Chemical and Biochemical Engineering Department					
Sl. No	**Old**	**New**	**Name of Course**	**L-T-P-C**	**(UG/PG)**
1	CL 101	CL101T	Introduction to Chemical Engineering	3-0-0-6	UG
2	CL 201	CL301T	Introduction to Transport Phenomena	3-0-0-6	UG
3	CL 202	CL201T	Reaction engineering	3-0-0-6	UG
4	CL 203	CL202T	Mass transfer	3-0-0-6	UG
5	CL 211	CL201L	Chemical Engineering lab -1) Thermodynamics and Fluid mechanics	0-0-3-3	UG
6	CL 213	CL302L	Chemical Engineering Lab III Mass Transfer and reaction engineering	0-0-3-3	UG
7	CL 212	CL301L	Chemical Engineering Lab II (Heat transfer and Solid mechanics)	0-0-3-3	UG
8	CL 301	CL302T	Process Equipment Design and Economics	3-0-0-6	UG
9	CL 302	CL401T	Safety in Chemical Industry	3-1-0-6	UG
10	CL 401	CL402T	Chemical Reaction Engineering-II	3-0-0-6	UG
11	CL 402	CL403T	Advanced Transport phenomena	3-0-0-6	UG
12	CL 403	CL404T	Process plant utilities	3-1-0-6	UG
13	CL 404	CL303T	Colloid and Interfacial Engineering	3-1-0-6	UG
14	CL 204	CL203T	Introduction to Chemical Engineering Thermodynamics	3-0-0-6	UG
15	CL 801	CL601T	Advanced Chemical Engineering Thermodynamics	3-0-0-6	PG
16	CL 802	CL603T	Computational Techniques for Multiphase Flows (CTMF)	2-1-0-6	PG
17	CL 803	CL602T	Advanced separation processes	3-0-0-6	PG
18	CL 601	CL601S	Seminar	0-0-4-4	PG
19	CL 304	CL405T	Bioprocess Engineering	3-0-0-6	UG
20	CL 205	CL305T	Mechanical Operations	3-0-0-6	UG
21	CL 405	CL304T	Applications of Mass Transfer	3-0-0-6	UG
22	CL 303	CL401S	Scientific presentation	3-0-0-3	UG
23		CL204T	Fluid Mechanics and Mechanical Operations	2-1-0-6	UG
24		CL306T	AI in Chemical Engineering	1-2-0-6	UG
25		CL205T	Heat Transfer for Chemical Engineers	3-0-0-6	UG

26		CL206T	Materials Science for Chemical Engineers	3-0-0-6	UG
27		CL301C	Numerical Methods in Chemical Engineering	2-0-2-6	UG
28		CL307T	Process Dynamics and Control	2-1-0-6	UG
29		CL308T	Advanced Chemical Reaction Engineering	2-1-0-6	UG
30		CL604T	Fundamentals of Microfluidics	3-0-0-6	UG
31		CL605T	Molecular Simulations in Chemical and Biochemical Engineering	2-1-0-6	UG/PG
32		CL309T	Chemical Process Technology	3-0-0-6	UG
33		CL606T	Principles and Applications of Electrochemistry	3-0-0-6	UG/PG
34		CL303L	Chemical Engineering Lab IV (Process Control)		
35		CL607T	Introduction to Battery Technology	3-0-0-6	UG/PG
36		CL608T	Fuel Cell Technology	3-0-0-6	UG/PG
37		CL609T	Introduction to Nanoscience and Nanotechnology	3-0-0-6	UG/PG
38		CL610T	Sustainability and Green Technologies in Chemical Engineering	3-0-0-6	
39		CL611T	Process Modelling and Simulation	3-0-0-6	

1	**Title of the course** (L-T-P-C)	**Introduction to Chemical Engineering (3-0-0-6)**
2	**Pre-requisite courses(s)**	NIL
3	**Course content**	Historical overview of Chemical Engineering: Concepts of unit operations and unit processes, and more recent developments, Features of organized chemical processing- from chemistry to chemical engineering. The Chemical Industry-scope, features & characteristics. and scope. Principles of balancing with examples to illustrate differential and integral balances, lumped and distributed balances. Material balances in simple systems involving physical changes and chemical reactions; systems involving recycle, purge. and bypass. Properties of substances: single component & multicomponent, single and multiphase systems. Use of Compressibility charts, vapour pressure correlations/charts & Psychometric charts. Ideal liquid and gaseous mixtures. Energy balance calculations in simple systems. Introduction to Computer aided calculations-steady state material and energy balances.
4	**Texts/References**	1. R. M. Felder and R.W. Rousseau, Elementary Principles of Chemical Processes, 3rd ed., John Wiley, New York, 2004. 2. D. M. Himmelblau and J. B. Riggs, Basic Principles and Calculations in Chemical Engineering. 7th ed., Prentice Hall, 2003. 3. B. I. Bhatt and S. M. Vora, Stoichiometry. 4th ed., McGraw Hill, 2004.

1	**Title of the course** (L-T-P-C)	**Introduction to Transport Phenomena** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Nil
3	**Course content**	Introduction: Vectors/Tensors, Viscosity, Shell balance: Falling film, Circular tube; Equations of Change for isothermal systems: Continuity, Motion, Energy, Substantial derivatives; Unidirectional flows: Pipe flow, Variable viscosity falling film, Couette viscometer, Rotating Sphere; Unsteady flows: Startup Plate flow, Parallel plates, Oscillating plate; Thermal conductivity and mechanism of energy transport; Shell energy balances and temperature distributions in solids and laminar flow; The equations of change for nonisothermal systems; Diffusivity and the mechanisms of mass transport; Concentration distributions in solids and laminar flow; Equations of change for multicomponent systems; Introduction to the concept of heat and mass transfer coefficients.
4	**Texts/References**	1. R.B.Bird, W.E. Stewart and E.N. Lightfoot, Transport Phenomena, 2nd ed., Wiley, 2006

1	**Title of the course** (L-T-P-C)	**Reaction engineering** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Nil
3	**Course content**	Kinetics Reaction rate, order, rate constant; Batch reactors Design + basics; Kinetic constants from batch reactor data; Ideal flow reactors Mass and Energy balances; Isothermal, adiabatic and non-isothermal operation; Catalysts, Catalytic rates, Reaction mechanisms; Internal/External transport in catalysts; Non-catalytic solid-gas reactions; Reactor design for ideal flow reactors; Yield and Selectivity; Concept of RTD; Segregation and Maximum Mixedness models
4	**Texts/References**	1. H.S.Fogler, Elements of Chemical Reaction Engineering, 2nd ed., Prentice Hall, New Jersey, 1992. 2. 2. O.Levenspiel, Chemical Reaction Engineering, 2nd ed., Wiley Eastern,1992 3. 3. J.M.Smith, Chemical Engineering Kinetics, 3rd ed., McGraw Hill, 1980.

1	**Title of the course** (L-T-P-C)	**Mass transfer** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	NIL
3	**Course content**	Principles of Mass transfer: Constitutive laws of diffusion; unsteady state diffusion; Convective mass transfer. Interphase mass transfer and mass transfer coefficients; Mass transfer theories/models; Equilibrium stages and transfer units: number and height of transfer units; stage efficiency. Gas absorption: plate and packed column design. Distillation: batch distillation, continuous fractionation, other types of distillation (e.g., azeotropic), solvent extraction, drying, cooling towers.
4	**Texts/References**	1. R.E.Treybal, Mass Transfer Operations, 3rd Edition, McGraw Hill, New Delhi, 1983. 2. E.D. Cussler, Di usion - Mass Transfer in Fluid Systems, Cambridge University Press, Cambridge 1984. 3. A. S. Foust, Principles of Unit Operations, 2nd Edition, Wiley, New York, 1980. 4. C.J. Geankoplis, Transport Processes and Unit Operations, 3rd Edition, Prentice Hall, India, 1993.

