B TECH. CHEMICAL ENGINEERING

Year	THIRD SEMESTER						FOURTH SEMESTER					
	Sub. Code	**Subject Name**	**L**	**T**	**P**	**C**	**Sub. Code**	**Subject Name**	**L**	**T**	**P**	**C**
II	MAT 2124	Engineering Mathematics - III	2	1	0	3	MAT 2224	Engineering Mathematics - IV	2	1	0	3
	CHE 2121	Chemical Engineering Thermodynamics	3	1	0	4	CHE 2221	Particle Technology	2	1	0	3
	CHE 2122	Chemical Process Calculations	2	1	0	3	CHE 2222	Mass Transfer -II	2	1	0	3
	CHE 2123	Momentum Transfer	3	1	0	4	CHE 2223	Chemical Reaction Engineering	3	1	0	4
	CHE 2124	Mass Transfer I	2	1	0	3	CHE 2224	Pollution Control and Safety in Chemical Industry	2	1	0	3
	CHM 2121	Physical and Organic Chemistry	3	1	0	4	CHE 2225	Heat Transfer Operations	2	1	0	3
	CHM 2141	Physical and Organic Chemistry Lab	0	0	3	1	CHE 2241	Momentum Transfer Lab	0	0	3	1
			15	6	3	22	CHE 2242	Numerical Methods for Chemical Engineers Lab	0	0	3	1
									13	**6**	**6**	**21**
	Total Contact Hours (L + T + P)		24				**Total Contact Hours (L + T + P) + OE**		25			
	FIFTH SEMESTER						SIXTH SEMESTER					
III	HUM 3021	Engineering Economics and Financial Management	3	0	0	3	HUM 3022	Essentials of Management	3	0	0	3
	CHE 3121	Process Dynamics and Control	3	1	0	4	CHE ****	Flexible Core1 (A1/B1)	2	1	0	3
	CHE 3122	Process Modelling and Simulation	2	1	0	3	CHE ****	Flexible Core2 (A2/B2)	3	1	0	4
	CHE 3123	Process Design of Chemical Equipment	2	1	0	3	CHE ****	Program Elective-I/Minor Specialization	3	0	0	3
	CHE 3124	Transport Phenomena	2	1	0	3	CHE ****	Program Elective-II/ Minor Specialization	3	0	0	3
	IPE 4302	Open Elective-1 Creativity, Problem Solving and Innovation	3	0	0	3	*** ****	Open Elective-2	3	0	0	3
	CHE 3141	Heat Transfer Lab	0	0	3	1	CHE 3241	Process Modelling and Simulation Lab	0	0	3	1
	CHE 3142	Mass Transfer Lab	0	0	3	1	CHE 3242	Reaction Engineering and Process Control Lab	0	0	3	1
			15	**4**	**6**	**21**			**17**	**2**	**6**	**21**
	Total Contact Hours (L + T + P) + OE		25				**Total Contact Hours (L + T + P) + OE**		25			
	SEVENTH SEMESTER						EIGHTH SEMESTER					
IV	CHE ****	Program Elective –III/ Minor Specialization	3	0	0	3	CHE 4291	Industrial Training				1
	CHE ****	Program Elective–IV/ Minor Specialization	3	0	0	3	CHE 4292	Project Work				12
	CHE ****	Program Elective–V	3	0	0	3	CHE 4293	Project Work (B. Tech Honours) **				20
	CHE ****	Program Elective –VI	3	0	0	3	CHE ****	B Tech Honours (Theory 1)** (V Semester)				4
	CHE ****	Program Elective–VII	3	0	0	3	CHE ****	B Tech Honours (Theory 2)** (VI Semester)				4
	CHE ****	Open Elective-3	3	0	0	3	CHE ****	B Tech Honours (Theory 3)** (VII Semester)				4
	CHE 4191	Mini Project (Minor specialization) *				8						
			18	**0**	**0**	**18/26**						**13/33**
	Total Contact Hours (L + T + P) +OE		18									

*Applicable to students who opted for minor specialization, || **Applicable to eligible students who opted for and successfully completed the B Tech – Honours requirements

Flexible Core- A CHE 3221: Chemical Process Industries (A1) CHE 3223: Chemical Reactor Theory (A2) **Flexible Core- B** CHE 3222:Computer-Aided Simulations in Chemical Process Plants (B1) CHE 3224:Artificial Intelligence and Machine Learning in Chemical Engineering (B2) **Minor Specializations:** **I. Petroleum Engineering** CHE 4401: Oil and Gas Reservoir Engineering CHE 4402: Petroleum Refinery Engineering (Theory & Lab) CHE 4403: Natural Gas Engineering CHE 4404: Process Integration for Petroleum Industries **II. Pollution Control Engineering** CHE 4405: Industrial Waste Water Engineering (Theory & Lab) CHE 4406: Solid and Hazardous Waste Management CHE 4407: Air Pollution Monitoring and Control CHE 4408: Environmental Impact Assessment and Management Plan **III. Renewable Energy Engineering** CHE 4409: Renewable Energy CHE 4410: Solar Energy CHE 4411: Fuel Cell and Hydrogen Energy CHE 4412: Bio Energy Engineering	**Other Programme Electives:** CHE 4441 Advanced Process Control CHE 4442 Applied Interfacial Engineering CHE 4443 Clean Technologies in Process Industries CHE 4444 Energy Engineering CHE 4445 Green Processes CHE 4446 Industrial Safety and Risk Management CHE 4447 Introduction to Biochemical Engineering CHE 4448 Materials Science and Engineering CHE 4449 Membrane Science and Technology CHE 4450 Molecular Modelling and Simulation CHE 4451 Non-Newtonian Fluid Flow in Process Industries CHE 4452 Petrochemicals CHE 4453 Process Data Analysis CHE 4454 Process Instrumentation CHE 4455 Project Engineering CHE 4456 System Identification CHM 4441 Analytical Techniques and Instrumentation **Open Electives:** CHE 4311 Industrial Pollution Control CHE 4312 Risk and Safety Management in Industries CHE 4313 Water Treatment Technology CHE 4314 Introduction to Petroleum Engineering	

THIRD SEMESTER

MAT 2124: ENGINEERING MATHEMATICS-III [2 1 0 3]

Course outcomes:

CO1	Apply the concepts of Fourier Series, Fourier transforms & their properties
CO2	Apply analyticity of a complex functions and its properties.
CO3	Apply the concepts of contour integration
CO4	Identify the concept of vector differential and integral calculus & their properties
CO5	Apply the concepts of linear PDEs, to solve One dimension Heat and Wave equation by different methods.

Syllabus:

Fourier series and transforms: Periodic Functions, odd and even functions, Euler's formulae. Half range expansions, Harmonic analysis. Fourier integrals & transforms, Parseval's identity.

Complex Variable: 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.

Vector Calculus: Gradient, divergence and curl, their physical meaning and vector identities. Line, surface and volume integrals. Green's theorem, divergence and Stokes' theorem, applications.

Partial differential equations: 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.

Reference Books:

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

CHE 2121: CHEMICAL ENGINEERING THERMODYNAMICS [3 1 0 4]

Course outcomes:

CO1: Analyze the equilibrium, energy, and transformation of energy for a process.
CO2: Explain the behavior of gases and differentiate real gas behavior.
CO3: Apply thermodynamic principles to analyze the properties of pure fluids, mixtures, and phase equilibrium.
CO4: Evaluate the thermodynamic properties of solutions containing various components.
CO5: Determine the equilibrium yield and the equilibrium constant of a chemical reaction.

Syllabus:

Basic concepts and definition: internal energy, work, heat, equilibrium, reversible process, intensive and extensive function. First law of thermodynamics for non-flow and flow process, State and path function, Enthalpy, Heat capacity. Volumetric properties of pure fluids: PVT behaviour of pure substances, ideal gas law, isobaric, isothermal, adiabatic and polytropic process. equation of state for real gases, the principles of corresponding states, compressibility factors.

Second law of thermodynamics: Spontaneous process, qualitative difference between heat and work, heat reservoir, heat pump, heat engine, Kelvin Plank statement, Clausius statement, irreversibility, entropy, Carnot principle, postulates, thermodynamic temperature scale, third law of thermodynamics.

Thermodynamic relations: Classification of thermodynamic processes, Helmholtz and Gibbs free energy, fundamental property relations, Maxwell's relations and their applications, Clausius Clapeyron equation, modified equations for U, H and S, relationship between Cp and Cv, ratio of heat capacity, effect of pressure and volume on Cp and Cv, Gibbs Helmholtz equations.

Phase equilibria: Thermodynamic properties of pure substances: Fugacity and Fugacity Coefficients, Activity and Activity Coefficients, partial molar properties, chemical potential, Gibbs-Duhem equation, Property changes of mixing, Duhem theorem

Chemical reaction equilibria: criteria of equilibrium, reaction stoichiometry, equilibrium constant, Gibbs free energy change, choice of standard state, feasibility of chemical reactions, effect of temperature on equilibrium constant, evaluation of equilibrium constants. Relation of equilibrium constants to composition: gas-phase reactions, liquid-phase reactions, equilibrium conversions for single reactions: single- phase reactions

References:

1. K.V. Narayanan, A Textbook of Chemical Engineering Thermodynamics, Prentice Hall of India, 2006.
2. J.M Smith, H.C.VanNess and M.M.Abbot, Introduction to Chemical Engineering Thermodynamics,(7e), McGraw Hill, 2004.
3. T.E. Daubert, Chemical Engineering Thermodynamics, McGraw –Hill, 1985.
4. Y.V.C. Rao, Chemical Engineering Thermodynamics, Universities Press, 1997.

CHE 2122: CHEMICAL PROCESS CALCULATIONS [2 1 0 3]

Course outcomes

CO1 Apply the basic concepts of units and dimensions and convert quantities between different unit systems.

CO2 To solve general problems related to the chemical process variables, gas laws and properties of gases

CO3 To formulate, interpret and solve steady state material balances involving unit operations

CO4 To formulate, and solve problems related to material balance involving unit processes

CO5 To formulate, and solve problems related to energy and energy balance operations with and without chemical reaction

Syllabus:

Units and dimensions – Conversion of equations, Systems of units, Dimensional analysis, and homogeneity and dimensionless quantities; Physical and chemical properties of compounds and mixtures – Techniques of problem solving, Choice of basis, Compositions, Chemical equations and stoichiometry

Properties of gases and mixture of gases – Gas laws, Ideal gas law calculations, real gas relationship; Humidity – Relative humidity and percent saturation, dew point, dry bulb and wet bulb temperature, calculations using humidity charts

Material balances in unit operations and processes – Concepts of steady and unsteady state processes, Material balances in unit operations involving crystallization, evaporation, distillation, mixing, drying, extraction and leaching, Material balances with chemical reactions, material balances in recycle, bypass and purge systems with or without chemical reactions

Energy balances – Heat capacities of substances and mixtures, mean heat capacity based calculations, Heat of reaction, heat of formation and heat of combustion, Standard state, Calculation of standard heat of reaction, Hess law, Adiabatic reaction temperature and theoretical flame Temperature, Balances on non-reactive and reactive systems.

