oil, Desalting of crude oil, Atmospheric distillation and vacuum distillation units.	8
3.	**Conversion Processes:** Thermal conversion processes, Conventional vis-breaking and soaker visbreaking process, Coking processes, Catalytic conversion processes, Fluid catalytic cracking, Catalytic reforming, Hydrocracking, Catalytic alkylation, Catalytic isomerization and catalytic polymerization, Distillation Conversion Method.	12
4.	**Finishing Processes:** Sulphur conversion processes, Sweetening processes, Solvent extraction process, Hydro treating process.	4
5.	**Lube oil Manufacturing Processes:** Solvent extraction of lube oil fractions, Manufacture of petroleum wax, Hydro finishing process,	3
6	**Petrochemicals:** Primary petrochemicals such as acetylene, propylene, butadiene, benzene, toluene, naptha, xylene and their derived polymers.	5

8. Books:

(A) Text Books

S.No.	**Authors / Name of Book / Publisher**	**Year of Publication**
1	BhaskaraRao, B.K., "Modern Petroleum Refining Processes", 6thEd.,Oxford& IBH Publishing Company Pvt. Ltd. New Delhi.	2018
2	Prasad, R., "Petroleum Refining Technology", Khanna Publishers	1998
3	Mall, I.D. Petrochemical Process Technology, 2nd Ed., Laxmi Publications Private Limited.	2017

(B) Reference Books

S.No.	**Authors / Name of Book / Publisher**	**Year of Publication**
1.	Nelson, W. L., 'Petroleum Refinery Engineering', 4thEd.,Tata McGraw Hill Publishing Company Limited.	1958
2.	Garry,J.H., "Petroleum Refining Technology and Economics", 5th Ed., CRC Press	2007
3.	Wells G. M., "Handbook of petrochemicals and processes", Gower Publishing	1991
4.	Spitz P. H., "Petrochemicals: The rise of an industry", John Wiley & Sons.	1988
5.	Sarkar, G.N., "Advanced Petroleum Refining", 2nd Ed., Khanna Publishers.	1996

1. Subject Code:22CHT356 **Course Title: Process Equipment Design**

2. Contact Hours: L:3 T: 1 P:0
3. Credits: 4 Semester: VI
4. Pre-requisite: Heat Transfer, Mass Transfer-I, Mass Transfer-II.
5. Course Objective: To learn the design procedures of process equipment used in chemical process industries
6. Course Outcomes: Upon completion of this course, the students will be able to:
   i. Design shell and tube heat exchanger design
   ii. Design distillation column
   iii. Design packed bed, absorption column
   iv. Design agitated vessels and evaporators
7. Details of Course:

Unit No.	Contents	Contact Hours
1.	**Shell and Tube Heat Exchanger Design:** Kern method; Bell's method of Shell-and-tube heat exchanger design, Plate heat exchanger design; Finned tube heat exchanger.	10
2.	**Condenser design:** horizontal condenser, vertical condenser, **Reboilers:** Design of forced-circulation reboiler, kettle and thermosyphon reboilers. **Evaporators:** Design of single and multi-effect evaporators.	10
3.	**Gas-Liquid Contact Systems:** Distillation column, tray hydraulics of sieve and valve trays; Absorption tower, Design of packed bed columns.	10
4.	**Agitated Vessels:** Design of mixing vessels, gas-spraying systems; impellers, propellers, anchors and helical ribbon-type agitators.	10

8. Books:

(A) Text Books

S.No.	Authors / Name of Book / Publisher	Year of Publication
1	Sinnott, R.K., "Coulson and Richardson's Chemical Engineering Design," 6th Ed., Butterworth-Heinemann	2021
2	McCabe, W. L., Smith, J. C. and Harriot, P., "Unit Operations of Chemical Engineering", 7thEd., McGraw-Hill, NY.	2017
3	Kern, D. Q., "Process Heat Transfer," McGraw-Hill.	1950

(B) Reference Books

S.No.	Authors / Name of Book / Publisher	Year of Publication
1	Ludwig, E.E., Applied Process Design for Chemical and Petrochemical Plants, Vol. 1,2, and 3, 4th Ed., Gulf Professional Publishing.	2007
2	Evans, F.L., "Equipment Design Handbook for refineries and Chemical Plants," 2ndEd., Vol. 2, Gulf Publishing.	1980
3	Smith, B.D., "Design of Equilibrium Stage Processes," McGraw-Hill.	1963

CourseTitle:ManagementPrinciplesforEngineers
(To be taught by Department of Management Studies)

	L	T	P	C
Prerequisite:Nil.	3	0	0	3

CourseLearningObjectives

Bytheendofthis coursestudentwillbeableto:

1. Understandtheglobaltransitiontowards anewnormalofmanagement.
2. Demonstratethemanagerialroles,skillsandfunctionsforresponsiblemanagement.
3. DeveloptheunderstandingandcognizanceoftheimportanceofProfessionalmanagement(ethical,responsible,andsustainable).
4. Performvarioustoolsandtechniquestobe usedintheperformanceofthemanagerialjob.
5. Makeeffectiveapplicationofacquiredknowledgetodiagnoseandsolveorganizationalproblemsand develop optimalmanagerial decisions.
6. Diagnoseandcommunicatethecomplexitiesassociatedwithmanagementofvariousissues intheorganizationsandintegratethelearninginhandlingthesecomplexities.

CourseContent

- Management:Nature,ScopeandFunctions,ManagerialRolesandLevelsofManagement;
- GeneralManagementProcessesandPrinciples,Management Practices;
- EssentialsofPlanning;Strategies,policiesandplanningpremises;Decisionmaking;
- Organizing:OrganizationalDesign&OrganizationalStructures;
- Leading:Motivation;Leadership, PowerandAuthority;LeadershipStyles;
- Controlling;StepsandtypesofControlProcess;
- Dimensions of Management: Ethical management, Responsible Management,SustainableManagement.

References

1. Robbins,StephenP.andCoulter,Mary(2019)'Management',14thedition,PrenticeHallofIndia
2. Laasch,O.(2021).PrinciplesofManagement-PracticingEthics,Responsibility,Sustainablity,2nd Edition,SagePublications.
3. Hill,CharlesWLandMcShane,StevenL.(2017)PrinciplesofManagement,SpecialIndianEdition,McGrawHill Education
4. Robbins,StephenP.,Decenzo,DavidA.&Bhattacharya,Sanghamitra(2009)FundamentalsofManagement,latestedition,Pearson Education
5. Koontz,HaroldandWeihrich,Heinz&RamachandraAryasriA.(2016).PrinciplesofManagement,Latestedition, McGrawHillEducation

1. Subject Code: 22CHP359 **Course Title: Petroleum Lab**

2. Contact Hours: L: 0 T: 0 P: 2

3. Credits: 1 Semester: VI

4. Pre-requisite: Nil

5. Course Objective: To make students do hands on practice on the characterization of petroleum products.

6. Course outcome: Upon completion of this course, the students will be able to:

   i. Hands-on practice for characterization of crude oil and different petroleum products by standard methods

   ii. Development of practical skills leading to research initiatives

7. Details of Course:

Experiment No.	**Objective**	**Contact Hours**
1.	To determine the vapour pressure of volatiles, non-viscous petroleum products except liquefied petroleum gases using Reid Vapour Pressure Apparatus.	2
2.	To determine the percentage of carbon residue of sample fuel oils using Rams Bottom Apparatus.	2
3.	To find out the smoke point of kerosene oil.	2
4.	To determine Flash Point of sample oil using Penskymarten's.	2
5.	To determine Flash point of kerosene using Abel apparatus.	2
6.	Distillation plant and distilled water.	2
7.	To determine Distillation of petroleum products.	2
8.	To determine Aniline Point of given sample.	2
9.	To determine viscosity of petroleum products and lubricants by Saybolt Viscometer Apparatus.	2
10.	To determine Cloud point and pour point of given sample.	2
11.	To determine the calorific value of given sample using bomb calorimeter apparatus.	2

8. Books:

(A)Text & Reference Books

S.No.	Authors / Name of Book / Publisher	Year of Publication
1	Nelson, W. L. Petroleum Refinery Engineering, 4thEd., Tata McGraw Hill Publishing Company Limited	1958
2	Prasad, R., "Petroleum Refining Technology", Khanna Publishers	1996