1	**Title of the course** (L-T-P-C)	**Chemical Engineering Lab II (Heat transfer and Solid mechanics) (0-0-3-3)**
2	**Pre-requisite courses(s)**	--
3	**Course content**	Heat Transfer: Experimental on Conduction, convection, radiation, heat exchanger, thin-metal foil technique Solid mechanics: Tensile and compression testing of materials, impact, torsion, hardness, thick and thin pressure vessels, strain gauges.
4	**Texts/References**	--

1	**Title of the course** (L-T-P-C)	**Chemical Engineering lab -1 (Thermodynamics and fluid mechanics) (0-0-3-3)**
2	**Pre-requisite courses(s)**	--
3	**Course content**	Thermoynamics: Determination of partial molar enthalpies, vapour pressures, infinite dilution activity coefficient, vapour-liquid equilibrium, adiabatic calorimetry. Fluid mechanics: Flow visualization, Flow rate, velocity and pressure measurements, calibration of flow-meters, flow-through pipes and piping elements including Bernouli's principle, Impact of fluid-jets on substrates.
4	**Texts/References**	

1	**Title of the course** (L-T-P-C)	**Chemical Engineering Lab III (mass transfer and reaction engineering) (0-0-3-3)**
2	**Pre-requisite courses(s)**	--
3	**Course content**	*Mass transfer*: Experiments on hydrodynamics of a packed column, Differential distillation, drying, Cooling tower, gas liquid absorption *Reaction engineering*: Experiments on esterification kinetics, Batch reactive distillation, mi-cellar catalysis, homogeneous reaction, metal recovery from dilute solutions, reaction in CSTR, reaction in PFR
4	**Texts/References**	

1	**Title of the course** (L-T-P-C)	**Process Equipment Design and Economics** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Nil
3	**Course content**	Mechanical design of process equipment: pressure vessels, tall columns, etc., process piping design; Materials and Fabrication Selection; Design Strategy and Optimum Equipment Design: Economic Design criteria; Cost and Asset Accounting; Cost Estimation; Interest and Investment Costs; Taxes and Insurance; Depreciation; Profitability, Alternative Investments and Replacement; Illustrative Case Study in Process Equipment Design and Costing of Equipment in each of the following categories: Material Transfer, Handling and Treatment Equipment Heat Transfer Equipment: Shell and tube heat exchangers (Kern and Bell-Delaware design methods), Plate heat exchangers, Evaporators Mass Transfer Equipment: Absorption/ Stripping columns (packed/tray), Multicomponent distallation colum (FenskeUnderwood-Gilliland correlations) Reactors: choice of reactors, non-isothermal reactors, reactor.
4	**Texts/References**	1.R.E.Treybal, Mass Transfer Operations, 3rd Edition, McGraw Hill, New Delhi, 1983. 2.E.D. Cussler, Di usion - Mass Transfer in Fluid Systems, Cambridge University Press, Cambridge 1984. 3.A. S. Foust, Principles of Unit Operations, 2nd Edition, Wiley, New York, 1980. 4.C.J. Geankoplis, Transport Processes and Unit Operations, 3rd Edition, Prentice Hall, India, 1993.

1	**Title of the course** (L-T-P-C)	**Safety in Chemical Industry** **(3-1-0-6)**
2	**Pre-requisite courses(s)**	None
3	**Course content**	Concepts and definition, safety culture, Storage of dangerous materials. Plant layout. Safety systems. Technology and process selection. Scale of disaster. Vapour Cloud Explosions. Control of toxic chemicals. Runway reactions. Relief Systems. Risk and hazard management. Safety versus production. Risk assessment and analysis. Hazard models and risk data. Identification, minimisation and analysis of hazard. Tackling disasters. Plan for emergency. Risk management routines. Emergency shut down systems. Human element in the design of safety.
4	**Texts/References**	F.P. Lees, Loss Prevention in Process Industries, Vol. 1 and 2, Butterworth, 1983. R.W. King and J. Magid, Industrial Hazards and Safety Handbook, Butterworth, 1982. A. Khulman, Introduction to Safety Science, TUV Rheinland, 1986. W.E. Baker, Explosion Hazards and Evaluation, Elsevier, Amsterdam, 1983. O.P. Kharbanda and E.A. Stallworthy, Management of Disasters and How to Prevent them, Grower, 1986.

1	**Title of the course** (L-T-P-C)	**Chemical Reaction Engineering-II** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Reaction Engineering
3	**Course content**	Multiphase reactors (Gas-Liquid; Liquid-Liquid); Yield, Selectivity, Reactor Design for Multiple Reactions; Models of Industrial Reactors: Pressure Drop considerations, Heat management, non-isothermal reactors, Steady State multiplicity; Residence Time Distribution: Theory; Evaluation from Tracer Experiments; Non-Ideal Reactor Modelling: Use of RTD; Zero, One and Two Parameter Models; Compartment Modelling; Applications: Polymerisation; Combustion; Biochemical Reactions; Multi- functional Reactors; Stochastic approaches to kinetics.
4	**Texts/References**	1. H.S. Fogler, Elements of Chemical Reaction Engineering, Prentice Hall, 2nd ed., New Jersey, 1992. 2. O. Levenspiel, Chemical Reaction Engineering, Wiley Eastern, 2nd ed., 1972. 3. J.M. Smith, Chemical Engineering Kinetics, 3rd ed., McGraw Hill, 1980.

1	**Title of the course** (L-T-P-C)	**Advanced Transport phenomena** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Reaction Engineering
3	**Course content**	Introduction: Review of Transport Equations, Scaling and Ordering analysis, Asymptotic solutions. Exact solutions: Pul-satile flow in circular tube, Creeping flows and streamfunction solutions. Motion of deformable and slender bodies: Condi-tions at an deformable interface, Creeping flow past a drop, Marangoni E ects, Flows past Sphere and Oblate Solid bodies, Slender-Body Theory. Asymptotic Approximations for simple flows: Pulsatile flow limiting cases, Motion of fluid through curved tube, Bubble growth in Quiescent fluid. Thin films and Lubrication: Eccentric Couette cylinder, Lubrication theory, Slider block, Cylinder and Plane. Convective Heat and Mass transfer: Heat transfer from sphere ($Pe \ll 1$) in uniform and shear flow, Low Re expansion for $Pe \ll 1$, $Pe \gg 1$ for low Re, Mass transfer from a Drop Laminar Boundary layer Theory: Review of Boundary Layer Equations and Solution, Boundary layer separation, Approximate method to estimate shear stresses, Spherical bubble, Limiting cases of Thermal boundary layers. Natural convection: Boussinesq Equations, Combined forced and free convection, The Raleigh-Benard Problem.
4	**Texts/References**	L. G. Leal, Laminar Flow and Convective Transport Processes, Butterworth-Heinemann, 1992.

1	**Title of the course** (L-T-P-C)	**Process plant utilities** **(3-1-0-6)**
2	**Pre-requisite courses(s)**	None
3	**Course content**	Fuel as a source of energy; Conventional and unconventional sources of energy; Properties and classification of coal: Types and properties of liquid and gaseous fuels: Combustion calculations; Steam as a surce of energy; Steam generation: Guidelines for efficient use of steam: Water treatment and recycling.
4	**Texts/References**	S.Sarkar. "Fuels and Combustion". 2nd Edition. Orient Longmans, Bombay. 1990.

1	**Title of the course** (L-T-P-C)	**Colloid and Interfacial Engineering (3-1-0-6)**
2	**Pre-requisite courses(s)**	None
3	**Course content**	Phenomenology of colloidal materials, Brownian diffusion. Long range van der Waals forces. Double layer forces and short range forces, DLVO theory of stability of lyphobic colloids. Electrokinetic phenomena. Association Colloids. Interfacial tension. Wetting and contact angle. Capillary hydrostatics. Interfacial science in Detergents. Personal Products, Pharmaceutical. Food. Textile. Paint and Petroleum Industries**.**
4	**Texts/References**	P.C.Hiemenz and R.Rajgopalan. "Principles of Colliod and Surface Chemistry", 3rd ed., Dekkar, 1997. C.A.Miller and P.Neogi. "Interfacial Phenomena: Equilibrium and Dynamic Effects", Dekker, 1985. V.G.Levich, "physicochemical Hydrodynamics", Prentice Hall Inc., 1962. R.J.Hunter, "Foundations of Colloid Science", Vols. I & II, Oxford Science Publications, 1989. D.A.Edwards, H.Brenner and D.T.Wasan, "Interfacial Trasport Processes and Rheology", Butterworth, Heinmen, 1991.