References:

1. David M. Himmelblau, Basic Principles and Calculations in Chemical Engineering, Eastern Economy ed., Prentice Hall of India (P) Ltd. 6th Ed. 2009.
2. Richard Felder and Ronald W. Rausseau, Elementary Principles of Chemical Processes, 2nd edition, John Wiley and Sons, 2004.
3. A. Hougen, K.M. Watson and R.A. Ragatz, Chemical Process Principles, Part – I, John Wiley and Asia Publishing Co. 1970.
4. Bhat B.I. and S.M. Vora, Stoichiometry 2nd ed., Tata McGraw-Hill, NY 1976
5. Anderson & Wenzel, Introduction to Chemical Engineering, McGraw Hill, New York, 1961
6. Kirk and Bride, Chemical Engineering Fundamentals, McGraw-Hill, 1947

CHE 2123: MOMENTUM TRANSFER [3 1 0 4]

Course outcomes:

CO1	Analyze the concepts of fluid statics and its application to pressure measurement through problem solving.
CO2	Formulate the fundamental equations of mass balance and energy balance and apply them to pump work and other industrial applications.
CO3	Analyze the concepts of flow measurement systems, compare and contrast between different flow measuring instruments, working principle and operational details along with selection of appropriate flow meter in industrial applications.
CO4	Explain the types of fluids, fluid flow concepts, shear stress-velocity relations, boundary conditions and demonstrate them through problem solving.
CO5	Appraise and solve compressible flow problems, flow past immersed bodies, fluid transportation systems and dimensional analysis.

Syllabus:

Properties of fluids – Rheological classification - Fluid statics – Static pressure – Variation of pressure with elevation – Pressure measurement –Manometers – Introduction to fluid flow – Types of flow – Basic equations of fluid flow – Continuity equation – One dimensional Euler and Bernoulli equation and applications – Flow measurement –Venturi, Orifice and Pitot-tube – Variable area meter – Flow measurement in open channels Laminar flow – Steady incompressible viscous flow through circular pipes – Hagen-Poiseuilli equation - Turbulence – Turbulent flow in smooth pipes – Velocity profiles – Darcy equation – Flow in noncircular conduits – Losses in pipe flow -Power law of fluids – Flow of liquids in thin layers – Fluid flow past immersed bodies – Boundary layer and friction drag - Drag coefficient – Motion of particles through fluids – Flow of fluids thorough bed of solids – Ergun equation – Principles of fluidization – Hydrodynamic characteristics – Pneumatic conveyance – Agitation and mixing of liquids –Dimensional analysis – Flow of compressible fluids – Basic equations of one dimensional flow – Reversible adiabatic flow – Effect of area variation – Flow in convergent and divergent nozzles - Fluid transportation machinery – Pumps and classification of pumps– Pump characteristics.

References:

1. McCabe and Smith, Unit Operations in Chemical Engineering, (7e), McGraw-Hill, NY,2017
2. Coulson and Richardson, Chemical Engineering – Vol. I, Asian Books, New Delhi, 6e, 2006,
3. Foust et al, Principles of Unit Operations, (2e), John Wiley and Sons, NY, 2015
4. Badger and Banchero, Introduction to Chemical Engineering, Tata McGraw Hill, Singapore, 1e, 2017,

CHE 2124: MASS TRANSFER -I [2 1 0 3]

Course outcomes:

CO1	Examine the basic mechanism of diffusion of species in gases, liquids and solids
CO2	Evaluate the inter-phase mass transfer coefficients.
CO3	Illustrate the contact patterns of gas-liquid phases in an absorption operation.
CO4	Interpret the phenomena of adsorption operation.
CO5	Analyse the principles of drying and crystallization operations

Syllabus:

Introduction to mass transfer operations, Diffusion and mass Transfer: Molecular diffusion in fluids and solid, mass transfer coefficients, interphase mass transfer coefficient. Gas Liquid Operations: Equipment for gas liquid operations, Gas absorption. Solid-Fluid Operations: Crystallisation, Adsorption, Drying.

References:

1. Treybal, R.E. Mass Transfer Operations (3e), McGraw Hill Education, 2017.
2. McCabe, W., Smith, J., Harriott, P., Unit Operations of Chemical Engineering (7e), McGraw Hill Education, 2017.
3. Dutta, B.K., Principles of Mass Transfer and Separation Processes, Prentice Hall India Learning Private Limited, 2006.

CHM 2121: PHYSICAL AND ORGANIC CHEMISTRY [3 1 0 4]

Course outcomes:

CO1 Identify the principles of thermodynamic treatment of solutions and summarise the process chemical kinetics.

CO2 Analyze phase equilibria and apply conductometry and potentiometry in practical applications..

CO3 Illustrate different stereoisomers and analyze the correlation between structure and reactivity of intermediates.

CO4 Analyze and correlate molecular structure with acidity, basicity, and aromaticity.

CO5 Predict the structure – property of biomolecules

Syllabus:

Thermodynamic treatment of solutions: Ideal mixtures, Partial molal Quantities, Liquid-vapour free energies, vapour pressure and solution properties, Raoult's law, Thermodynamics of ideal solutions- Free energy, volume change, enthalpy and entropy changes of mixing for ideal solutions, Henrry's law, Gibb's Duhem relation,Vapor-pressure lowering, boiling point elevation, freezing point lowering, osmotic pressure, Numericals on determination of molar mass from colligative properties. Phase Equilibria: Pressure-Temperature Phase diagrams, Clausius –Clapeyron equation, Liquid surfaces, Surface tension and vapor pressure, Phase rule, Immiscible liquids, Eutectic formation, solid compound formation Liquid – vapor, pressure –composition diagrams, Boiling point diagrams, Distillation, adsorption of gases, adsorption isotherm: gases and liquids.Electroanalytical methods of analysis: Introduction, Principle, applications, advantages and limitations of Conductometric Titrations, and Potentiometric Titrations Chemical Kinetics: Introduction, Rate equation, First-order rate equations, second order rate equations, Half-life, Arrhenius equation, Numericals.Stereochemistry: Constitutional isomerism - Geometrical isomerism - syn-anti, E-Z notations - Optical isomerism, Molecules with one and two chiral centres, Polarimeter, specific rotation, RS configuration, Enantiomers, Diasteromers, meso compounds.. Reaction Intermediates: Structure, Stability and reactions of free radicals, Carbocations, carbanions and carbenes.Strengths of organic acids and bases: Monobasic, dibasic, aliphatic & aromatic acids, Aliphatic and aromatic bases, Factors affecting strength of acids and bases, Aromatic and Heterocyclic compounds: Structure of benzene and aromaticity, Effect of substituents in mono and disubstituted benzene. Classification of Heterocyclic compounds, Basicity.Carbohydrates: Classification, Aldose to ketose and vice versa transformations - Aldo-hexose, epimerisation, Monosaccharides, Physical and Chemical Properties of glucose and fructose, Disaccharides - Sources, structure and properties of sucrose, lactose and maltose, Polysaccharides - Source, structure and properties of starch and cellulose. Amino acids & Proteins: Classification, Synthesis of amino acids, Physical and chemical properties. Peptides - Classification & synthesis, Proteins - Classification - Color tests - Structure, Enzymes - Theories of enzymatic actions, Properties, Applications in industry. Dyes: Theories of dyes - Valence Bond and Molecular Orbital approach to color, Bathochromic and Hypsochromic shift, Classification of dyes based on application

References:

1. B.R. Puri, L.R. Sharma, M.S. Pathania, Principles of Physical Chemistry, 43rd Edition, Vishal Publications, Jalandhar, 2008.
2. P. Atkins, J. de Paula, Physical Chemistry, 7th Edition, Oxford Publication, New York, 2002.
3. D. A. Skoog, D. M. West, F. J. Holler, S. R. Gouch, Fundamentals of Analytical Chemistry, 8th Edition, Thomson Brooks/Cole, Singapore, 2004.
4. S. H. Maron C. F. Prutton, Principles of Physical Chemistry, 4th edition, Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi, 1972.

CHM 2141: PHYSICAL AND ORGANIC CHEMISTRY LAB [0 0 3 1]

CO1 Explain the principles of conductometry and potentiometry and perform related experiments..
CO2 Perform experiments to determine percentage composition, density and surface tension of binary mixture using refractometer, viscometer and stalagmometer.
CO3 Carry out reactions like saponification, inversion and find the rate and order of some reactions.
CO4 Develop skills in organic synthesis, recrystallization and determination of melting point of prepared compounds.
CO5 Analyse different organic compounds quantitatively.

Syllabus:

Physical Chemistry: Titration using conductometric method, potentiometric mthod, Percentage composition of binary mixture using viscometer and Abbe's refractometer, Bimolecular kinetics. Organic Chemistry: Preparation of m-dinitrobenzene, benzoic acid, and salicylic acid; Determination of the % purity of phenol and acetic acid.

References:

1. B.R. Puri, L.R. Sharma, M.S. Pathania, Principles of Physical Chemistry, 43rd Edition, Vishal Publications, Jalandhar, 2008.
2. P. Atkins, J. de Paula, Physical Chemistry, 7th Edition, Oxford Publication, New York, 2002.
3. D. A. Skoog, D. M. West, F. J. Holler, S. R. Gouch, Fundamentals of Analytical Chemistry, 8th Edition, Thomson Brooks/Cole, Singapore, 2004.
4. S. H. Maron C. F. Prutton, Principles of Physical Chemistry, 4th edition, Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi, 1972.

FOURTH SEMESTER

MAT 2224: ENGINEERING MATHEMATICS-IV [2 1 0 3]

Course outcomes:

CO1	Determine the solution of boundary value problems of ODE and PDE using finite difference methods.
CO2	Discuss the relevance of probability in engineering problems and explain the concepts of random variable.
CO3	Identify situations where different discrete probability distributions can be applied and use suitable continuous distributions to various situations.
CO4	Formulate the linear programming problems and solve by graphical, simplex, penalty cost or two-phase methods.
CO5	Solve difference equations by Z-transforms.

Syllabus:

Optimization Techniques: Formation of Linear Programming problem, Graphical method, Simplex method, Penalty cost and two-phase methods. Probability & Random variables: 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. Probability distributions: Binomial, Poisson, uniform, normal, gamma, Chi-square and exponential. Numerical methods: 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. Z transform: 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. Eewin Kreyszig, Advanced Engineering Mathematics, 7th edition, 1993, John Wiley & Sons, Inc.
2. Meyer P.L., Introduction to probability and Statistical applications, 2nd edition, 1970, American Publishing Co.
3. Hamdy A Taha - Operation research, 7th edition, 2002, Pearson Education, Inc.
4. Grewal B.S - Higher Engineering Mathematics, 43rd ed
5. ition, 2014, Khanna Publishers.
6. Sastry S.S - Introductory methods for Numerical Analysis, 5th edition, 2012, PHI Learning Private Limited.

CHE 2221: PARTICLE TECHNOLOGY [2 1 0 3]

Course outcomes:

CO1 Explain the basic principle of screening operation.
CO2 Illustrate the concepts of size reduction operations.
CO3 Examine the basic principle of the solid-liquid separation operation.
CO4 Analyse the concept of filtration, and centrifugation operation
CO5 Design the continuous thickener in a steady-state operation.

Syllabus:

Particle size analysis, Sphericity of particle, Shape factor, Specific surface area and specific number of particle in the sample mixture, Sieve methods of analysis, Ideal and actual screen, Effectiveness and capacity of screen, Screening equipment, Size reduction, Energy relationships, Size reduction equipment, Crushers, Grinders, Separation based on motion of particle through fluids, Settling, Free and hindered settling, Terminal settling velocity of solid particles, Classifier, Sedimentation, Clarifier, Design of continuous thickener, Filtration and Centrifugation operation.

