

B Tech in 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 2103	Engineering Mathematics – III	2	1	0	3	MAT 2204	Engineering Mathematics – IV	2	1	0	3		
	CHE 2101	Chemical Process Calculations	3	1	0	4	CHE 2201	Chemical Engineering Thermodynamics – II	2	1	0	3		
	CHE 2102	Momentum Transfer	3	1	0	4	CHE 2202	Heat Transfer Operations	3	1	0	4		
	CHE 2103	Mechanical Operations	3	1	0	4	CHE 2203	Mass Transfer – I	2	1	0	3		
	CHE 2104	Chemical Engineering Thermodynamics – I	2	1	0	3	CHM 2201	Physical Chemistry	3	0	0	3		
	CHM 2101	Organic Chemistry	3	0	0	3	*** **	Open Elective – I	3	0	0	3		
	CHE 2111	Chemical Engineering Drawing	0	0	3	1	CHE 2211	Momentum Transfer and Mechanical Operations Lab	0	1	3	2		
	CHM 2111	Organic Chemistry Lab	0	0	3	1	CHM 2211	Physical Chemistry Lab	0	0	3	1		
		16	5	6	23			15	5	6	22			
III	FIFTH SEMESTER							SIXTH SEMESTER						
	CHE 3101	Mass Transfer – II	2	1	0	3	HUM 4001	Essentials of Management	2	1	0	3		
	CHE 3102	Chemical Reaction Engineering – I	2	1	0	3	CHE 3202	Chemical Reaction Engineering – II	2	1	0	3		
	CHE 3103	Transport Phenomena	2	1	0	3	CHE 3203	Process Dynamics and Control	3	1	0	4		
	CHE 3104	Chemical Process Industries	4	0	0	4	*** **	Program Elective – II	3	0	0	3		
	CHE 3105	Computational Methods in Chemical Engineering	3	1	0	4	*** **	Program Elective – III	3	0	0	3		
	*** **	Program Elective – I	3	0	0	3	*** **	Open Elective – II	3	0	0	3		
	CHE 3111	Heat Transfer Lab	0	1	3	2	CHE 3211	Mass Transfer Lab	0	1	3	2		
		16	5	3	22	CHE 3212	Computational Methods in Chemical Engineering Lab	0	0	3	1			
								16	4	6	22			
IV	SEVENTH SEMESTER							EIGHTH SEMESTER						
	HUM 4002	Engineering Economics and Financial Management	2	1	0	3	CHE 4297	Seminar				1		
	CHE 4101	Process Modeling and Simulation	3	1	0	4	CHE 4298	Industrial Training				1		
	CHE 4102	Design and Drawing of Chemical Equipments	3	1	0	4	CHE4299	Project Work/Practice School				12		
	*** **	Program Elective – IV	3	0	0	3								
	*** **	Program Elective – V	3	0	0	3								
	*** **	Program Elective – VI	3	0	0	3								
	CHE 4111	Process Modeling and Simulation Lab	0	0	3	1								
CHE 4112	Reaction Engineering and Process Control Lab	0	1	3	2									
		17	4	6	23						14			

Minor Specializations

I. Environmental Biotechnology

1. BIO 4001:Bioremediation
2. BIO 4002:Design of Biological Treatment Processes
3. BIO 4003:Microbial Treatment of Wastewater
4. BIO 4004:Solid Waste Management

II. Petroleum Engineering

1. CHE 4001:Natural Gas Engineering
2. CHE 4002:Oil and Gas Reservoir Engineering
3. CHE 4003:Petrochemicals
4. CHE 4004:Petroleum Refinery Engineering

III. Pollution Control Engineering

1. CHE 4005:Environmental Impact Assessment and Management Plan
2. CHE 4006:Industrial Waste Water Engineering
3. CHE 4007:Pollution Control Engineering
4. CHE 4008:Solid Waste Engineering and Management

IV. Business Management

1. HUM 4011:Financial Management
2. HUM 4012:Human Resource Management
3. HUM 4013:Marketing Management
4. HUM 4014:Operations and Systems Management