(B) Reference Books

S.No.	Authors / Name of Book / Publisher	Year of Publication
1	BhaskaraRao, B.K., "Modern Petroleum Refining Processes", 6thEd., Oxford& IBH Publishing Company Pvt. Ltd. New Delhi.	2018
2	Mall, I.D. Petrochemical Process Technology, 2nd Ed., Laxmi Publications Private Limited.	2017

1. Subject Code: 22CHP360 **Course Title: Process Equipment Design Lab**

2. Contact Hours: L: 0 T: 0 P: 2

3. Credits: 1 Semester: VI

4. Pre-requisite: Process Equipment Design.

5. Course Objective: To learn the design procedures of process equipment used in chemical process industries

6. Course Outcome:Upon completion of this course, the students will be able to:

i. Design shell and tube heat exchanger design
ii. Design distillation column
iii. Design packed bed, absorption column
iv. Design agitated vessels and evaporators

7. Details of Course:

Experiment No.	**Objectives**	**Contact Hours**
1	To study Aspen Plus manual and practice some simple flow sheeting problems. The objectives are: a. To know the various units available (reactor, distillation column, heat exchanger, etc.) b. To know how to connect the input and output ports of the units c. To carry out the flash calculation d. To add the components in the flowsheet	6
2	Material and energy balance calculations	3
3	To calculate the overall heat transfer coefficient of a shell and tube heat exchanger	3
4	To design a shell and tube heat exchanger using Kern's method	3
5	To design a shell and tube condenser	3
6	To design a thermosyphon reboiler	3
7	To design a plate heat exchanger	3
8	To carry out flash calculation manually and in Aspen Plus	3
9	To find number of theoretical plates graphically and in Aspen Plus	3
10	Cost estimation and profitability analysis	3

8. Books:

(A)Text Books

S. No.	Authors / Name of Book / Publisher	Year of Publication
1	Sinnott, R.K., "Coulson and Richardson's Chemical Engineering Design," 6th Ed., Butterworth-Heinemann	2021
2	McCabe, W. L., Smith, J. C. and Harriot, P., "Unit Operations of Chemical Engineering", 7th Ed., McGraw-Hill, NY.	2017
3	Ludwig, E.E., Applied Process Design for Chemical and Petrochemical Plants, Vol. 1, 2, and 3, 4th Ed., Gulf Professional Publishing.	2007

VII Semester:

S.No.	Course Code	Course Title	Category	Type	Credit	L	T	P
1.	22CHS403	Training Seminar	PC	Theory	2	0	0	4
2.	22CHW404	Minor Project	Project	Theory	3	0	0	6
4.		Program Elective-I	PE	Theory	3	3	0	0
5.		Program Elective-II	PE	Theory	4	3	1	0
		Program Elective-III	PE	Theory	3	3	0	0
6.		Open Elective-I	OE	Theory	3	3	0	0
Total					**18**	**12**	**1**	**10**

Program Elective-I		**Program Elective-II**	
22CHT925	Operation Research	22CHT922	CFD in Chemical Engineering
22CHT929	Solid & Hazard Waste Management	22CHT923	Mechanical Design of Process Equipment
22CHT924	Nano-materials & Characterization	22CHT921	Advanced Process Control
	Program Elective-III		
22CHT927	Polymer Science and Technology		
22CHT928	Process Integration		
22CHT926	Optimization of Chemical Processes		

SEMESTER – VII
Program Elective – I

1. Subject Code: 22CHT925 **Course Title: Operation Research**

2. Contact Hours: L: 3 T: 0 P: 0
3. Credits: 3 Semester: VII
4. Pre-requisite: Nil.
5. Objective: The Objective of the paper is to introduce the basic concepts of Operational Research and linear programming to the students.
6. Course Outcomes: Upon completion of this course, the students will be able to:
   i. Be able to understand the characteristics of different types of decision-making environments and the appropriate decision making approaches and tools to be used in each type.
   ii. Be able to build and solve Transportation Models and Assignment Models.
   iii. Be able to design new simple models, like: CPM, to improve decision-making and develop critical thinking and objective analysis of decision problems.
7. Details of Course:

Unit No.	Contents	Contact Hours
1.	**Introduction & Linear Programming Problem:** Nature and meaning of operations research, general methods for solving operations research problems, main characteristics of operations research in decision making, Role of computers in operations research. Formulation of LP problem, graphical solution of LP problem, general formulation of LP problem, slack and surplus problem, standard form of LP problem, matrix form of LP problem, some important definitions, assumptions in LPP, limitations of LP, Applications of LP.	8
2.	**Simplex Method:** Definition and notations, computational procedure, artificial variable technique- two phase method, Big-M method, disadvantages of Big M method over two phase method, degeneracy problem, method to resolve degeneracy, special cases- alternative solution, unbounded solutions, non-existing solution, solution of simultaneous equations by simplex method, flow chart of simplex method. **Duality in Linear Programming:** Concept of duality, primal-dual problems, rules for converting any primal problem into its dual, duality theorems, primal and dual correspondence, duality and simplex method, shadow prices in LP, advantages of duality. **Dual Simplex Method:** Computational procedure of dual simplex method, advantages of dual simplex over simplex method, different between simplex and dual simplex methods.	12
3.	**Assignment Problem:** Introduction, mathematical formulation of assignment problem, fundamental theorems, Hungarian method, unbalanced assignment problem, variations of assignment problem-	6

	maximal assignment problem, restriction on assignment, traveling salesman problem- formulation and solution procedure.	
4.	**Transportation Models:** Introduction, mathematical formulation, feasible, basic feasible and optimum solutions, tubular representation, loops in table, IBFS to transportation problem, moving towards optimum solution, degeneracy in transportation problem, unbalanced transportation problem, time minimizing transportation problem, transshipment problem.	6
5.	**Network Scheduling by PERT/CPM:** Introduction, Networks and basic components, Rules of network construction, Time calculations in networks, Critical Path Method (CPM), PERT, PERT calculations, Negative float and negative slack, Advantages of network.	8

8. Books:

(A) Text Books

S. No.	Authors / Name of Book / Publisher	Year of Publication
1	Operations Research, P K Gupta and D S Hira, S. Chand and Company LTD. Publications, New Delhi.	2007
2	Operations Research, An Introduction, Seventh Edition, Hamdy A. Taha, PHI Private Limited.	2006

(B) Reference Books

S. No.	Authors / Name of Book / Publisher	Year of Publication
1	Operations Research, Theory and Applications, Sixth Edition, J K Sharma, Trinity Press, Laxmi Publications Pvt. Ltd.	2016
2	Taha, H.A., “Operations Research, an introduction", 8th th edition, Prentice Hall.	2011
3	Rao, S.S., “Engineering Optimization: Theory and Practice,” 4th ed., New Age International, New Delhi.	2000

1. Subject Code: 22CHT929 **Course Title: Solid and Hazard Waste Management**

2. Contact Hours: L: 3 T: 0 P: 0

3. Credits: 3 Semester: VII

4. Pre-requisite: Nil.

5. Objective: Understanding the problems of municipal, biomedical, hazardous, electronic, and industrial wastes.

6. Course Outcomes: Upon completion of this course, the students will be able to:

   i. Carry out sampling and characterization of solid waste; analysis of hazardous waste constituents including QA/QC issues.
   ii. Understand health and environmental issues related to solid waste management.
   iii. Apply steps in solid waste management-waste reduction at source, collection techniques, materials and resource recovery/recycling, transport, optimization of solid waste transport, treatment and disposal techniques.
   iv. Economics of the onsite vs. offsite waste management options.