References:

1. Warren L. McCabe, Julian C. Smith, and Peter Harriott, Unit Operations of Chemical Engineering (7e), McGraw Hill Publication, NY, 2017.
2. Alan S. Foust, Leonard A. Wenzel, Curtis W. Clump, Louis Maus, and L. Bryce Andersen, Principles of Unit Operations, (2e), John Wiley and Sons, NY, 2015.
3. Walter L. Badger and Julius T. Banchero, Introduction to Chemical Engineering, Tata McGraw-Hill, NY, 2017.
4. J.M. Coulson, J.R. Richardson J.R. Backhurst, and J.H. Harker, Chemical Engineering –Volume 2, Particle Technology and Separation Processes, (6e), 2019.

CHE 2222: MASS TRANSFER II [2 1 0 3]

Course outcomes:

CO1	Apply the principles of distillation for the separation of binary Compounds using flash vaporization and differential distillation methods
CO2	Develop a theoretical design of fractionating column using Ponchon-Savarit method.
CO3	Determine the number of theoretical stages of a distillation column using Mc Cabe-Thiele method.
CO4	Determine the minimum solvent requirement for Liquid-Liquid Extraction to achieve the desired separation.
CO5	Evaluate the operating parameters in the Solid-Liquid Extraction operation.

Syllabus:

Distillation: binary component distillation- Flash vaporization, simple distillation, steam distillation, multicomponent distillation: Flash vaporization, simple distillation, Multi stage tray towers: Ponchon and Savarit & McCabe and Thiele. Liquid-Liquid Extraction: Liquid Equilibria, separation of solute by stage-wise, cross current and continuous contact of solvent. Solid-Liquid Extraction: Introduction, applications, cross current and counter current leaching.

References:

1. Treybal R.E., Mass Transfer Operations (3e), McGraw Hill Education, 2017.
2. McCabe W., Smith J., Harriott P., Unit Operations of Chemical Engineering (7e), McGraw Hill Education, 2017.
3. Dutta B.K., Principles of Mass Transfer and Separation Processes, Prentice Hall India Learning Private Limited, 2006. 4. Kaushik N., Membrane Separation Processes, PHI Learning, 2008

CHE 2223: CHEMICAL REACTION ENGINEERING [3 1 0 4]

Course outcomes:

CO1 Develop reaction mechanisms, rate equations for elementary and non-elementary reactions.
CO2 Compare the performance of Ideal Batch and Flow Reactors
CO3 Analyze the performance of Multiple ideal reactor combinations & Recycle reactor
CO4 Examine reactors for Multiple reactions
CO5 Evaluate conditions and consequences of non-ideality in reactors

Syllabus:

Elementary and Non-elementary reaction kinetics, Kinetics of homogeneous chemical reactions, Rate expressions, Temperature dependence of rate, differential, integral, half-life and total pressure method.

Isothermal reactor design, Design of batch, semi-batch, CSTR and PFR, Reactors in series or/and parallel, Recycle reactor.

Series and parallel reactions in flow reactors, Product distribution, Yield and selectivity, Maximizing the desired product in parallel, series reactions, series-parallel reactions and Denbigh reactions.

Enzymatic Reaction - Michaelis-Menten Kinetics, Competitive and Non-competitive inhibition, Microbial Fermentation- substrate limiting and product limiting- batch/ plug flow and mixed flow fermenters.

References:

1. Fogler S. H., Elements of Chemical Reaction Engineering(4e), Prentice Hall, 2005.
2. Levenspiel O., Chemical Reaction Engineering (3e), Wiley & Sons, 2003.
3. Rawlings J.B. and Ekerd, J.G., Chemical Reactor Analysis and Design Fundamentals, Nole. Hill, 2002.
4. Smith, J.M, Chemical Engineering Kinetics (3e), McGraw-Hill, International student edition
5. Davis M.E., Davis R.E., Fundamentals of Chemical Reaction Engineering (1e), McGraw-Hill, 2003
6. Missen R.W., Mims C.A., Saville B.A., Introduction to chemical reaction engineering and kinetics, John Wiley & Sons Inc.

CHE 2224: POLLUTION CONTROL AND SAFETY IN CHEMICAL INDUSTRY [2 1 0 3]

Course outcomes:

CO1 Discuss the importance of biosphere and ecosystem in a global and societal context.
CO2 Apply appropriate control and preventive measures for water pollution.
CO3 Analyse the appropriate control and preventive measures for air pollution
CO4 Categorise the major process and hazards involved in thermal, oil, soil, radioactive and noise pollution.
CO5 Explain the various environmental safety standards and legislations in pollution control

Syllabus:

Man, and environment Nutrient and hydrologic cycles, Types of pollution -Legislation to environmental pollution Aspects of pollution control -Evaluation and characterization of wastewater Treatment methods -Advanced wastewater treatment Sludge treatment and disposal Solid -waste management. Noise pollution and control: Ambient and stack gas -sampling analysis of air pollutants, Principles of air pollution Plume behaviour- Meteorological factors affecting air Pollution. Equipment for control and abatement of air pollution - Pollution control of effluent in chemical industries such as Fertilizer, Petroleum refinery, Pulp and paper and Tannery industries.

Scientific and engineering aspects of safety in industries- considerations- hazards of industrial chemicals- fire and explosion- prevention and control: Ventilation and lighting – personal and protective devices- legal aspects and labour relations in safety.

References:

1. Mahajan S.P. “Pollution Control in Process Industries”, Tata Mc Graw Hill, 2008.
2. Rao C.S., “Environmental Pollution Control Engineering” (2e), New Age International Publishers, 2006.
3. Cavaseno V, “Industrial Air Pollution Engineering”, McGraw Hill, NY, 1980

CHE 2225 : HEAT TRANSFER OPERATIONS [2 1 0 3]

Course outcomes:

CO1 Explain the concepts of conduction, convection, and radiation.
CO2 Estimate heat transfer rate for Conductive Heat Transfer
CO3 Determine the Heat Transfer Coefficient for convective heat transfer
CO4 Determine overall Heat transfer Coefficient using LMTD and NTU methods for Heat Exchangers
CO5 Evaluate spectral intensity for Radiation Heat Transfer

Syllabus:

Mechanism of heat transfer; Heat transfer flux and resistance. Conduction: Thermal conductivity; Fourier's law of conduction; Conduction through the plane, cylindrical and spherical and composite walls; Heat losses and insulation. Convection: Natural and forced convection; Individual film and overall heat transfer coefficients; Convection in laminar and turbulent flows. Heat exchanger: Types of heat exchangers; Co-current and counter-current flows; Equivalent diameter; Fouling factors; Process design of heat exchangers including double pipe heat exchanger, shell and tube heat exchanger, and cross flow heat exchangers.

Radiation: Radiant energy distribution, Black body; Emissive power; Exchange of energy between two surfaces; Radiosity, Spectral Irradiation.

References:

1. F.P. Incropera and D.P. Dewitt – Introduction to Heat and Mass Transfer, 6th Edition (wiley), 2007
2. J.M. Coulson and J.F. Richardson –Chemical Engineering, Vol. 1, 3rd Edition, Pergamon and ELBS, 1977.
3. Krieth –Fundamentals of Heat Transfer, 4th Edition, Harper & Law, 1986
4. McCabe and Smith –Unit Operations of Chemical Engineering 7th edition

CHE 2241: MOMENTUM TRANSFER LAB [0 0 3 1]

Course outcomes:

CO1 Analyze fluid flow problems using the equation of continuity.
CO2 Evaluate the frictional losses in flow through pipes.
CO3 Distinguish between the closed channel and open channel flow measurements.
CO4 Estimate the flow rate and pressure drop in fluid-solid systems.

Syllabus:

Bernoulli's Experiment – Calibration of flow meters, flow through circular pipe, annulus, v-notch, packed bed and fluidized bed – Centrifugal pump characteristics.

References:

1. F.P. Incropera and D.P. Dewitt – Introduction to Heat and Mass Transfer, 6th Edition (wiley), 2007
2. Krieth –Fundamentals of Heat Transfer, 4th Edition, Harper & Law, 1986

CHE 2242: NUMERICAL METHODS FOR CHEMICAL ENGINEERS LAB [0 0 3 1]

Course outcomes:

CO1	Solve mathematical problems using MATLAB and EXCEL.
CO2	Formulate algorithms and programs for different numerical methods.
CO3	Simulate various chemical engineering problems using numerical methods.
CO4	Develop codes to solve engineering problems.

Syllabus:

Chemical engineering problems related to Process Calculations, Momentum Transfer, Heat Transfer and Mass Transfer-I will be solved using numerical methods such as Bisection method, False position method, Secant method, Newton-Raphson method, Linear Algebraic Equations, Runge-Kutta method, Predictor-Corrector method, Shooting method, Finite difference method, Crank-Nicholson method; Bender Schmidt method with the help of computer software such as MAT LAB and EXCEL.

References:

1.Numerical methods in Engineering and Science- B.S. Grewal, Khanna publishers

2.Numerical methods for engineers, Steven Chapra, Raymond Canale,

3.Problem Solving in chemical and Biochemical engg with POLYMATH, EXCEL and MATLAB, Micheal Cutlip and Mordechai Shacham, , Prentice Hall , 2nd edition,2008

FIFTH SEMESTER:

CHE 3051: ENGINEERING ECONOMICS AND FINANCIAL MANAGEMENT [3 0 0 3]

Course outcomes:

CO1: Compute the worth of money at various points of time
CO2: Describe and apply the basic techniques of financial statement analysis
CO3: Assess the impact of risk in projects
CO4: Construct advanced control strategies to improve the single loop control system

Syllabus:

Nature and significance, Micro & macro differences, Law of demand and supply, Elasticity & equilibrium of demand & supply. Time value of money, Interest factors for discrete compounding, Nominal & effective interest rates, Present and future worth of single, Uniform gradient cash

flow. Bases for comparison of alternatives, Present worth amount, Capitalized equivalent amount, Annual equivalent amount, Future worth amount, Capital recovery with return, Rate of return method, Incremental approach for economic analysis of alternatives, Replacement analysis.

Break-even analysis for single product and multi product firms, Breakeven analysis for evaluation of investment alternatives. Physical & functional depreciation, Straight line depreciation, Declining balance method of depreciation, Sum-of-the-years digits method of depreciation,

Sinking fund and service output methods, Introduction to balance sheet and profit & loss statement. Ratio analysis - Financial ratios such as liquidity ratios, Leverage ratios, Turn over ratios, and profitability ratios.

References:

1. Prasanna Chandra., Fundamentals of Financial Management, Tata Mc-Graw Hill Companies, New Delhi, 2005.
2. James L Riggs, David D Bedworth and Sabah U Randhawa., Engineering Economics, Tata McGraw – Hill Publishing Company Ltd, New Delhi, 2004.
3. T. Ramachandran., Accounting and Financial Management, Scitech Publications Pvt. Ltd. India, 2001.
4. Eugene F. B. & Joel F. H., Fundamentals of Financial Management, (12e), Cengage Learning Publisher, 2009.
5. M. Y. Khan & P. K. Jain., Financial Management, (5e), Tata McGraw Hill Publication, New Delhi, 2008.
6. Thuesen G.J., Engineering Economics, Prentice Hall of India, New Delhi, 2005.
7. Blank Leland T. Tarquin Anthony J. Engineering Economy, McGraw Hill, Delhi, 2002.
8. Chan S. Park, Fundamentals of Engineering Economics, (3e), Pearson Publication, 2013.

