# Chemical and Biochemical Engineering Department

| Sl. No | Course code | Name of Course | L-T-P-C | Proposed Level (UG/PG) |
|---|---|---|---|---|
| 1 | CL 101 | Introduction to Chemical Engineering | 3-0-0-6 | UG |
| 2 | CL 201 | Introduction to Transport Phenomena | 3-0-0-6 | UG |
| 3 | CL 202 | Reaction engineering | 3-0-0-6 | UG |
| 4 | CL 203 | Mass transfer | 3-0-0-6 | UG |
| 5 | CL 204 | Chemical Engineering lab -1) | 0-0-3-3 | UG |
| 6 | CL 205 | Chemical Engineering Lab III | 0-0-3-3 | UG |
| 7 | CL 301 | Process Equipment Design and Economics | 3-0-0-6 | UG |
| 8 | CL 302 | Safety in Chemical Industry | 3-1-0-6 | UG |
| 9 | CL 401 | Chemical Reaction Engineering-II | 3-0-0-6 | UG |
| 10 | CL 402 | Advanced Transport phenomena | 3-0-0-6 | UG |
| 11 | CL 403 | Process plant utilities | 3-1-0-6 | UG |
| 12 | CL 404 | Colloid and Interfacial Engineering | 3-1-0-6 | UG |
| 13 | CL 204 | Introduction to Chemical Engineering Thermodynamics | 3-0-0-6 | UG |
| 14 | CL 801 | Advanced Chemical Engineering Thermodynamics | 3-0-0-6 | PG |
| 15 | CL 802 | Computational Techniques for Multiphase Flows (CTMF) | 3-0-0-6 | PG |
| 16 | CL 803 | Advanced separation processes | 3-0-0-6 | PG |
| 17 | CL 601 | Seminar | 0-0-4-4 | PG |
| 18 | CL 405 | Applications of Mass Transfer | 3-0-0-6 | UG |
| 19 | | Bioprocess Engineering | 3-0-0-6 | UG |
| 20 | | Mechanical Operations | 3-0-0-6 | UG |
| 21 | | Applications of Mass Transfer | 3-0-0-6 | UG |
| 22 | CL 303 | Scientific presentation | 3-0-0-3 | UG |

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| 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.<br>2. D. M. Himmelblau and J. B. Riggs, Basic Principles and Calculations in Chemical Engineering. 7th ed., Prentice Hall, 2003.<br>3. B. I. Bhatt and S. M. Vora, Stoichiometry. 4th ed., McGraw Hill, 2004. |

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| 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 |

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| 1 | **Title of the course** (L-T-P-C) | **Reaction engineering**<br>**(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.<br>2. 2. O.Levenspiel, Chemical Reaction Engineering, 2nd ed., Wiley Eastern,1992<br>3. 3. J.M.Smith, Chemical Engineering Kinetics, 3rd ed., McGraw Hill, 1980. |

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| 1 | **Title of the course** (L-T-P-C) | **Mass transfer**<br>**(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.<br>2. E.D. Cussler, Di usion - Mass Transfer in Fluid Systems, Cambridge University Press, Cambridge 1984.<br>3. A. S. Foust, Principles of Unit Operations, 2nd Edition, Wiley, New York, 1980.<br>4. C.J. Geankoplis, Transport Processes and Unit Operations, 3rd Edition, Prentice Hall, India, 1993. |

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| 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.<br>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** | |

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| 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** | |

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| 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.<br>2.E.D. Cussler, Di usion - Mass Transfer in Fluid Systems, Cambridge University Press, Cambridge 1984.<br>3.A. S. Foust, Principles of Unit Operations, 2nd Edition, Wiley, New York, 1980.<br>4.C.J. Geankoplis, Transport Processes and Unit Operations, 3rd Edition, Prentice Hall, India, 1993. |

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| 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.<br>R.W. King and J. Magid, Industrial Hazards and Safety Handbook, Butterworth, 1982.<br>A. Khulman, Introduction to Safety Science, TUV Rheinland, 1986.<br>W.E. Baker, Explosion Hazards and Evaluation, Elsevier, Amsterdam, 1983.<br>O.P. Kharbanda and E.A. Stallworthy, Management of Disasters and How to Prevent them, Grower, 1986. |

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| 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.<br>2. O. Levenspiel, Chemical Reaction Engineering, Wiley Eastern, 2nd ed., 1972.<br>3. J.M. Smith, Chemical Engineering Kinetics, 3rd ed., McGraw Hill, 1980. |

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| 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 << 1) in uniform and shear flow, Low Re expansion for Pe << 1, Pe >> 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. |

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| 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. |

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| 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.<br>C.A.Miller and P.Neogi. "Interfacial Phenomena: Equilibrium and Dynamic Effects", Dekker, 1985.<br>V.G.Levich, "physicochemical Hydrodynamics", Prentice Hall Inc., 1962.<br>R.J.Hunter, "Foundations of Colloid Science", Vols. I & II, Oxford Science Publications, 1989.<br>D.A.Edwards, H.Brenner and D.T.Wasan, "Interfacial Trasport Processes and Rheology", Butterworth, Heinmen, 1991. |

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| 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"<br>ii) Stanley I. Sandler "Chemical, Biochemical, and Engineering Thermodynamics 4th Edition"<br>iii) J.M. Smith, H.C. Van Ness, M.M. Abott, M.T. Swihart “Introduction to Chemical Engineering Thermodynamics 8th Edition" |

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| 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"<br>ii) Stanley I. Sandler "Chemical, Biochemical, and Engineering Thermodynamics 4th Edition"<br>iii) J.M. Smith, H.C. Van Ness, M.M. Abott, M.T. Swihart “Introduction to Chemical Engineering Thermodynamics 8th Edition" |

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|---|---|---|
| 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.<br>ii) Stanley I. Sandler; "Chemical, Biochemical, and Engineering Thermodynamics 5th Edition", Wiley, 2017.<br>iii) J.M. Smith, H.C. Van Ness, M.M. Abott,, M.T. Swihart, “Introduction to Chemical Engineering Thermodynamics 9th Edition", McGraw-Hill, 2019.<br>iv) McQuarrie D.A, “Statistical Mechanics”, Viva Books Private Limited, 2018.<br>v) Hill Terrel, An Introduction to Statistical Thermodynamics, Dover, 1960.<br>vi) Allen MP, Tildesley DJ, Computer simulation of liquids, Oxford, 1989.<br>vii) Callen, HB. Thermodynamics and an Introduction to Thermodstatics, 2ndEdition, John Wiley and Sons, 1985.<br>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. |

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| 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** | 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<br>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).<br>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);<br>Mixture model; Eulerian-Lagrangian Two-Fluid Model framework.<br>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.<br>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.<br>2. Tryggvason, Grétar, Ruben Scardovelli, and Stéphane Zaleski. Direct numerical simulations of gas–liquid multiphase flows. Cambridge university press, 2011.<br>3. Crowe, Clayton T., et al. Multiphase flows with droplets and particles. CRC press, 2011.<br>4. Anderson, John David, and John Wendt. Computational fluid dynamics. Vol. 206. New York: McGraw-Hill, 1995.<br>5. Versteeg, Henk Kaarle, and Weeratunge Malalasekera. An introduction to computational fluid dynamics: the finite volume method. Pearson education, 2007.<br>6. Ranade, Vivek V. Computational flow modeling for chemical reactor engineering. Vol. 5. Academic press, 2002. |

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| 1 | **Title of the course** (L-T-P-C) | **Advanced separation processes**<br>**(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:**<br>1. Rousseau, R. W. (1987), Handbook of Separation Process Technology, John Wiley & Sons.<br>2. Humphrey, J. L. and Keller, G. E., (1997), Separation Process Technology, McGraw- Hill, NY.<br>3. Norman, N, Li, Anthony G. Fane, Winston Ho, W. S., Matsuura. T. (2008), Advanced Membrane Technology and Applications, Wiley.<br>**Reference Books:**<br>1. Kister, H. Z., (1992), Distillation Design, McGraw-Hill.<br>2. Ernest J. H., Seader J. D., D. Keith Roper (2011), Separation Process Principles, 3rd Edition Wiley.<br>3. Taylor, R., Krishna, R. (1993), Multicomponent Mass Transfer, John Wiley & Sons.<br>4. Swain A., Patra H., Roy G. K. (2010) Mechanical Operations, McGraw Hill Education. |

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| 1 | **Title of the course** (L-T-P-C) | **Bioprocess Engineering**<br>**(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.<br><br>**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).<br><br>**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.<br><br>**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.<br>2. Michael L. Shuler, Fikret Kargi, Matthew DeLisa. Bioprocess Engineering: Systems, Equipment, and Facilities. Prentice Hall, second edition, 2017.<br>3. Roger G. Harrison, Paul W. Todd, Scott R. Rudge. Bioseparations Scienceand Engineering. Oxford University Press, second edition, 2015.<br>4. Carl-Johan Franzén and Christian Larsson. Bioreactors: Design, Operation and Novel Applications. CRC Press, first edition, 2016. |

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| 1 | **Title of the course** (L-T-P-C) | **Mechanical Operations**<br>**(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<br>2. J. M. Coulson, J. F. Richardson, J. R. Backhurst and J. H. Harker. Chemical Engineering, Vol-2, fifth edition., Elsevier, 2015 |

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| 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.<br>2. E.D. Cussler, Diffusion - Mass Transfer in Fluid Systems, Cambridge UniversityPress, Cambridge 1984.<br>3. A. S. Foust, Principles of Unit Operations, 2nd Edition, Wiley, New York, 1980.<br>4. C.J. Geankoplis, Transport Processes and Unit Operations, 3rd Edition, Prentice Hall, India, 1993. |