7. Details of Course:

Unit No.	Contents	Contact Hours
1.	Introduction of solid wastes including municipal, hospital, industrial, battery, electronics, and agro solid waste; legal issues and requirements for solid waste management and health and environmental issues related to solid waste management. Sampling and characterization of solid waste. Analysis of hazardous constituents in solid waste including QA/QC issues.	7
2.	Health and environmental issues related to solid waste management, Waste reduction at source - municipal and industrial wastes, Material and resource recovery/recycling from solid wastes.	8
3.	Methods of waste collection, collection techniques, waste container compatibility, waste storage requirements, transportation of solid wastes. Processing of solid waste: segregation, particle size reduction, autoclaving, microwaving, incineration, non-incineration thermal techniques, composting, bio-remediation, use of refuse derived fuels, land fill. Leachate treatment.	15
4.	Economics of on-site vs. off-site waste treatment and disposal (individual vs. common disposal). Waste minimization and concept of industrial ecology and industrial symbiosis, Integrated waste management practices.	10

8. Books:

(A) Text Books

S. No.	Authors / Name of Book / Publisher	Year of Publication
1	Batstone R., Smith J.E. (Jr.) and Wilson D. The Safe Disposal of Hazardous Wastes-the Special Needs and Problems of Developing Countries, The World Bank Technical Paper No. 93, Vol. I, II and III, Washington, DC, The World Bank.	1989
2	Central Public Health and Environmental Engineering Organization (CPHEEO), Manual on Municipal Solid Waste Management, New Delhi, Controller of Publications.	2000
3	Freeman H.M. Standard Handbook of Hazardous Waste Treatment and Disposal, New York, McGraw-Hill.	1988

(B) Reference Books

S. No.	Authors / Name of Book / Publisher	Year of Publication
1	Tchobanoglous G., Theisen H. and Vigil S. Integrated Solid Waste Management: Engineering Principles and Management Issues, New York, McGraw-Hill.	1993
2	Vesilind P.A., Worrell W.A. and Reinhart D.R. Solid Waste Engineering, Australia, CL Engineering.	2001

1. Subject Code: 22CHT924 **Course Title: Nano-materials & Characterization**

2. Contact Hours: L: 3 T: 0 P:0
3. Credits: 3 Semester: VII
4. Pre-requisite: Nil.
5. Objective: To study the concept of nanotechnology, and understand the fabrication, characterization, and applications of nano-materials
6. Course Outcomes: Upon completion of this course, the students will be able to:
   i. Understand the concept of nano-material synthesis.
   ii. Understand the various characterization techniques for the characterization of nano-materials.
7. Details of Course:

Unit No.	Contents	Contact Hours
1.	Introduction of the course with course handout; Definitions and Concepts: Nanoscience, Nanotechnology, Nanoparticles, Technology that enables science. Nano in nature, Current themes in nanoscale science and technology. Commercial applications of nanotechnology, Nano-based products, The social dimensions of nanotechnology. Introduction to physics of solid state, Size dependence of properties, Energy bands of insulators, conductor and semiconductor	4
2.	Non-traditional nano-fabrication: Top-down approach, Bottom-up approach, Classification of synthesis methods, Physical methods-Mechanical milling, Laser Ablation method. Physical vapour deposition-inert gas condensation, Evaporation (Thermal, e-beam), Sputtering, Plasma Arcing, chemical vapour deposition (RF-plasma enhanced CVD and Microwave plasma enhanced CVD).Liquid Phase synthesis, Co-precipitation, Chemical reduction method, Nucleation and growth, Role of capping/stabilizing agent and surfactant. Hydrothermal/solvothermal method, Crystal growth process, Factors affecting the growth, Apparatus, Synthesis and characterization of nanoparticles. Sol-Gel method, Mechanism of sol and gel formation, Synthesis of Xerogel and Aerogel. Si processing fabrication, Nanodevices, CMOS, MOSFET devices, Lithography techniques. Optical lithography, Electron lithography, X-ray lithography	7
3.	Crystalline and amorphous solid, Types of Crystalline solids, Lattice, Unit cell, Crystal system. Atomic arrangements in unit cells, crystal planes, X-ray diffract from crystal planes, Miller indices of crystal planes, Basics of diffraction. X-ray diffraction, Bragg's law, Diffraction pattern study, Application of XRD. Methods of measuring properties, Surface area analysis, BET method, Pore size study	5
4.	Quantum confinement, Quantum dots, Difference between bulk semiconductor, Thin film semiconductor, Quantum wire and quantum dots; Discrete energy levels. Fabrication of quantum dots, Patterned	7

	growth, Self-organized growth, Applications of quantum dots. Process of self-assembly , Semiconductor island, Monolayer formation. Carbon nanostructures, Nature of carbon bond, New carbon structures, Discovery of C_{60}. Structure of C_{60} and its crystal, Superconductivity of C_{60}, Fullerenes. Carbon nanotubes, Fabrication, Structure. Properties of carbon nanotubes, Electrical, vibrational and mechanical properties; Applications of carbon nanotubes.	
5.	Optical spectroscopy of nanostructures, Fundamentals of Raman Spectroscopy, Light scattering phenomenon, Types of scattering, Stokes Scattering, Anti-stokes Scattering, Raman vs. Rayleigh scattering, Mechanism of Raman and Rayleigh scattering, Raman vs. IR, Raman scattering spectrum and infrared absorption spectrum, Energy level diagrams, Polarizability, Dipole moment, Raman-active and Non-Raman-active Vibrations (III), Raman Depolarization Ratios, Raman ative and IR active, Study of Raman spectra, Infrared spectroscopy for nanostructures, FTIR, Asymmetric and non-asymmetric stretchings, Bending vibration mode, Library of FTIR spectra, Components of IR instruments, Data interpretation from IR spectrum	6
6.	Scanning probe microscopy, Fundamental of electron microscopy, Magnification and resolution, Light microscope, Wave-particle duality for electrons. Electron sources, source characteristics, source types, source characteristics, Physics of electron emission, operation of electron gun. Mechanism of electron-solid interaction, Transmission electron microscope, Components of TEM, TEM imaging, Sample preparation for TEM, Scanning electron microscopy, SEM vs TEM, Components of SEM. FE-SEM vs SEM, SEM imaging, Sample preparation, EDAX analysis, Interpretation of data from SEM and TEM images. Selected area electron diffraction, Indexing of diffraction pattern, Bravais-lattice and cell parameters, Revision of scanning probe microscopy	6

8. Books:

(A) Text Books

S. No.	**Authors / Name of Book / Publisher**	**Year of Publication**
1	C. P. Jr. Poole and F. J. Owens, Introduction to Nanotechnology, John Wiley.	2003
2	J. D. Plummer, M. D. Deal and P. B. Griffin, Silicon VLSI Technology, Prentice Hall.	2000
3	C. Kittel, Introduction to Solid State Physics-A Chapter about Nanotechnology, John Wiley.	2004

SEMESTER – VII
Program Elective – II

1. Subject Code: 22CHT922 **Course Title: CFD in Chemical Engineering**

2. Contact Hours: L: 3 T: 1 P: 0

3. Credits: 4 Semester: VII

4. Pre-requisite: Nil.

5. Course Objective: To provide brief introduction of Computational Fluid Dynamics along with chemical engineering application specifically, analysis of fluid mechanics and heat transfer related problems.

6. Course Outcomes:Upon completion of this course, the students will be able to:
   i. Solve PDE
   ii. Use Finite Difference and Finite Volume methods in CFD modelling
   iii. Generate and optimize the numerical mesh
   iv. Simulate simple CFD models and analyze its results

7. Details of Course:

Unit No.	Contents	Contact Hours
1.	**Introduction**: Illustration of the CFD approach, CFD as an engineering analysis tool, Review of governing equations, Modeling in engineering, Partial differential equations- Parabolic, Hyperbolic and Elliptic equation, CFD application in Chemical Engineering, CFD software packages and tools.	6
2.	**Principles of Solution of the Governing Equations:** Finite difference and Finite volume Methods, Convergence, Consistency, Error and Stability, Accuracy, Boundary conditions, CFD model formulation. **Mesh Generation**: Overview of mesh generation, Structured and Unstructured mesh, Guideline on mesh quality and design, Mesh refinement and adaptation.	12
3.	**Solution Algorithms**: Discretization schemes for pressure, momentum and energy equations - Explicit and implicit Schemes, First order upwind scheme, second order upwind scheme, pressure-velocity coupling algorithms, velocity-stream function approach, solution of Navier-Stokes equations. **CFD Solution Procedure:** Problem setup – creation of geometry, mesh generation, selection of physics and fluid properties, initialization, solution control and convergence monitoring, results reports and visualization.	12
4.	**Case Studies**: Benchmarking, validation, Simulation of CFD problems by use of general CFD software, Simulation of coupled heat, mass and momentum transfer problem.	10