CHE 3121: PROCESS DYNAMICS AND CONTROL [3 1 0 4]

Course outcomes:

CO1: Develop process models and apply mathematical techniques for modelling dynamic process Systems
CO2: Apply transfer function model and analyse the dynamic responses of first order and higher order systems
CO3: Analyse classical control actions and their performance in a closed loop system
CO4: Assess the stability of feedback controllers for dynamic systems.
CO5: Construct advanced control strategies to improve the single loop control system

Syllabus:

Introduction to process control: components of control system, control relevant process modelling; Laplace Transform; Linearization; Transfer function models: effect of poles, zeros and time delays on system response; Dynamics of First, Second and Higher order systems; Control system instrumentation; Introduction to Feedback control: effect of proportional, integral and derivative action, responses of P, PI and PID controllers; Controller selection, design and tuning; Stability analysis of closed loop systems, Frequency response: Bode diagrams; Nyquist Plot; Multivariable and advanced control strategies

References:

1. Stephanopoulos G., Chemical Process Control: An Introduction to Theory and Practice (1e), Pearson Education India, 2015.
2. Seborg D.E., Edgar T.F., Mellichamp D.A., Doyle III F. J., Process Dynamics and Control (4e), John Wiley and Sons, 2016.
3. Coughanowr D.R., LeBlanc E.S., Process Systems Analysis and Control (3e), McGraw Hill, 2009.
4. Marlin T.E., Process Control: Designing of Processes and Control Systems for dynamic performance (2e), Mc Grew Hill, 2000.
5. Bequette B.W., Process Control, Modelling, Design and Simulation, Prentice Hall International, 2003.

CHE 3122: PROCESS MODELLING AND SIMULATION [2 1 0 3]

Course outcomes

CO1 Identify the basics of modelling and simulation
CO2 Apply unsteady state concept to solve mass, heat and momentum balance problems
CO3 Develop unsteady state lumped parameter models and formulate the solution
CO4 Develop steady state and unsteady state distributed parameter models and formulate the solution

Syllabus:

Models and model building, principles of model formulation, precautions in model building, Classification of models. Lumped parameter Models: steady and unsteady state- tank model, Reaction –kinetic systems, Vapour –liquid equilibrium operation. Distributed parameter models (steady state): solution of split boundary value problems, counter current heat exchanger, tubular reactor with axial dispersion, Distributed parameter models (unsteady state, one dimension): Finite difference method, convection problems- explicit and implicit centred difference methods; diffusive problems- Crank Nicolson finite difference scheme, heat exchanger, gas absorbers and dynamics of tubular reactor with dispersion.

References:

1. Ramirez W.F., Computational Methods in Process Simulations (2e), Butterworth publishers, 1997.
2. Franks R.E., Modelling and simulation in Chemical Engineering, John Wiley & Sons, 1972.
3. Hangos K., Cameron I., Process Modelling and Model Analysis, Academic Press, 2001.
4. Ramakrishna D., Population Balance-Theory and Applications to Particulate systems in Engineering (1e), Academic Press, 2000.

CHE 3123: PROCESS DESIGN OF CHEMICAL EQUIPMENT [2 1 0 3]

Course outcomes:

CO1	Designing of shell and tube heat exchangers
CO2	Designing of Condensers and Reboiler
CO3	Designing of Single and Multiple Effect Evaporators
CO4	Designing of Separators: Distillation column for Binary and Multicomponent systems, and Absorption column
CO5	Apply mechanical design concepts to design process equipment

Syllabus:

Introduction to Process equipment design, Design of shell and tube heat exchangers, Design of condensers, Design of single and multiple effect evaporators, design of distillation columns & absorption columns. Introduction to mechanical design, Vessel classification, design codes and general design consideration, Design of pressure vessels under internal pressure, and external pressure.

References:

1. Coulson and Richardson's Vol 6, Chemical Engineering design (4e), Elsevier Butterworth-Heinemann Publishers, 2005.
2. Kern D.Q., Process Heat transfer, McGraw-Hill Publishers, 2017.
3. R.W. Serth, Process Heat Transfer: Principles and Applications, (1st Edition), Elsevier, The Boulevard, Langford Lane, Kidlington, Oxford, 2007
4. Joshi M.V., Mahajani V.V., Process Equipment Design (4e), MacMillan Publishers, 2009
5. Indian Standard for unfired pressure vessel, IS 2825-1969

CHE 3124: TRANSPORT PHENOMENA [3 0 0 3]

Course outcomes:

CO1 Examine various equations of transport processes
CO2 Develop shell balances for conservation of momentum transport
CO3 Develop shell balances for conservation of energy transport
CO4 Develop shell balances for conservation of mass transport

Syllabus:

Prediction of transport coefficients: viscosity, thermal conductivity and diffusivity and their dependence with temperature, pressure and composition. Kinetic theories of viscosity, thermal conductivity and diffusivity. Shell balance for momentum, energy and mass transfer: unidimensional velocity-temperature and concentration profiles momentum, energy and mass flux at the surface. Introduction to general transport equations for momentum, energy and mass transfer in Cartesian – cylindrical and spherical co-ordinates- simple solutions in one dimension.

References:

1. Bird R.B., Stewart W.E., Lightfoot E.W., Transport Phenomena (2e), John-Wiley, 2002
2. Brodkey R.S., Hershey C.,Transport Phenomena- A unified approach, McGraw Hill Book Company,1988
3. Slattery J.C., Advanced Transport Phenomena, Cambridge University Press, 1999
   Geankoplis C.J, Transport Process and Unit Operation (3e) , Prentice-Hall , 1993

CHE 3161: HEAT TRANSFER LABORATORY [0 0 3 1]

Course outcomes:

CO1 Appraise the safety precautions to be taken and perform the experiments individually

CO2. Analyze steady-state and unsteady-state heat conduction, natural and forced convection, and radiation

CO3 Comprehend and interpret the experimental results

CO4 Evaluate performance of various heat transfer equipment

CO5 Interpret technical data from data sheets and graphs.

Syllabus:

Experiments are based on the following topics: conduction, convection, radiation, overall heat transfer coefficient, dirt resistance calculation, bare and finned tube heat exchangers, film and drop condensation.

References:

1. Kern D.Q., Process Heat Transfer, McGraw Hill, 2009.
2. McCabe and Smith, Unit Operations in Chemical Engg, (7e), McGrawHill 2005.
3. Coulson and Richardson, Chemical Engineering, Vol.1 (6e), Elsevier India private limited 2006.
4. Dutta B. K., Heat transfer: Principles and Applications, PHI, 2001.

CHE 3142: MASS TRANSFER LAB [0 0 3 1]

Course outcomes:

CO1	Apply the principles of simple and steam distillation and evaluate the design parameters for packed bed distillation column.
CO2	Evaluate the efficiency and model parameters for the given batch adsorption system.
CO3	Estimate the diffusivity of organic vapour and determine the mass transfer coefficient of the given system.
CO4	Determine the percentage recovery and overall efficiency of the extraction and leaching operation.
CO5	Determine the rate of drying for a given sample material.

Syllabus:

Experiments are based on following topics: Vapour-liquid equilibria, Simple distillation – vaporization and thermal efficiency of steam distillation – distillation under total reflux in a packed column – studies in batch adsorption – diffusivity by Stephen's method – mass transfer coefficient in dissolution of solid – liquid-liquid extraction –simple and cross-flow leaching – experimental determination of liquid-liquid equilibrium data – drying of solids in fluidized bed dryer

References:

1. Treybal, R.E. Mass Transfer Operations (3e), McGraw Hill Education, 2017.
2. McCabe, W., Smith, J., Harriott, P., Unit Operations of Chemical Engineering (7e), McGraw Hill Education, 2017.
3. Dutta, B.K., Principles of Mass Transfer and Separation Processes, Prentice Hall India Learning Private Limited, 2006

SIXTH SEMESTER

HUM 3022 ESSENTIALS OF MANAGEMENT [3 0 0 3]

Course outcomes

CO1	Apply management concepts and understand the importance of social responsibility & ethics in practical aspects of business.
CO2	Apply fundamental principles of planning and strategic methodologies in various management contexts.
CO3	Apply the concept of organizing for the effective functioning of an organization.
CO4	Demonstrate knowledge of various staffing processes in an organizational setup.
CO5	Synthesize principles of motivation, leadership, and communication for effective control.

Syllabus:

Basis of Management theory and practise: Introduction to Business, Classification of Industries, Importance of management for an engineer, Manager – Definition & classification, managers and administrators, Systems Approach to Management, Functions of Managers, 3 Managerial Skills, 14 Principles of Management by Henri Fayol, Mintzberg's 10 roles played by managers. External Environment, Social Responsibility of managers, Ethics in managing – an integrated approach, Trust as the Basis for Change Management. International Business. Essentials of planning: Types of Plans, Steps in Planning, Objectives, Evolving Concepts in Management by Objectives, Nature and Purpose of Strategies and Policies, Strategic Planning Process - SWOT & TOWS Matrix: A Modern Tool for Analysis of the Situation, Blue Ocean Strategy: In Pursuit of Opportunities in Uncontested, The Portfolio Matrix: A Tool for Allocating Resources, Porter's Industry Analysis and Generic Competitive Strategies. Naure of organizing: Process, Urwick's Principles of Organizing, Span of Management, factors affecting the span, Various methods of Departmentation, Line and Staff concepts (Line, Staff and Functional Staff authority), Delegation- Definition, Principles and Steps.Talent acquisition and management: Difference between HRM and HRD; Job Analysis, Job Description and Job Specification; Recruitment - methods and sources. Selection Process, Techniques and Instruments; Induction and Orientation. Systems Approach to Staffing. Approaches to Manager Development and Training. Leadership and Motivation: Differences between - Leading and Managing, Leader and Manager; Differences between - motives, motivators and motivation. Theories of Motivation - Maslow's Need Hierarchy, Herzberg's Two-Factor Theory and McGregor X and Y. Motivational Techniques. Leadership Styles - Likert's Four Systems of Management, Theories, Leadership Grid. Committees, Teams, and Group Decision-Making. Communication - Difference between General and Managerial Communication, Types of Communication, Barriers of Communication. Controlling: Process (steps), Management Control Techniques (Budgetary, Non-budgetary and Network) and types of control.

Reference:

1. Subrata Das (2022), "Ethics and Human Values in Engineering Practices", Woodhead Publishing India in Textiles, New Delhi.
2. Harold Koontz & Heinz Weihrich (2020), "Essentials of Management", Mc Graw Hill, New Delhi.
3. Poornima M Charantimath (2018), "Entrepreneurship Development", Pearson Education.
4. Mike W.Martin And Ronald Schinzinger (2017), "Ethics In Engineering", 4th Edition, Tata Mcgraw Hill, New Delhi.

CHE 3221: CHEMICAL PROCESS INDUSTRIES [3 0 0 3]

Course outcomes:

CO1 Examine the structure and operations of Indian chemical industries by interpreting manufacturing processes and process flow diagrams for industrial and synthesis gases, as well as chlor-alkali compounds, to assess their industrial significance.

