B.Tech. in Chemical Engineering
(Course Structure & Syllabus III Semester Onwards)

Year	THIRD SEMESTER						FOURTH SEMESTER					
	Course code	Course Name	L	T	P	C	Course Code	Course Name	L	T	P	C
II	BB0025	Value Ethics and Governance	2	0	0	2	EO2001	Economics	3	0	0	3
	MA2105	Engineering Mathematics-III	2	1	0	3	MA2208	Engineering Mathematics-IV	2	1	0	3
	CE2101	Chemical Process Calculations	3	1	0	4	CE2201	Chemical Reaction Engineering-I	3	1	0	4
	CE2102	Momentum Transfer Operations	3	1	0	4	CE2202	Heat Transfer Operations	3	1	0	4
	CE2103	Chemical Engineering Thermodynamics	3	1	0	4	CE2203	Mass Transfer-I	3	1	0	4
	CE2104	Transport Phenomena	3	1	0	4	XXXXXX	Open Elective-I	3	0	0	3
	CE2130	Transport Phenomena Lab-I	0	0	4	2	CE2230	Transport Phenomena Lab-II	0	0	4	2
							CE2231	Process Equipment Design Lab	0	0	3	1
			16	5	4	23			17	4	7	24
	Total Contact Hours (L+T+P)		25				Total Contact Hours (L+T+P)+OE		28			
III	FIFTH SEMESTER						SIXTH SEMESTER					
	BB0026	Organisation and Management	3	0	0	3	CE3201	Process Plant Design	3	1	0	4
	CE3101	Mass Transfer-II	3	1	0	4	CE3202	Chemical Process Industries	3	1	0	4
	CE3102	Chemical Reaction Engineering-II	3	1	0	4	CE3203	Process Dynamics and Control	3	1	0	4
	CE3103	Process Modeling and Simulation	3	0	2	4	CE32XX	Program Elective-I	3	0	0	3
	CE3104	Process Safety Analysis	3	1	0	4	CE32XX	Program Elective-II	3	0	0	3
	XXXXXX	Open Elective -II	3	0	0	3	XXXXXX	Open Elective-III	3	0	0	3
	CE3130	Transport Phenomena Lab- III	0	0	4	2	CE3230	Chemical Reaction Engineering Lab	0	0	4	2
							CE3231	Process Dynamics and Control Lab	0	0	3	1
			18	3	6	24			18	3	7	24
	Total Contact Hours (L+T+P) + OE		27				Total Contact Hours (L+T+P)+OE		28			
IV	SEVENTH SEMESTER						EIGHTH SEMESTER					
	CE41XX	Program Elective-III	3	0	0	3	CE4270	Major Project	0	0	0	12
	CE41XX	Program Elective-IV	3	0	0	3						
	CE41XX	Program Elective -V	3	0	0	3						
	CE41XX	Program Elective-VI	3	0	0	3						
	CE41XX	Program Elective-VII	3	0	0	3						
	CE4170	Minor Project	0	0	4	2						
	CE4171	Industrial Training	0	0	2	1						
			15	0	6	18						12
	Total Contact Hours (L+T+P)		21				Total Credit= 169(including first year)					

THIRD SEMESTER

BB0025: VALUE ETHICS AND GOVERNANCE [2 0 0 2]

Relevance of Value Education in day-to-day life. Mantra for success - Value, Moral and Ethics. Determinants of human nature (Three Gunas) and its impact on human life. Relevance of Personality, Attitude, Behavior, Ego, Character, introspection, Motivation, Leadership and 4 Qs with relevant Case StudiesX.Governance: Understanding of Public and Private sector Governance systems; Courts & CAG. Public Sector Governance: Need, relevance, stakeholders. Private Sector Governance: Proprietary, Partnership, Company (Pvt Ltd & Ltd), Company' Act 2013, Board of Directors; its Roles and Responsivities. Regulatory bodies; its role in ethical governance. Projects on PPP mode-relevance & prospects.CSR: Relationship with Society, Philanthropy and Business strategy, CSR Policy, Triple Bottom Line. Suggestive Case Studies:Uphar Theatre Tragedy- Engineering Ethics, Bhopal Gas Tragedy-Operational Engineering Ethics, Satyam Case- Financial Reporting Ethics, Enron Case- Business Ethics, Navin Modi Case- Financial Fraudulence.

References:

1. Professional Module of ICSI.
2. Ghosh B.N., *Business Ethics & Corporate Governance*, (1e) McGraw Hill, 2011.
3. Mandal S.K., *Ethics in Business & Corporate Governance*, (2e), McGraw Hill, 2012.
4. Ray C.K., *Corporate Governance, Value & Ethics*, Vaya Education of India, 2012.
5. Chatterjee Abha, *Professional Ethics*, (2e) Oxford Publications.

MA2105: ENGINEERING MATHEMATICS III [2 1 0 3]

Periodic Functions, odd and even functions, Euler's formulae. Half range expansions, Harmonic analysis. Fourier integrals & transforms, Parseval's identity. Functions of complex variable. Analytic function, C-R equations, differentiation, Integration of complex function, Cauchy's integral formula. Taylor's and Laurent Series, Singular points, Residues, Cauchy's residue theorem. Conformal mappings, bilinear transformations. Gradient, divergence and curl, their physical meaning and vector identities. Line, surface and volume integrals. Green's theorem, divergence and Stokes' theorem, applications. Formation, solutions of equations involving derivatives with respect to one variable only. Solutions by indicated transformations and separation of Variables. Derivation of one dimensional wave equation (vibrating string) and its solution by using the method of separation of Variables. D'Alembert's solution of wave equation. Derivation of one dimensional heat equation using Gauss divergence theorem and solution of one dimensional heat equation. Solution by separation of variables.

References:

1. Eewin Kreyszig, *Advanced Engineering Mathematics*, 7(e), John Wiley & Sons, Inc.1993.
2. R. Spiegel Murray, *Vector Analysis*, 2(e), Schaum Publishing Co., 2009.
3. B.S. Grewal, *Higher Engineering Mathematics*, 43(e), Khanna Publishers, 2014.
4. B.V. Ramana, *Engineering Mathematics*, 2(e), Tata McGraw Hill Publishing Company limited, 2007.

CE2101: CHEMICAL PROCESS CALCULATIONS [3 1 0 4]

Guidelines for Problem Solving; Review of Basic concepts – Process variables & properties, Degree of Freedom, Material balances: Steady State Material Balances – in non-reacting systems and reacting system, Recycle & purge, elemental vs. species balance, combustion of fossil fuels. Multiphase equilibrium: Single component and multicomponent phase equilibrium, Steady State Material balances in Multiphase systems. Energy Balances: Steady State Energy Balances – in non-reacting & reacting systems, De-Coupled & coupled mass & energy balances, Calculations for network of units with recycle & bypass, Process Flow sheeting with sequential modular calculations, Unsteady State Balances. Humidification: Terminology of humidity, Humidity charts, heating and cooling problems of moist air.

References:

1. D.M. Himmelblau, J.B. Riggs, Basic Principles and Calculations in Chemical Engineering, (8e) Pearson, TN, 2015.
2. R.M. Felder, R.W. Rousseau, Elementary Principles of Chemical processes, (3e), Wiley, 2004.
3. B.I. Bhatt, S.B. Thakore, Stoichiometry, (5e), McGraw Hill, 2010.