8. Books:

(A) Text Books

S. No.	Authors / Name of Book / Publisher	Year of Publication
1	Niyogi, P. Chakrabarty, S.K. and Laha, M.K., "Introduction to computational fluid dynamics', Pearson education.	2006
2	Ranade, V.V., "Computational flow modeling for chemical reactor engineering", Academic Press.	2002
3	Muralidhar, K.,andSundararajan,T. "Computational Fluid Flow and Heat Transfer", Narosa Publishing. House	2003

(B) Reference Books

S. No.	Authors / Name of Book / Publisher	Year of Publication
1	P.S. Ghosdastidar, "Computer Simulation of Flow and Heat Transfer", Tata McGraw-Hill.	1998
2	Suhas V. Patankar. "Numerical Heat Transfer and Fluid Flow", Taylor and Francis.	2018
3	LI J., G. H. Yeoh, C Liu. "A Computational Fluid Dynamics", ELSEVER.	2008
4	Anderson J.D. "Computational Fluid Dynamics", Mc-Graw Hills.	1995
5	J H Ferziger and M Peric, "Computational Methods for Fluid Dynamics", Springer.	2002
6	ANSYS Manual.	

1. Subject Code: 22CHT923 Course Title: Mechanical Design of Process Equipment

2. Contact Hours: L:3 T:1 P:0

3. Credits: 4 Semester: VII

4. Pre-requisite: Nil.

5. Objective: To understand the mechanical design methods for various process equipment.

6. Course Outcomes: Upon completion of this course, the students will be able to:

i. Determine the parameters of equipment design and important steps involved in design.

ii. Students demonstrated ability to design various components of process equipment as heads, shell, flanges and fittings and supports and complete design of a chemical ·

iii. Design pressure vessels

iv. Students understood design of storage vessel, mechanical design of various process equipment such as heat exchanger, distillation column, piping, reactors, etc.

7. Details of Course:

Unit No.	Contents	Contact Hours
1.	**Design Preliminaries:** Introduction, General design procedure, Equipment classification, Design codes, Design considerations, Design pressure, Design temperature, Design stress, Factor of safety, Design wall thickness, Corrosion allowance, Weld joint efficiency factor, Design loadings, Stress concentration, Thermal stress and Criteria of failure.	6
2.	**Pressure Vessels:** Classification of pressure vessels; Design of cylindrical and spherical shells under internal and external pressure; Selection and design of closures; Optimum length to diameter ratio of pressure vessel using common types of closures; Design of jacketed portion of vessels; Selection and design of nozzles; Elementary idea of compensation for openings; Selection of gaskets; Selection and design of flanges; Pipe thickness calculation under internal and external pressure; Introduction to inspection and non-destructive testing; Complete design calculations and shop drawing for at least one pressure vessel using heads and flanges as per code specifications.	18
3.	**Tall Tower Design:** Design of shell, skirt, bearing plate and anchor bolts for tall tower used at high wind and seismic conditions. **Supports:** Design of lug support and saddle support including bearing plates and anchor bolts.	8
4.	**Storage Tanks:** Filling and breathing losses; Classification of storage tanks; Design of liquid and gas storage tanks. **Heat Exchange Equipment:** Mechanical design and drawing of heat exchangers. **Foundation and Supports:** Foundation and supports for equipment/vessels, tall towers.	8

8. Books:

(A) Text Books

S. No.	Authors / Name of Book / Publisher	Year of Publication
1	Bhattacharya, B. C., "Introduction to Chemical Equipment Design: Mechanical Aspects," CBS Pub., Delhi.	2017
2	Joshi, M. V. and Mahajani, V. V., "Process Equipment Design," 5th Ed., Macmillan, Delhi.	2016

(B) Reference Books

S. No.	Authors / Name of Book / Publisher	Year of Publication
1	Sinnott, R.K., "Coulson and Richardson's Chemical Engineering," Vol 1A, 7thEd., Butterworth Heinmann, New Delhi.	2017
2	Brownell, L. E. and Young, H. E., "Process Equipment Design," John Wiley.	2004
3	Dawande, S. D., "Process Design of Equipment," 6th Ed., Central Techno. Pub. Nagpur,	2012
4	IS: 2825-1969, "Code of Practice for Mechanical Design of Unfired Pressure Vessels".	
5	IS: 803-1962, "Code of Practice for Design, Fabrication and Erection of Mild Steel Cylindrical Welded Oil Storage Tanks".	
6	IS: 1239-1968, "Specification of Mild Steel Tubes".	
7	IS: 4503-1967, "Specifications for Shell and Tube Type Heat Exchanger".	
8	IS Code for Pipe Line.	
9	ASTM and ASME codes.	

1. Subject Code: 22CHT921 Course Title: Advanced Process Control

2. Contact Hours: L: 3 T: 1 P: 0

3. Credits: 4 Semester: VII

4. Pre-requisite: Nil.

5. Course Objective: Develop understanding about the advanced control methods such as multivariable control, digital control, artificial intelligence techniques used in process industries.

6. Course Outcomes: Upon completion of this course, the students will be able to:

i. Understand the multivariable control and interaction among control loops
ii. Understand and analyze the digital control systems
iii. Understand the process identification techniques and model predictive control
iv. Work in MATLAB and Simulink

7. Details of Course:

Unit No.	Contents	Contact Hours
1.	Review of conventional control systems. Ratio, selective and split range control, cascade control	8
2.	Design of feed-forward control systems; Adaptive and Inferential Control; multivariable control; Control loop interaction and design of decouplers;	8
3.	Discrete-time systems; Z-transforms; Stability analysis of discrete-time systems;	8
4.	Design of digital feedback controller; deadbeat and Dahlin's controllers; Ringing and placement of poles; Process Identification and Adaptive control.	8
5.	Model predictive control; Artificial neural network and Fuzzy logic control. LTI models in MATLAB and Simulink.	8

8. Books:

(A) Text Books

S.No.	Authors / Name of Book / Publisher	Year of Publication
1	Stephanopoulos, G., "Chemical Process Control", PHI, New Delhi.	2015

(B) Reference Books

S.No.	Authors / Name of Book / Publisher	Year of Publication
1	Coughanowr, D. R., LeBlanc, S.E., "Process Systems Analysis and Control", 3rd Ed., McGraw Hill.	2009
2	Bequette, B.W., "Process Control - Modeling, Design and Simulation," Pretice Hall	2003
3	Seborg, D.E., Edgar, T.F., Mellichamp, D.A., Doyle III, F.A., "Process Dynamics and Control," 4th Ed., Wiley.	2016
4	Astrom, K. J. and Wittenmark, B., "Computer Controlled Systems: Theory and Design", 3rd Ed., Prentice Hall.	2012

SEMESTER – VII
Program Elective – III

1. Subject Code: 22CHT927 **Course Title: Polymer Science and Technology**

2. Contact Hours: L: 3 T: 0 P: 0

3. Credits: 3 Semester: VII

4. Pre-requisite: Nil.

5. Objective: To understand various fundamental concepts of polymers and related phenomena.

6. Course Outcomes: Upon completion of this course, students will be able to:

i. Understand the basic concept of monomer, polymer and repeating units and their properties

ii. Understand the basic concepts of degree of polymerization

iii. Understand in detail about the chemistry of polymers and the possible chemical modification

iv. Understand the physical and chemical characterization of raw materials

7. Details of Course:

Unit No.	Contents	Contact Hours
1	**Chemistry of Polymerization Reactions:** Functionality, polymerization reactions, polycondensation, addition free radical and chain polymerization. Co-polymerisation, block and graft polymerizations, stereospecific polymerization.	12
2	**Polymerization Kinetics:** Kinetics of radical, chain and ionic polymerization and co-polymerization systems.	10
3	**Molecular Weight Estimation:** Average molecular weight: number average and weight average. Theoretical distributions, methods for the estimation of molecular weight.	6
4	**Polymerization Processes:** Bulk, solution, emulsion and suspension polymerization.Thermoplastic composites, fibre reinforcement fillers, surface treatment reinforced thermoset composites – Resins, Fibres, additives, fabrication methods.	6
5	**Rheology:** Simple Rheological response, simple linear viscoelastic models – Maxwell, Voigt, material response time, temperature dependence of viscosity, Rheological studies.	6