CO2 Evaluate the industrial processes and flow diagrams of sulfur, phosphate, and fertilizer compounds to assess their impact on large-scale production and sustainability.

CO3 Evaluate the manufacturing processes and process flow diagrams of paper & pulp and oil & fat industries, highlighting improvements in efficiency, waste management, and technological integration.

CO4 Evaluate the manufacturing methodologies and process flow diagrams of sugar, fermentation, and petroleum compounds to assess their impact on industrial productivity, resource utilization, and environmental sustainability.

CO5 Evaluate the production and process flow diagrams of polymer and rubber compounds in industries, highlighting process optimizations, sustainability factors, and technological advancements.

Syllabus:

Indian industry - A brief review- Industrial gases. Chloralkali industry. Hydrochloric acid, Soda ash. Fertilizer industry: Ammonia, Nitric acid, Urea. Oils, fats and waxes: Hydrogenation of oil, Soaps and detergents, Glycerin recovery. Petroleum industry. Pulp and paper - Pulping methods, black liquor – Paper and paperboard. Sugar and starch: Sugar – Starch and modified starches, Glucose – Fermentation, Industrial alcohol – Absolute alcohol – Acetone and Butanol. Polyethylene – Viscose rayon, Nylon 6 and Nylon 66. Natural and synthetic rubber

References:

1. Charles E. Dryden, Outlines of Chemical Technology, Edited and Revised by M. Gopala Rao and Marshall Sittig, Affiliated East Press Ltd., 3rd Edn., 1997.
2. Austin G.T., Shreve’s Chemical Process Industries, 5th Edn, McGraw-Hill, 2017.
3. Groggins, P .H, Unit processes in organic synthesis Tata McGraw-Hill, 2004.

CHE 3222: COMPUTER-AIDED SIMULATIONS IN CHEMICAL PROCESS PLANTS [2 1 0 3]

Course outcomes:

CO1	Analyse the role of property estimation methods in process simulation.
CO2	Recommend design, rating and simulation of chemical engineering equipment for given case.
CO3	Simulate and design mixer, splitter, pump, flash column, heat exchanger, reactor and distillation column.
CO4	Explain sequential modular approach and equation-oriented approach.
CO5	Apply Aspen Plus software to simulate a chemical process and Make use of sensitivity, design and optimization tools in Aspen Plus software.

Syllabus:

Introduction to steady-state flow sheeting and the design process. Steady state process simulation using sequential modular approach and equation-oriented approach. Convergence of tear streams. Introduction to process simulation, computerized physical properties calculations, thermodynamic property analysis, flowsheet features, simulation of simple units – Mixers/Splitters, Pressure Changers, Heater, Reactors, Design and rating of Heat Exchangers, Design of Distillation Column and Column Internals. Model Analysis Tools: Optimization and Sensitivity, Flow sheeting Options: Design Specifications, Simulation of Plant-wide Structure /Chemical Plants. Case studies.

References

1. Process Flow sheeting, Westerberg A. W., Hutchison H. P., Motard R. L. and Winter P., Cambridge University Press, 2011.
2. Process Plant Simulation, Babu B. V., Oxford University Press, 2004.
3. Introduction to Software for Chemical Engineers, Mariano Martin Martin, CRC Press, 2015.
4. “ASPEN PLUS® Chemical Engineering Applications”, Kamal I. M. Al-Malah, Wiley, 2017.
5. Advanced CO2 Capture Technologies, Absorption, Adsorption, and Membrane Separation Methods, Shin-ichi Nakao, Katsunori Yogo, Kazuya Goto, Teruhiko Kai, Hidetaka Yamada, Springer, 2019.

CHE 3223: CHEMICAL REACTOR THEORY [3 1 0 4]

Course outcomes:

CO1 Use RTD methods to diagnose nonideal flows in reactors and calculate conversions in nonideal reactors.
CO2 Design non-isothermal reactors for reactions and optimize operating conditions.
CO3 Describe the mass, heat transfer and reaction phenomena occurring in heterogeneous reactions and model these.
CO4 Make informed choices of reactor types and catalyst kinetics.
CO5 Write and simplify appropriately the overall rate and balance equations for catalytic/multiphase reactions.

Syllabus:

RTD in chemical reactors, distribution functions and models. Temperature effects, Design of adiabatic/non-adiabatic and non-isothermal batch and flow reactors, Optimum temperature progression, multiple steady states. Heterogeneous reactions, Rate equations, F-S non-catalytic reactions, models, Kinetic regimes, Heterogeneous catalysis, classification of catalysts, Kinetics of heterogeneous solid catalyzed gas reactions, Mathematical models, mechanism, External transport processes, Intra pellet mass transfer, Multiphase reactors kinetics and design.

References:

1. Octave Levenspiel, Chemical Reaction Engineering, Wiley & Sons - 3rd Edition, 2003.
2. Scott Fogler, H, Elements of Chemical Reaction Engineering.
3. Rawlings J.B. and Ekerd, J.G., Chemical Reactor Analysis and Design Fundamentals Nole. Hill 2002.
4. Smith, J.M, Chemical Engineering Kinetics, 3rd edition, McGrawl-Hill, International student edition.
5. Davis M.E., Davis R.E., Fundamentals of Chemical Reaction Engineering (1e), McGraw-Hill, 2003
6. Missen R.W., Mims C.A., Saville B.A., Introduction to chemical reaction engineering and kinetics, John Wiley & Sons Inc.

CHE 3224: ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING IN CHEMICAL ENGINEERING [3 1 0 4]

Course outcomes:

CO1	Assess the importance of machine learning concepts in the chemical engineering domain, their applications in the chemical engineering domain, and able to distinguish between supervised and unsupervised learning algorithms.
CO2	Formulate the problem for regression and classification and obtain the solution using MATLAB.
CO3	Analyze the concept of underfitting and overfitting of the model and take the correct decision to address the bias and variance of a model.
CO4	Develop the support vector machine algorithms as classification learning algorithms and their solution using MATLAB.
CO5	Formulate unsupervised learning algorithm and develop a principal component analysis algorithm using MATLAB.

Syllabus:

Introduction to AI & ML, supervised and unsupervised learning. Linear regression, Cost/ Objective function. Gradient descent algorithm, Linear regression with multiple variables-gradient descent algorithm. Classification, objective function of logistic regression. Concept of regularization. Neural networks. Bias-Variance trade-off, Support vector machines, Clustering algorithm. Orthogonal projection, PCA, PLS. An algorithm developed and analysed in MATLAB / PYTHON software. Application in process system engineering.

References:

1. Stephen Marsland, “Machine Learning” , Second edition CRC Press, 2014
2. Steven L. Brunton and J. Nathan Kutz, “Data-Driven Science and Engineering: Machine Learning, Dynamical Systems, and Control” Edn., 2, Cambridge University Press; 2022.
3. Alpaydin Ethem, “Introduction to Machine Learning”, Edn. 2, PHI, New Delhi.
4. Shalev-Shwartz Shai;Ben-David Shai, “Understanding machine learning”, Cambridge Univerwity Press, 2017.
5. Saikat Dutt, Subramanian Chandramouli and Amit Kumar Das, “Machine Learning” 1st edition, Pearson, 2018.

CHE 4401: OIL & GAS RESERVOIR ENGINEERING [3 0 0 3]

Course outcomes:

CO1	Explain the basic concepts of reservoir engineering & hydrocarbon phase behavior and solve problems related to reservoir hydrocarbon volume.
CO2	Construct the Pressure-Volume-Temperature (PVT) analysis for reservoir fluids.
CO3	Derive the material balance equations for oil reservoirs for different drive mechanisms.
CO4	Explain Darcy's law and its applications for oil reservoir well stimulation.
CO5	Derive the basic differential equation for radial flow in a porous medium and solve it for various flow conditions, EOR.

Syllabus:

Basic concepts of reservoir engineering: calculation of hydrocarbon volumes, fluid pressure regimes, recovery factor, volumetric gas reservoir study, hydrocarbon phase behavior; PVT analysis for oil: definition of parameters, fluid sampling, laboratory testing and conversion to field conditions; Material balance applied to oil reservoirs: general form of equation, reservoir drive mechanisms, solution gas drive, gas cap drive, natural water drive; Darcy's law and applications: Darcy's law, fluid potential, radial steady state flow, well stimulation, two phase flow: effective and relative permeability, supplementary recovery; Radial flow differential equation, conditions of solution; Application of the stabilized inflow equations; Enhanced Oil Recovery (EOR).

References:

1. Dake L. P., Fundamental of Reservoir Engineering, Elsevier, 2011.
2. Smith H. C., Tracy G. W., and Farrar R. L., Applied Reservoir Engineering: Volume I and II, OGCI, 1999.
3. Salter A., Baldwin J., and Jespersen R., Computer-Aided Reservoir Management, Pennwell, 2000.
4. Ahmed Tarek, Reservoir Engineering Handbook (4e), Gulf professional publishers, 2010.

CHE 4407: AIR POLLUTION MONITORING AND CONTROL [3 0 0 3]

Course outcomes:

CO1 : Apply various air pollution monitoring techniques
CO2 : Identify the major air pollutants and know the regulations of air pollution
CO3 : Analyse the methods of controlling the air pollutants
CO4 : Evaluate various methods of collection of common air pollutants.
CO5 : Design and calculate the pollutant concentration using air pollution models

Syllabus:

The earth's atmosphere, structure and composition, air pollution history, sources and emissions, meteorology and instruments, gas sampling, atmospheric motion and pollutant transport, , atmospheric stability, gas phase chemistry and photochemical smog, air pollution monitoring, aerosols and particulate matter, SOx, NOx, VOCs, CO2, CO, particulate matter and their reduction, exposure and health effects, climate change, air pollution modelling, fixed box, Gaussian plume models.

References:

1. Air Pollution, M N Rao and H V N Rao, McGraw Hill Education Pvt Ltd 2013
2. Martin Crawford, Pollution control theory, McGraw Hill, NY, 1976
3. Joe LedBetter, Air Pollution Part A & B, Marcel and Dekker, 1972
4. S. M. Khopkar, Environmental pollution Monitoring and control, New age Int, ND -2004
5. K.E Noll and T.L.Miller, Air Monitoring survey design, (1e), Ann Arber Science, 1977

CHE 4409: RENEWABLE ENERGY [3 0 0 3]

Course outcomes:

CO1 Apply the concepts of solar radiation, solar drying, and active and passive heating to measure and estimate solar radiation.

CO2 Estimate the solar thermal power generation and understand the concepts of thermochemical energy storage and solar refrigeration.

CO3 Design the wind turbine and estimate the power generated using wind energy, wind power density, HAWT, and VAWT analysis.

CO4 Calculate the volume and size of a biogas reactor and analyze the biomass gasifier's efficiency. Design a hydropower plant by estimating the plant's efficiency, discharge, and capacity.

Syllabus:

Solar radiation, measurement and estimation; empirical relations, solar collectors and types, Solar drying, Active and passive heating and cooling of buildings, Solar thermal power generation, and Solar pond. wind power density, power in a wind stream, wind turbine efficiency, solidity, HAWT, VAWT, and tower design. Biomass classification, handling of biomass. Biogas technology, Pyrolysis, and Gasification techniques. Hydroelectric power plants, types and components, site feasibility studies.