CE2102: MOMENTUM TRANSFER OPERATIONS [3 1 0 4]

Newton's law of viscosity, viscometers, fluid statics, Review of Navier-Stokes' (NS) equations; non-dimensionalization of NS equations; analogies; correlations for fluid flow Short introduction to non-Newtonian flows, Engineering Bernoulli Equation; f vs. Re charts; K factors and equivalent lengths for various fittings; hydraulic diameter; Head vs. Q plots of centrifugal pumps; Net positive suction head (NPSH), cavitation and priming; pipeline system design including pseudo-steady state approximation; flow measurements; compressors and blowers. Compressible flows in conduits. Mixing and Agitation: Power consumption; mixing times; scale-up, Characterization of solids; fundamentals of two-phase flow; flow through packed beds and in fluidized beds (pressure drops, loading and flooding); pneumatic and hydraulic transportation. Filtration, Centrifuges and cyclones.

References:

1. N. de Nevers, Fluid Mechanics for Chemical Engineers, (3e), McGraw Hill Education, 2017.
2. W.L. McCabe, J.C. Smith, P. Harriott, "Unit operations of Chemical Engineering", (7e) McGraw Hill Education, 2017.

3. A.S. Foust, L.A. Wenzel, C.W. Clump, L. Maus, L.B. Andersen, Principles of Unit Operations, (2e), Wiley India, 2008.
4. J.M. Coulson, J.F. Richardson, J.R. Backhurst, J.H. Harker, Coulson and Richardson's Chemical Engineering Volume 1: Fluid Flow, Heat Transfer and Mass Transfer, (6e) Butterworth-Heinemann/Elsevier, 2003.
5. R.B. Bird, W.E. Stewart, E.N. Lightfoot, Transport Phenomena, (2e) John Wiley & Sons, 2006.
6. C.J. Geankoplis, Transport Processes and Separation Process Principles, (4e), Prentice Hall of India, 2015.

CE2103: CHEMICAL ENGINEERING THERMODYNAMICS [3 1 0 4]

Laws of Thermodynamics, P–V–T Relations of Pure Fluids - Graphical, Tabular and Mathematical representation; Generalized compressibility chart; Generalized EOS; Thermodynamic Potentials; Maxwell Relations, Thermodynamic Property Relations, Thermodynamic properties of real gases, Multicomponent mixtures, Properties of solutions, Phase Equilibrium (VLE, LLE, VLLE), Review of Thermochemistry; Chemical reaction equilibria.

References:

1. J. M. Smith, H. C., Van Ness, M. M. Abbott, Introduction to Chemical Engineering Thermodynamics, (6e), McGraw-Hill, 2001.
2. Y.V.C. Rao, Chemical Engineering Thermodynamics, University Press, 1997.
3. B.G. Kyle, Chemical and Process Thermodynamics, (3e), PHI, 1999.

CE2104: TRANSPORT PHENOMENA [3 1 0 4]

Momentum Transport- Viscosity and mechanisms of momentum transport, shell momentum balances and velocity distribution in laminar flow, the equations of change for isothermal systems, velocity distributions with more than one independent variable, interphase transport in isothermal systems, macroscopic balances for isothermal flow systems. Energy Transport- Thermal conductivity and mechanisms of energy transport, shell energy balances and temperature distributions in solids and laminar flow, the equations of change for non-isothermal systems, temperature distributions with more than one independent variable, interphase transport in non-isothermal systems, macroscopic balances for non-isothermal systems, energy transport by radiation. Mass Transport- Diffusivity and mechanisms of mass transport, concentration distributions in solids and laminar flow, equations of change for multicomponent systems, interphase transport in non-isothermal mixtures, macroscopic balances for multicomponent systems.

References:

1. R.B. Bird, W.E. Stewart, E.N. Lightfoot, Transport Phenomena, (2e) John Wiley & Sons, 2006.
2. A.S. Foust, L.A. Wenzel, C.W. Clump, L. Maus, L.B. Andersen, Principles of Unit Operations, (2e), Wiley India, 2008.
3. C.J. Geankoplis, Transport Processes and Separation Process Principles, (4e), Prentice Hall of India, 2015.
4. W.M. Deen, Analysis of Transport Phenomena, (2e), Oxford University Press, 2013.
5. W.J. Thompson, Introduction to Transport Phenomena Prentice Hall, 1999.
6. R.S. Brodkey, H.C. Hershey, Transport Phenomena a Unified Approach, McGraw Hill Publishers, 2003.

CE2130: TRANSPORT PHENOMENA LAB I [0 0 4 2]

This course will include practical experiments for momentum transfer: venturimeter, orifice meter, Reynolds experiment, agitated vessel, rotameter, friction factor, Bernoulli's principle, centrifugal pump, and filtration.

FOURTH SEMESTER

EO2001: ECONOMICS [3 0 0 3]

Introduction: Definition, nature and scope of economics, introduction to micro and macroeconomics; Microeconomics: Consumer behaviour, cardinal and ordinal approaches of utility, law of diminishing marginal utility, theory of demand and supply, law of demand, exceptions to the law of demand, change in demand and change in quantity demanded, elasticity of demand and supply, Indifference curve, properties, consumer equilibrium, Price and income effect; Production: Law of production, production function, SR and LR production function, law of returns, Isoquant curve, characteristics, Isocost, producer's equilibrium; Cost and revenue analysis: Cost concepts, short run and long- run cost curves, TR, AR, MR; Various market situations: Characteristics and types, Break-even analysis; Macro Economics: National Income, Monetary and Fiscal Policies, Inflation, demand and supply of money, consumption function and business cycle.

References:

1. H.L Ahuja, *Macroeconomics Theory and Policy*, (20e), S. Chand Publication.
2. H.C. Peterson, *Managerial Economics*, (9e), 2012.
3. P.L. Mehta, *Managerial Economics*, Sultan Chand & Sons.
4. G.J. Tuesen, H.G. Tuesen, *Engineering Economics*, PHI.
5. J.L. Riggs, D.D. Bedworth, Sabah U Randhawa, *Engineering Economics*, Tata McGraw Hill.

MA2208: ENGINEERING MATHEMATICS IV [2 1 0 3]

Formation of Linear Programming problem, Graphical method, Simplex method, Penalty cost and two phase methods. Finite sample spaces, conditional probability and independence, Bayes' theorem. One dimensional random variable, mean, variance, Chebyshev's inequality. Two and higher dimensional random variables, covariance, correlation coefficient, regression, least squares principles of curve fitting. Binomial, Poisson, uniform, normal, gamma, Chi-square and exponential. Finite difference expressions for first and second order derivatives (ordinary and partial).Solution of BVP's in ODE. Classification of second order linear partial differential equations. Numerical solutions of two dimensional Laplace and Poisson equations by standard five point formula. Solution of one dimensional heat and wave equations by explicit methods. Crank-Nicolson method. Finite element method, Introduction, simple applications. Difference equations representing physical systems, the z transforms, properties of z transforms, initial and final value theorems, solution of difference equations by the method of z transforms, convolution theorem.

References:

1. Erwin Kreyszig, *Advanced Engineering Mathematics*, 7(e), John Wiley & Sons, Inc. 1993.
2. P.L. Meyer, *Introduction to probability and Statistical applications*, 2(e), American Publishing Co 1970.
3. A Taha Hamdy*, Operation research*, (7e), Inc. Pearson Education, 2002.
4. B.S. Grewal, *Higher Engineering Mathematics*, 43(e), Khanna Publishers, 2014.
5. S.S. Sastry, *Introductory methods for Numerical Analysis*, (5e), PHI Learning Private Limited, 2012.

CE2201: CHEMICAL REACTION ENGINEERING I [3 1 0 4]

Kinetics of homogeneous chemical reactions, Rate expressions, Temperature dependence of rate differential, integral, half-life and total pressure method theories, Elementary and Non elementary reaction kinetics - pseudo, steady state hypothesis mechanism. Isothermal reactor design. Design of batch, semi-batch, CSTR's and PFR's. Multiple reactor systems, reactors in series or/and parallel, CSTRs series performance analysis, batch, semi-batch, continuous and recycle reactors. Multiple reaction systems, series and parallel reactions in flow reactors, product distribution, yield and selectivity. Maximizing the desired product in parallel reactions, different reactors and schemes for minimizing the unwanted product, maximizing the desired product in series reactions. Non isothermal homogeneous reactions, temperature effects, principles of stability, design procedures for adiabatic and non-isothermal conditions for batch semi-batch and flow reactors. Optimum temperature progression, multiple reactions and effect of temperature on product distribution.

References:

1. O. Levenspiel, *Chemical Reaction Engineering*, (3e), Wiley India Pvt Ltd., 2010.
2. H. S. Fogler, *Elements of Chemical Reaction Engineering*, (4e), Prentice-Hall of India, Delhi, 2003.
3. J. M. Smith, *Chemical Engineering Kinetics*, (3e), McGraw-Hill, 1981.
4. O. Levenspiel, *The Chemical Reactor Omnibook,* OSU Bookstores, Corvallis Oregon, 1993.
5. G. F. Froment, K. B. Bischoff, *Chemical Reactor Analysis and Design*, (3e), John Wiley and Sons, 2010.
6. Richardson, J.F., and Peacock D.G., *Coulson and Richardson's Chemical Engineering,* vol. 3, (3e), Asian Books Pvt. Ltd., New Delhi, 1998.

CE2202: HEAT TRANSFER OPERATIONS [3 1 0 4]

Introduction – Modes of heat transfer, heat transfer equipment. Conduction – Steady state conduction in one dimension, Fourier's law, thermal conductivity, steady state conduction of heat through composite solid, variable area and in bodies with heat sources. Convective heat transfer – Overall heat transfer coefficient, heat transfer between fluids separated by plane wall, cylindrical wall, thermal contact resistance, critical insulation thickness; Forced convection – flow over flat plate, thermal boundary layer, flow across a cylinder. Dimensionless groups in heat transfer, correlations for heat transfer coefficient for both internal and external flows; Free convection – heat transfer correlations, combined free and forced convection. Radiation heat transfer – Basic concepts, blackbody radiation, Planck's Law, Wien's displacement law, Stefan-Boltzmann Law, Kirchhoff's Law, grey body; Radiation intensity of black body, radiation shield, view factor, combined radiation, conduction and convection. Heat transfer in boiling and condensation – Boiling phenomena and boiling curve, mechanism of nucleate boiling, correlations for pool boiling, forced convection boiling; Condensation phenomena, condensation outside horizontal tube or tube bank, inside a horizontal tube, effect of non-condensable gases, drop wise condensation. Heat exchanger design – Double pipe heat exchanger design using Kern method, shell and tube heat exchanger design using Kern method and Bell Delaware method, effectiveness NTU method of heat exchanger analysis. Evaporators – Types of evaporators and their construction and operation, principles of evaporation and evaporators – capacity & economy, boiling point rise, heat transfer coefficient, enthalpy of solution, Evaporator selection and vapor recompression. Crystallization – Crystal geometry, principles of crystallization- equilibria & yields, nucleation, crystal growth, crystallization equipment

References:

1. Y.A. Cengel, Heat and Mass Transfer: A Practical Approach, (3e) McGraw Hill, 2006.
2. D.Q. Kern, Process Heat Transfer, McGraw Hill, 1997.
3. J. P., Holman, Heat Transfer, (10e) McGraw Hill, 2018.
4. W.L. McCabe, J.C. Smith, P. Harriott, "Unit operations of Chemical Engineering", (7e) McGraw Hill Education, 2017.
5. J.M. Coulson, J.F. Richardson, J.R. Backhurst, J.H. Harker, Coulson and Richardson's Chemical Engineering Volume 1: Fluid Flow, Heat Transfer and Mass Transfer, (5e) Butterworth-Heinemann/Elsevier, 2003.
6. A.J. Chapman, Heat Transfer, (4e), Persons, 2016.

CE2203: MASS TRANSFER I [3 1 0 4]

Introduction to mass transfer operations. Theory of interphase mass transfer, estimation of mass transfer coefficient, individual and overall mass transfer coefficients for gas-liquid and liquid-liquid operations. Gas Absorption, graphical calculation of number of theoretical stages for absorption and stripping column. Adsorption, adsorption isotherm, batch and continuous stage adsorption, design of adsorption column, and adsorption equipment. Vapor gas mixtures, terminology, Psychometric chart, water cooling operations, gas-liquid contact operations, adiabatic operations. Types of equipment, design calculations, cooling towers, design of cooling towers, recirculating liquid-gas humidification cooling.

References:

1. J.D. Seader, E.J. Henley, *Separation Process Principles*, (2e), Wiley, 2010.
2. R.E. Treybal*, Mass Transfer Operations,* (3e), McGraw Hill, 2012.
3. C.J. Geankoplis, *Transport Processes and Separation Process Principles*, (4e), Prentice Hall of India, 2015.
4. A.S. Foust, L.A. Wenzel, C.W. Clump, L. Maus, L.B. Andersen, *Principles of Unit Operations*, (2e), Wiley India, 2008.
5. W.L. McCabe, J.C. Smith, P. Harriott, *Unit operations of Chemical Engineering*, (7e) McGraw Hill Education, 2017.
6. R.K. Sinnott, G.Towler, Coulson & Richardson's*, Chemical Engineering Design*, Vol. 6, (5e), Elsevier, 2006.

CE2230: TRANSPORT PHENOMENA LAB II [0 0 4 2]

This course will include practical experiments for heat transfer: shell and tube heat exchanger, plate type heat exchanger, condensers, Stefan-Boltzmann's experiment, evaporator, thermal conductivity of liquid and agitated vessel.

CE2231: PROCESS EQUIPMENT DESIGN LAB [0 0 3 1]

This course will contain mechanical design of process equipment including reactors, pressure vessels, storage tank, columns, support and drawing of any two of the equipment.

FIFTH SEMESTER

BB0026: ORGANISATION AND MANAGEMENT [3 0 0 3]

Meaning and definition of an organization, Necessity of Organization, Principles of Organization, Formal and Informal Organizations. Management: Functions of Management, Levels of Management, Managerial Skills, Importance of Management, Models of Management, Scientific Management, Forms of Ownership, Organizational Structures, Purchasing and Marketing Management, Functions of Purchasing Department, Methods of Purchasing, Marketing, Functions of Marketing, Advertising. Introduction, Functions of Personal Management, Development of Personal Policy, Manpower Planning, Recruitment and Selection of manpower**.** Motivation – Introduction, Human needs, Maslow's Hierarchy of needs, Types of Motivation, Techniques of Motivation, Motivation Theories, McGregor's Theory, Herzberg's Hygiene Maintenance Theory. Leadership - Introduction Qualities of a good Leader, Leadership Styles, Leadership Approach, Leadership Theories. Entrepreneurship-Introduction, Entrepreneurship Development, Entrepreneurial Characteristics, Need for Promotion of Entrepreneurship, Steps for establishing small scale unit**.** Data and Information; Need, function and Importance of MIS; Evolution of MIS; Organizational Structure and MIS, Computers and MIS, Classification of Information Systems, Information Support for functional areas of management.

Reference:

1. Koontz, Harold, Cyril O'Donnell, and Heinz Weihrich, *Essentials of Management*,(1e) Tata McGraw-Hill, New Delhi, 1978.
2. Robbins, Stephen P, and Mary Coulter, *Management, Prentice Hall*, (2e) New Delhi, 1997.
3. E. S. Buffa and R. K. Sarin, *Modern Production / Operations Management*, (8e), Wiley, 1987
4. H. J. Arnold and D. C. Feldman, *Organizational Behavior*, McGraw – Hill, 1986.
5. Aswathappa K, *Human Resource and Personnel Management*, Tata McGraw Hill, 2005.
6. William Wether & Keith Davis, *Human Resource and Personnel Management*, McGraw Hill, 1986.

CE3101: MASS TRANSFER II [3 1 0 4]

Distillation, concept of vapor liquid equilibrium, Raoult's law, deviations from ideal law, azeotropic distillation and steam distillation. Enthalpy concentration diagrams, binary and multi component systems, dew and bubble point calculations, flash vaporization, simple distillation, binary component distillation, Ponchan Savarit method: minimum reflux ratio, optimum reflux ratio- total reflux ratio, partial condenser, total condenser, McCabe Thiele method: concept of q line, optimum reflux ratio- total reflux ratio, partial condenser, total condenser. Multi component distillation: azeotropic, extractive, molecular distillation. Liquid-Liquid Extraction: liquid-liquid-equilibria, ternary systems triangular and rectangular coordinates-choice of solvent-single stage and multi stage cross current, equipment's such as mixer settler, packed and tray towers. Leaching, Drying and design criteria, Design of rotary dryers.

References:

1. J.D. Seader, E.J. Henley, Separation Process Principles, (2e), Wiley, 2010.
2. R.E. Treybal, Mass Transfer Operations, (3e), McGraw Hill, 2012.
3. C.J. Geankoplis, Transport Processes and Separation Process Principles, (4e), Prentice Hall of India, 2015.
4. C.J. King, Separation Processes, (2e), Tata McGraw Hill, 1982.
5. A.H.P. Skelland, Diffusional Mass Transfer, (2e), John Wiley, 1985.

CE3102: CHEMICAL REACTION ENGINEERING II [3 1 0 4]

Isothermal non-ideal flow reactors, RTD in chemical reactors, distribution functions. Conversion in non-ideal flow reactors, single and multi-parameter models for non-ideal flow, concepts of mixing, micro and macro mixing. Heterogeneous reactions, rate equation for heterogeneous systems, contacting patterns for two phase systems, fluid particle non-catalytic reactions, different models, derivation of rate equations, application to design fluid-fluid non-catalytic reactions. Introduction to slurry reactors, trickle bed reactors, and fluidized bed reactors.

References:

1. H. S. Fogler, Elements of Chemical Reaction Engineering, (4e), Prentice-Hall of India, 2003.
2. O. Levenspiel, Chemical Reaction Engineering, (3e), Wiley India Pvt Ltd., 2010.
3. J.M. Smith, Chemical Engineering Kinetics, (3e), McGraw-Hill, 1981.
4. J. J. Carberry, Catalytic Reaction Engineering, McGraw-Hill, 1976.
5. O. Levenspiel, The Chemical Reactor Omnibook, OSU Bookstores, Corvallis Oregon, 1993.

CE3103: PROCESS MODELING AND SIMULATION [3 0 2 4]

Fundamentals and industrial applications of process modeling and simulation, macroscopic mass, energy and momentum balances, integration of fluid thermodynamics, chemical equilibrium, reaction kinetics and feed/ product property estimation in mathematical models. Steady state lumped systems, modeling of chemical process equipment (reactors, distillation, absorption, extraction columns, evaporators, and heat exchangers). Modeling and simulation of complex industrial systems in petroleum, petrochemicals, polymer, basic chemical industries; Commercial steady state and dynamic simulators; Simulation of process flow sheets.

References:

1. K. Hangos, I.T. Cameron, Process Modeling and Model Analysis, Academic Press, 2001.
2. J. Ingham, I.J. Dunn, E. Heinzle, J.E. Prenosil, J.B. Snape, Chemical Engineering Dynamics: An Introduction to Modelling and Computer Simulation, (3e), Wiley-VCH Verlag GmbH & Co. KGaA, 2007.
3. B.V. Babu, Process Plant Simulation, Oxford University Press, 2004.
4. W.L. Luyben, Process Modeling, Simulation and Control for Chemical Engineers, McGraw Hill, 1989.
5. C.D. Holland, Fundamentals and Modeling of Separation Processes, Prentice Hall, 1975.
6. D.M. Himmelblau, K.B. Bischoff, Process analysis and simulation: Deterministic systems, John Wiley, 1968.

CE3104: PROCESS SAFETY ANALYSIS [3 1 0 4]

Introduction – Accident and loss statistics, inherent safety, safety culture, ethics; Toxicology- How toxicants enter and are eliminated from biological organisms, toxicological studies, dose vs response, relative toxicity, threshold limit values; Industrial Hygiene: Government regulations, identification, evaluation of exposures to volatile toxicants, dusts, noise, toxic vapors, control; Source Models: Flow of liquid through hole, hole in a tank, pipes; Flow of vapor through holes, gases through pipes; Flashing liquids, liquid pool evaporation or boiling, toxic release and dispersion models; Fires and explosion: Fire triangle, fire vs explosion, flammability characteristics of liquid and vapors, TNT equivalency, energy of chemical and mechanical explosions, vapor cloud explosions, BLEVE, inerting, static electricity, explosion proof equipment and instruments, sprinkler systems; Relief systems: Relief concepts, location of reliefs, relief scenarios, relief systems for flares, scrubbers, condensers, knock out drum; Relief sizing: Spring operated for liquid/vapor/gas service, rupture disk relief for liquid/vapor/gas, reliefs for thermal expansion of process fluids; Hazard Identification: Surveys, HAZOP, safety reviews Risk assessment: Probability theory, event trees, fault trees, QRA, LOPA, Accident investigations

References:

1. D.A. Crowl, J.F. Louvar, Chemical Process Safety, (3e), Pearson, 2015.
2. Center for Chemical Process Safety (CCPS), Introduction to Process Safety for Undergraduates and Engineers, Wiley, 2016.
3. R.E. Sanders, Chemical Process Safety, (3e), Elsevier, 2006.
4. J.A. Klein, B.K. Vaughen, Process Safety: Key Concepts and Practical Approaches, CRC press, 2017.

CE3130: TRANSPORT PHENOMENA LABORATORY III [0 0 4 2]

This course will include practical experiments for mass transfer: Vapour Liquid equilibrium, distillation, liquid-liquid extraction, leaching, crystallization, leaching, drying, and mass transfer with and without reaction.

SIXTH SEMESTER

CE3201: PROCESS PLANT DESIGN [3 1 0 4]

Process Design and Development: The hierarchy of chemical process design, general design considerations, nature of process synthesis and analysis. Development of a conceptual design and determining the best flow sheet: input information and batch versus continuous, Input/output structure of the flow sheet; Recycle structure of flow sheet; Separation system; Heat Exchanger Networks. Plant Design: Process design development and general design considerations. Process Economics: Economic feasibility of project using order-of-magnitude cost estimates, plant and equipment cost estimation, product cost estimation.

References:

1. J. M. Douglas, Conceptual Design of Chemical Processes, McGraw-Hill, 1988.
2. M.S. Peters, K.D. Timmerhaus, R.E. West, Plant Design and Economics for Chemical Engineers, (5e), McGraw-Hill, 2003.
3. W.D. Seider, J.D. Seader, D.L. Lewin, Product and Process Design Principles: Synthesis, Analysis, and Evaluation, (3e), John-Wiley and Sons, 2008.
4. R. Turton, R.C. Bailie, W.B. Whiting, J.A. Shaeiwitz, D. Bhattacharyya, Analysis, Synthesis and Design of Chemical Processes, (4e), Prentice Hall India Learning Private Limited, 2015.
5. G. Towler R.K. Sinnott., Chemical Engineering Design: Principles, Practice and Economics of Plant and Process Design, CBSPD, 2009.
6. D.F. Rudd, C.C. Watson, Strategy of Process Engineering, John Wiley and Sons, 1968.
7. A.W. Westerberg, H.P. Hutchison, R.L. Motard, P. Winter, Process Flowsheeting, Cambridge University Press, 2011.

CE3202: CHEMICAL PROCESS INDUSTRIES [3 1 0 4]

Overview of typical chemical processes, unit operations and unit processes, Indian chemical process industries, inorganic chemical industry, study aspects of chemical process industries- raw materials, process, chemical reactions, process and block flow diagram, major engineering issues and uses of industries for water conditioning and treatment, common salt (NaCl) manufacture, coal gasification, manufacture of ammonia, urea, nitric acid and ammonium nitrate.

References:

1. G.M. Rao, M. Sitting, Dryden's Outlines of Chemical Technology – for the 21st Century, (3e), East-West Press, 1997.
2. G.T. Austin, Shreve's Chemical Process Industries (5e), Tata McGraw-Hill, 2012.
3. P.H. Groggins, Unit processes in organic synthesis (5e), McGraw-Hill, 2004.

CE3203: PROCESS DYNAMICS AND CONTROL [3 1 0 4]

Introduction to process control, Laplace transforms. Linear open-loop systems, First-Order Systems: transfer function, transient response (step response, impulse response, and sinusoidal response), and 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. Linear closed-loop systems. Control system: components of a control system, block diagram, negative feedback and positive feedback, servo problem and regulator problem. Controller transfer functions (P, PI, PD, PID), controller tuning. Advanced Control Schemes: cascade, feed-forward, ratio control, dead-time compensation, internal model control. Instrumentation: final control element, measuring devices for flow, temperature, pressure and level.

References:

1. D.R. Coughanowr, Process Systems Analysis and Control, (3e), McGraw Hill, 2008.
2. D.E. Seborg, D.A. Mellichamp, T.F. Edgar, Process Dynamics and Control, (3e), John Wiley & Sons, 2010.
3. C.D. Johnson, Process control instrumentation technology, Prentice-Hall, 2006.
4. G. Stephanopoulos, Chemical Process Control, PHI, 2008.
5. W.L. Luyben, Process Modeling, Simulation and Control for Chemical Engineers, (2e), McGraw Hill, 1990.

CE3230: CHEMICAL REACTION ENGINEERING LAB [0 0 4 2]

This course will include practical experiments for reaction engineering: Plug flow reactor (PFR), continuous stirred tank reactor (CSTR), CSTR in Series, combination of reactors, gas-solid reactions and photochemical reactor.

CE3231: PROCESS DYNAMICS AND CONTROL LAB [0 0 4 2]

This course will include practical experiments for Process Dynamics and Control: first order system, second order system, valve characteristics, and computational process control.

SEVENTH SEMESTER

CE4170: MINOR PROJECT [0 0 4 2]

The minor project will be carried out by the student at the university (on campus). It may include but not limited to literature survey, case study, experimental or simulation studies. It will be done individually or in a group.

CE4171: INDUSTRIAL TRAINING [0 0 2 1]

Each student has to undergo industrial training for a period of 4-6 weeks. This may be taken in a phased manner during the vacation starting from the end of sixth semester. Student has to submit to department a training report in the prescribed format and also make a presentation of the same. The report should include the certificate issued by the industry.

EIGHTH SEMESTER

CE4270: MAJOR PROJECT [0 0 0 12]

The project work may be carried out in the institution/industry/research laboratory or any other competent institution. The duration of the project work shall be minimum of 16 weeks which may be extended up to 24 weeks.

PROGRAM ELECTIVE-I

CE3240: ENGINEERING MATERIALS [3 0 0 3]

Structure of materials-crystal structure, substructure, microstructure; Materials classifications –engineering standards, material selection (CES type packages); Material properties – mechanical, electrical, physical, corrosion, etc. properties; Material treatment –heat treatment, various types of heat treatment such as annealing, normalizing, quenching, tempering (Austempering, Martempering), and various case hardening processes, surface treatment, etc.; Ferrous materials-various types of carbon steels, alloy steels and cast irons, its properties and uses, effects of different alloying elements, super alloys; Non-Ferrous metals and alloys-non-ferrous metals such as Cu, Al, Zn, Cr, Ni etc. and its applications, Various type of Brass and Bronze, bearing materials, its properties and uses. Aluminum alloys such as Duralumin; Ceramics – classification, characterization, properties; Plastics – Various types of polymers/plastics and its applications, Mechanical behaviour and processing of plastics, Future of plastics; Composite materials – structure, properties, classification, processing; other materials: brief description of other material such as optical and thermal materials, Introduction to smart materials & nano-materials and their potential applications; Electric properties, Semiconductors and Super conductors- Energy band concept of conductor, insulator and semi-conductor. Intrinsic & extrinsic semi-conductors. Super conductivity and its applications; Magnetic Properties: concept of magnetism - dia, para, ferro hysteresis. Soft and hard magnetic materials; Surface engineering and applications – techniques, coatings, processing and heat treatment.

References:

1. W.D. Callister, D.G. Rethwisch, R. Balasubramaniam, Callister's Material Science and Engineering, (2e), Wiley India Pvt Ltd., 2014.
2. W.F. Smith, J. Hashemi, R. Parkash, Material Science and Engineering, McGraw Hill, 2014.
3. V. Raghvan, Materials Science and Engineering, (5e), PHI Learning, 2013,
4. F.J. Shackelford, Introduction to Materials Science for Engineers, (7e), Pearson Prentice Hall, 2009.
5. L.H. Van Vlack, Elements of Material Science and Engineering, (6e), Pearson, 2002

CE3241: PROCESS SYNTHESIS [3 0 0 3]

Introduction to Process Systems Engineering; Strategy of Reaction Synthesis; Engineering Data on Reaction Paths; Screening of Reaction Paths; Reaction Paths with Recycle; Conservation of Mass; Material Balancing Pathways; Synthesis of Material Flow; Species Allocation; Introduction to Separation Technology; Solid-Solid separation methods; Liquid-Liquid separation techniques; Reduction of Separation Load; Selection of Separation Phenomena; Integration of Auxiliary Operations; Energy Balance; Sensible and Latent Heat; Heat of Chemical Reactions; Heat energy management and Heat-Exchanger Networks; Case studies from chemical and petroleum processing plants.

References:

1. D.F. Rudd, G.J. Powers, J.J. Siirola, Process Synthesis, Prentice-Hall international series in the physical and chemical engineering sciences, 1973.
2. R.M. Murphy, Introduction to Chemical Processes: Principles, Analysis, Synthesis, Mc Graw Hill, 2017.
3. R. Smith, Chemical Process: Design and Integration, John Wiley & Sons, 2005.
4. W.D. Seider, J.D. Seader, D.L. Lewin, Product and Process Design Principles: Synthesis, Analysis, and Evaluation, (3e), John-Wiley and Sons, 2008.
5. R. Smith, Chemical Process Design, McGraw-Hill, New York, 1995.

PROGRAM ELECTIVE-II

CE3242: BIOPROCESS ENGINEERING [3 0 0 3]

Basics of biology and bioprocess engineering. Microbial growth and kinetics. Enzymes and enzyme kinetics. Bioreactor Engineering, Fermentation mechanisms and kinetics. Types of fermenters, modeling of batch and continuous fermentor. Bioreactor design and mixing phenomena. Sterilization of media and air, sterilization equipment and design. Downstream Processing (Recovery and Purification of Products): membrane separation processes, chromatographic methods, and electrokinetic separations: electro-dialysis, electrophoresis. Waste water treatment: activated sludge process, anaerobic digestion, trickling filter.

References:

1. M.L. Shuler, F. Kargi, Bioprocess Engineering Basic Concepts, (2e), Prentice Hall of India, 2017.
2. J.E. Bailey, D.F. Ollis, Biochemical Engineering Fundamentals, (2e), McGraw Hill, 2017.
3. P. Doran, Bioprocess Engineering Principles, (2e), Elsevier, 2012.
4. K. Schugerl, K.V. Bellgardt, Bioreaction Engineering: Modeling and Control, Springer Verlag, Heidelberg, 2000.
5. S. Aiba, A.E. Humphrey, N.F. Millis, Biochemical Engineering, (2e), Academic Press, 1973.
6. H.W. Blanch, D.S. Clark Biochemical Engineering, (2e), CRC Press, New York, 1997.

CE3243: CATALYTIC PROCESSES [3 0 0 3]

Introduction to history of catalysis, catalytic processes in industry, chemical kinetics of catalyzed reactions: rate expression, adsorption isotherms, temperature and pressure dependency. Heterogeneous catalysis: industrial reactors, ideal reactors, reaction combined with transport, reaction kinetics determination. Introduction to Homogenous catalysis with transition metal complexes, catalysts testing and reactors configurations, catalyst deactivations, mechanism and kinetics study, kinetic modeling and parameter estimations, Preparation of catalyst supports and mesoporous materials, supported catalysts, catalyst characterization techniques.

References:

1. R.A. Van Santen, P.W.N.M. Van Leeuwen, J.A. Moulijn, B.A. Averill, Catalysis: An integrated Approach, (2e), Elsevier, Amsterdam, 1999.
2. G. Ertl, H. Knozinger, J. Weitkamp, Handbook of Heterogeneous Catalysis, Vol 1-5, (2e) Wiley – VCH, 2008.
3. B. Viswanathan, S. Sivasanker, A.V. Ramaswamy, Catalysis: Principles & Applications, CRC Press, 2002.
4. J. M. Smith, Chemical Engineering Kinetics, (3e), McGraw-Hill, 1981.
5. J.J. Carberry, Chemical and Catalytic Reaction Engineering, McGraw Hill, 1976.
6. C.H. Bartholomew, R.J. Farrauto, Fundamentals of Industrial Catalytic Processes, (2e), Wiley- VCH, 2005.

PROGRAM ELECTIVE-III

CE4140: PETROLEUM PRODUCTION TECHNOLOGIES [3 0 0 3]

Introduction to exploration and onshore/offshore production facilities and processes, oil, natural gas and produced water properties for designing and analyzing oil and gas production systems. Performance of oil and gas wells such as reservoir deliverability, wellbore performance, choke performance, well deliverability. Production enhancement- matrix acidizing, hydraulic fracturing Equipment design- well tubing, separation systems, transportation systems.

References:

1. B. Guo, W.C. Lyons, A. Ghalambor, Petroleum Production Engineering, A Computer Assisted Approach, Gulf Professional Publishing, 2011.
2. M.J. Economides, A.D. Hill, C. Ehlig-Economides, D. Zhu, Petroleum Production Systems, (2e), Prentice Hall, 2012.
3. W. Lyons, Working Guide to Petroleum and Natural Gas Production Engineering, Gulf Professional Publishing, 2010.
4. H.K. Abdel, M. Aggour, M. A. Fahim, Petroleum and Gas Field Processing, Marcel Dekker, 2003.

CE4141: CONVENTIONAL AND NON-CONVENTIONAL ENERGY RESOURCES [3 0 0 3]

Introduction of coal, natural gas and oil as sources of energy. Introduction to world energy scenario. Application of coal in industries. *In situ* coal Gasification. Oil and Gas from condensate and oilfields. Scope of Oil and Natural gas industry. Concepts of thermodynamics and system energy in Natural Gas Engineering. Physical properties of natural gas and the associated hydrocarbon liquids. Reservoir aspects of natural gas and oil. Conversion of coal and gas to liquid. Renewable energy resources, radiation, solar geometry, radiation models; Solar thermal, optical efficiency, thermal efficiency, concentrators, testing procedures, introduction to thermal systems (flat plate collector), biomass, biomass resources, wood composition, biogas, biodiesel, ethanol; Wind, types of wind machines, hydro resources, types of hydro turbine, small hydro systems; Other systems, geothermal, wave energy, ocean energy.

References:

1. R. F. Probstein, R.E. Hicks, Synthetic Fuels, Dover Publications, 2013.
2. D.D. Hall, R.P. Grover, Biomass: Regenerable Energy, John Wiley & Sons, 1987.
3. T. Twidell, T. Weir, Renewable Energy Resources, E & F N Spon Ltd, 1986.
4. J.A. Duffie, W.A. Beckman, Solar Engineering of Thermal Processes, (4e), John Wiley, 2013.

PROGRAM ELECTIVE-IV

CE4142: PETROLEUM REFINERY OPERATIONS [3 0 0 3]

Petroleum resources, petroleum industry in India. Composition and classification of petroleum crude, ASTM, TBP and FEV distillation. Properties and specifications of petroleum products – LPG, Gasoline, naphtha, kerosene, diesel oil, lubricating oil, wax etc. Design and operation of topping and vacuum distillation units. Tube still furnaces. Solvent extraction processes for lubricating oil base stocks and for aromatics from naphtha and kerosene, solvent dewaxing. Thermal and catalytic cracking, vis-breaking and coking processes, reforming, hydro processing, alkylation, polymerization and isomerization. Safety and pollution considerations in refineries.

References:

1. J.H. Gary, G.E., Handwerk, Petroleum Refining, Technology and Economics, (5e), CRC Press, 2007.
2. W. L. Nelson, Petroleum Refinery Engineering, (4e), McGraw Hill, 1987.
3. B.K.B. Rao, Modern Petroleum Refining Processes, Oxford-IBH, 2008
4. R.N. Watkins, Petroleum Refinery Distillation, (2e), Gulf Publishing, 1979.
5. K.A. Kobe, J.J. McKetta, Advances in Petroleum Chemistry and Refining, Wiley Interscience, 1958.

CE4143: ENVIRONMENTAL SYSTEMS ENGINEERING [3 0 0 3]

Characterization of Industrial wastewater, primary, secondary and tertiary treatment, segregation, screening, equalization, coagulation, flocculation, precipitation, flotation, sedimentation, aerobic treatment, anaerobic treatment, absorption, ion exchange, membrane filtration, electro dialysis, sludge dewatering and disposal methods. 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. Hazardous and non-hazardous waste, methods of treatment and disposal, land filling, leachate treatment and incineration of solid wastes.

References:

1. M.L. Davis, D.A. Cornwell, Introduction to Environmental Engineering, (5e), McGraw-Hill, 2014.
2. G. Tchobanoglous, F.L. Burton, H.D. Stensel Wastewater Engineering: Treatment and Reuse, (4e), McGraw-Hill, 2003.
3. G.M. Masters, W.P. Ela, Introduction to Environmental Engineering and Science, Pearson Education Inc., 2015.
4. H. S. Peavy, D.R. Rowe, G. Tchobanoglous, Environmental Engineering, McGraw Hill, 2013.
5. S.C. Bhatia, Environmental Pollution and Control in Chemical Process Industries, Khanna Publishers, Delhi, 2001.
6. H.C. Perkins, Air Pollution, McGraw Hill, 1974.

PROGRAM ELECTIVE-V

CE4144: PETROCHEMICAL PRODUCTION TECHNOLOGIES [3 0 0 3]

Survey of petrochemical industry; Availability of feed stocks; Production, purification and separation of feed stocks; Methane and synthesis gas derivatives, Ethylene and Ethylene derivatives, Propylene and propylene derivatives, Chemicals from C_2, C_3, C_4 and higher carbon compounds, Oxo reactions, etc. Production of chemicals from acetylene; Catalytic reforming of naphtha and isolation of aromatics; Chemicals from aromatics and BTX derivatives; Polymers, elastomers, polyurethanes, Synthetic fibers, detergents, rubbers and plastics; Petroleum coke.

References:

1. B.K.B. Rao, A Text on Petrochemicals, (2e), Khanna publishers, 1996.
2. I.D. Mall, Petrochemical Process Technology, Mac Millan India Ltd, 1997.
3. S. Matar, L.F. Hatch, Chemistry of Petrochemical Processes, (2e), Gulf Publishers, 2001.

CE4145: ENERGY AND PROCESS INTEGRATION [3 0 0 3]

Introduction: energy targeting and the pinch principle, problem table, cascade diagram, composite / grand composite curves, pinch point, utility pinch; Maximum Energy Recovery Network – pinch design method, grid\diagram, stream splitting / matching; Evolution / Evaluation of Networks – Euler's principle, identification and breaking of loops using paths; Capital cost targeting, Continuous Targeting – area / cost targeting, vertical heat transfer, threshold problem, super targeting; Distillation Column Targeting Principles, grand column composite curves, column composite curves, evaluation of energy saving options; Introduction to heat and power systems.

References:

1. U.V. Shenoy, Heat exchanger network synthesis: Process optimization by energy and resource analysis, Gulf publishing, 1995.
2. J. M. Douglas, Conceptual Design of Chemical Processes, McGraw-Hill, 1988.
3. W.D. Seider, J.D. Seader, D.L. Lewin, Product and Process Design Principles: Synthesis, Analysis, and Evaluation, (3e), John-Wiley and Sons, 2008.
4. I.C. Kemp, Pinch analysis and process integration: A user guide on process integration for the efficient use of energy, (2e) Butterworth-Heinemann, 2006.
5. J. J. Klemes, P.S. Varbanov, S.R.W.W. Alwi Z.A. Manan, Process Integration and Intensification: Saving Energy, Water and Resources, (2e), De Gruyter, 2014.

PROGRAM ELECTIVE-VI

CE4146: PROCESS OPTIMIZATION [3 0 0 3]

Formulation of the objective function. Unconstrained single variable optimization: Newton, Quasi-Newton methods, polynomial approximation methods. Unconstrained multivariable optimization: Direct search method, conjugate search method, steepest descent method, conjugate gradient method, Newton's method. Linear Programming: Formulation of LP problem, graphical solution of LP problem, simplex method, duality in Linear Programming, two-phase method. Nonlinear programming with constraints: Necessary and sufficiency conditions for a local extremum, Quadratic programming, successive quadratic programming, Generalized reduced gradient (GRG) method. Use of MS-Excel and MATLAB for solving optimization problems. Introduction to global optimization techniques. Applications of optimization in Chemical Engineering.

References:

1. T.F. Edgar, D.M. Himmelblau, L.S. Ladson, Optimization of Chemical Process, (2e), McGraw-Hill, 2001.
2. C.O. Godfrey, B.V. Babu, New Optimization Techniques in Engineering, Springer-Verlag, Germany, 2004.

3. G.S. Beveridge, R.S. Schechter, Optimization Theory and Practice, McGraw- Hill, New York, 1975.
4. G.V. Reklaitis, A. Ravindran, K. Ragsdell, M., Engineering Optimization-Methods and Applications, (2e) Wiley India Pvt Ltd., 2006.

CE4147: PROCESS ECONOMICS AND MANAGEMENT [3 0 0 3]

Cash flow concepts, present future and annual values, net present value, present value ratio, rate of return, breakeven, depreciation and taxes, project definition, project network, scheduling resource and cost, managing project risk, project progress, performance measurement, and evaluation.

References:

1. F.J. Stermole, J.M. Stermole, Economic Evaluation and Investment Decision Methods, and Investment Evaluation Corporation, (15e) Golden CO (USA), 2014.
2. H.A. Taha, Operations Research: An Introduction, (2e), Prentice Hall, 1997.

PROGRAM ELECTIVE-VII

CE4148: PROCESS INTENSIFICATION [3 0 0 3]

Introduction to process intensification (PI): sustainability related issues in process industry; definitions of process intensification; fundamental principles and approaches of PI; design of a sustainable and inherent safer processing plants. Mechanisms involved in PI: intensified heat transfer, intensified mass transfer, electrically enhanced processes, micro fluidics; compact and micro heat exchangers; Reactors: reactor engineering theory, spinning disc reactors, oscillatory baffled reactors, micro reactors, reactive separations, membrane reactors, supercritical operations, field enhanced reactors, rotating fluidized beds. Intensification and Separation Processes: distillation (reactive, extractive), centrifuges, membranes, drying, precipitation and crystallization; Intensified mixers, PI case study.

References:

1. D. A. Reay, C. Ramshaw, A.P. Harvey, Process Intensification: engineering for efficiency, sustainability and flexibility, (2e), (IChemE) Butterworth Harriman, London, 2008.
2. A. Stankiewicz, J.A. Moulijn, (Eds), Re-Engineering the Chemical Processing Plant: Process Intensification, CRC Press, 2003.
3. J.G. Segovia-Hernandez, A. Bonilla-Petriciolet, (Eds), Process Intensification in Chemical Engineering Design Optimization and Control, Springer, 2016.
4. F.J. Keil, (Ed), Modelling of Process Intensification, Wiley International, 2007.
5. A.A. Kiss, Process Intensification Technologies for Biodiesel Production, Springer, 2014.
6. H. Mothes, Process Design Synthesis, Intensification and Integration of Chemical Processes, Manufective, 2015.

CE4149: ADVANCED SEPARATION TECHNOLOGIES [3 0 0 3]

Separation process in chemical and biochemical industries, categorization of separation processes, equilibrium and rate governed processes. Introduction to various new separation techniques e.g. Membrane separation, ion-exchange foam separation, supercritical extraction, liquid membrane permeation, PSA & Freeze drying. 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, Electrodialysis and Pervaporation. Gaseous separation by membranes. Ion Exchange, 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 removal of ionic impurities from effluents. Introduction to foam separation, micellar separation, supercritical fluid extraction, liquid membrane permeation and chromatographic separations.

References:

1. C.J. King, Separation Processes, (2e), Dover Publishers, 1982.
2. S. Sourirajan, T. Matsura, Reverse Osmosis and Ultra-filtration - Process Principles, NRC Publications, 1985.
3. M.C. Porter, Handbook of Industrial Membrane Technology, Noyes Publication, 1990.
4. J.D. Henry, N.N. Li, New Separation Techniques, AIChE Today Series, AIChE 1975.
5. T. A. Hatton, J.F. Scamehorn, J.H. Harvell, Surfactant Based Separation Processes, Vol. 23, Surfactant Science Series, Marcel Dekker Inc.,1989.
6. M.A. McHugh, V.J. Krukonis, Supercritical Fluid Extraction, Butterworths,1985.

OPEN ELECTIVES

CE2280: MATERIAL SCIENCE ENGINEERING AND APPLICATIONS [3 0 0 3]

Introduction to solid state Physics and Chemistry: Crystalline and amorphous solids, crystal structure, bonding in solids, crystal imperfections, thermodynamics of solids, diffusion in solids. Chemical analysis of materials: X-ray diffraction, electron diffraction, neutron diffraction, introduction to surface science, Fourier transform infrared spectroscopy, Raman Spectroscopy, X-ray photoelectron spectroscopy, scanning electron microscope, transmission electron microscope, energy dispersive X-ray spectroscopy, X-ray florescence, luminescence. Physical Metallurgy: Phase rule, phase transformation (fundamentals of crystallization), corrosion of metals, theories and types of corrosion, preventive measures against corrosion, ferrous alloys, steels and its types, non-ferrous alloys (including aluminum, copper, nickel, magnesium, titanium) and processing of metals. Polymeric Materials: Polymer science and process of polymerization, types of polymers, carbon-based polymers, biocompatible and biodegradable polymers, self-healing polymers, elastomers and processing of polymeric materials. Ceramic Materials: Crystalline and Non-crystalline ceramic materials, classification of ceramics materials, ceramic phase diagram, mechanical properties of ceramics, cements, processing of ceramic materials. Reinforced materials (polymers and concrete): Particle reinforced materials, fiber reinforced materials, mechanical properties of reinforced materials. Material Properties and Applications: Electrical properties, magnetic properties, thermal properties, semiconductor properties and optical properties of materials and their respective applications. Nanotechnology and Nanomaterials: Introduction to nanomaterials, top-down and bottom-up approach for nanomaterial synthesis (crystallization), nanostructure materials, carbon nanotechnology, semiconductor nanomaterials, metallic nanomaterials, nanomaterials for biomedical, chemical, electronics and mechanical applications.

References:

1. W.F. Smith, J. Hashemi, R. Prakash, “Material Science and Engineering”, (5e), McGraw Hill Publishers, 2014.
2. W.D. Callister Jr., D.G. Rethwisch, R. Balasubramaniam, “Callister’s Material Science and Engineering”, (2e), Wiley India Pvt. Ltd., 2014.
3. J.F. Shackelford, M.K. Muralidhar, “Introduction to Material Science for Engineers”, (6e), Pearson India, 2007.
4. K. Raghavan, “Materials Science and Engineering: A First Course”, (6e), Prentice Hall of India, 2015.
5. M. Fontana, “Corrosion Engineering”, (3e), McGraw Hill Publishers, 2005.
6. H.L. Willard, L.L. Merritt Jr., J.A. Dean, F.A. Settle Jr., “Instrumental Methods of Analysis”, 7ed, CBS Publishers and Distributers, 1986.

CE3180: CORROSION ENGINEERING [3 0 0 3]

Introduction: What is corrosion? Need for corrosion prevention, Economic loss due to corrosion, environment of corrosion, Corrosion Engineering. Electrochemistry: Thermodynamics related to corrosion, Solution thermodynamics, activity related to ionic species, cell potential and EMF Series, potential-pH (Pourbaix) diagram, electrode kinetics. Chemical Engineering Fundamentals: Diffusion, Fick’s law, Rate of reaction, Arrhenius Law, temperature dependence of reaction. Corrosion Principles: rate expression for corrosion, electrochemical aspects, environmental effects, Metallurgical and Other aspects. Forms of Corrosion: Galvanic, Crevice, Pitting, Intergranular, Erosion, Stress corrosion, Selective leaching, Hydrogen damage. Corrosion Testing. Materials: Metals and Alloys, Non-metals, Thermoplastics, Thermosetting plastics and others. Corrosion Prevention: Material Selection, Alteration of Environment, Design, Cathodic and Anodic Protection, Coatings. Handling of Mineral Acids: Sulfuric acid, Nitric Acid, Hydrochloric acid, Hydrofluoric acid, Phosphoric acid. Corrosion due to other environments. Modern Theory of Corrosion Prevention: Predicting corrosion behavior, corrosion prevention, Corrosion rate measurement. High Temperature corrosion: Mechanism and kinetics, High Temperature Materials, Metal-gas reactions.

References:

1. M.G. Fontana, Corrosion Engineering, (3e), McGraw Hill Publishers, 1967
2. S. Glasstone, An Introduction to Electrochemisty, Affiliate East West Press Private Limited, 2017
3. P. Atkins, J. de Paula, J. Keeler, Atkins’ Physical Chemistry, (11e), Oxford University Press, 2018
4. D.A. Jones, Principles and Prevention of Corrosion, (2e), Pearson, 1995.

CE3280: RENEWABLE AND NON-RENEWABLE ENERGY RESOURCES [3 0 0 3]

Introduction of coal, natural gas and oil as sources of energy. Application of coal in industries. Coal Gasification. Oil and Gas from condensate and oilfields, Oil and Natural gas industry. Physical properties of natural gas and the associated hydrocarbon liquids. Reservoir aspects of natural gas and oil. Conversion of coal and gas to liquid. Carbon capture and Storage. Renewable energy resources, radiation, solar geometry, radiation models; Solar thermal, optical efficiency, thermal efficiency, concentrators, testing procedures, introduction to thermal systems (flat plate collector), biomass, biomass resources, wood composition, biogas, biodiesel, ethanol; Wind, types of wind machines, hydro resources, types of hydro turbine, small hydro systems; Other systems, geothermal, wave energy, ocean energy, Fuel Cell.

References:

1. R. F. Probstein, R.E. Hicks, Synthetic Fuels, Dover Publications, 2013.
2. D.D. Hall, R.P. Grover, Biomass: Regenerable Energy, John Wiley & Sons, 1987.
3. T. Twidell, T. Weir, Renewable Energy Resources, E & F N Spon Ltd, 1986.
4. J.A. Duffie, W.A. Beckman, Solar Engineering of Thermal Processes, (4e), John Wiley, 2013.