1	**Title of the course** (L-T-P-C)	**Thermodynamics for chemical engineers (3-0-0-6)**
2	**Pre-requisite courses(s)**	Nil
3	**Course content**	Thermodynamics introduction and basic definitions; Importance of PVT relation and equation of state; First law of thermodynamics, applications and limitations; Second law of thermodynamics and its applications; Irreversibility and availability; Thermodynamic potentials & property relations; Thermodynamic property estimation for ideal gas, real gas, and multicomponent mixtures; Solution thermodynamics: ideal and real solutions and the concept of excess properties; Phase equilibrium including vapor-liquid, liquid-liquid, and solid-liquid equilibrium; Chemical reaction equilibrium.
4	**Texts/References**	i) Y V C Rao; "Chemical Engineering Thermodynamics" ii) Stanley I. Sandler "Chemical, Biochemical, and Engineering Thermodynamics 4th Edition" iii) J.M. Smith, H.C. Van Ness, M.M. Abott, M.T. Swihart “Introduction to Chemical Engineering Thermodynamics 8th Edition"

1	**Title of the course** (L-T-P-C)	**Introduction to Chemical Engineering Thermodynamics (3-0-0-6)**
2	**Pre-requisite courses(s)**	Nil
3	**Course content**	Thermodynamics introduction and basic definitions; Importance of PVT relation and equation of state; First law of thermodynamics, applications and limitations; Second law of thermodynamics and its applications; Irreversibility and availability; Thermodynamic potentials & property relations; Thermodynamic property estimation for ideal gas, real gas, and multicomponent mixtures; Solution thermodynamics: ideal and real solutions and the concept of excess properties; Phase equilibrium including vapor-liquid, liquid-liquid, and solid-liquid equilibrium; Chemical reaction equilibrium
4	**Texts/References**	i) Y V C Rao; "Chemical Engineering Thermodynamics" ii) Stanley I. Sandler "Chemical, Biochemical, and Engineering Thermodynamics 4th Edition" iii) J.M. Smith, H.C. Van Ness, M.M. Abott, M.T. Swihart "Introduction to Chemical Engineering Thermodynamics 8th Edition"

1	**Title of the course** (L-T-P-C)	**Advanced Chemical Engineering Thermodynamics (3-0-0-6)**
2	**Pre-requisite courses(s)**	Nil
3	**Course content**	Review of classical thermodynamics (1st and 2nd law, Thermodynamic functions, Maxwell`s relations, Equations of State for gases, Theory of corresponding states, Phase rule, Mixtures, Gibbs-Duhem relation), Classical mechanics and quantum mechanics, Canonical, Microcanonical and Grand Canonical ensemble, Boltzmann, Fermi-dirac and Bose Einstein statistics, Fluctuations, Monoatomic and Diatomic Gases, Introduction to Classical Statistical Mechanics, Phase space, Liouville equation, Crystals, Intermolecular forces and potential energy functions, imperfect monoatomic Gases, Molecular theory of corresponding states, Introduction to molecular simulations, Mixtures, Partial molar properties, Gibbs-Duhem equations, Fugacity and Activity coefficients, Ideal and Non-ideal solutions, Molecular theories of activity coefficients, Lattice models, Multiphase multicomponent phase equilibrium, VLE/SLE/LLE/VLLE, Chemical equilibrium and combined phase and reaction equilibria.
4	**Texts/References**	i) Y V C Rao, "Chemical Engineering Thermodynamics", Universities Press,1997. ii) Stanley I. Sandler; "Chemical, Biochemical, and Engineering Thermodynamics 5th Edition", Wiley, 2017. iii) J.M. Smith, H.C. Van Ness, M.M. Abott,, M.T. Swihart, "Introduction to Chemical Engineering Thermodynamics 9th Edition", McGraw-Hill, 2019. iv) McQuarrie D.A, "Statistical Mechanics", Viva Books Private Limited, 2018. v) Hill Terrel, An Introduction to Statistical Thermodynamics, Dover, 1960. vi) Allen MP, Tildesley DJ, Computer simulation of liquids, Oxford, 1989. vii) Callen, HB. Thermodynamics and an Introduction to Thermodstatics, 2ndEdition, John Wiley and Sons, 1985. viii) Prausnitz, J.M., Lichtenthaler R.M. and Azevedo, E.G., Molecular thermodynamics of fluid-phase Equilibria (3rd edition), Prentice Hall Inc., New Jersey,1996.

1	**Title of the course** (L-T-P-C)	**Computational Techniques for Multiphase Flows (CTMF)** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Nil
3	**Course content**	The Computational Techniques for Multiphase Flows course can be highly beneficial for UG and PG students, especially those pursuing studies in engineering, physics, or applied mathematics. The course provides an in-depth understanding of the fundamental principles of multiphase flow phenomena. This includes the various types of multiphase flows, their characteristics, and the challenges involved in modelling and simulating them. UG and PG students can learn how to apply these techniques to solve real-world multiphase flow problems. I. Introduction to Multiphase Flows: Basics of Multiphase Flows and Classifications; Characteristics of Multiphase Flows; Applications of Multiphase Flows. Revisit of Governing Equations for Multiphase Flows: Conservation Equations, Mass Conservation; Momentum Conservation; Energy Conservation II. Multiphase Flow Simulation Techniques: Introduction to interphase capturingmethods; Volume of Fluid (VOF) method; Surface tension modeling; Interfacereconstruction and advection schemes; Static and dynamic contact angles; Level Set (LS) method; Coupled Level-Set and Volume of Fluid(CLSVOF). III. Eulerian–Eulerian and Eulerian-Lagrangian models; Kinetic Theory of Granular Flows (KTGF); Restitution and Specularity Coefficients; Drag models for multiphase systems; Two-Fluid Model (TFM); Mixture model; Eulerian-Lagrangian Two-Fluid Model framework. IV. Demonstration and Hands-on simulations: Modelling of multiphase problemsusing commercial or open-source software such as packed bed and fluidizedbed reactors; Gas-liquid bubble column and gas–liquid–solid three-phase bubble column (i.e., slurry bubble column); Droplet and bubbly flows; Sediment transport in pipelines and bends. V. Case Studies and Projects: Real-world examples of multiphase flow problemsand recent research articles on two-phase and three-phase flows i.e., gas- particle and liquid-particle flows; Free surface flows
4	**Texts/References**	1. Yeoh, Guan Heng, and Jiyuan Tu. Computational techniques for multiphase flows. Butterworth-Heinemann, 2019. 2. Tryggvason, Grétar, Ruben Scardovelli, and Stéphane Zaleski. Direct numerical simulations of gas–liquid multiphase flows. Cambridge university press, 2011. 3. Crowe, Clayton T., et al. Multiphase flows with droplets and particles. CRC press, 2011. 4. Anderson, John David, and John Wendt. Computational fluid dynamics. Vol. 206. New York: McGraw-Hill, 1995. 5. Versteeg, Henk Kaarle, and Weeratunge Malalasekera. An introduction to computational fluid dynamics: the finite volume method. Pearson education, 2007. 6. Ranade, Vivek V. Computational flow modeling for chemical reactor engineering. Vol. 5. Academic press, 2002.

1	**Title of the course** (L-T-P-C)	**Advanced separation processes** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	CL203, ME301 (Heat and Mass Transfer) or equivalent
3	**Course content**	Review of conventional processes and recent advances in separation process, analyse the thermodynamics, advanced mass transfer and diffusion theories underpinning the multi-component separation processes. Membranes: adsorption, permeation, Pervaporation, Dialysis and Electrodialysis, Reverse Osmosis, Ultrafiltration, Microfiltration. Apply conceptual procedures for the design of next generation separation devices, combine the simulation tools and analysis methods to determine the energy efficiency, cost-effectiveness and sustainability of design solutions.
4	**Texts/References**	**Textbooks:** 1. Rousseau, R. W. (1987), Handbook of Separation Process Technology, John Wiley & Sons. 2. Humphrey, J. L. and Keller, G. E., (1997), Separation Process Technology, McGraw- Hill, NY. 3. Norman, N, Li, Anthony G. Fane, Winston Ho, W. S., Matsuura. T. (2008), Advanced Membrane Technology and Applications, Wiley. **Reference Books:** 1. Kister, H. Z., (1992), Distillation Design, McGraw-Hill. 2. Ernest J. H., Seader J. D., D. Keith Roper (2011), Separation Process Principles, 3rd Edition Wiley. 3. Taylor, R., Krishna, R. (1993), Multicomponent Mass Transfer, John Wiley & Sons. 4. Swain A., Patra H., Roy G. K. (2010) Mechanical Operations, McGraw Hill Education.

1	**Title of the course** (L-T-P-C)	**Bioprocess Engineering** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Nil
3	**Course content**	**Introduction to Bioprocess Engineering:** Introduction to bioprocess engineering: Traditional and modern bioprocess engineering overview, integrated bioprocess, upstream and downstream operations, process flow sheets; Material balance and energy balance for different systems; thermodynamic efficiency of growth, Enzyme technology - Enzyme kinetics, immobilization, and industrial production. **Fermentation Processes:** Fermentation processes: Outline, overview & types, design, parameters & construction of fermenter and ancillaries; Application in the biotechnology industry; Kinetic models for microbial growth; Behavior of microbes in different reactors; Requirements for fermentation processes and optimization techniques (Plackett-Burman Design). **Separation Technology:** Solids removal operations - settling, centrifugation and filtration; Product isolation - adsorption and extraction; Purification techniques - precipitation, ultrafiltration, chromatography and electrophoresis; Product polishing operations - crystallization and drying; Integrated bio-reaction and bio-separation processes: Membrane bioreactors, extractive fermentation. **Bioprocess Engineering and Industry:** Environmental biotechnology - wastewater engineering, bioremediation; Bioprocess instrumentation; Biological systems for the production of commercial goods and services.
4	**Texts/References**	1. Michael L. Shuler and Fikret Kargi. Bioprocess Engineering: Basic Concepts.Prentice Hall, third edition, 2002. 2. Michael L. Shuler, Fikret Kargi, Matthew DeLisa. Bioprocess Engineering: Systems, Equipment, and Facilities. Prentice Hall, second edition, 2017. 3. Roger G. Harrison, Paul W. Todd, Scott R. Rudge. Bioseparations Scienceand Engineering. Oxford University Press, second edition, 2015. 4. Carl-Johan Franzén and Christian Larsson. Bioreactors: Design, Operation and Novel Applications. CRC Press, first edition, 2016.

1	**Title of the course** (L-T-P-C)	**Mechanical Operations** **(3-0-0-3)**
2	**Pre-requisite courses(s)**	Nil
3	**Course content**	Principles of crushing and grinding, Laws of crushing and grinding. Determination of mean particle size, Size distribution equations. Characteristics of industrial crushers and mills. Industrial screening, effectiveness of screens, cyclones. Fluid-particle mechanics, free and hindered settling. Industrial classifiers, clarifiers and thickeners, gravity separation, tabling and jigging. Floatation and its kinetics. Mixing of liquids and solids, power requirement in mixing. Principles of filtration, filtration equipment. Introduction to storage and conveying.
4	**Texts/References**	1. W. L. McCabe, J. C. Smith and P. Harriott. Unit Operations of Chemical Engineering, seventh edition., Mc-Graw Hill, 2005 2. J. M. Coulson, J. F. Richardson, J. R. Backhurst and J. H. Harker. Chemical Engineering, Vol-2, fifth edition., Elsevier, 2015

1	**Title of the course** (L-T-P-C)	**Applications of Mass Transfer** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	CL 203 (Mass Trasfer)
3	**Course content**	**Liquid-Liquid Extraction**: Liquid equilibria, single-stage and multi-stage extraction, Fractional extraction, emulsions, and dispersions. **Cooling tower:** saturated and unsaturated vapor-gas mixtures, Air-watersystem, gas-liquid contact operations, adiabatic, non-adiabatic operations. **Adsorption**: Types of adsorptions, Adsorption Equilibria, Heat of adsorption, adsorption operations, single stage and multistage operations, Ion exchange. **Drying:** Drying Operations, Batch drying and mechanisms, continuous drying **Leaching:** Steady and unsteady state operation, methods of calculations, stage efficiency, single and multi-stage leaching
4	**Texts/References**	1. R.E.Treybal, Mass Transfer Operations, 3rd Edition, McGraw Hill, New Delhi,1983. 2. E.D. Cussler, Diffusion - Mass Transfer in Fluid Systems, Cambridge UniversityPress, Cambridge 1984. 3. A. S. Foust, Principles of Unit Operations, 2nd Edition, Wiley, New York, 1980. 4. C.J. Geankoplis, Transport Processes and Unit Operations, 3rd Edition, Prentice Hall, India, 1993.

1	**Title of the course** (L-T-P-C)	**Fluid Mechanics and Mechanical Operations** **2-1-0-6**
2	**Pre-requisite courses(s)**	--
3	**Course content**	Introduction of fluid mechanics, Fluid statics, surface tension, Newtonian and non-Newtonian fluids, transport properties, shell balances including differential form of Bernoulli equation and energy balance, equation of continuity, equation of motion, equation of mechanical energy, Macroscopic friction factors, dimensional analysis and similitude, Internal incompressible viscous flow in pipes and channels , fully developed laminar, Elementary boundary layer theory, multiple pipe flow systems and turbulent flow. Flow past immersed bodies including packed and fluidized beds, turbulent flow: fluctuating velocity, universal velocity profile and pressure drop. Transportation and metering of fluids, pump types, pump characteristics curves, Net Positive Suction Head (NPSH), Pump Priming and Cavitation, blowers and compressors, direct flow measurement (pitot tube, rotameter, orifice meter etc., indirect methods and commercial flow meters; Mixing and Agitation, power consumption, impeller types and flow patterns, mixing times. Particle size and shape, particle size distribution, size reduction and classification of solid particles; free and hindered settling; centrifuge and cyclones; thickening and classification, filtration, agitation and mixing; conveying of solids.
4	**Texts/References**	**1.** F.M. White, Fluid Mechanics, 8th Edition, Tata McGraw Hill Education, 2016. **2.** Fox, R. W., McDonald, A. T., & Mitchell, J. W., Fox and McDonald's Introduction to Fluid Mechanics, 10th Edition, Wiley, 2020. **3.** McCabe, W. L., Smith, J. C., & Harriott, P., Unit Operations of Chemical Engineering, 7th Edition, McGraw-Hill, 2004. **4.** Çengel, Y. A., & Cimbala, J. M., Fluid Mechanics: Fundamentals and Applications, 5th Edition, McGraw-Hill, 2024. **5.** Richardson, J. F., Harker, J. H., & Backhurst, J. R., Coulson and Richardson's Chemical Engineering: Volume 2 – Particle Technology and Separation Processes, 5th Edition, Butterworth-Heinemann, 2002.

1	**Title of the course** (L-T-P-C)	**Bioprocess Engineering** **3-0-0-6**
2	**Pre-requisite courses(s)**	--
3	**Course content**	**Introduction to Bioprocess Engineering:** Introduction to bioprocess engineering: Traditional and modern bioprocess engineering overview, integrated bioprocess, upstream and downstream operations, process flow sheets; Material balance and energy balance for different systems. thermodynamic efficiency of growth, Enzyme technology - Enzyme kinetics, immobilization, and industrial production. **Fermentation Processes: Fermentation processes:** Outline, overview & types, design, parameters & construction of fermenter and ancillaries; Application in the biotechnology industry; Kinetic models for microbial growth; Behavior of microbes in different reactors; Requirements for fermentation processes and optimization techniques (Plackett-Burman Design). **Separation Technology:** Solids removal operations - settling, centrifugation and filtration; Product isolation - adsorption and extraction; Purification techniques - precipitation, ultrafiltration, chromatography and electrophoresis. Product polishing operations - crystallization and drying; Integrated bio-reaction and bio-separation processes: Membrane bioreactors, extractive fermentation. **Bioprocess Engineering and Industry:** Environmental biotechnology - wastewater engineering, bioremediation; Bioprocess instrumentation. Biological systems to produce commercial goods and services.
4	**Texts/References**	**1.** Michael L. Shuler and Fikret Kargi. Bioprocess Engineering: Basic Concepts. Prentice Hall, third edition, 2002. **2.** Michael L. Shuler, Fikret Kargi, Matthew DeLisa. Bioprocess Engineering: Systems, Equipment, and Facilities. Prentice Hall, second edition, 2017. **3.** Roger G. Harrison, Paul W. Todd, Scott R. Rudge. Bio separations Science and Engineering. Oxford University Press, second edition, 2015. **4.** Carl-Johan Franzén and Christian Larsson. Bioreactors: Design, Operation and Novel Applications. CRC Press, first edition, 2016.

1	**Title of the course** (L-T-P-C)	**AI in Chemical Engineering** **1-2-0-6**
2	**Pre-requisite courses(s)**	CS101-Programming Languages, CS209- Artificial Intelligence, CS214- Artificial Intelligence Lab
3	**Course content**	**PART 1:** Programming Languages, Machine Learning Models, Software and Tools Overview of MATLAB and python, Different machine and deep learning models, concept of hybrid modeling, Overview of Pytorch, Keras, TensorFlow, Jupyter Notebook, and Google Colab **PART 2:** Databases and Codes Open-source databases and codes, strategy for creating customized database from scratch, different file formats, overview of tools for database/descriptor generation, strategies for data cleaning and refinement **PART 3:** Case Studies Thermophysical property prediction: aqueous solubility, liquid viscosity, polymer melting point and glass transition temperature, vapor liquid equilibrium (VLE) Catalyst and electrolyte design: reaction yield prediction, optimization of catalyst property, battery electrolyte optimization Chemical process optimization: process flow sheet synthesis, optimization of reactor performance, tuning of PID controller Applications in Biology: Drug discovery- new molecule generation, binding affinity, and molecular toxicity prediction_Protein modeling and engineering- prediction of protein 3D structure, prediction of thermostabilizing mutations
4	**Texts/References**	**1.** José A. Romagnoli, Luis Briceño-Mena, Vidhyadhar Manee, "AI in Chemical Engineering: Unlocking the Power Within Data", 1st Edition, CRC Press, 2025, ISBN 9781032597003 **2.** Bharath Ramsundar, Peter Eastman, Pat Walters, and Vijay Pande. "Deep Learning for the Life Sciences", O'Reilly Media, Inc., 2019, ISBN: 9781492039839 **3.** Edgar I. S. Medina, Ehecatl A. D. R. Chanona, and Caroline Ganzer. "Machine Learning in Chemical Engineering (v1.0.0)", 2023, Zenodo. https://doi.org/10.5281/zenodo.7986905 **4.** Fiammetta Caccaval, Carina L. Gargalo, Krist V. Gernaey, and Ulrich Krühne. "SPyCE: A structured and tailored series of Python **5.** courses for (bio)chemical engineers", 2023, https://doi.org/10.1016/j.ece.2023.08.003 **6.** Thomas E. Quantrille, and Y. A. Liu. "Artificial Intelligence in Chemical Engineering" Academic Press Inc, 1992, ISBN:9780125695503.

1	**Title of the course** (L-T-P-C)	**Heat Transfer for Chemical Engineers** **3-0-0-6**
2	**Pre-requisite courses(s)**	--
3	**Course content**	**Introduction:** Overview of heat transfer and its significance, difference between thermodynamics and heat transfer, basic modes of heat transfer **Conduction:,** Fourier's law, thermal conductivity, steady-state heat conduction through a plane, composite wall, cylinder, sphere, heat generation inside solids, unsteady-state heat conduction, types of thermal insulation, critical thickness and optimum thickness of insulation, extended surfaces, fin performance evaluation, effectiveness of fins. **Convection:** Free and forced convection inside and outside the tubes as well as over the plates, individual and overall heat transfer coefficients. Heat transfer in laminar flow and turbulent flow, dimensional analysis, dimensionless numbers in heat transfer, heat transfer correlations for natural convection. Condensation and Boiling, Condensation over flat plates, condensation inside and outside the tubes in horizontal, vertical, and inclined positions, film condensation, and dropwise condensing. Estimation of the film coefficient of heat transfer for condensing vapors, turbulence in condensing film. Heat Transfer to boiling liquids, pool boiling, and forced convection boiling, boiling curve and its characteristics. **Radiation:** Radiation heat transfer, laws of radiation, concepts of black body, gray body, greenhouse effect, emissive power, heat flux by radiation, view factors, radiation shield, luminous and non-luminous gases, heat exchangers, and heat transfer fluids. **Application in Various Unit Processes and Operations**: Chemical and bioreactors, shell and tube heat exchangers, LMTD and NTU approaches, condensers, furnaces, boilers, distillation columns, multi- effect evaporators, solar thermal systems etc, strategy for thermal management and optimization, pinch analysis and design of heat exchanger network
4	**Texts/References**	**1.** Dutta B.K., Heat Transfer Principles and Applications, 2 nd Edition, 2023, PHI Learning Pvt..Ltd, New Delhi, ISBN-10: 81963789122. **2.** J. P. Holman, Souvik Bhattacharyya, Heat Transfer, 10th Edition, 2017, McGraw-Hill Education, ISBN-10: 9780071069670 **3.** Donald Kern, Process Heat Transfer, Indian Edition, 2017, McGraw Hill Education, ISBN- 10:0074632175 **4.** Frank P. Incropera, David P. DeWitt, Fundamentals of Heat and Mass Transfer, ohn Wiley & Sons; 5th edition (20 August 2001), ISBN-10 0471386502.

1	**Title of the course** (L-T-P-C)	**Materials Science for Chemical Engineers** **3-0-0-6**
2	**Pre-requisite courses(s)**	--
3	**Course content**	**Introduction:** Introduction to materials and their principle properties, Atomic bonding, crystal structure and defects, Basic principles in their selection for fabrication and erection of the chemical plant. **Deformation:** Plastic deformation - Mechanism of plastic deformation, slip, work hardening, deformation in polycrystalline materials, Effect of cold working and annealing, hot working. Elastic deformation, Anelastic deformation, Viscoelastic deformation – models for viscoelastic behavior. **Fracture:** Types of fracture, cleavage, brittle, ductile, Griffith crack theory, Theories of crack initiation, ductile-brittle transition. **Testing of materials**: Destructive tests - Tensile testing, stress-strain curves, condition for necking, compression testing, Hardness testing. Creep-testing method, creep curve, requirements for creep resistance materials. Fatigue – testing method fatigue prevention. Non-destructive tests. Thermal properties: Heat capacity and specific heat, Thermal expansion, thermal conductivity, thermal shock. Heat treatment: Annealing, quenching, normalizing, hardening, martempering, Aus tempering, case hardening, cyaniding, nitriding, flame hardening, induction hardening, diffusion coating, furnaces, and temperatures. Phase diagram: Basic terms, Hume - Rothery rules of solid solubility, Gibb's phase rule, polymorphism, solidification of pure metal. Types of cooling curves, plotting of equilibrium diagram, lever rule, common types of phase diagram, other transformations in alloy system; Non-equilibrium cooling.
4	**Texts/References**	**1.** William D. Callister Jr., David G. Rethwisch. "Materials Science and Engineering: An Introduction", Wiley, 10th Edition, January 2018 ISBN: 978-1-119-40549-8, **2.** James F. Shackelford. "Introduction to Materials Science for Engineers", Pearson College Div; 8th edition, 2 April 2014, ISBN-10 :0133826651 **3.** Donald R. Askeland, Pradeep P. Fulay, Wendelin J. Wright. "The Science and Engineering of Materials". Cl-Engineering; 6th edition (21 June 2010), ISBN-10 : 0495296023 **4.** V. Raghavan. "Materials Science and Engineering: A First Course". Prentice Hall India Learning Private Limited; 6th edition (1 January 2015), ISBN-10 9788120350922: **5.** Hajra Choudhury S. K, "Material science and processes", Imprint unknown (1 March 1978), ISBN-10: 0906216001.

1	**Title of the course** (L-T-P-C)	**Numerical Methods in Chemical Engineering** **2-0-2-6**
2	**Pre-requisite courses(s)**	--
3	**Course content**	Solution of simultaneous linear and non-linear equations; Eigenvalues and eigenvectors of matrixes; Statistical analysis of data; Curve fitting; Approximation of functions; Interpolation; Numerical integration and differentiation, solutions of cubic equations of state, P-x-y diagram using gamma-phi approach Solution of ordinary differential equations - initial and boundary value problems, Batch and stirred tank reactors, Chemical reaction and diffusion in pore problems, Tubular reactor with first and second order reactions, Chemical reaction and diffusion in a spherical catalyst pellet problem Solution of partial differential equations; Analysis of error and stability in numerical computing. One dimensional transient heat conduction, transient conduction rectangle/sphere/cylinder Implementation of numerical methods on computer through programming in FORTRAN/C++ and commercial software such as MATLAB.
4	**Texts/References**	**1.** S. C. Chapra and R. P. Canale, Numerical methods for engineers (8th ed), Tata McGraw- Hill, 2021. **2.** S. K. Gupta, Numerical methods for engineers (3rd ed), New Age International, 2015 **3.** F. Gerald, and P. O. Wheatley, Applied numerical methods (7th ed), Pearson Education, 2022. **4.** R. M. Somasundaram and R. M. Chandrasekaran, Numerical methods with C++ programming, Prentice-Hall of India, 2005. **5.** Numerical Methods for Chemical Engineering, Applications in MATLAB, Kenneth J. Beers, Cambridge University Press, 2007

1	**Title of the course** (L-T-P-C)	**Process Dynamics and Control** **2-1-0-6**
2	**Pre-requisite courses(s)**	--
3	**Course content**	First Principles model development; dynamics of first, second and higher order linear systems, open loop and closed loop systems; linearization; feedback control; stability; root locus diagram; frequency response analysis; Bode stability criterion; Nyquist stability criterion; design of controller; dynamics of some complex processes; control valves and introduction to real time computer control of process equipment; cascade, feed forward, adaptive control; SISO; MIMO; A/D conversion, PLC architecture; Multi-variable control strategies.
4	**Texts/References**	**1.** G. Stephanopoulos, Chemical Process Control: An Introduction to Theory and Practice, Prentice-Hall, New Jersey, 2015. **2.** D. R. Coughanowr, and L. B. Koppel, Process systems Analysis and Control, 3 rd Ed., Mc-Graw-Hill, 2009. **3.** W. L. Luyben, Process Modelling Simulation and Control for Chemical Engineers, McGraw Hill, 1990 (this is the latest edition).

1	**Title of the course** (L-T-P-C)	**Advanced Chemical Reaction Engineering** **2-1-0-6**
2	**Pre-requisite courses(s)**	--
3	**Course content**	Unsteady state ideal reactors (isothermal and non-isothermal), Non-ideal Reactors and Reactor Safety: Dispersion Models, The Tank in Series model, Convection and laminar flow, Segregation and RTD, Reactor Stability & Reactor Safety. Gas-Solid Reactions: Shrinking core and volume reaction models to treat External diffusion, Internal Diffusion & Reaction control reactions. Catalytic rate equation, catalyst deactivation, catalytic reactor design, Various fluid-particle reactors and its designs. Gas-Liquid Reactions: Rate equation for mass transfer and reaction limited reactions, Factors important to design Gas-liquid reactors and various gas-liquid contactors and its design aspects. Solid- Solid Reactions: Kinetic models and reactor design for solid processing units. Special, Reactors and, photoreaction and photoreactors, Vacuum and aerosol systems for material synthesis. Fundamentals of catalysis, including kinetics and mechanistic models. Heterogeneous and homogenous catalysis. The fundamentals of electrocatalysis and the effects of coupling proton and electron transfer for catalytic redox reactions. Surface properties and function in heterogeneous catalysis, Fischer- Tropsch process etc.,
4	**Texts/References**	Text books: **1.** H.S.Fogler, Elements of Chemical Reaction Engineering, 5th ed., Prentice Hall, New Jersey, 2016. **2.** O.Levenspiel, Chemical Reaction Engineering, 3nd ed., Wiley Eastern, 2021. **3.** J.M.Smith, Chemical Engineering Kinetics, 3rd ed., McGraw Hill, 2013. **4.** J. F. Hartwig, Organotransition Metal Chemistry: From Bonding to Catalysis, 1stEd, University Science Books, 2010.

1	**Title of the course** (L-T-P-C)	**Fundamentals of Microfluidics** **3-0-0-6**
2	**Pre-requisite courses(s)**	--
3	**Course content**	Introducing microfluidics and its diverse engineering applications. Microfabrication techniques such as lithography, etching, deposition, laser cutting, machine milling, and 3D printing. Classical fluid flow laws at the micro-scale due to free molecular flow and the limitations of the continuum assumption. The electric double layer and Debye length, followed by electro-osmosis, electrophoresis, and electro-wetting. The module delves into capillary effects and passive flow control strategies, along with techniques for droplet manipulation, including merging, splitting, and transport within microfluidic devices. Micro heat pipes and their role in advanced cooling applications. Topics such as viscous heating and entropy generation in micro-channels. Heat transfer mechanisms in micro-reactors and multi-channel stacks. The Taylor dispersion in non-circular micro-channels, providing insight into mass transfer phenomena at small scales. Effective mixing strategies, including chaotic advection, slanted groove, and staggered herringbone designs. The optimization of microfluidic networks for enhanced separation and sorting processes.
4	**Texts/References**	• Colin, S. Microfluidics. ISTE Ltd and John Wiley & Sons Inc., 2010. • Nguyen, N.-T., Wereley, S. T., & Shaegh, S. A. M. Fundamentals and Applications of Microfluidics (3rd ed.). Artech House., 2019. • Chakraborty, S. Microfluidics and Microscale Transport Processes. CRC Press, 2012. • Song, Y., Cheng, D., & Zhao, L. (Eds.). Microfluidics: Fundamentals, Devices, and Applications. Springer, 2018.

1	**Title of the course** (L-T-P-C)	**Molecular Simulations in Chemical and Biochemical Engineering** **2-1-0-6**
2	**Pre-requisite courses(s)**	--
3	**Course content**	PART 1: Fundamentals of molecular simulations -Ab-initio Methods, Basis Sets, Hartree-Fock Theory, Density Functional Theory, Geometry Optimization, Vibrational Analysis PART 2: Statistical mechanics, elementary concepts of temperature, ensembles and fluctuations, partition function, ensemble averaging, ergodicity. PART 3: Molecular Dynamics Methodology - Force Field, Integrating Algorithms, Periodic Box and Minimum Image Convention, Long Range Forces, Non-Bonded Interaction, Temperature Control, Pressure Control, Estimation of Pure Component Properties, Radial Distribution Function; Molecular Dynamics Packages. PART 4: Monte Carlo simulation - Monte Carlo integration, simple biasing methods, Markov chain, transition-probability matrix, Metropolis algorithm, Monte Carlo simulation in different ensembles PART 5: Tutorial on modeling and simulation of small molecules, proteins, and polymers and their various applications using software such as VASP, Gaussian, Material Studio, GROMACS etc.
4	**Texts/References**	• Dann Frenkel, and Berend Smit, "Understanding Molecular Simulation: From Algorithms to Applications", 3rd Edition, Academic Press, 2023, ISBN 9780323902922 • Michael P. Allen, and Dominic J. Tildesley "Computer Simulation of Liquids", 2nd Edition, Oxford Press, 2017, ISBN 9780198803201 • Andrew R. Leach "Molecular Modelling: Principles and Applications", 2 nd Edition, Pearson, 2001, ISBN: 9780582382107 • K. Binder " The Monte Carlo Method in Condensed Matter Physics", Vo 71, Springer Verlag Inc, 1992, ISBN: 9780387543697.

1	**Title of the course** (L-T-P-C)	**Chemical Process Technology** **3-0-0-6**
2	**Pre-requisite courses(s)**	--
3	**Course content**	Introduction and overview of Chemical Process Technology. Preparation of proce flow diagrams, Instrumentation diagrams and Process symbols. Petroleum refinery processes: Introduction to crude oil, Crude refining processes physical processes (Desalting/dehydration, Crude distillation, Propane deasphalti Solvent extraction and dewaxing, Blending, (ii) Chemical process (thermal process Visbreaking, Delayed coking, Flexicoking), Catalytic Processes – Hydrotreatir Catalytic reforming, Catalytic cracking, Hydrocracking, Catalytic dewaxir Alkylation, Polymerization, Isomerization. Petrochemical Industries: production of petrochemical feedstocks, olefins a aromatics, intermediates from olefins and aromatics. Manufacture of ethyler propylene, butylenes, benzene, toluene etc. Inorganic Chemical Industries: chloro-alkali industries, manufacture of acids-sulfur nitric, phosphoric acids, Fertilizers- ammonia, urea, Ammonium sulfate, ammoniu nitrate, Urea, SSP and TSP and miscellaneous fertilizers. Natural products -manufacture of sugar, starch, and its derivatives, Pulp, Paper, oil a fats, Rayon industries. Edible oils: extraction and refining, fat splitting, soaps a detergents. Polymerization industries (ethylene, polyethylene, propylene,polypropyler butylenes, benzene, toluene, PVC and polyester synthetic fibers etc.
4	**Texts/References**	• Johannes Rudolf Wagner, William Crookes, Ferdinand Fischer, Manual of Chemical Technology, Legare Street Press (27 October 2022), ISBN-10 : 1016845154 • 2. Marshall Sitting, Charles Dryden, M. Gopala Rao, DRYDEN'S Outlines of Chemical Technology, East-West Press, Shree Hari Publications (1 January 2019) • Philip Groggins, Unit Processes In Organic Synthesis, Fifth Edition, Tata McGraw Hill Education (1 January 2004), ISBN-10: 0074621432 • Soni P.L. and Kalyal; Textbook of Inorganic Chemistry, Sultan Chand & Sons (1 January 2013), New Delhi, ISBN-10 : 8180547922 • Randolph Norris Shreve, Joseph Andrew Brink, Chemical Process Industries, McGraw-Hill, 1977, ISBN 0070571457, 9780070571457

1	**Title of the course** (L-T-P-C)	**Principles and Applications of Electrochemistry** **3-0-0-6**
2	**Pre-requisite courses(s)**	--
3	**Course content**	Basic Principles: Introduction to electrochemistry and fundamentals, Nernst equation, Electrode kinetics, Volta and Galvani potentials, Faraday's laws of electrolysis, electrochemical potential, electrochemical equilibrium, Enthalpy, and Gibbs free energy calculation. Electric double layer, electrochemical cell, standard electrode potential, Butler-Volmer formulation, Tafel equation, Pourbaix diagram, reversible electrode. Electrochemical mass transport. Electrochemical techniques: Potential Step voltammetry, pulse voltammetry, cyclic voltammetry. Controlled current methods and current-interrupt measurements. Impedance spectroscopy. Their applications in the characterization of electrodes/electrochemical devices. Applied aspects: Batteries. Fuel cells. Hydrogen production. Electrochemical conversion of small molecules to products/fuels. Corrosion.
4	**Texts/References**	• Prentice, G., 1991, Electrochemical Engineering Principles, Prentice Hall. (ISBN: 9780132490382) • Allen J. Bard, Larry R. Faulkner, 2005, Electrochemical Methods: Fundamentals and Applications, John Wiley & Sons; 2nd Edition. (ISBN: 97804710437720) • Fuller, T.F., Harb, J. N., 2018, Electrochemical Engineering, Wiley. (ISBN: 9781119004257)

1	**Title of the course** (L-T-P-C)	**Introduction to Battery Technology** **3-0-0-6**
2	**Pre-requisite courses(s)**	--
3	**Course content**	Battery Technology introduction and motivation; Battery classifications, components, operational principles, and key battery characteristics, including cell potential, capacity, specific energy, and energy density. Battery Chemistry, thermodynamics, electrode kinetics, Electrical double-layer capacitance; Ionic adsorption and transport Electrode and electrolyte materials for battery applications; Physicochemical characterization of battery materials; Performance evaluation using non-destructive electrochemical techniques such as Cyclic Voltammetry (CV), Chronoamperometry (CA), Chronopotentiometry (CP), Differential Pulse Voltammetry (DPV), Galvanostatic Charge Discharge (GCD), Electrochemical Impedance Spectroscopy (EIS), and Galvanostatic Intermittent Titration Technique (GITT). Battery theory and design; Recent developments in battery technology, Battery management systems; Batteries for electric vehicles. Advanced battery technologies - advanced battery materials, solid-state batteries, thermal batteries, and redox flow batteries. Battery recycling, sustainability, and environmental impact.
4	**Texts/References**	Textbooks 1. Kiehne, H. A. (2003). "Battery Technology Handbook". 2nd Edition, CRC Press. ISBN: 9780824742492 2. Rahn, C. D., & Wang, C. Y. (2013). "Battery Systems Engineering". John Wiley & Sons, Ltd. ISBN: 9781119979500 References 1. Huggins, R. A. (2009). "Advanced Batteries: Materials Science Aspects". Springer. ISBN: 9781441945501 2. Kirby W. Beard. Linden's Handbook of Batteries, Fifth Edition (McGraw-Hill Education: ISBN: 978-1260115925 3. "Lithium-Ion Batteries: Advances and Applications" — Gianfranco Pistoia (editor). "Lithium-Ion Batteries: Fundamentals and Applications" — Yoshio, Brodd & Kozawa

1	**Title of the course** (L-T-P-C)	**Fuel Cell Technology** **3-0-0-6**
2	**Pre-requisite courses(s)**	--
3	**Course content**	Fuel Cell Technology introduction and motivation, Fundamentals of electrochemistry and Electrochemical Techniques, Types of fuel cells, Fuel cell thermodynamics, Fuel cell kinetics: symmetry factor, Tafel slope, charge transfer resistance, Charge transfer coefficient derivation, origin of overpotential in Fuel cells, Activation overpotential, Concentration overpotential, Limiting current density Electrochemical charge transport in fuel cells, Laplace's equation, Ohmic overpotential Fuel cell components: Bipolar plate, Bipolar plate, Electrolyte, PEM, Electrode, Catalyst, Fuel cell characterization, Ex-situ characterization, In-situ characterization, EIS and membrane characterization
4	**Texts/References**	**Textbooks** 1. . O'Hayre, S. W. Cha, W. G. Colella, F. B. Prinz, 2016, Fuel Cell fundamentals, 3rd Edition. John Wiley & Sons, New Jersey. (ISBN: 9781119113805) 2. Allen J. Bard, Larry R. Faulkner, 2005, Electrochemical Methods: Fundamentals and Applications, John Wiley & Sons; 2nd Edition. (ISBN: 97804710437720) **References** **1.** John Newman, Nitash P. Balsara, 2021, Electrochemical Systems, 4th Edition, Wiley. (ISBN: 9781119514602) **2.** Marc Koper (Editor), 2009, Fuel Cell Catalysis: A Surface Science Approach, Wiley. (ISBN: 9780470463741)

1	**Title of the course** (L-T-P-C)	**Introduction to Nanoscience and Nanotechnology** **3-0-0-6**
2	**Pre-requisite courses(s)**	--
3	**Course content**	Fundamentals of nanoscience, nanoscale phenomena, nanotechnology applicatio historical development of the field, length scales, surface-to- volume ratio effec quantum confinement, and density of states in low-dimensional systems Crystallography basics, Moore's law and scaling limits, size-dependent optical, electrical, thermal and magnetic properties, surface and interface effects, bulk vers nano behavior. Classification and Synthesis: Zero, one, two and three-dimensional nanomaterials, carbon nanomaterials, core-shell structures, anisotropic and hybr nanostructures, top-down synthesis approaches; lithography, ball mill, bottom- techniques including sol-gel processing, precipitation, hydrothermal synthes chemical vapor deposition, physical vapor deposition, microfluidic synthesis, micelle and green synthesis routes, with focus on size and morphology control. Characterization and Applications of Nanomaterials: XRD, DLS, Zetasizer, SEI TEM, AFM, UV-Vis and FTIR techniques, with emphasis on basic data interpretatio structure-property correlation, applications in nanoelectronics, flexible devices, ener storage systems such as batteries and supercapacitors, solar cells, photocatalys nanomedicine and drug delivery, gas sensing technologies, environmental remediatio and agriculture, and concludes with discussions on nanotoxicology, environmen impact, regulatory aspects, ethical considerations.
4	**Texts/References**	1. Hornyak, Gabor L.; Tibbals, H.F.; Dutta, Joydeep; Moore, John J. Introduction to Nanoscience and Nanotechnology, CRC Pr I Llc (2008), ISBN-10 : 9781420047790; ISBN-13 : 978-1420047790 2. Peter Atkins, Julio de Paula, Atkins' Physical Chemistry, Seventh edition, Oxford University Press (2001). ISBN-10: 0198792859, ISBN-13: 978-0198792857 3. C. N. Rao, A. Muller, A. K. Cheetham, "Nanomaterials chemistry", First Edition, Vch Verlagsgesellschaft Mbh, 2007, ISBN-10 : 9783527316649,ISBN-13: 978-3527316649 A.W. Adamson and A.P.Gast, Physical Chemistry of surfaces, Sixth Edition,Wiley India Pvt Ltd, 2011, ISBN-10 : 9788126534173, ISBN-13 : 978-8126534173 4. Guozhong Cao, Ying Wang, "Nanostructures and Nanomaterials: Synthesis, Properties, and Applications", Imperial College Pr, 2004, ISBN-10 : 1860944809, ISBN-13 : 978-1860944802 5. C. Brechignac, P. Houdy, M. Lahmani, "Nanomaterials and Nanochemistry", Springer, 2008, ISBN-10 : 3540729925, ISBN-13 : 978 3540729921 6. Kenneth J. Klabunde, "Nanoscale materials in chemistry", Second Edition, John Wiley & Sons Inc, 2009, ISBN-10 : 0470222700,ISBN-13 : 978-0470222706

1	**Title of the course** (L-T-P-C)	**Sustainability and Green Technologies in Chemical Engineering** **3-0-0-6**
2	**Pre-requisite courses(s)**	--
3	**Course content**	1. **Introduction and need for sustainability**: Introduction to the United Nations sustainable development goals wit focus on releva goals for chemical engineering. Anthropogeni climate change, necessity for cle energy, need for deep cuts I carbon emissions, responsible consumption and producti (chemicals & commodities), importance of water treatment and wast recycling a improvising the existing chemical processes Characterize the various problems a introducing sustainabl solutions. 2. **Decarbonization of energy sector** Effective utilization of coal and natural ga implementation of nuclea power and geothermal energy, utilizing wind and solar pow harnessing hydropower, electrifying transportation with batteries an fuel cells. Industr case studies on decarbonization of energy sector. 3. **Carbon capture techniques and green chemistry:** Understanding carbon footpri post-combustion, oxyfuel, and pre combustion, carbon capture from air and seawat carbon sequestration – mineralization and deep sea injections, innovations in eco-friendly materials or green chemicals (example: Choice of electrochemi ammonia synthesis over Haber Bosch process). 4. **Waste management and recycling** Concept of reduce, reuse and recycle, case studi of successful recycling operations (recycling of plastic waste, e-waste, urban mining with principles of hydrometallurgy, pyrometallurgy and mechanica processing). Waste water treatment: Importance of water quality and availability overview physical, chemical, and biological treatment methods. 5. **Process intensification of chemical industries**: Importance and principles of proce intensification, techniques of process intensification (microreactors, membra technology, microwave and ultrasound assisted process), real world and emergi technologies examples (petrochemicals and pharmaceuticals), role of research advancing sustainability.
4	**Texts/References**	7. Piemonte, V., De Falco, M., & Basile, A. Sustainable Development in Chemical Engineering: Innovative Technologies. John Wiley & Sons, 2013. 8. Segovia-Hernández, J. G., Ramírez-Corona, N., & Aristizábal-Marulanda, V. (Eds.). Contributions of Chemical Engineering to Sustainability, 1st Edition, Springer, 2024 9. Sankaranarayanan, K. Efficiency and Sustainability in the Energy and Chemical Industries, 3rd Edition, CRC Press, 2023. 10. Dunmade, I. S., Daramola, M. O., & Iwarere, S. A. (Eds.). Sustainable Engineering: Concepts and Practices. Springer Nature, 2024 11. Allen, D. T., & Shonnard, D. R. Green Engineering: Environmentally Conscious Design of Chemical Processes. Prentice Hall, 2001. 12. Jiménez-González, C., & Constable, D. J. C. Green and Sustainable Chemistry and Engineering: A Practical Design Approach, 2nd Edition, John Wiley & Sons, 2025

1	**Title of the course** (L-T-P-C)	**Process Modelling and Simulation** **3-0-0-6**
2	**Pre-requisite courses(s)**	-
3	**Course content**	Concept of mathematical modelling of processes, Classification of models: deterministic and stochastic models, lumped and distributed parameter models, transport phenomena, empirical and unit models Development of simple models based on mass and energy balance for heating or cooling of stirred tank using jacket or coil. Modelling of heat and mass transfer equipment: counter-current heat exchanger, multi-component flash drum, distillation column. Modelling of reactors: isothermal and non-isothermal batch and continuous reactors, etc. Case studies in simulation of reactors, separation columns, etc. Introduction to process simulators. Concept of process optimization, problem statement. Types of optimization problems. Unconstrained optimization problems, Search methods: Interval halving method, Golden section search, etc., Descent methods: Steepest descent, Newton's methods, etc. Constrained optimization: Lagrange multipliers, Kuhn Tucker's conditions, Linear programming and applications. Use of available computer programs and case study.
4	**Texts/References**	1. Upreti, S. R., Process Modeling and Simulation for Chemical Engineers: Theory and Practice, John Wiley & Sons Ltd, 2017. 2. Dobre, T. G., Sanchez, J. G., Chemical Engineering: Modeling, Simulation and Similitude, first edition, Wiley-VCH Verlag GmbH & Co. KGaA, 2007. 3. Jana, A. K., Chemical Process Modelling and Computer Simulation, third edition, PHI Learning, 2018. 4. Luyben, W. L., Process Modeling, Simulation and Control for Chemical Engineers, second edition, McGraw Hill, 1996. 5. Edgar, T. F., Himmelblau, D. M., Lasdon, L. S., Optimization of Chemical Processes, second edition, McGraw Hill, 2001.