References:

1. Goswami D.Y., Frank Kreith, Jan. F. Kreider, "Principles of Solar Engineering", 3rd Edition, Taylor & Francis.2015.
2. Mukund & Patel R., Wind and Solar Power Systems., 3rd Edition, Taylor & Francis, 2021.
3. Chakravarthy A, "Biotechnology and Alternative Technologies for Utilization of Biomass or Agricultural Wastes", Oxford & IBH publishing Co 1989.

CHE 4402: PETROLEUM REFINERY ENGINEERING (THEORY & LAB) [2 0 3 3]

Course outcomes:

CO1	Classify the crude oil based on its physical properties.
CO2	Apply the distillation process to separate the crude oil using ADU & VDU.
CO3	Analyze the properties of petroleum products and its suitability for the transport and other fuels.
CO4	Make use of hydro de sulphurization, de asphalting and solvent extraction process, purify the products to get value added products.
CO5	Testing the petroleum products for flash, fire, aniline, smoke and average boiling points, viscosity, and Reid vapour pressure in the laboratory.

Syllabus:

Theory: Crude oil origin, Indian scenario of crude, crude composition, characterization and classification; Refinery products and test methods; Design of crude oil distillation column; Refinery processes: thermal, catalytic, and hydrocracking, catalytic reforming, isomerization, alkylation, polymerization, lube oil processing, coking, hydro treatment, gas processing.

Laboratory: Experiments are based on determination of vapour pressure, flash point, fire point, pour point, smoke point, aniline point, viscosity, viscosity index, calorific value, carbon residue, softening point, and penetration index of petroleum fractions.

References:

1. Bhaskara Rao B. K., Modern Petroleum Refining Processes (5e), Oxford& IBH, 2009.
2. Indra Deo Mall, Petroleum Refining Technology (1e), CBS Publishers, 2017
3. Nelson W. L., Petroleum Refining Engineering (4e), McGraw-Hill, 1974.
4. Meyers R. A., Handbook of petroleum refining processes (3e), McGraw-Hill, 2004.
5. James G Speight, The Chemistry and Technology of Petroleum (4e), CRC Press, 2006.

CHE 4409: SOLID AND HAZARDOUS WASTE MANAGEMENT [3 0 0 3]

Course outcomes:

CO1	To summarize the source and physicochemical properties of municipal solid wastes and to design the appropriate methods for storage, collection, and transfer of solid wastes.
CO2	To analyze the size reduction and separation, waste processing techniques, and thermal processes for solid waste
CO3	To examine the bioremediation techniques like composting, anaerobic conversion.
CO4	To demonstrate the design and operation of sanitary landfill and to explain hazardous waste management systems.

Syllabus:

Classification of solid wastes, Functional elements of Solid Waste Management (SWM), Regulatory aspects of SWM, Waste Characteristics, Environmental and health effects, Solid waste storage and collection, Transfer stations, Waste Processing techniques, Source reduction, recycle and recovery, Sanitary landfill, Landfill liners, Leachate and landfill gas management, Composting, Biogasification, Incineration, Introduction to Hazardous Waste Management (HWM), Guidelines for (HWM), International regulatory framework for HWM, Characterization of hazardous wastes, Packing and labelling of hazardous wastes, Storage, transport and disposal of hazardous wastes, Concept of Integrated waste management.

References:

1. Tchobanoglous G., Theisen H., Eliassen R., Solid Wastes: Engineering Principles and Management Issues, McGraw Hill, 1977.
2. Freeman H. W., Standard Handbook of Hazardous waste Treatment and Disposal (2e), McGraw Hill, 1997.
3. McBean E. A., Rovers F. A., Farquhar G. J., Solid Waste landfill Engineering and Design, Prentice Hall, 1995.
4. Lees F., Lees' Loss Prevention in the Process Industries: Hazard identification, assessment and control (3e), Butterworth-Heinemann, 2004.
5. Rao M. N., Sultana R., Kota S. H., Solid and Hazardous Waste Management: Science and Engineering (1e), B S Publications (imprinted by Elsevier), 2016.

CHE 4410: SOLAR ENERGY [3 0 0 3]

Course outcomes:

CO1 - Utilize the solar spectrum, radiation data, and energy collection methods for various solar technologies

CO2 - Develop optimized solar collector designs considering material selection, angle orientation, and thermal performance

CO3 - Design suitable solar-based solutions for cooking, drying, distillation, refrigeration, and ventilation using solar chimneys

CO4 - Examine solar thermal power generation methods to address real world energy challenges

CO5 - Analyze and differentiate the design, operation, and performance characteristics of Photovoltaic systems

Syllabus:

Solar spectrum, Solar radiation data, collection of solar energy, Flat plate collectors, parabolic collectors, compound parabolic collectors, Solar air heater, Solar water heater, Solar concentrators, characteristic parameters, types of concentrators materials in concentrators, Solar cooking, Solar drying, Solar distillation and solar refrigeration, Solar Chimney, Solar thermal power generation, Central Power Station System, Distributed PV System, Standalone PV system, grid Interactive PV System, hybrid solar PV system, materials for solar PV cells.

References:

1. Sukhatme. S.P., J.K.Nayak "Solar Energy", 4th edition, Tata McGraw Hill Publishing Company Ltd., New Delhi,2017.
2. Tiwari. G.N., Solar Energy – "Fundamentals Design, Modelling & Applications", Narosa Publishing House, New Delhi, 2020.
3. Chetan Singh Solanki, Solar Photovoltaics, "Fundamentals, Technologies and Applications", PHI Learning Private Limited, New Delhi, 2015.
4. John R. Balfour, Michael L. Shaw, Sharlave Jarosek., "Introduction to Photovoltaics", Jones & Bartlett Publishers, Burlington, 2011.
5. D. Yogi Goswami, Frank Kreith, Jan. F. Kreider, "Principles of Solar Engineering", 2ndEdition, Taylor & Francis, 2000
6. Garg.H. P, Prakash. J, "Solar Energy Fundamentals and Applications", Tata McGraw-Hill, 2005.

CHE 4312: RISK AND SAFETY MANAGEMENT IN INDUSTRIES [3 0 0 3]

Course outcomes:

CO1 : Identify the various safety analysis procedures in the industries
CO2 : Analyse hazards and risk assessment in the process industries
CO3 : Evaluate the root causes of major industrial disasters
CO4 : Explain the role of management and safety engineer in implementation of a safety program in a plant.

Syllabus:

Safety in plants: Hazard analysis, damage minimization, fires, fire extinguishers, handling, contamination removal, reduction methods, personal protective devices, Plant and personal safety. Pressure vessels, handling and transportation of liquids and gases under high pressure, explosive chemicals and handling. First aid principles and methods, plant inspection. Engineering design for safety considerations. Hazards in workplaces, workers' exposure to hazardous chemicals, threshold limit values of chemicals, engineering control of hazards and accidents due to fire, explosives and natural causes in different industries. Safety management, safety performance, motivation of employees, supervisors, managers and management, legal aspects of safety.

References:

1. Willie Hammer, Dennis Price, Occupational Safety Management and Engineering, Prentice Hall, fifth edition
2. Safety Analysis: Principles and Practice in Occupational Safety, Harms-Ringdahl, Lars, CRC Press; 2nd edition (19 September 2019)
3. Muir G.D, Hazards in Chemical Laboratory, (2e), The Chemical Society, London, 2nd Edition
4. Handley W., Industrial Safety Handbook, McGraw-Hill Companies; 2nd Revised edition

CHE 3241: PROCESS MODELLING AND SIMULATION LAB [0 0 3 1

Course outcomes:

CO1	Apply steady-state concepts for the simulation of the flash drums, reactors, distillation, absorbers, etc., using ASPEN PLUS.
CO2	Apply steady-state concepts to optimize, design specifications, and perform sensitivity analysis of various parameters for reactors, distillation, and absorbers using ASPEN PLUS.
CO3	Develop a steady state simulator of chemical plant using ASPEN PLUS.
CO4	Formulate Exchanger Design and Rating (EDR) Using ASPEN EDR.
CO5	Assess the simulation of the chemical plants and total annualized costs using ASPEN HYSYS.

Syllabus:

Experiments based on simulation of steady state – flash drum, reactors, distillation column, absorber, heat exchanger and chemical plants using ASPEN PLUS. Simulation of unsteady state operation of chemical plants using ASPEN DYNAMICS

References

1. Introduction to Software for Chemical Engineers, Mariano Martin, CRC Press, 2015.
2. “ASPEN PLUS® Chemical Engineering Applications”, Kamal I. M. Al-Malah, Wiley, 2017

CHE3242: REACTION ENGINEERING AND PROCESS CONTROL LAB [0 0 3 1]

Course outcomes:

CO1 Plan experiments and present the experimental data meaningfully.

CO2 Apply theoretical concepts for data analysis and interpretation.

CO3 Draw a conclusion from experimental results related to Chemical reaction engineering and Process dynamics & control.

Syllabus:

Syllabus: Experiments based on the following topics: Homogeneous non-catalytic liquid phase kinetic studies using batch reactor, semi-batch reactor, PFR and CSTR. Studies on recycle reactor. RTD Studies in PFR and CSTR - Dynamic response of systems: first order non-linear, thermometric; second order non-interacting and interacting by introducing a step input. Linearization of a non-linear system and comparison of dynamic response with the actual response, Valve characteristics, Studies on P, PI, and PID controllers; control of systems with cascading and ratio effects

References

1. Fogler S. H., Elements of Chemical Reaction Engineering(4e), Prentice Hall, 2005.
2. Levenspiel O., Chemical Reaction Engineering (3e), Wiley & Sons, 2003.

VII SEMESTER

I. Minor Specialization on Petroleum Engineering

CHE 4403: NATURAL GAS ENGINEERING [3 0 0 3]

Course outcomes:

CO1	Classification of different types of wells, well integrity tests, PVT Behavior of gas wells, pseudocritical properties, and z-factor.
CO2	Construction of gas well deliverability or inflow performance relationship (IPR).
CO3	Construction of well (WPR), choke performance relationship (CPR) and nodal analysis
CO4	Design of production separators, dehydration units, and absorber columns.
CO5	Assess the importance of hydrocarbon dew point system, compressors and measurement of the natural gas

Syllabus:

Natural gas industry, types of natural gas resources; Properties of natural gas; Gas reservoir deliverability: analytical and empirical methods, construction of IPR curve, shale gas wells, well deliverability testing; Well bore performance: single-phase gas well and mist flow in gas wells; Choke performance: sonic and subsonic flow, dry and wet gas flow through chokes; Well deliverability: nodal analysis, production forecast; Natural gas processing: separation of gas and liquids, stage and low temperature separation; dehydration; Compression and cooling; Natural gas measurement and transportation; Liquid loading, hydrate cleaning and pipeline cleaning; Advances in natural gas production engineering.

References:

1. Guo B., Ghalambor A., Natural Gas Engineering Handbook, Gulf Publishing Company, 2nd Edition - 2012
2. Katz D. L., Lee R. L., Natural Gas Engineering, McGraw Hill, 1990.
3. Guo B., Lyons W. C., Ghalambor A., Petroleum Production Engineering: A Computer Assisted Approach, 1st Edition, Elsevier, 2007.
4. Ahmed T., McKinney P. D., Advanced Reservoir Engineering, Elsevier, 1st Edition – 2004.