8. Books:

(A) Text Books

S. No.	Authors / Name of Book / Publisher	Year of Publication
1.	Billmayer, F.W., JR., “Textbook of Polymer Science”, John Wiley and Sons.	1994
2.	Fried, J. R., “Polymer Science and Technology”, PHI.	2005

(B) Reference Books

S. No.	Authors / Name of Book / Publisher	Year of Publication
1.	Schmidt, A. K. and Marlies, G. A., “High Polymers - Theory and Practice”, McGraw Hill.	1948
2.	McKelvey, J. M., “Polymer Processing,” John Wiley.	1962
3.	Rodringuez, “Principles of Polymer Systems”, Tata McGraw Hill.	1970

1. Subject Code: 22CHT928 **Course Title: Process Integration**

2. Contact Hours: L: 3 T: 0 P: 0

3. Credits: 3 Semester: VII

4. Pre-requisite: Nil.

5. Course Objective: To understand the energy and mass targets in design of processes.

6. Course Outcomes: Upon completion of this course, the students will be able to:

i. Understand of the fundamentals of process integration.
ii. Perform pinch analysis.
iii. Analyze and design heat exchanger networks.
iv. Minimize the water consumption and waste generation.

7. Details of Course:

Unit No.	Contents	Contact Hours
1.	**Introduction:** Process integration, Role of thermodynamics in process design, Concept of pinch technology and its application.	6
2.	**Heat Exchanger Networks:** Heat exchanger networks analysis**,** Simple design for maximum energy recovery, Loop Breaking & Path Relaxation, Targeting of energy, area, number of units and cost, Trading off energy against capital.	16
3.	**Network Integration:** Super targeting, maximum energy recovery (MER), Network for multiple utilities and multiple pinches, Grand Composite curve (GCC).	8
4.	**Mass Integration:** Distillation sequences. **Heat and Power Integration:** Columns, Evaporators, Dryers, and reactors. **Case studies:** Waste and wastewater minimization, Flue gas emission targeting.	10

8. Books:

(A) Text Books

S. No.	Authors / Name of Book / Publisher	Year of Publication
1	Linnhoff, D.W., User Guide on Process Integration for the Efficient Use of Energy, Institution of Chemical Engineers.	1994
2	Smith, R., Chemical Process Design and Integration, John Wiley &Sons.	2005

(B) Reference Books

S. No.	Authors / Name of Book / Publisher	Year of Publication
1	Shenoy, V. U., Heat Exchanger network synthesis, Gulf Publishing.	1995
2	Kumar, A., Chemical Process Synthesis and Engineering Design, Vol. Tata McGraw Hill.	1982

1. Subject Code: 22CHT926 **Course Title: Optimization of Chemical Processes**

2. Contact Hours: L:3 T:0 P:0

3. Credits: 3 Semester: VII

4. Pre-requisite: Nil.

5. Course Objective: To study and apply optimization techniques in the chemical process industry.

6. Course Outcomes: Upon completion of this course, the students will be able to:

i. Formulate the objective functions for constrained and unconstrained optimization problems
ii. Use different optimization strategies
iii. Use of different optimization techniques for problem solving
iv. Solve transportation problems

7. Course Details:

Unit No	**Contents**	**Contact Hours**
1.	Problem formulation for the optimization, Basic concept ofoptimization. **Unconstrained Single Variable Optimization:** Newton, Quasi-Newton methods, polynomial approximation methods.	8
2.	**Unconstrained Multivariable Optimization**: Direct search method, conjugate search method, steepest descent method, conjugate gradient method, Newton's method	8
3.	**Linear Programming:** Formulation of LP problem, graphicalsolution of LP problem, simplex method, duality in LinearProgramming, two-phase method.	8
4.	**Non-linear Programming with Constraints:** Necessary and sufficiency conditions for a local extremum, Quadratic programming, Successive linear programming, successive quadratic programming, Penalty and Barrier method, Generalized reduced gradient (GRG) method. Genetic Algorithm, MILP.	8
5.	**Introduction to Transportation Problems**, Solving Various types of Transportation Problems, Assignment Problems, Project Management, Critical Path Analysis, PERT. Applications of optimization in Chemical Engineering.	8

8. **Books:**

(A) Text Books

S.No.	**Authors / Name of Book / Publisher**	**Year of Publication**
1	Edgar, T.F., Himmelblau, D. M., Lasdon, L. S., "Optimization of Chemical Process", 2nd Ed., McGraw-Hill.	2001
2	Rao, S. S., "Optimisation Techniques", Wiley Eastern, New Delhi.	1985

(B) Reference Books

S.No.	**Authors / Name of Book / Publisher**	**Year of Publication**
1	Godfrey, C.O. and Babu, B.V., "New Optimization Techniques in Engineering", Springer-Verlag, Germany.	2004
2	Beveridge, G. S. and Schechter, R. S., "Optimization Theory and Practice", McGraw- Hill, New York.	1970
3	Reklaitis, G.V., Ravindran, A. and Ragsdell, K. M., "Engineering Optimization- Methods and Applications", John Wiley, New York.	1983
4	Taha, S.M., "Operations Research, an introduction", 6th Ed., Prentice Hall.	1997

VIII Semester:

S. No.	Course Code	Course Title	Category	Type	Credit	L	T	P
1.	22CHW453	Major Project OR In Lieu of the Major Project any two courses offered in the Program Electives – IV, V OR VI to be opted	Project	Practical/ Theory	6 OR 6	0 6	0 0	12 0
2.		Program Elective-IV	PE	Theory	3	3	0	0
3.		Program Elective-V	PE	Theory	3	3	0	0
4.		Program Elective-VI	PE	Theory	3	3	0	0
5.		Open Elective - II	OE	Theory	3	3	0	0
Total					**18**	**12/ 18**	**0**	**12/ 0**

Program Elective-IV		**Program Elective-V**	
22CHT934	Hydrogen and Fuel Cell Technology	22CHT933	Data Science for Chemical Engineers
22CHT938	Waste to Energy Technologies	22CHT937	Process Piping and Design
22CHT931	Advanced Separation Processes	22CHT936	Process Modeling and Simulation

Program Elective-VI	
22CHT932	Bio-Process Engineering
22CHT930	Advanced Mass Transfer
22CHT935	Polymer Process Modeling

SEMESTER – VIII
Program Elective – IV

1. Subject Code: 22CHT934 **Course Title: Hydrogen & Fuel Cell Technology**

2. Contact Hours: L: 3 T: 0 P: 0

3. Credits: 3 Semester: VIII

4. Pre-requisite: Nil.

5. Course Objective: To gain insight about hydrogen energy, fuel cells, their working principle, types of fuel cells and performance analysis.

6. Course Outcome:Upon completion of this course, the students will be able to:
   i. Gain knowledge on fuel cell working principle, types of fuel cell, voltage loss and it reason
   ii. Understand the role of fluid dynamics, reaction kinetics and mass transfer principles in fuel cell operation. Stacking of fuel cell and fuel processing for fuel cell

7. Details of Course:

Unit No.	Contents	Contact Hours
1	**Introduction to hydrogen energy systems**: Current scenario of hydrogen production, general introduction to infrastructure requirement for hydrogen production, dispensing and utilization.	**2**
2	**Hydrogen production pathways:** *Thermal*: Steam reformation, Thermo chemical water splitting, Gasification, Pyrolysis and Partial oxidation methods. *Electrochemical*: Electrolysis, Photo-electro chemical. *Biological*: Anaerobic Digestion, Fermentative Micro-organisms **Hydrogen Storage**: General storage methods, compressed storage, Zeolites, Metal hydride storage, chemical hydride storage and cryogenic storage. **Hydrogen Utilization:** Overview of hydrogen utilization, I.C. Engines, gas turbines, hydrogen burners, power plant, refineries, domestic, marine applications, fuel cell.	**10**
3	**Introduction to Fuel Cell**: A simple fuel cell, fuel cell advantages, fuel cell disadvantages, fuel cell types basic fuel cell operation, fuel cell performance characterization and modeling, fuel cell technology, fuel cells and the environment.	2
4	**Fuel Cell Thermodynamics:** Thermodynamics review, Heat potential of a fuel: enthalpy of reaction, Work potential of a fuel: Gibbs Free Energy, Predicting eversible voltage of a fuel cell under non-Standard-state conditions, fuel cell efficiency, Thermal and Mass balances in fuel cells, Thermodynamics of reversible fuel cells	4
5	**Fuel Cell Reaction Kinetics:** Introduction to electrode kinetics, activation energy of charge transfer reactions, activation energy determines reaction rate, net rate of a reaction calculation, rate of reaction at equilibrium: exchange current density, potential of a reaction at equilibrium: Galvani potential, potential and rate: Butler–	10

	Volmer equation, exchange currents and electrocatalysis: Improving kinetic performance, simplified activation kinetics: Tafel equation. **Fuel Cell Charge Transport:** Charges move in response to forces, charge transport results in a voltage loss, characteristics of fuel cell charge transport resistance, physical meaning of conductivity, review of fuel cell electrolyte classes.	
6	**Fuel Cell Mass Transport:** Transport in electrode versus flow structure, transport in electrode: diffusive transport, transport in flow Structures: convective transport. **Overview of Fuel Cell Types:** introduction, phosphoric acid fuel cell, polymer electrolyte membrane fuel cell, alkaline fuel cell, molten carbonate fuel cell, solid-oxide fuel cell, other fuel cells	4
7	**Overview of Fuel Cell Systems:** Fuel cell subsystem, thermal management subsystem, fuel delivery/processing subsystem, power electronics subsystem, case study of fuel cell system design: stationary combined heat and power systems. **Fuel Processing Subsystem Design:** Fuel reforming overview, water gas shift reactors, carbon monoxide clean-up, reformer and processor efficiency losses, reactor design for fuel reformers and processors.	6

8. Books:

(A) Text Books

S.No.	Authors / Name of Book / Publisher	Year of Publication
1	Fuel Cell Fundamentals (3rd Ed.) by O'Hayre, Ryan/ Colella, Whitney/ Cha, Suk-Won. Wiley Publications.	2016

(B) Reference Books

S.No.	Authors / Name of Book / Publisher	Year of Publication
1	James Larminie and Andrew Dicks,Fuel Cell Systems Explained, 2ndEd., John Wiley & Sons Inc.	2000
2	Supramaniam Srinivasan, Fuel Cells: From Fundamentals to Applications, Springer.	2010
3	FranoBarbir,PEM Fuel Cells Theory and Practice, Elsevier Academic Press.	2005

1. Subject Code: 22CHT 938 **Course Title: Waste to Energy Technologies**

2. Contact Hours: L: 3 T: 0 P: 0

3. Credits: 3 Semester: VIII

4. Pre-requisite: Nil.

5. Course Objective: To provide knowledge about conversion of waste in to useful energy.

6. Course Outcomes:Upon completion of this course, the students will be able to:

i. Apply the knowledge about the operations of Waste to Energy Plants
ii. Learn about the best available technologies for waste to energy
iii. Analyse the various aspects of Waste to Energy Management Systems

7. Details of Course:

Unit No.	Contents	Contact Hours
1.	**Introduction**: Introduction to energy from waste, characterization and classificationof wastes, availability of agro based, forest, industrial, municipal solid waste in India,proximate& ultimate analyses, heating value determination of solid, liquid and gaseous fuels. **Densification:** Densification of agro and forest wastes, technological options, combustion characteristics of densified fuels, usage in boilers, brick kilns and lime kilns.	8
2.	**Waste to Energy Through Thermal Routes:** Incineration, pyrolysis and gasification and hydro-thermal liquefaction. Reactors, co-processing ofvarious types of wastes, downstream applications of products, hydrogen production,storage and utilization, gas cleanup.	8
3.	**Waste to energy through biochemical routes:** Municipal and industrial wastewater rand their energy potential, anaerobic reactor configuration for fuel gas productionfrom wastewater and sludge. Separation of methane and compression. Concept ofmicrobial fuel cells, gas generation and collection in landfills, bio-hydrogenproduction through fermentation, composting of solid wastes.	8
4.	**Waste to energy through chemical routes:** Production of bio diesel from discardedoils through trans-esterification, characterization of biodiesel, usage in CI engineswith and without retrofitting, algal biodiesel.	8
5.	**Waste Bio-refinery:** Types of bio-refineries, case studies, and concepts of Life Cycle Assessment and Techno-economical analysis.	8

8. Books:

(A) Text Books

S.No.	Authors / Name of Book / Publisher	Year of Publication
1	Rogoff, M.J. and Screve, F., "Waste-to-Energy: Technologies and Project Implementation", 2nd Ed., Elsevier Store.	2011
2	Young G.C., "Municipal Solid Waste to Energy Conversion processes", John Wiley and Sons.	2010
3	Mondal, P. and Dalai, A., " Utilization of natural resources", CRC Press	2017

(B) Reference Books

S.No.	Authors / Name of Book / Publisher	Year of Publication
1	Harker, J.H. and Backhusrt, J.R., "Fuel and Energy", Academic Press Inc.	1981
2	EL-Halwagi, M.M., "Biogas Technology- Transfer and Diffusion", ElsevierApplied Science.	1986
3	Hall, D.O. and Overeed, R.P.," Biomass - Renewable Energy", John Willy andSons.	2007

1. Subject Code: 22CHT 931 **Course Title: Advanced Separation Processes**

2. Contact Hours: L: 3 T: 0 P: 0

3. Credits: 3 Semester: VIII

4. Pre-requisite: Nil.

5. Objective: To learn concept and design aspects of advanced separation techniques.

6. Course Outcomes: Upon completion of this course, the students will be able to:

i. Choose a suitable separation technique for separation of product mixture
ii. Understated the concept of membrane based separation technique
iii. Understand the fundamental of ion exchange and other advanced separation techniques

7. Details of Course:

Unit No.	Contents	Contact Hours
1.	Introduction: Separation process in chemical and Biochemical Industries, Categorization of separation processes, equilibrium and rate governed processes.	4
2.	Membrane based Separation Technique (MBSTs): Historical background, physical and chemical properties of membranes, Techniques of membrane preparation, membrane characterization, various types of membranes and modules. Osmosis and osmotic pressure. Working principle, operation and design of Reverse osmosis, Ultrafiltration, Microfiltration, Nano-filtration, Electrodialysis and Pervaporation. Gas separation by membranes and liquid membranes.	14
3.	Ion Exchange: History, basic principle and mechanism of separation, Ion exchange resins, regeneration and exchange capacity. Exchange equilibrium, affinity, selectivity and kinetics of ion exchange. Design of ion exchange systems and their uses in the removal of ionic impurities from effluents.	10
4.	Reactive distillation, supercritical fluid extraction, and chromatographic separation. Pressure & temperature swing adsorption.	12

8. Books:

(A) Text Books

S. No.	Authors / Name of Book / Publisher	Year of Publication
1.	Marcel Mulder, Basic Principles of Membrane Technology, 2^{nd} Ed., Springer	1996
2.	B K Dutta, Principles of Mass Transfer and Separation Processes, PHI Learning.	2007

(B) Reference Books

S. No.	Authors / Name of Book / Publisher	Year of Publication
1.	Henry, J. D. and Li, N. N., "New Separation Techniques", AIChE Today Series, AIChE.	1975
2.	Hatton, T. A., Scamehorn, J. F. and Harvell, J. H., "Surfactant Based Separation Processes", Vol. 23, Surfactant Science Series, Marcel Dekker Inc., New York.	1989
3.	McHugh, M. A. and Krukonis, V. J., 'Supercritical Fluid Extraction", Butterworths, Boston.	1985
4.	King, C.J., "Separation Processes", Tata McGraw-Hill.	1982
5.	Sourirajan, S. and Matsura, T., "Reverse Osmosis and Ultra-filtration - Process Principles," NRC Publications, Ottawa.	1985
6.	Porter, M. C., "Handbook of Industrial MembraneTechnology," Noyes Publication, New Jersey.	1990

SEMESTER – VIII
Program Elective – V

1. Subject Code: 22CHT 933 Course Title: Data Science for Chemical Engineers

2. Contact Hours: L: 3 T:0 P: 0

3. Credits: 3 Semester: VIII

4. Pre-requisite: Nil

5. Course Objective: The objective of this course is to provide an understanding for the graduate student on various data science concepts, Design of experiments and optimization along with nonlinear regression.

6. Course Outcomes: Upon completing this course, the student will able to:

i. Learn the fundamental of Measures of central tendencies, measures of dispersion and perform Test of Hypothesis as well as calculate confidence interval for a population parameter for single sample and two sample cases. Understand the concept of p-values

ii. Learn non-parametric test such as the Chi-Square test for Independence as well as Goodness of Fit

iii. Compute and interpret the results of Bivariate and Multivariate Regression and Correlation Analysis, for forecasting and also perform ANOVA and F-test

iv. Develop the forecasted non-linear model using various design of experiments techniques comprising interaction effects and optimization using optimizers

7. Details of Course:

Unit No.	Contents	Contact Hours
1.	Elementary concept of statistics: Measures of Central Tendencies, Dispersion, Skewness, Kurtosis moments, uses and Limitation of moments, Theory of Probability.	8
2.	Probability Distribution: Discrete Distribution (Binomial and Poison Distribution), Continuous Distribution (Exponential Distribution and Gamma Distribution), Normal Distribution, Lidenberg-Levy Theorem	8
3.	Correlation and Regression: Pearson Product Moment Correlation, Spearman Rank Correlation coefficient, Tetrachoric, Phi coefficient, Biserial, point biserial, Partial Correlation, Linear and Non Linear Regression Models, Residual Analysis.	8
4.	Sampling Distribution: Hypothesis testing, significance tests, type I and II error, student t-test, Chi square test, analysis of variance (ANOVA).	8
5.	Design of experiments and optimization: Response Surface Methodology, Robust Design, Full Factorial Design, Static and dynamic optimization, Sequential Simplex Method, Pontryagin's maximum principle.	8

8. Books:

(A) Text Books

S. No.	Authors / Name of Book / Publisher	Year of Publication
1	Holman, J.P."Experimental Methods for Engineers", 8thEd., McGraw-Hill, Singapore.	2011
2	Himmelblau, D.M., "Process Analysis by Statistical Analysis," John Wiley and Sons.	1970
3	Montgomery, D.C., "Design and Analysis of Experiments," 10thEd., John Wiley and Sons.	2019
4	Feller, W., "An Introductionto Probability Theory," Vols. 1 and 2, 3rdEd., John Wiley and Sons.	2008

(B) Reference Books

S. No.	Authors / Name of Book / Publisher	Year of Publication
1	Box, G.E.P., Hunter, W.G., and Hunter, J.S., "Statistics for Experimenters," 2ndEd., John Wiley and Sons.	2005
2	Draper, N.R. and Smith, H., "Applied Regression Analysis", Volume 1, 3rdEd., Wiley.	1998

1. Subject Code: 22CHT937 **Course Title: Process Piping and Design**

2. Contact Hours: L: 3 T: 0 P: 0

3. Credits: 3 Semester: VIII

4. Pre-requisite: Nil.

5. Objectives: To provide a comprehensive understanding of the principles of process piping design.

6. Course outcome: Upon completion of this course, the students will be able to:

   i. Understand the concept of fluid flow in the pipe.
   ii. Get a basic knowledge of the design pressure considerations, stress analysis, and sizing of the piping system.
   iii. Design a complete piping system, including piping, pumping, and energy requirements for different processes as well as utilities.

7. Details of the course

Unit No.	**Contents**	**Contact Hours**
1.	Introduction to various codes (IS, BS, ASME, etc.) used in chemical process industries and utilities. Introduction to pipe schedules, Piping Material classification and specifications for Carbon Steel Piping classes, Alloy Steel Piping classes, Stainless Steel Piping classes, and Non-Metallic Piping classes. New materials for liquid and gaseous transportation.	8
2.	Newtonian and Non-Newtonian fluid flow through process pipes, Shear stress, Shear rates behaviour, apparent viscosity, and its shear dependence, Power law index, Yield Stress in fluids, Time-dependent behaviour, Thixotropic and Rheopectic behaviour, mechanical analogues, velocity pressure relationships for fluids.	7
3.	Pressure drops for the flow of Newtonian and non-Newtonian fluids through pipes, effect of Reynolds, and apparent Reynolds number.	7
4.	Pipes of circular and non-circular cross-section velocity distribution average velocity and volumetric rate of flow. Flow through curved pipes (Variable cross sections). Effects of pipe fittings on pressure losses. Pipes for sudden expansion and contraction effects, pipe surface roughness effects, pipe bends, and shearing characteristics.	7
5.	Pipeline design and power losses incompressible fluid flow, Multiphase flow, gas-liquid, solid-fluid, flow in vertical and horizontal pipelines, Lockhart-Martinelli relations, and flow pattern regimes. Plant design and piping layouts.	12

8. **Books:**

(A) Text Books

S. No.	**Authors / Name of Book / Publisher**	**Year of Publication**
1	Coulson, J.M. and Richardson, J.F., "Chemical Engineering," Vol. I and VI, Butterworth Heinemann.	1999
2	Govier, G.W. and Aziz K., "The Flow of Complex Mixtures in Pipe," 2nd Ed., Society of Petroleum Engineers.	2021

(B) Reference Books

S. No.	**Authors / Name of Book / Publisher**	**Year of Publication**
1	Green D.W. and Southard M. Z., "Perry's, Chemical Engineers Handbook,"9th Ed., McGraw Hill, New York.	2018
2	Chhabra R. P., Richardson J.F., "Non-Newtonian Flow and Applied Rheology: Engineering Applications," 2ndEd., Elsevier Science.	2011
3	ASME 31.3 Process Piping Petroleum Refinery	2013

1. Subject Code: 22CHT936 Course Title: Process Modeling and Simulation

2. Contact Hours: L:3 T:0 P:0
3. Credits: 3 Semester: VIII
4. Pre-requisite: Nil.
5. Objective: To study the modeling & simulation techniques of chemical processes and to gain skills in using process simulators.
6. Course Outcomes: Upon completion of this course, the students will be able to:
   i. Analyze physical and chemical phenomena involved in various process
   ii. Develop mathematical models for various chemical processes
   iii. Understood several mathematical techniques to solve and various simulation approaches
   iv. Learned the artificial intelligence based modelling
7. Details of Course:

Unit No.	Contents	Contact Hours
1.	**Introduction and Fundamentals of Process Modelling and Simulation:** industrial usage of process modelling and simulation; Classification of models, Model building, Modelling difficulties, Degree-of-freedom analysis, Selection of design variables, Macroscopic mass, energy and momentum balances; incorporation of fluid thermodynamics, chemical equilibrium, reaction kinetics and feed/ product property estimation in mathematical models. Review of numerical techniques for solving steady state and unsteady state models.	12
2.	**Model Development and Simulation of Steady State:** Lumped models of chemical process equipment like reactors, distillation, absorption, extraction columns, evaporators, and heat exchangers etc. Unsteady state lumped systems and dynamic simulation; Computer algorithms for numerical solution of steady state and unsteady state models. Microscopic balances for steady state and dynamic simulation; process modeling with dispersion; axial mixing; diffusion, etc.	16
3.	**Simulation Approach**: Sequential modular approach, Equation oriented approach, Partitioning and tearing, Use of process simulation software (Aspen Plus/ Aspen Hysys) for flow sheet simulation.	6
4.	Introduction to application of artificial intelligence based modeling methods using Artificial Neural Networks, Fuzzy logic, etc.	6

8. Books:

(A) Text Books

S. No.	Authors / Name of Book / Publisher	Year of Publication
1	Luyben, W. L., “Process Modeling, Simulation and Control for Chemical Engineers,” McGraw Hill.	1998
2	Himmelblau, D. M., & Bischoff, K. B., “Process analysis and simulation: Deterministic systems,” John Wiley, New York.	1968
3	Ramirez, W.F., “Computational Methods for Process Simulation,” 2^{nd}Ed., Butterworth-Heinemann.	1997

(B) Reference Books

S. No.	Authors / Name of Book / Publisher	Year of Publication
1	Ingham, J., Dunn, I. J., Heinzle, E., Prenosil, J.E., Snape, J.B., “Chemical Engineering Dynamics: An Introduction to Modelling and Computer Simulation,” 3^{rd}Ed., Wiley-VCH Verlag GmbH.	2007
2	Denn, M. M., Process Modeling, Longman Sc& Tech.	1987
3	Holland, C. D., “Fundamentals and Modeling of Separation Processes”, Prentice Hall.	1975
4	Aris, R. and Varma, A. (Editors), “The Mathematical Understanding of Chemical Engineering Systems: Selected Papers of N. R. Amundson,” Pergamon Press.	1980
5	Babu, B.V., “Process Plant Simulation,” Oxford University Press.	2004

SEMESTER – VIII
Program Elective – VI

1. Subject Code: 22CHT932 **Course Title: Bioprocess Engineering**

2. Contact Hours: L:3 T:0 P:0

3. Credits: 3 Semester: VIII

4. Pre-requisite: Nil.

5. Objective: To impart the knowledge of enzyme kinetics, cell growth and application of the same for the production of biochemical products and biological wastewater treatment techniques.

6. Course Outcome: Upon completion of this course, the students will be able to:

i. Understand the role of chemical engineers in bioprocess industries.

ii. Understand concept of Enzyme and its working, cell growth kinetics and inhibition kinetics

iii. Design of downstream equipment for product separation

iv. Design of bioreactor/ fermenter

7. Details of Course:

Unit No.	Contents	Contact Hours
1.	**Introduction:** Interaction of chemical engineering principles with biological sciences. Life processes, unit of living system, microbiology, reaction in living systems, Chemicals of Life.	12
2.	**Biocatalysts:**Enzyme Kinetics, Mechanism and Inhibition models, Immobilized Enzymes-Methods, Kinetics and diffusion limitations	8
3.	**Fermentation:**Fermentation mechanisms and kinetics. **Cell Growth-** kinetic models of microbial growth and product formation, Stoichiometry of cell growth. Fermenter types; Modeling of batch and continuous fermentor. Bioreactor design, mixing phenomena in bioreactors.	12
4.	**Sterilization:** Sterilization of media and air, sterilization equipment, batch and continuous sterilize design.	2
5.	**Overview of Separation and Purification Techniques:** Biochemical product recovery and separation. Membrane separation process: reverse osmosis, dialysis, ultrafiltration; Chromatographic methods: adsorption chromatography, gel filtration, affinity chromatography etc. Electro-kinetic separation: electro-dialysis, electrophoresis.	6

8. Books:

(A) Text Books

S.No.	Authors / Name of Book / Publisher	Year of Publication
1	Shuler, M.L. and Kargi, "Bioprocess Engineering Basic Concepts," 2nd Ed., Prentice Hall of India, New Delhi,	2001

(B) Reference Books

S.No.	Authors / Name of Book / Publisher	Year of Publication
1	Bailey &Ollis, Biochemical Engg. Fundamentals, 2nd Ed. McGraw Hill.	2007
2	Dubey R.C., "A Textbook of Biotechnology", 5th Ed. S. Chand and Co., New Delhi.	2014
3	Schugerl, K. and Bellgardt, K. V., Bioreaction Engineering: Modeling and Control, Springer Verlag, Heidelberg.	2011
4	Doran P., Bioprocess Engineering Principles, 2nd Ed. Academic Press, NewYork.	2012
5	Blanch H. W. and Clark D. S., Biochemical Engineering, 2nd Ed. Dekker, NewYork.	1997
6	Aiba, S., Humphrey, J. Biochemical Engineering, Academic Press.	1973

1. Subject Code: 22CHT 930 **Course Title: Advanced Mass Transfer**

2. Contact Hours: L: 3 T: 0 P: 0

3. Credits: 3 Semester: VIII

4. Pre-requisite: Nil.

5.Course Objective: To understand the principles and operation of advanced separation processes.

6. Course Outcome:Upon completion of this course, the students will be able to:

i. Solve problems related to binary and multi-component distillation.
ii. Use of operational and design aspects of enhanced distillation processes.
iii. Use the concepts of membrane separation techniques for industrial separations.
iv. Exposure to other new separation techniques - surfactant based, supercritical fluid extraction and bio-filtration.

7. Details of Course:

Unit No.	Contents	Contact Hours
1.	**Mass Transfer with Reactions:** Steady and unsteady state	7
2.	**Multi-component Multistage Distillation:** Approximate methods, Equilibrium-based methods, Rate based models for Distillation, Pseudo-components based distillation.	7
3.	**Enhanced Distillation:**Azeotropic and extractive distillation, Salt distillation, Reactive distillation, Thermally coupled distillation, Dividing wall distillation, and Cryogenic distillation.	7
4.	**Membrane Separation:** Synthesis and characterization of membranes, Transport processes in membrane, Modeling of reverse osmosis (RO), Ultrafiltration (UF) and gas separation. Pervaporation through non-porous membranes, Dialysis and electro-dialysis and hybrid membrane processes.	7
5.	**Surfactant Based Separation Processes:** Concept, modeling, design aspects and applications of Supercritical Fluid Extraction and Bio-filtration.	6

8. Books:

(A) Text Books

S.No.	Authors / Name of Book / Publisher	Year of Publication
1	Seader, J.D., and Henley, E.J., Separation Process Principles, 4^{th}Ed., John Wiley.	2016
2	Holland, C.D., Fundamentals of Multicomponent Distllation, McGraw-Hill.	1982

(B) Reference Books

S.No.	Authors / Name of Book / Publisher	Year of Publication
1	Sherwood, T.K., Pigford, R.L., and Wilkes, C.R., Mass Transfer, McGraw Hill.	1975

1. Subject Code: 22CHT 935 **Course Title: Polymer Process Modeling**

2. Contact Hours: L:3 T:0 P:0
3. Credits: 3 Semester: VIII
4. Pre-requisite: Nil.
5. Objective: To learn variety of polymer flow process and advanced transport mechanism.
6. Course Outcomes: Upon completion of this course, the students will be able to:
   i. Understand the concept of advanced transport phenomena for the case of polymers
   ii. Develop and solve complex mathematical model based on fluid mechanics, heat transfer and mass transfer.
   iii. Develop the ability to create analytical solution of polymer processing flow problems based on Poiseuille flow and counter flow and calculation for extrusion, calendaring, coating, injection molding, and mixing etc.
   iv. Develop the ability of applying shell elemental balances and learn by simplifying the offending complexity of partial differential equation.
   v. Understand and incorporation of rheological study in the model.
7. Details of Course:

Unit No.	Contents	Contact Hours
1.	Classification of Polymer Processing Operations. Simple Model Flows: Poiseuille flow and couette flow for analyzing processing operations with examples.	8
2.	Flow down a Rectangular Channel and Application to analysis of wire coating and failure of this model	8
3.	**Extrusion and Extruders:** Newtonian Isothermal Analysis, variable channel depth, adiabatic analysis, optimal design, non-Newtonian isothermal analysis, non-Newtonian adiabatic analysis, Twin screw extruder, Banbury and other mixing equipment in polymer processing.	9
4.	**Calendering:** Newtonian model of calendaring, power law model, calendar fed with a finite sheet, thermoforming, rotational molding	8
5.	Roller and Blade Coating, Film Blowing. Fiber spinning injection molding, blow molding. Compression and transfer molding. Reaction injection molding.	7

8. Books:

(A) Text Books

S. No.	Authors / Name of Book / Publisher	Year of Publication
1	Middleman, S., "Fundamentals of Polymer Processing," McGraw-Hill Book Company, NY.	1977
2	Morrison, F.A., “Understanding Rheology,” Oxford University Press.	2001

(B) Reference Books

S. No.	Authors / Name of Book / Publisher	Year of Publication
1	Tadmor, Z. and Gogos C.G., “Principles of Polymer Processing,” Wiley- Interscience, New York.	1979