Other Programme Electives

1. CHE 4009:Advanced Bio Chemical Engineering
2. CHE 4010: Advanced Chemical Reaction Engg.
3. CHE 4011:Advanced Process Control
4. CHE 4012:Advanced Separation Processes
5. CHE 4013:Advanced Thermodynamics
6. CHE 4014:Air Pollution Control & Equipment Design
7. CHE 4015:Bio Energy Engineering
8. CHE 4016:Energy Engineering
9. CHE 4017:Applied Interfacial Engineering
10. CHE 4018:Introduction to Bio Chemical Engineering
11. CHE 4019:Membrane Science & Technology
12. CHE 4020:Optimization of Chemical Processes
13. CHE 4021:Pinch Technology
14. CHE 4022:Process Instrumentation
15. CHE 4023:Project Engineering
16. CHE 4024:Risk & Safety Management in Process Industries
17. CHE 4025: Upstream and Downstream Bioprocessing
18. CHM 4001:Analytical Techniques and Instrumentation
19. CHM 4002:Catalysis and Colloidal Systems

Open Electives

1. CHE 3281:Introduction to Chemical Engineering
2. CHE 3282: Industrial Pollution Control

THIRD SEMESTER

MAT 2103: ENGINEERING MATHEMATICS – III [2 1 0 3]

Fourier Series, Half range expansions, Harmonic analysis. Fourier integrals & transforms, Parseval's identity. **Complex Variable**: Functions of complex variable. Analytic function, 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, Line, surface and volume integrals. Green's theorem, divergence and Stokes' theorem. **Partial Differential Equations**: one dimensional wave equation and one dimensional heat equation, their solutions.

References:

1. Erwin Kreyszig, *Advanced Engineering Mathematics*, (5e), Wiley Eastern, 1985
2. Murray R. Spiegel, *Vector Analysis*, Schaum Publishing Co., 1959
3. B.S. Grewal, *Higher Engg. Mathematics*, Khanna Publishers, 1989
4. Ramana B V, *Engineering Mathematics*, Tata McGraw Hill.

CHE 2101: CHEMICAL PROCESS CALCULATIONS [3 1 0 4]

Chemical engineering as a Profession – Role of Chemical Engineer – Unit operations and unit processes – Units and dimensions – Physical and chemical properties of compounds and mixtures – Techniques of problem solving – Choice of basis – Chemical equations and stoichiometry – Properties of gases – Ideal and real gases – Phase equilibrium – Vapor pressure – Raoult's law – Calculation of bubble point and dew point – Humidity and Saturation – Humidity charts and their use – Concepts of steady and unsteady state processes and material balance equations – Material balances involving unit operations and unit processes – Material balance with recycle, bypass and purge – Energy and energy balances – Balances on non-reactive and reactive systems – Heat of reaction, heat of formation and heat of combustion – Standard state – Calculation of heat of reaction at temperature different from standard state – Adiabatic reaction temperature and theoretical flame temperature.

References:

1. A. Hougen, K.M. Watson, R.A. Ragatz, *Chemical Process Principles, Part – I*, John Wiley and Asia Publishing Co., 1970.
2. Bhat B.I., S.M. Vora, *Stoichiometry (2e)*, Tata McGraw-Hill, NY, 1976
3. David M. Himmelblau, *Basic Principles and Calculations in Chemical Engineering*, (6e), Prentice Hall of India (P) Ltd., 2009.
4. Richard Felder and Ronald W. Rousseau, *Elementary Principles of Chemical Processes*, (2e), John Wiley and Sons, 2004.

5. Morton M. Denn, *Chemical Engineering- an Introduction*, Cambridge University Press, NY, 2012.

CHE 2102: MOMENTUM TRANSFER [3 1 0 4]

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 – Laminar flow – Steady incompressible viscous flow through circular pipes – Hagen-Poiseuille equation – Flow between parallel plates – Flow through annuli – 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 through 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 – Flow measurement – Venturi, Orifice and Pitot-tube – Variable area meter – Flow measurement in open channels – Introduction to unsteady flow – Time required for emptying tank – Fluid transportation machinery – Pumps and classification of pumps – Pump characteristics

References:

1. McCabe and Smith, *Unit Operations in Chemical Engineering*, (5e), McGraw-Hill, NY, 1993.
2. Coulson and Richardson, *Chemical Engineering –Vol I*, (3e), Pergamon and ELBS, 1977.
3. Foust et al, *Principles of Unit Operations*, (2e), John Wiley and Sons, NY, 1980.
4. Badger and Banchero, *Introduction to Chemical Engineering*, McGraw-Hill, NY, 1990.

CHE 2103: MECHANICAL OPERATIONS [3 1 0 4]

Particle size analysis – Representation of size analysis – Shape factor – sieve methods of analysis – Surface area determination – Number of particle in the sample mixture – Industrial screening – Screening equipment – Efficiency of screen and performance of screen – Storage of solids – Types of conveyers – Selection of conveyer – Size reduction – Energy relationships – Size reduction equipment – Crushers, grinders, ultrafine grinders and cutting machines – Open circuit and closed circuit grinding – Classifiers – Types of classifiers – Gravity settling – Centrifugal separation – Cyclone separator - Principles – Design of centrifuge- Tubular bowl centrifuge- disc-stack centrifuge- Electrostatic precipitator – Filtration – Filtration equipment – Selection, design and operation of filters – Filter aids – Thickening – Batch and continuous thickener – Design of continuous thickener – Magnetic separation – Separation based on motion of particles

through fluids – Jigging – Dense media separation – Agitation and mixing of liquids- Flow patterns in Agitated vessel – Mixing of powders and plastic masses

References:

1. McCabe and Smith, *Unit Operations in Chemical Engineering*, (5e), McGraw-Hill, NY,1993
2. Foust et al, *Principles of Unit Operations*, (2e),John Wiley and Sons, NY,1980
3. Badger and Banchero, *Introduction to Chemical Engineering*, McGraw-Hill, NY, 1990
4. Coulson and Richardson, *Chemical Engineering –Vol II*, (3e),Pargamon and ELBS, 1970

CHE 2104: CHEMICAL ENGINEERING THERMODYNAMICS – I [2 1 0 3]

Basic concepts and definition: Classical and Statistical thermodynamics, system, boundary, surroundings, internal energy, work, heat, equilibrium, reversible process, intensive and extensive function, ideal gas temperature scale.

First law of thermodynamics for non-flow process, flow process, State and path function, Enthalpy, Heat capacity

PVT behavior of gases: Ideal gas, definition, ideal gas law, equation of state for real gases, graphical representation of P-V-T behavior, V-T diagram, P-V diagram and P-T diagram, Thermodynamic analysis of processes. Generalized correlations for thermodynamic property of gases, reduced equation of state, two parameter and three parameter correlations

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.

Applications of laws of thermodynamics:

Refrigeration, choice of refrigerant, Carnot cycle, vapour compression cycle, air refrigeration, Heat pumps, Liquefaction processes, free expansion, isotropic expansion, Steam power plant, Rankine cycle, Reheat and regenerative cycles. Internal combustion engines.

References:

1. K.V. Narayanan, *A Text Book 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, *An Introduction Thermodynamics*, Universities Press, 2004

CHM 2101: ORGANIC CHEMISTRY [3 0 0 3]

Stereochemistry: Constitutional, geometrical and optical isomerisms, Determination of specific rotation, RS configuration, Enantiomers, Diastereomers, Meso compounds.

Reaction intermediates: Structure, stability and reactions of free radicals, carbocations, carbanions & carbenes, Transient techniques.

Strengths of organic acids and bases: Monobasic, dibasic, aliphatic & aromatic acids, Effect of structure on acidity, Hydrogen bond, Steric inhibition to resonance, Effects of solvents, Aliphatic & aromatic bases.

Aromatic & heterocyclic compounds: Structure of benzene, Mechanism of electrophilic substitution reactions of benzene, Effect of substituents, Classification of heterocyclic compounds, Reactions.

Carbohydrates: Classification, Reactions, Monosaccharides, Physical & chemical properties, Disaccharides & polysaccharides - sources, structure & properties.

Amino acids & proteins: Classification, Synthesis, Physical & chemical properties, Peptides, Proteins, Enzymes – classification, synthesis, reactions, comparison & applications in industry.

Dyes: Valence bond & molecular orbital approach to color, Bathochromic and Hypsochromic shifts, Classification schemes, applications & structures, Azodyes, Anthraquinone dyes, Fluorescent brightening agents.

Industrial processes: Pharmaceutical processes, - Alkylation, Condensation & cyclization, Oxidation, Perfume & Flavor chemistry, Condensation, Esterification, Hydrogenation, Nitration & Grignard processes.

References:

1. I.L. Finar, *Organic Chemistry, Vol I, (6e)*, Pearson Education, Singapore, 2009
2. R.T. Morrison, R.N. Boyd, *Organic Chemistry, (6e)*, Prentice – Hall, New Delhi, 2007
3. P.Y. Bruice, *Organic Chemistry, (3e)*, Dorling Kindersley, New Delhi, 2009
4. G.T. Austin, *Shreve's Chemical Process Industries, (5e)*, McGraw-Hill, Singapore, 1986

CHE 2111: CHEMICAL ENGINEERING DRAWING [0 0 3 1]

Introduction to AutoCAD, Basic drawing and editing commands, making changes in drawings, organizing drawing with layers, adding dimensions and text to drawings, advanced editing in AutoCAD, hatching.

Assembly drawing of some of the following:

Valves: Globe valve, Ball valve, Non-rising stem gate valve, Three-way stop valve, Needle valve, Gate valve, Diaphragm valve

Pumps: Centrifugal, Rotary, Vane and Gear pumps

Steam traps: Bucket type, Inverted bucket type and Thermodynamic steam traps

Joints: Cotter and Pin joint, Cotter joint with sleeve, Socket and Spigot cotter joint, Strap joint with Gib and Cotter

Pipe joints: Flanged pipe joint, Hydraulic pipe joint, Gland and Stuffing box, Expansion joint, Union joint

References:

1. Millan Alan R. *ABC of AutoCAD*, Tech Publications.
2. McCarthy Tim, *AutoCAD express*, Narosa Publications.
3. VenugopalK, *Engineering Drawing and Graphics with AutoCAD*, Newage Publications
4. N D Bhatt, V M Panchal, *Machine Drawing, (49e)*, Charotar Publishing House Pvt. Ltd., 2014
5. Gopal Krishna, *Machine Drawing*

CHM 2111: ORGANIC CHEMISTRY LAB [0 0 3 1]

1. Preparation of m-dinitrobenzene from nitrobenzene by nitrogen and organic qualitative analysis-I
2. Preparation of acetanilide from aniline by acetylation and organic qualitative analysis-II
3. Preparation of p-bromo acetanilide from acetanilide by bromination and organic qualitative analysis-III
4. Preparation of benzoic acid from benzaldehyde by oxidation and organic qualitative analysis-IV
5. Preparation of salicylic acid from methyl salicylate by hydrolysis and organic qualitative analysis-V
6. Determination of the % purity of phenol by Winkler's method
7. Determination of the amount of acetone by iodoform method
8. Determination of the % purity of acetic acid by titration method
9. Determination of the amount of acetamide by alkali hydrolysis method
10. Determination of acid value, iodine value and saponification value of the given sample of oil

References:

1. III Semester Chemical lab Manual, Chemistry Department, MIT, Manipal,
2. V. Venkateshwaran, R. Veeraswamy, A.R. Kulandaivelu, *Basic Principles of Practical Chemistry*, 1stEdn., Sultan Chand and Sons, 1993.
3. K.K. Sharma, D.S. Sharma, *An Introduction to Practical Chemistry*, Vikas Publishing House, 1996.

FOURTHSEMESTER

MAT 2202: ENGINEERING MATHEMATICS – IV [2 1 0 3]

Optimization Techniques: formation of LPP, Solution by 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, curve fitting. **Probability distributions:** Binomial, Poisson, uniform, normal, gamma, Chi-square and exponential. **Numerical methods-** Solution of BVP's in ODE. Numerical solutions of two dimensional Laplace, Poisson equations, one dimensional heat and wave equations by explicit methods. Crank-Nicolson method. Finite element method, Introduction, simple applications **Z transform:** properties of z transforms, initial and final value theorems, solution of difference equations by the method of z transforms, convolution theorem.

References:

1. Kreyzig E, *Advanced Engineering Mathematics*, (7e), Wiley Eastern.
2. Meyer P. L. *Introduction to probability and Statistical applications*, (2e), American Publishing Co.
3. Hamdy A Taha - *Operation research*, (7e), PHI
4. Grewal B.S - *Higher Engineering Mathematics*, Khanna Publishers.
5. Sastry S.S - *Introductory methods for Numerical Analysis*, (2e), Prentice Hall

CHE 2201: CHEMICAL ENGINEERING THERMODYNAMICS – II [2 1 0 3]

Thermodynamic properties of pure substances: fugacity, fugacity coefficient, compressibility factor, activity.

Solution thermodynamics: Ideal and non-ideal gas mixtures and liquid solutions, partial molar properties, physical significance and determination methods, chemical potential.

Gibbs-Duhem equation: general form, various forms of Gibbs-Duhem equation, applications, limitations; Property changes of mixing, excess properties. Criteria of phase equilibrium, Duhemtheorem. Vapour liquid equilibrium, VLE equation, low pressure VLE, Phase diagrams for binary solution, T-x-y and P-x-y diagrams. Effect of pressure on VLE. Azeotropes and its types.

Activity coefficient; equations used for the determination, Margules, van Laar, Wilson equations, VLE at high pressures, bubble point, dew point calculations, Thermodynamic consistency tests for VLE data.

Chemical reaction equilibrium; 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 van't Hoff constant, Effect of parameters like temperature, pressure, composition on the equilibrium conversion.

References:

1. K.V. Narayanan, *A Text Book 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 2202: HEAT TRANSFER OPERATIONS [3 1 0 4]

Introduction to Modes of heat transfer and its applications

Conduction - Steady state Heat conduction – Development of equations for conduction through plane and curved surfaces like spheres, cylinders etc.– Compound resistances – Critical thickness of insulation – Heat transfer with internal heat generation – Introduction to transient heat conduction-Introduction to Multidimensional heat conduction

Convection – Forced and Natural convection –Individual and Overall heat transfer Coefficient-Determination of Individual heat transfer coefficients for different systems – Analogies between transfer of heat and momentum- Principles of design of heat exchangers – Co-current and counter-current flow –Dirt factors – LMTD- Enthalpy balances in an exchanger -Effectiveness of heat exchanger.

Extended surfaces – Types of fins – Heat transfer in rectangular and pin fins – Fin effectiveness – Fin efficiency-Heat transfer to fluids with phase change – Heat transfer to boiling liquids – Types of condensation

Introduction to radiation heat transfer – Kirchhoff's law- Stefan Boltzmann–View factors – Net radiation between two large parallel planes – Radiation with shields – Temperature measurement of gases and radiation errors

Evaporation – Types of Evaporation equipment – Mass & Energy balances – Calculations for single effect and multi-effect systems – Performance of Evaporators, Design calculations – Vapor Recompression

Crystallization –Types, Equilibria and yield – super saturation–Mier's theory – Nucleation and crystal growth – Delta L law – Material and Energy balances – Swenson-Walker crystallizer – Calculations

References:

1. McCabe and Smith, *Unit Operations in Chemical Engineering*, (5e), McGraw-Hill, NY,1993
2. J.P.Holman, *Heat transfer*,McGraw-hill, 1976.
3. Badger and Banchero, *Introduction to Chemical Engineering*, McGraw-Hill, NY, 2010
4. Coulson and Richardson, *Chemical Engineering –Vol I*, (3e), Pergamon and ELBS, 1970
5. Donald Q. Kern, *Process Heat Transfer*, McGraw-Hill, 1950

CHE 2203: MASS TRANSFER – I [2 1 0 3]

Diffusion: Introduction to mass transfer operations- molecular diffusion in gases and liquids-steady state diffusion under stagnant and laminar flow conditions–diffusion in multi component mixtures–Diffusion in solids–molecular and Knudsen diffusion in porous solids–unsteady state diffusion in solids.

Interphase Mass Transfer and Mass Transfer coefficient: Theories of interphase mass transfer- estimation of mass transfer coefficient - Individual and overall mass transfer coefficients for gas-liquid and liquid-liquid operations–Material balance approach for steady state mass transfer processes–concept of equilibrium curve and operating line–stages and Murphree stage efficiency.

Absorption: Gas Absorption—calculation of number of theoretical stages for Absorption and stripping column (Graphical)—estimation of number of plates by Kremser equation—Packed tower absorber – HETP—HTU and NTU calculations – Design of absorption column—Equipment for gas-liquid operations.

Adsorption: Adsorption—adsorption isotherm—batch and continuous stage wise adsorption operation—unsteady state fixed bed adsorbers—break through curves - process design of adsorption column- Adsorption equipment.

Humidification and Dehumidification: Vapor gas mixtures terminology – Psychometric chart – Water cooling operations—Gas-Liquid contact operations—Adiabatic operations—Types of Equipment – Design calculations – Cooling towers –design of cooling towers—Recirculating Liquid-gas humidification cooling

References:

1. R.E. Treybol, *Mass Transfer Operations*, (2e), McGraw Hill, 1981.
2. Foust, A.S., Wenzel, L.A., Clump, C.W., Naus, L., and Anderson, L.B., *Principles of Unit operations*, (2e), Wiley, 1980.
3. McCabe and Smith, *Unit Operations in Chemical Engineering*, (5e), McGraw-Hill, NY, 1993
4. Hill G B, *Cooling towers principles and practice*, BH, London, 1990

CHM 2201: PHYSICAL CHEMISTRY [3 0 0 3]

Solution chemistry: Expressing concentrations, Vapor pressure of a liquid, Raoult's law, Ideal and non-ideal solutions, Azeotrope, Distillation of miscible liquids, Partially miscible liquid-liquid equilibrium, Thermodynamics of mixture, Henry's law, Relationship between Henry's & Raoult's law, Numerical problems.

Colligative properties: Introduction, Determination of molar masses. Experimental measurement of vapour pressure lowering, osmotic pressure, boiling point elevation & depression of freezing point, Abnormal colligative properties- Vant Hoff's factor, Degree of association & dissociation, Numerical problems.

Phase equilibria: Gibb's phase rule, Derivation of phase rule, Single component systems, Reduced phase rule, Two-component system, Formation of compounds with congruent melting point, Formation of compounds with incongruent melting point.

Adsorption phenomena: Adsorption of gases on solids, Factors affecting adsorption, Different types of adsorption isotherms, Freundlich's & Langmuir's theory, BET theory of multilayer adsorption, Adsorption from solutions.

Electroanalytical methods: Principle and types of conductometric titrations, Potentiometric titrations, Advantages and limitations, Cyclic voltammetry.

References:

1. P. Atkins, J. de Paula, *Physical Chemistry*, (7e), Oxford Publication, New York, 2002.
2. D. A. Skoog, D. M. West, F. J. Holler, S. R. Gouch, *Fundamentals of Analytical Chemistry*, (8e), Thomson Brooks, Singapore, 2004.

CHE 2211: MOMENTUM TRANSFER AND MECHANICAL OPERATIONS LAB

[0 1 3 2]

The experiments involve:

Reynolds Experiment – Calibration of flow meters, flow through circular pipe, annulus, v-notch, packed bed and fluidized bed – Centrifugal pump characteristics – Screen effectiveness, verification of laws of size reduction, particle size analysis, filtration, sedimentation.

CHM 2211: PHYSICAL CHEMISTRY LAB [0 0 3 1]

1. Titration of a given mixture of weak and strong acids against a strong base by conductometric method
2. Precipitation titration between lithium sulphate and barium chloride by conductometric method
3. Redox titration of Mohr's salt against $K_2Cr_2O_7$ by potentiometric method
4. Colorimetric determination of Copper
5. Percentage composition of binary mixture using viscometer
6. Bimolecular reaction between $K_2S_2O_8$ and KI
7. Determination of velocity constant for the saponification of ethyl acetate
8. Determination of surface tension of a liquid using stalagmometer
9. Kinetics of inversion of sucrose using polarimeter
10. Determination of percentage composition of binary mixture using Abbe's refractometer

References:

1. IV Semester Chemical lab Manual, Chemistry Department, MIT, Manipal,
2. V. Venkateshwaran, R. Veeraswamy, A.R. Kulandaivelu, *Basic Principles of Practical Chemistry, (1e)*, Sultan Chand and Sons, 1993.
3. K.K. Sharma, D.S. Sharma, *An Introduction to Practical Chemistry*, Vikas Publishing House, 1996.

FIFTH SEMESTER

CHE 3101: MASS TRANSFER – II [2 1 0 3]

Distillation: vapour liquid equilibrium concept - Raoult's law - deviations from ideal law - concept of azeotropic and types – steam distillation – Enthalpy concentration diagrams – binary and multi component systems – dew and bubble point calculations – flash vaporization – simple distillation-binary component distillation - continuous rectification – methods for identifying the theoretical trays: 1) PonchanSavarit method: minimum reflux ratio, optimum reflux ratio- total reflux ratio, partial condenser, total condenser, 2) McCabe – Thiele method: concept of q line, optimum reflux ratio- total reflux ratio, partial condenser, total condenser. Multi component distillation: azeotropic, extractive, molecular distillation.

Liquid-Liquid Extraction: liquid-Liquid-Equilibria- Ternary systems – triangular and rectangular coordinates-choice of solvent-single stage and multi stage cross current, equipment's such as mixer settler, packed and tray towers.

Leaching: Concept of Leaching, effect of temperature and size of feed on leaching, Batch leaching processes.

Drying – Theory, Types and mechanism of drying operation – Hysteresis – Rate curves – Batch and continuous drying–Direct and indirect drying – Through circulation drying – Industrial dryers – Design criteria – Design of rotary dryers

Recent advances in mass transfer operations: Introduction to membrane process- advantages-disadvantages- types membranes – preparation of membrane-pore measuring techniques

References:

1. R.E. Treybal, *Mass Transfer operation*, McGraw-Hil, 1968
2. McCabe and Smith, *Unit Operations of Chemical Engineering*, (5e), McGraw-Hill 1993
3. Coulson-Richardson, *Chemical Engineering –Vol-II*, Paragmon and ELBS, 1970
4. Kausik Nath, *Membrane separation process*

CHE 3102: CHEMICAL REACTION ENGINEERING – I [2 1 0 3]

Kinetics of homogeneous chemical reactions – Rate expressions – Temperature dependence of rate –Differential, integral, half-life and total pressure method –theories, Elementary and Non elementary reaction kinetics - Pseudo, steady state hypothesis – mechanism.

Isothermal reactor design – Design of batch, semi-batch, CSTR's and PFR's – Problems on optimization, Multiple reactor systems – Reactors in series or/and parallel combinations – CSTRs series – Performance analysis –Batch, Semi-Batch, Continuous and Recycle reactors.

Multiple reaction system – Series and parallel reactions in flow reactors - Product distribution – Yield and selectivity – Maximizing the desired product in parallel reactions – Different reactors and schemes for minimizing the unwanted product – Maximizing the desired product in series reactions.

Enzymatic reaction fundamentals – Michaelisand Menten Equation – Batch reactor calculations – Inhibition of enzyme reactions – Multiple enzyme and substrate systems, Design and analysis of biological reactors – Cell growth – Batch bioreactor – Chemostat system – Oxygen limited fermentation – Scaleup.

References:

1. Scott Fogler H, *Elements of Chemical Reaction Engineering*, (4e), PHI, 2005.
2. Octave Levenspiel, *Chemical Reaction Engineering*, (3e), Wiley & Sons, 2003.
3. Rawlings J.B, Ekerd, J.G., *Chemical Reactor Analysis and Design Fundamentals* Nole Hill 2002.
4. Smith J.M, *Chemical Engineering Kinetics*, (3e), McGrawl-Hill, International student edition.

CHE 3103: TRANSPORT PHENOMENA [2 1 0 3]

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- uni-dimensional 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

Velocity, temperature, concentration distribution with more than one independent variable, Velocity and temperature distribution in turbulent flow; Boundary layer concept of momentum and energy transport

References:

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

CHE 3104: CHEMICAL PROCESS INDUSTRIES [4 0 0 4]

Indian industry – A brief review - Detailed description of the processes along with neat flow diagrams, engineering problems that are encountered frequently during the process and major uses and application are to be discussed for the following.

Industrial gases: Carbon dioxide – Hydrogen – Oxygen – Nitrogen – Synthesis gas

Chloroalkali industry: Common salt – Caustic soda – Chlorine – Hydrochloric acid – Bleaching powder – Soda ash

Sulfur and sulfuric acid: Extraction of sulfur – Production of sulfuric acid from sulfur and other sources – Recent advances

Fertiliser industry: Ammonia – Nitric acid – Ammonium nitrate – Ammonium sulfate – Ammonium chloride – Urea

Phosphate industry: Elemental Phosphorous – Phosphoric acid – Superphosphates – NPK fertilizers

Oils, fats and waxes: Edible oils – Extraction of vegetable oil – Hydrogenation of oil – Soaps and detergents – Manufacturing processes – Glycerin recovery

Pulp and paper: Chemical and mechanical pulp – Pulping methods – Chemical recovery of black liquor – Paper and paper board

Sugar and starch: Sugar – Starch and modified starches – Glucose – Fermentation – Media for growth - Industrial alcohol – Absolute alcohol – Acetone and Butanol

Polymerisation: Classification of polymers – Modes of polymerization – Polyvinyl chloride – Polyethylene – Viscose rayon , Nylon 6 and Nylon 66 – Natural and synthetic rubber

References:

1. Faith Keyes, et.al, *Industrial Chemicals*, (4e), Wiley Interscience, 1975.
2. Charles E Dryden, *Outlines of Chemical Technology*, (2e), East Press Ltd., 1975.
3. CHEM TECH – Vol 1 – 4, Chemical Engineering Education Development Centre, IIT, Madras, 1975 –78.
4. Austin G.T., *Shreve's Chemical Process Industries*, (5e), McGraw-Hill, 1986.

CHE 3105: COMPUTATIONAL METHODS IN CHEMICAL ENGINEERING [3 1 0 4]

Introduction to numerical computing, approximation and errors in computing

Numerical Solution to non-linear, transcendental and polynomial equations –Bisection method, False position method, Secant method, Wegstien method, Newton-Raphson method, Bairstow's method

Numerical solution to Linear Algebraic Equations- Gauss elimination, Gauss-Jordan, Crout'sreduction; Iterative methods- Gauss-Seidal, Relaxation method, Eigen Value problems – power method, Jacob's method

Interpolation with equal interval –Newton forward formula; Gauss's forward and backward interpolation, Interpolation with unequal intervals- Lagrangian polynomials, divided difference.

Numerical Integration and differentiation – Derivatives using Newton's forward and backward interpolation formulae, Composite Trapezoidal, Romberg Integration.

Ordinary differential equations (ODE)- Initial value problem, Euler and Modified Euler method, Runge-Kutta methods, Predictor-Corrector methods, boundary value problems

Partial differential equation (PDE)- Shooting method, Finite difference method, solution to Elliptic, Parabolic and hyperbolic equations; Crank-Nicholson method; Bender Schmidt method

(Problems from Chemical engg subjects like Process Calculation, Momentum Transfer, Heat Transfer and Mass Transfer-I should be solved using the above numerical techniques wherever possible.)

References:

1. MichealCutlip, MordechaiShacham, *Problem Solving in chemical and Biochemical Engineering with POLYMATH, EXCEL and MATLAB*,(2e), Prentice Hall, 2008
2. AlkisConstantinides, NavidMostoufi,*Numerical methods for chemical engineers with MATLAB Applications*, Prentice Hall,2000
3. E. Balagurusamy,*Numerical Methods*, Tata McGraw Hill Publishing Company Ltd.,1997

CHE 3111: HEAT TRANSFER LAB [0 1 3 2]

Experiments based on conduction, convection and radiation – Different types of heat exchangers and condensers – Estimation of thermal conductivity, thermal diffusivity, and emissivity.

SIXTH SEMESTER

HUM 4001: ESSENTIALS OF MANAGEMENT [2 1 0 3]

Definition of management and systems approach, Nature & scope, The functions of managers, Corporate social responsibility. Planning: Types of plans, Steps in planning, Process of MBO, How to set objectives, Strategies, Policies & planning premises, Strategic planning process and tools. Nature & purpose of organising, Span of management, factors determining the span, Basic departmentalization, Line & staff concepts, Functional authority, Art of delegation, Decentralisation of authority. HR planning, Recruitment, Development and training. Theories of motivation, Special motivational techniques. Leadership - leadership behaviour & styles, Managerial grid. Basic Control Process, Critical Control Points & Standards, Budgets, Non-budgetary control devices. Profit & loss control, Control through ROI, Direct, Preventive control. Managerial practices in Japan & USA & application of Theory Z. The nature & purpose of international business & multinational corporations, unified global theory of management. Entrepreneurial traits, Creativity, Innovation management, