B.Tech. Chemical Engineering (2025-26) onwards (160 Credits)

III Semester

CHE2101 Process Calculations [3 1 0 4]

Review of Basic concepts – Process variables & properties, Degree of Freedom, Material balances: Steady State Material Balances – in non-reacting systems and reacting systems, 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 a 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*, 9th ed. PHI Learning Pvt Ltd, 2022.
2. R.M. Felder, R.W. Rousseau, *Elementary Principles of Chemical Processes*, 4th ed. Wiley, 2020.
3. B.I. Bhatt, S.B. Thakore, *Stoichiometry: Material and Energy Balance Computations*, 6th ed. McGraw-Hill, 2021.

CHE2102 Fluid Mechanics [3 1 0 4]

Dimensional analysis and similitude, Newtonian and non-Newtonian fluids, viscometers, fluid statics, surface tension, Reynolds Transport Theorem, Review of Navier-Stokes (NS) equations. Creeping flow, Stokes' law, and terminal velocity. Introduction to turbulence, analogies, and correlations for fluid flow. Engineering Bernoulli Equation; major and minor losses; f vs. NRe 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, flow meters, compressors and blowers. Fluid-particle mechanics: Flow around immersed bodies, concept of drag, boundary layer separation; Fluid-particle mechanics: Motion of particles in a fluid, effect of particle shape, influence of boundaries on terminal velocity; Fluid flow through granular and packed beds of particles: Ergun equation, Kozeny-Carman equation, Darcy's law, permeability; Mixing and Agitation: Power consumption, mixing times, scale-up.

References

1. W. L. McCabe, J. C. Smith, and P. Harriott, *Unit Operations of Chemical Engineering*, 8th ed. New York: McGraw-Hill International, 2022.
2. N. De Nevers, *Fluid Mechanics for Chemical Engineers*, 4th ed. New York: McGraw-Hill International, 2021.

3. Foust, A.S., Wenzel, L.A., Clump, C.W., Maus, L., Andersen, L.B., *Principles of Unit Operations*, John Wiley & Sons, 2015.
4. J. M. Coulson, J. F. Richardson, J. R. Backhurst, and J. H. Harker, Coulson and Richardson's Chemical Engineering Volume 1A: Fluid Flow — Fundamentals and Applications, 7th ed. Oxford, U.K.: Butterworth-Heinemann/Elsevier, 2018.

CHE2104 Chemical Engineering Thermodynamics I [3 1 0 4]

Definitions & concepts: SI Units; System; Thermodynamic Properties of Fluids: Mathematical, Tabular and Graphical representation of data; Ideal gas Van der Waals Equation of state; Compressibility chart; Thermodynamic Diagrams including Mollier diagram; Steam Tables, Zeroth Law of thermodynamics; First Law of Thermodynamics & its applications to Non flow processes, Applications of First Law of Thermodynamics of Flow Processes – Steady State / Transient; Applications of First Law of Thermodynamics to Chemically Reacting Systems Second Law of Thermodynamics & its Applications; Thermodynamic Potentials, Maxwell's Relations; Thermodynamic Relations and Availability, Power Cycles, Refrigeration Cycles; Gas-Vapor Mixtures and Psychrometry.

References:

1. Y. V. C. Rao, *An Introduction to Thermodynamics*. Hyderabad, India: Universities Press, 2004.
2. J. M. Smith, H. C. Van Ness, M. M. Abbott, and M. T. Swihart, *Introduction to Chemical Engineering Thermodynamics*, 9th ed. New York, NY, USA: McGraw-Hill, 2022.

CHE2105 Heat Transfer Operations [3 1 0 4]

Fourier's law, thermal conductivity, steady state conduction. Convective heat transfer – Overall heat transfer coefficient, heat transfer 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 the Kern method, shell and tube heat exchanger design using the Kern method and the Bell-Delaware method, effectiveness, and NTU method of heat exchanger analysis.

References:

1. Y.A. Çengel, A.J. Ghajar, *Heat and Mass Transfer: Fundamentals and Applications*, 5th ed. New York, NY, USA: McGraw-Hill Education, 2015.
2. D.Q. Kern, *Process Heat Transfer*, 2nd ed. Hoboken, NJ, USA: Wiley, 2009.

3. J.P. Holman, *Heat Transfer*, 10th ed. New York, NY, USA: McGraw-Hill Education, 2010.
4. W. L. McCabe, J. C. Smith, and P. Harriott, *Unit Operations of Chemical Engineering*, 8th ed. New York, NY, USA: McGraw-Hill Education, 2022.
6. 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*, 5th ed. Butterworth-Heinemann/Elsevier, 2003.

CHE2106 Transport Phenomena [3 1 0 4]

Transport coefficients - viscosity, thermal conductivity, and diffusivity. Dependence of transport coefficients on temperature, pressure, and composition, Kinetic theory. Shell balance - momentum, energy, and mass transfer - unidimensional velocity, temperature, and concentration profiles, and flux at the surface - momentum, energy, and mass. Introduction to general transport equations for momentum, energy, and mass transfer in Cartesian, cylindrical, and spherical co-ordinates, solutions in one-dimensional velocity, temperature, and concentration distribution with more than one independent variable, velocity and temperature distribution in turbulent flow, concept of boundary layer of momentum transport and energy transport.

References:

1. R. B. Bird, W. E. Stewart, and E. N. Lightfoot, *Transport Phenomena*, 2nd ed. Singapore: John Wiley, 2006.
2. W. J. Thomson, *Introduction to Transport Phenomena*. Upper Saddle River, NJ, USA: Prentice Hall, 1999.
3. R. S. Brodkey and H. C. Hershey, *Transport Phenomena: A Unified Approach*. Breckenridge, CO, USA: Brodkey Publishing, 2003.

IV Semester

CHE2203 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, and PFRs. 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, utilizing different reactors and schemes to minimize the unwanted product, and maximizing the desired product in series reactions.

References:

1. Levenspiel, O., *Chemical Reaction Engineering*, 3rd ed. Wiley India Pvt Ltd., 2010.
2. H. S. Fogler, *Elements of Chemical Reaction Engineering*, 5th ed. Upper Saddle River, NJ, USA: Pearson, 2016.
3. G. F. Froment and K. B. Bischoff, *Chemical Reactor Analysis and Design*, 3rd ed. Hoboken, NJ, USA: Wiley, 2011.

CHE2204 Mass Transfer I [3 1 0 4]

Introduction to mass transfer operations, Diffusion, Fick's Law, 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 the number of theoretical stages for an absorption and stripping column. Adsorption, adsorption isotherm, batch and continuous stage adsorption, design of adsorption column, and adsorption equipment. Vapor gas mixtures, terminology, Psychrometric chart, water cooling operations, gas-liquid contact operations, and adiabatic operations. Types of equipment, design calculations, cooling towers, design of cooling towers, Humidification, recirculating liquid-gas humidification cooling.

References:

1. J.D. Seader, E.J. Henley, and D.K. Roper, *Separation Process Principles: Chemical and Biochemical Operations*, 3rd ed. Hoboken, NJ, USA: Wiley, 2010.
2. R.E. Treybal, *Mass Transfer Operations*, 3rd ed. McGraw-Hill, 2012.
3. C.J. Geankoplis, *Transport Processes and Separation Process Principles*, 4th ed. Prentice Hall of India, 2015.
4. R.K. Sinnott and G. Towler, *Coulson & Richardson's Chemical Engineering Design*, Vol. 6, 5th ed. Oxford, UK: Butterworth-Heinemann/Elsevier, 2013.

CHE2205 Chemical Engineering Thermodynamics II [3 1 0 4]

Review of I and II 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, and M. T. Swihart, *Introduction to Chemical Engineering Thermodynamics*, 9th ed. New York, NY, USA: McGraw-Hill, 2022.
2. Y. V. C. Rao, *Chemical Engineering Thermodynamics*. Hyderabad, India: Universities Press, 1997.
3. B. G. Kyle, *Chemical and Process Thermodynamics*, 3rd ed. Upper Saddle River, NJ, USA: Prentice-Hall, 1999.
4. D.M. Himmelblau, J.B. Riggs, *Basic Principles and Calculations in Chemical Engineering*, 8th ed. Pearson, TN, 2015.

CHE2230 Fluid Mechanics Lab [0 0 3 1]

Experimental studies on fundamental fluid flow principles and measurement techniques including calibration and use of flow meters such as rotameters, orifice meters, and venturi meters; velocity measurement using Pitot tubes; verification of Bernoulli's theorem; observation of flow regimes through Reynolds experiment; determination of head losses in pipelines due to major and minor losses; performance evaluation of centrifugal pumps; study of power consumption in agitated vessels.

References

1. W. L. McCabe, J. C. Smith, and P. Harriott, *Unit Operations of Chemical Engineering*, 8th ed. New York, NY, USA: McGraw-Hill Education, 2022.
2. N. De Nevers, *Fluid Mechanics for Chemical Engineers*, 4th ed. New York, NY, USA: McGraw-Hill Education, 2017.
3. A. S. Foust, L. A. Wenzel, C. W. Clump, L. Maus, and L. B. Andersen, *Principles of Unit Operations*, 2nd ed. Hoboken, NJ, USA: John Wiley & Sons, 2015.

CHE2231 Thermal Processes Lab [0 0 3 1]

Introduction to thermal conductivity of liquids; shell and tube, plate-type and cross-flow heat exchangers, heat transfer in an agitated vessel, heat transfer in a fluidized bed, two-phase heat transfer, unsteady-state heat transfer, drop-wise and film-wise condensation, vertical and horizontal condenser, single effect evaporator, study of Stefan-Boltzmann law of radiative heat transfer.

CHE2270 **Project Based Learning I** **[0 0 3 3]**

Project Based Learning will be a practical/simulation-based study in the emerging areas.

V Semester

CHE3103 Chemical Reaction Engineering II [3 1 0 4]

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 the effect of temperature on product distribution. Isothermal non-ideal flow reactors, RTD in chemical reactors, and 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, catalyst deactivation, 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.

References:

1. Levenspiel, O., *Chemical Reaction Engineering*, 3rd ed., Wiley India Pvt Ltd., 2010.
2. H. S. Fogler, *Elements of Chemical Reaction Engineering*, 5th ed. Upper Saddle River, NJ, USA: Pearson, 2016.
3. J. J. Carberry, *Chemical and Catalytic Reaction Engineering*, 2nd ed. New York, NY, USA: Dover Publications, 2001.

CHE3104 Mass Transfer II [3 1 0 4]

Distillation, concept of vapour-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, McCabe-Thiele method, concept of q line, optimum reflux ratio- total reflux ratio, partial condenser, total condenser. Ponchon Savarit method, minimum reflux ratio, 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 such as mixer-settlers, packed and tray towers. Leaching, Drying, and Design Criteria: Design of Rotary Dryers.

References:

1. J. D. Seader, E. J. Henley, and D. K. Roper, *Separation Process Principles: Chemical and Biochemical Operations*, 3rd ed. Hoboken, NJ, USA: Wiley, 2010.
2. R.E. Treybal, *Mass Transfer Operations*, 3rd ed., McGraw-Hill, 2012.
3. C. J. Geankoplis, *Transport Processes and Separation Process Principles*, 5th ed. Upper Saddle River, NJ, USA: Prentice Hall, 2018.
4. A.S. Foust, L.A. Wenzel, C.W. Clump, L. Maus, L.B. Andersen, *Principles of Unit Operations*, 2nd ed. Wiley India, 2008.

5. R.K. Sinnott and G. Towler, *Coulson & Richardson's Chemical Engineering Design*, Vol. 6, 5th ed. Oxford, UK: Butterworth-Heinemann/Elsevier, 2013.

CHE3105 Process Modeling and Simulation [3 1 0 4]

Introduction to process modelling: Role of models, Types of models, Model classification, Model formulation strategies. Macroscopic mass, energy, and momentum balances, integration of fluid thermodynamics, chemical equilibrium, reaction kinetics, degrees of freedom, and property estimation in mathematical models. Modeling of chemical engineering processes: isothermal systems with and without reactions and non-isothermal systems. Numerical methods for process simulation for linear and non-linear algebraic equations and ordinary and partial differential equations. Model Validation and Parameter Estimation. Hands-on practice with simulation tools, Case studies of typical unit operations and integrated process flowsheets, Parametric sensitivity analysis, and optimization.

References

1. K. Hangos and I. T. Cameron, *Process Modeling and Model Analysis*. San Diego, CA, USA: Academic Press, 2001.
2. J. Ingham, I. J. Dunn, E. Heinzle, J. E. Prenosil, and J. B. Snape, *Chemical Engineering Dynamics: An Introduction to Modelling and Computer Simulation*, 3rd ed. Weinheim, Germany: Wiley-VCH Verlag GmbH & Co. KGaA, 2007.
3. W. L. Luyben, *Process Modeling, Simulation and Control for Chemical Engineers*. New York, NY, USA: McGraw-Hill, 1990.

CHE3106 Process Dynamics and Control [3 1 0 4]

Introduction to process control, Measurement of process variables; sensors and transducers; P&ID equipment symbols, 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, 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. Feedforward control scheme.

References:

1. D. R. Coughanowr and S. LeBlanc, Process Systems Analysis and Control, 4th ed. New York, NY, USA: McGraw-Hill, 2021.
2. G. Stephanopoulos, Chemical Process Control: An Introduction to Theory and Practice, 2nd ed. New Delhi, India: Pearson India, 2015
3. D. A. Mellichamp, D. Seborg, and T. F. Edgar, *Process Dynamics and Control*, 3rd ed. Hoboken, NJ, USA: John Wiley & Sons, 2010.

CHE3130 Reaction Engineering Lab [0 0 4 2]

Introduction to reaction engineering lab, Different types of reactors and their kinetics: Plug flow reactors, Continuous Stirred Tank Reactors (CSTR) in series and standalone, Batch reactors for Isothermal and Non-Isothermal studies, Plug flow reactors for isothermal studies, Non-catalytic Solid-Gas reactions, RTD studies of CSTR and PFR, Hydrodynamic Studies of Trickle bed reactors, Ultrasound Assisted Adsorption.

CHE3131 Process Modelling and Simulation Lab [0 0 3 1]

Introduction to Aspen HYSYS, thermodynamic models and property methods, simulation of reactors, distillation column, heat exchangers, process flowsheet development, sensitivity analysis, and optimization studies.

CHE3170 Project Based Learning II [0 0 3 3]

Project Based Learning will be a practical/simulation-based study in the emerging areas.

VI Semester

CHE3201 Process Plant Design [3 1 0 4]

Process Design and Development: Hierarchy of Chemical Process Design and General Design Considerations. 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 the flow sheet, Separation system, and Heat Exchanger Networks. Plant Design: Process design development and general design considerations. Estimation of capital and manufacturing cost.

References

1. M. S. Peters, K. D. Timmerhaus, and R. E. West, *Plant Design and Economics for Chemical Engineers*, 5^{th} ed., McGraw-Hill, 2003.
2. R. K. Sinnott and G. Towler, *Chemical Engineering Design*, 6^{th} ed., Elsevier, 2020.
3. J. M. Coulson and J. F. Richardson, *Coulson & Richardson's Chemical Engineering – Volume 6: Chemical Engineering Design*, 5^{th} ed. Oxford, UK: Butterworth-Heinemann, 2013.
4. R. Turton, R. C. Bailie, W. B. Whiting, and J. A. Shaeiwitz, *Analysis, Synthesis, and Design of Chemical Processes*, 5^{th} ed. Upper Saddle River, NJ, USA: Prentice Hall, 2018.

CHE3230 Process Dynamics and Control Lab [0 0 3 1]

Study of the time response of first-order and second-order systems under different types of input changes such as step, impulse, and sinusoidal disturbances; analysis of single-tank, two-tank interacting and non-interacting systems, control valve characteristics with hysteresis; Performance evaluation of feedback control systems applied to level control in tanks, temperature control in reboilers, distillate level control in distillation columns, and pressure control in continuous stirred tank reactors (CSTRs).

References:

1. D. R. Coughanowr and S. LeBlanc, Process Systems Analysis and Control, 4th ed. New York, NY, USA: McGraw-Hill, 2021.

CHE3231 Mass Transfer Lab [0 0 4 2]

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

References:

1. J. D. Seader, E. J. Henley, and D. K. Roper, *Separation Process Principles: Chemical and Biochemical Operations*, 3^{rd} ed. Hoboken, NJ, USA: Wiley, 2010.
2. R.E. Treybal, *Mass Transfer Operations*, 3^{rd} ed. McGraw-Hill, 2012.

3. C. J. Geankoplis, *Transport Processes and Separation Process Principles*, 5^{th} ed. Upper Saddle River, NJ, USA: Prentice Hall, 2018.
4. B. K. Dutta, *Principles of Mass Transfer and Separation Processes*. New Delhi, India: Prentice-Hall of India, 2007.

CHE3270 Project Based Learning III [0 0 3 3]

Project Based Learning will be a practical/simulation-based study in the emerging areas.

Program Elective 1

CHE3140 Process Safety Analysis [3 0 0 3]

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 and J. F. Louvar, *Chemical Process Safety*, 3^{rd} ed. Boston, MA, USA: Pearson, 2015.
2. R.E. Sanders, *Chemical Process Safety*, 3^{rd} ed. Elsevier, 2006.
3. J.A. Klein, B.K. Vaughen, *Process Safety: Key Concepts and Practical Approaches*, CRC Press, 2017.

CHE3141 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. R.M. Murphy, *Introduction to Chemical Processes: Principles, Analysis, Synthesis*, McGraw-Hill, 2017.
2. R. Smith, *Chemical Process: Design and Integration*. Hoboken, NJ, USA: John Wiley & Sons, 2005.
3. W.D. Seider, J.D. Seader, D.L. Lewin, *Product and Process Design Principles: Synthesis, Analysis, and Evaluation*, 3rd ed. John-Wiley and Sons, 2008.

Program Elective 2

CHE32xx 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 sufficient conditions for a local extremum, Quadratic programming, successive quadratic programming, Generalized reduced gradient (GRG) method. 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*, 2nd ed. McGraw-Hill, 2001.
2. C.O. Godfrey, B.V. Babu, *New Optimization Techniques in Engineering*, Springer-Verlag, Germany, 2004.

CHE3244 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.

References

1. M.L. Shuler, F. Kargi, *Bioprocess Engineering Basic Concepts*, 2nd ed. Prentice Hall of India, 2017.

2. J.E. Bailey, D.F. Ollis, *Biochemical Engineering Fundamentals*, 2nd ed. McGraw Hill, 2017.

3. P. Doran, *Bioprocess Engineering Principles*, 2nd ed. Amsterdam, Netherlands: Elsevier, 2012.

Program Elective 3

CHE32xx Chemical Process Industries [3 0 0 3]

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*, 3rd ed. East-West Press, 1997.

2. G.T. Austin, *Shreve's Chemical Process Industries*, 5th ed. Tata McGraw-Hill, 2012.

3. P.H. Groggins, *Unit processes in organic synthesis,* 5th ed. McGraw-Hill, 2004.

CHE32xx Waste to Energy Conversion [3 0 0 3]

Introduction, characterization of wastes. Energy production from wastes through incineration, and energy production through gasification of wastes. Energy production through pyrolysis and gasification of waste, and utilization of syngas. Densification of solids, efficiency improvement of power plants, and energy production from waste plastics. Energy production from wastes, Plastic, and gas cleanup. Energy production from organic wastes through anaerobic digestion and fermentation, introduction to microbial fuel cells. Energy production from wastes through fermentation and transesterification. Cultivation of algal biomass from wastewater and energy production from algae.

References

1. M. J. Rogoff and F. Screve, *Waste-to-Energy: Technologies and Project Implementation*. Amsterdam, The Netherlands: Elsevier, 2011.
2. G. C. Young, *Municipal Solid Waste to Energy Conversion Processes*. Hoboken, NJ, USA: John Wiley & Sons, 2010.
3. P. Mondal and A. K. Dalai, Eds., *Sustainable Utilization of Natural Resources*. Boca Raton, FL, USA: CRC Press, 2017.

Program Elective 4

CHE32xx 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, and 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*, 2nd ed. Prentice Hall, 2012.
3. W. Lyons, *Working Guide to Petroleum and Natural Gas Production Engineering*, Gulf Professional Publishing, 2010.

CHE32xx Conventional and Non-Conventional Energy Resources [3 0 0 3]

Introduction of coal, natural gas, and oil as sources of energy. Introduction to the world energy scenario. Application of coal in industries. In situ coal Gasification. Oil and Gas from Condensate and Oil Fields. Scope of the 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. J.A. Duffie, W.A. Beckman, *Solar Engineering of Thermal Processes*, 4th ed. John Wiley, 2013.

VII Semester

Program Elective 5

CHE41xx 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*, 5th ed. CRC Press, 2007.

2. W. L. Nelson, *Petroleum Refinery Engineering*, 4th ed. McGraw-Hill, 1987.

3. B.K.B. Rao, *Modern Petroleum Refining Processes*, Oxford-IBH, 2008

CHE41xx 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*, 5th ed. McGraw-Hill, 2014.
2. G. Tchobanoglous, F.L. Burton, H.D. *Stensel Wastewater Engineering: Treatment and Reuse*, 4th ed. 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*, 4th ed. McGraw-Hill, 2013.

Program Elective 6

CHE41xx 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 C2, C3, C4 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*, 2nd ed. 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*, 2nd ed. Gulf Publishers, 2001.

CHE41xx Energy and Process Integration [3 0 0 3]

Introduction to process integration, role of thermodynamics in process design, targeting of energy, area, number of units, and cost, super targeting, concept of pinch technology and its application. Heat exchanger networks analysis, Maximum Energy Recovery (MER) networks for multiple utilities and multiple pinches, design of heat exchanger network. Heat integrated distillation columns, evaporators, dryers, and reactors. Heat and power integration. Case studies.

References

1. W.D. Seider, J.D. Seader, D.L. Lewin, *Product and Process Design Principles: Synthesis, Analysis, and Evaluation*, 3rd ed. John-Wiley and Sons, 2008.
2. I.C. Kemp, *Pinch analysis and process integration: A user guide on process integration for the efficient use of energy*, 2nd ed. Butterworth-Heinemann, 2006.
3. J. J. Klemes, P.S. Varbanov, S.R.W.W. Alwi Z.A. Manan, *Process Integration and Intensification: Saving Energy, Water and Resources*, 2nd ed. De Gruyter, 2014.