CHE 4404: PROCESS INTEGRATION FOR PETROLEUM INDUSTRIES [3 0 0 3]

Course outcomes:

CO1	Identify the importance and limitations of energy integration in process industries.
CO2	Estimate the minimum utility requirement through composite curves
CO3	Evaluate the area requirement for the given heat exchanger network
CO4	Explain Pinch design method for HEN synthesis and integration of process equipment

Syllabus:

Understand the importance of energy integration in a petroleum industry, Energy integration, Focus on Pinch Analysis, Key Steps of Pinch Technology, Basic Elements of Pinch Technology: Grid diagram, Composite curve, Problem table algorithm, Grand composite curve. Heat Exchanger Network (HEN): Energy targeting, Area targeting, Number of units targeting. Designing of HEN: Pinch design methods, Heuristic rules, Stream splitting, Design of maximum energy recovery (MER);Heat Integration of Equipment's.

References:

1. Kemp I. C., Pinch, Analysis and Process Integration: A User Guide on Process Integration for the efficient use of energy (2e), Butterworth-Heinemann (Elsevier), publisher, 2007.
2. Smith R. M., Chemical Process: Design and Integration, John Wiley & Sons, 2005.
3. Biegler, L. T.; Grossmann I. E.; Wasterberg, A. W., Systematic Methods of Chemical Proces Design, Prentice Hall, New-Jersey, 1997.

II. Minor Specialization on Pollution Control Engineering

CHE 4405: INDUSTRIAL WASTEWATER ENGINEERING (THEORY AND LAB) [2 0 3 3]

Course outcomes:

CO1	Analyse the various physical, chemical and biological characteristics of waste water and predict the downstream operations required
CO2	Discuss key unit operations using the knowledge of engineering approaches
CO3	Apply knowledge of various physicochemical units for wastewater treatment.
CO4	Analyze the kinetics of biological growth and its application in the design of biological reactors
CO5	Demonstrate testing water/industrial wastewater quality measurement testing as a hands-on practice

Syllabus:

Wastewater treatment quality criteria and effluent standards, Preliminary treatment processes, Primary treatment process, Biological treatment processes, microbial kinetics, nitrification and denitrification, Activated Sludge process, trickling filters and rotating biological contactors, advanced treatment processes Advanced treatment processes, Concept of zero liquid discharge. Lab may include tests for water/wastewater quality like pH, turbidity, DO, COD, BOD, TOC, total solids, fixed solids, dissolved solids, fluoride, residual chlorine, determination of particulate matter (PM2.5 and PM10) in air, desiccant dehumidifiers.

References:

1. Metcalf and Eddy, Wastewater Engineering: Treatment and Reuse (5e), McGraw Hill, 2013.
2. Edwards J. D., Industrial Waste Water Treatment: A Guide Book (1e), CRC Press, 2019.
3. Patwardhan A. D., Industrial Waste Water Treatment, Prentice Hall India, 2009.
4. Ranade V. V., Bhandari V. M., Industrial Wastewater Treatment, Recycling and Reuse (2e), Prentice Hall India, 2017.
5. Droste R. L., Theory and Practice of Water and Wastewater Treatment, John Wiley & Sons, 2018.
6. Larry .D. Benefield, Clifford W. Randall "Biological process design for wastewater treatment", Prentice Hall publishers,1989

CHE 4408: ENVIRONMENTAL IMPACT ASSESSMENT AND MANAGEMENT PLAN [3 0 0 3]

Course outcomes:

CO1	Critique the historical evolution of environmental impact assessment, identifying key drivers and consequences in environmental planning and management from a sustainability perspective
CO2	Determine the procedures, components, and laws of the EIA process and EM.
CO3	Evaluate the efficacy of diverse environmental management practices in achieving sustainable development goals.
CO4	Appraise the environmental, ethical and economic implications of environmental impact assessment as evidenced by case study outcomes

Syllabus:

Environmental impact assessment (EIA), history, Environmental movements, EIA laws and acts, EIA Methodologies, Adhoc methods, matrix methods, Network method etc., Cost/benefit Analysis, EIA 1994, 2006,2020, Methodology for the assessment of ground water, air, soil, water, case studies.

Environmental management - principles, problems and strategies, Environmental audit, introduction to ISO and ISO 14000, Life cycle assessment, Triple bottom line approach, Ecological footprint, Carbon trading, Sustainable development, case studies.

References:

1. L. W. Canter, Environmental Impact Assessment, (2e), McGraw-Hill, 1997
2. Environmental Impact Assessment Methodologies, by Y. Anjaneyulu, B.S. Publication, Sultan Bazar,

   Hyderabad (2006).
3. Environmental Impact Assessment, New age publishers, Barathwal 2012

III. Minor Specialization on Renewable Energy Engineering

CHE 4411: FUEL CELL & HYDROGEN ENERGY [3 0 0 3]

Course outcomes:

CO1	Explain the principles of hydrogen production, Storage and its utilization
CO2	Demonstrate the concept of Fuel Cell processing and the current scenario of this technology.
CO3	Analyze the electrochemical reactions of fuel cells and evaluate the voltage and energy output.
CO4	Design different types of fuel cells based on the input fuel.

Syllabus:

Hydrogen energy - Hydrogen: Hydrogen production methods, Storage and utilization. Fuel cell basics, Fuel cell thermodynamics, Fuel cell types, Fuel Cell Performance, Activation, Ohmic and Concentration over potential, Fuel cell design and components, Overview of intermediate/high temperature fuel cells, Current issues in fuel cells

References:

1. Larminie J. and Dicks A., Fuel Cell Systems Explained, 2nd Edition, Wiley (2003)
2. Xianguo Li, Principles of Fuel Cells, Taylor and Francis (2005)
3. Srinivasan S., Fuel Cells: From fundamentals to Applications, Springer (2006)
4. ‘O’Hayre, S.W.Cha, W.Colella and F.B.Prinz, Fuel Cell Fundamentals, Wiley (2005)
5. Bard A.J. and.Faulkner L.R, Electrochemical Methods: Fundamentals and Applications, 2nd Edition, Wiley 2000.
6. Faghri A and Zhang Y., Transport Phenomena in Multiphase Systems, Elsevier 2006.

CHE 4412: BIO ENERGY ENGINEERING [3 0 0 3]

Course outcomes:

CO1	Classify and explain the types, characteristics, and environmental impacts of biomass
CO2	Apply knowledge of the production, treatment, and storage of biomass fuels
CO3	Analyse the thermochemical and biochemical conversion of biomass
CO4	Discuss about the principles of biofuel production
CO5	Evaluate bioenergy systems and their potential for future energy supply

Syllabus:

Biomass sources and classification, Characteristics preparation, Chemical composition and properties of different biomass materials and bio-fuels. Sugarcane molasses and other sources for fermentation ethanol. Sources and processing of oils and fats for liquid fuels. Energy plantations. Briquette of loose biomass, drying storage and handling of biomass. Biogas technology, Feedstock for biogas production, Aqueous waste containing biodegradable organic matter, animal residues, microbial and biochemical aspects, operating parameters for biogas production, kinetics and mechanism, dry and wet fermentation. Digesters for natural applications, High rate digesters for industrial waste water treatment. Bio-ethanol and bio-diesel technology, Production of fuel ethanol by fermentation of sugars, gasohol as a substitute for petro, Trans-esterification of oils to produce bio-fuels, Pyrolysis and gasification of biomass, Thermochemical conversion lignocelluloses biomass, Biomass processing for liquid fuel production, Pyrolysis of biomass. Pyrolysis regime, effect of particle size, temperature and products obtained, Thermo-chemical gasification principles, Effect of pressure temperature and introduction of steam and oxygen. Combustion of biomass and co-generation systems, Combustion of woody biomass. Theory, calculation and design of equipment. Co-generation in biomass processing industries, Combustion of rice husk, use of bagasse for cogeneration.

References:

1. A Chakraverthy, Biotechnology and alternative technologies for utilization of biomass or agricultural wastes, (1e), Oxford & IBA, New Delhi. 1989.
2. K M Mittal, Biogas systems: Principles and applications, (1e), New Age International Publishers (P) Ltd. 1996.
3. P. Venkata Ramana, S. N. Srinivas, Biomass energy systems, (1e), Tata energy Research Institute New Delhi, 1996.

PROGRAM ELECTIVES

CHE 4444 ENERGY ENGINEERING [3 0 0 3]

Course outcomes:

CO1 Distinguish between the different types of solid fuels – requisite properties, testing methods, production, processing and utilization.

CO2 Analyze and understand different types of liquid and gaseous fuels- testing of properties, production, processing and utilization.

CO3 Evaluate different types of combustion techniques and related appliances, calculation of air requirement, furnaces- aerodynamics, construction and working.

CO4 Apply energy audit and energy conservation techniques and understand the basics of renewable energy sources.

Syllabus:

Classification. characterisation and testing of solid liquid and gaseous fuels. Theories on the origin and processing of solid and liquid fuels. Gaseous fuels- manufacture and properties. Terminology and types of combustion techniques - calculation of air requirement, grates, burners and stokers. Furnaces-Classification, construction and types used in process industries. Energy scenario in India, renewable sources of energy. Energy audit and energy conservation in different sectors.

References:

1. Sharma, S.P., Chander Mohan, "Fuels and Combustion", Tata McGraw-Hill, .
2. Saha, A.K., "Combustion Engineering and Fuel technology", Oxford Press.
3. Gilchrist, J.D., "Fuels, Furnaces and Refractories", Pergamon Press,
4. Manson L. Smith, Keri W. Stinson, "Fuels and Combustion", McGraw-Hill,

CHE 4445: GREEN PROCESSES [3 0 0 3]

Course outcomes:

CO1 **Apply** the twelve principles of green chemistry to develop sustainable and eco-friendly chemical processes.
CO2 **Analyze** green synthetic methods like microwave and electro-organic synthesis for eco-friendly chemical production.
CO3 **Apply** green chemistry materials such as catalysts, biodegradable polymers, and ionic liquids in sustainable synthesis.
CO4 **Evaluate** bio-energy conversion processes and their applications in renewable energy technologies.

Syllabus:

Introduction: Definition, the twelve basic principles of green chemistry. Green synthetic methods: Microwave synthesis, electro-organic synthesis, The design and development of environmentally friendly chemical pathways: challenges and opportunities. High-yield and zero-waste chemical processes. Representative processes. Materials for green chemistry and technology: Catalysis, environmental friendly catalysts, Bio-catalysis, biodegradable polymers, alternative solvents, ionic liquids Bio-energy: Thermo-chemical conversion: direct combustion, gasification, pyrolysis and liquefaction; Biochemical conversion: anaerobic digestion, alcohol production from biomass; Chemical conversion process: hydrolysis and hydrogenation; Biophotolysis: Hydrogen generation from algae biological pathways; Storage and transportation; Applications

References:

1. Mikami K., Green Reaction Media in Organic Synthesis, Wiley-Blackwell 2005.
2. Koichi T., Solvent-free Organic Synthesis Green chemistry, Wiley-VCH; 2003
3. Maartje F. K. and Thierry M., Supercritical Carbon Dioxide: in Polymer Reaction Engineering Green Chemistry, Wiley VCH 2005
4. Alvise P., Fulvio Z., and Pietro T., Methods and Reagents for Green Chemistry: An Introduction, Wiley Inter science 2007
5. Lancaster M,Green Chemistry, RSC 2002
6. Stanely E. Manahan, Green Chemistry and the Ten Commandments of Sustainability, ChemChar 2005
7. David T. A. and David R. S., Green Engineering: Environmentally conscious Design of Chemical Processes, Prentice Hall PTR 2001
8. Roger A. S., Isabel A., and Hanefeld U., Green Chemistry and Catalysis , Wiley VCH, 2007
9. James V. B., Heat Conduction Using Green's Function (Series in Computational and Physical Processes in Mechanics and Thermal Sciences) Taylor & Francis, 1992

CHE 4446: INDUSTRIAL SAFETY AND RISK MANAGEMENT [3 0 0 3]

Course outcomes:

CO1	Analyse hazards and risk assessment in the process industries
CO2	Identify the role of management and safety engineer in implementation of a safety program in a plant
CO3	Appraise the various safety analysis procedures in the industries
CO4	Evaluate root cause for the major industrial disasters

Syllabus:

Management of safety in Industry- Concept of Safety, Applicable areas, unsafe actions & Conditions. Safety Committee - Membership, Functions & Scope of Safety committee. Guidelines for safeguarding personnel. Safety education and training-Safety managements, fundamentals of safety tenets, measuring safety performance, motivating safety performance, legal aspects of industrial safety, safety audits.

Disaster Management - Designing, Importance & implementation of Disaster Control Action Plan; Hazard identification methodologies, risk assessment methods-PHA, HAZOP, MCA, ETA, FTA, Consequence analysis, Probit Analysis. Hazards in work places. Worker's exposures to hazardous chemicals. Hazards peculiar in industries.

References:

1. F.P.Lees, Loss prevention in process industries, 2/e, Butterworth-Heinemann,. 1996
2. W.Handley, Industrial Safety hand book, 2/e, McGraw- Hill, 1977
3. King R W ;Magid J, Industrial hazards and safety hand book, Butterworth, London, 1980.

CHE 4447: INTRODUCTION TO BIOCHEMICAL ENGINEERING [3 0 0 3]

Course outcomes:

CO1 Identify and summarize the foundational knowledge of microbiology.

CO2 Analyse and explain the roles and structures of essential biomolecules in cells

CO3 Develop the kinetics model for enzyme and its inhibition effects

CO4 Categorize the major metabolic pathways across different cells

CO5 Assess the cell growth through kinetic models

Syllabus:

Introduction; Principles of Microbiology; Chemicals of Life: Carbohydrates, Amino acids, Proteins, Lipids, Nucleic acids; Cell Nutrients, Growth Media; Kinetics of enzymes; Inhibition, production, purification, immobilization and application of enzymes; Metabolic pathways and energetic of the cell: Glucose, Nitrogen, and Hydrocarbon metabolism; Overview of biosynthesis, Anaerobic metabolism, Autotropic metabolism; Transport across cell membranes; Cell growth: Batch growth and Quantification of growth kinetics

References:

1. Bailey J.S., Ollis D.F., Biochemical Engineering Fundamentals (2e), McGraw-Hill, 2017
2. Shuler M.L., Kargi F., Delisa M., Bioprocess Engineering: Basic Concepts (3e), 2017
3. Blanch H.W., Clark D.S., Biochemical Engineering (2e), CRC Press, 1997

CHE 4449: MEMBRANE SCIENCE AND TECHNOLOGY [3 0 0 3]

Course outcomes:

CO1	To identify the basic concepts of membrane process, and its classifications
CO2	To identify the basic principles and materials properties for different membrane separation processes
CO3	To analyze the selection criteria for the best membrane modules for different applications
CO4	To design the suitable membrane separation technique for intended problem
CO5	To design the membrane based reactor systems for various applications

Syllabus:

Membrane preparation and structure, membrane permeability, flow pattern and classification: micro filtration, ultra filtration, nano filtration, reverse osmosis, electrodyalysis, dialysis, membrane modules and plant configuration, liquid separation: pervaporation, vacuum membrane distillation, transport through membrane, solution diffusion model and Donnan equilibrium, Kimura-Sourirajan model, Spiegler and Kedem model, Extended Nernst-Planck model.

Gas separation: complete mixing model (binary and multi component) for gas separation, cross flow model, counter current flow model, single stage membrane separation, multistage membrane separation and analogy with multi component distillation, differential permeation with point permeate withdrawal, bubble point type curve, dew point type curve.

Membrane reactor: perovskite type, bio catalytic membrane reactor, application of membrane in separation of optical isomers of valued bioactive materials. Transport through bio membrane like kidney.

References:

1. E. J. Hoffman, Membrane separations Technology: single-stage, Multistage, and Differential Permeation, (1e), Gulf Professional Publishing, 2003
2. M.H.V. Mulder, Membrane Separation, (1e), Springer Publ. -2007
3. K.S. Scott, Robert Hughes (Editors), Industrial Membrane Separation Technology, (1e), Blackie Academic & Professional Chapmann & Hall, Glasgaw, 1996

CHE 4450: MOLECULAR MODELLING AND SIMULATION [2 1 0 3]

Course outcomes:

CO1	Describe and apply the basic concepts of molecular modeling and simulation.
CO2	To identify the principles and material properties involved in different molecular modeling processes.
CO3	To evaluate and choose the most appropriate molecular modeling techniques for various applications.
CO4	To design effective molecular modeling approaches for specific problems.

Syllabus:

Introduction to molecular modelling, potential energy surfaces, molecular orbital theory, density functional theory, molecular mechanics and force fields, introduction to programming methods and algorithms used in the course, molecular dynamics simulations, molecular dynamics of hard spheres, periodic boundaries, ensembles, Monte Carlo simulations, free energy calculations, phase equilibria calculations, interfacial properties, rare events.

References:

1. M. P. Allen & D. J. Tildesley Computer Simulation of Liquids, Oxford University Press, 1987.
2. Daan Frenkel & Berend Smit Understanding Molecular Simulation, 2nd Ed. Elsevier 2002.
3. Anthony Stone, The Theory of Intermolecular Forces, 2nd Ed. Pearson, 2013.
4. Andrew Leach; Molecular Modelling – Principles and Applications, 2nd Ed. Prentice Hall, 2001

CHE 4451: NON-NEWTONIAN FLUID FLOW IN PROCESS INDUSTRIES [3 0 0 3]

Course outcomes:

CO1	Interpret the behaviour of non-Newtonian fluids and its importance in process industries
CO2	Determine the apparent viscosity of non-Newtonian fluid using the rheometry
CO3	Determine the friction factor and pressure drop in circular pipes with single and multi-phase flow of non-Newtonian fluids.
CO4	Determine the pressure drop of non-Newtonian fluid flow in noncircular pipes

Syllabus:

Classification of fluid behaviour and types of non-Newtonian fluids and their mathematical model representation, Rheometry for non-Newtonian fluids: capillary, rotational, normal stress, controlled stress, yield stress rheometers, Generalized Reynolds number of power law and Bingham plastic fluids and pressure drop calculation of Power law fluids and Bingham plastic fluids in pipes. Flow of Power law fluids in noncircular pipes, Flow regimes of gas –non-Newtonian fluids in pipes.

References:

1. Chhabra R. P. and Richardson J. F., Non-Newtonian flow in the process Industries, Butterworth and Heinemann, 1999.
2. McCabe W., Smith J., Harriott P., Unit Operations of Chemical Engineering (7e), McGraw Hill Education, 2017.
3. Carreau P. J., DeKee D. C. R., Chhabra R. P., Rheology of Polymeric Systems: Principles and Applications, Hanser Publishers, 1997.

CHE 4455: PROJECT ENGINEERING [3 0 0 3]

Course outcomes:

CO1	To organize the preliminary data requirements for the establishment of industry
CO2	To develop the piping and instrumentation of the process plant
CO3	To evaluate the piping design and the importance of project scheduling
CO4	To explain the importance of various accessories and to identify the optimum conditions of the chemical equipment

Syllabus:

Preliminary data on projects; Process engineering, Block flow diagram, Process flow diagram, Piping and instrumentation diagram, Pilot plants, General considerations for plant location and layout, piping design, Project engineering management, Project scheduling and its importance, PERT and CPM techniques, Piping design, plant utilities, insulation, instrumentation, safety in chemical plant, Gantt chart, Optimum project design, optimum production rates, selected examples such as heat exchangers, pumps , vessels, evaporators, and driers.

References:

1. Howard F. Rase, M.H. Barrow, Project Engineering of Process Plants, John Wiley, 1968
2. Warren Sieder, J.D. Seader, Daniel Lewin, Product and Process Design Principles, John Wiley, 2004
3. Peters M. S, Klaus D. T., Ronald E. W., Plant Design and Economics for Chemical Engineers, McGraw- Hill, 2003
4. Gavin T. & Ray S., Chemical Engineering Design-Principles, Practice and Economics of Plant and Process Design, Butterworth and Heinemann (Elsevier), 2020.

CHM 4441: ANALYTICAL TECHNIQUES AND INSTRUMENTATION [3 0 0 3]

Course outcomes:

CO1	Explain the interaction of electromagnetic radiation with matter and energy concepts.
CO2	Explain the principle and instrumentation involved in microwave, IR, Raman, UV-Visible and NMR spectroscopy.
CO3	Apply these spectroscopic techniques in analyzing the organic compounds.
CO4	Propose the chromatographic technique to be used for the separation of components from mixture.
CO5	Apply the concepts of electro-analytical method to identify the method to quantify the analyte

Syllabus:

Spectroscopic methods of analysis: Properties of EMR, General features of spectroscopy, types of molecular spectra, Interaction of EMR with matter, Instrumentation, Applications, Theory, Instrumentation and applications of Microwave, Raman, Infrared, UV-Visible, NMR spectroscopic techniques. Chromatographic Techniques: General concepts, Classification, Principles, Experimental techniques of CC, HPLC, TLC, GC and their applications. Electroanalytical methods: Basic principles and applications of conductometric, potentiometric titrations.

References

1. D.A. Skoog, J. Holler, F.T.A. Nieman, Principles of instrumental analysis, 5th Edn, Saunders, Philadelphia, 1992
2. D.A. Skoog, D.M. West and F.J. Holler, Fundamentals of analytical Chemistry, 5th Edn, Saunders college Publishing, Philadelphia, 1988
3. Vogel’s Textbook of Quantitative Chemical Analysis, GH Jeffery, John Wiley & Sons Inc, 5th Edn, 1989

VIII SEMESTER

CHE 4291: INDUSTRIAL TRAINING [0 0 0 1]

Course outcomes:

CO1	Understand and sharpen the real time technical / managerial skills required at the job.
CO2	Learn to apply the technical knowledge in real industrial situations
CO3	Gain experience in writing technical reports/projects.
CO4	Get in insight into the engineer's responsibilities and ethics.
CO5	Enhance his/her academic, professional and/or personal development.
CO6	Understand the social, economic and administrative considerations that influence the working environment of industrial organizations
CO7	Be able to practice communication and teamwork skills.
CO8	Opportunity to learn strategies like time management, multi-tasking etc in an industrial setup
CO9	Understand the importance of Planning and record self-learning and development necessary for life professional development

CHE 4299: PROJECT WORK [0 0 0 12]

Course outcomes:

CO1 Construct a scientific research plan to execute and finish within a stipulated time frame
CO2 Follow the SOPs (Standard operating procedures) and adhere to GLP (Good Laboratory Practices)
CO3 Apply theoretical concepts to solve practical problems
CO4 Analyse and report the results from the practical research exercise in written and oral forms
CO5 Acquire collaborative skills through working in a team to achieve common goals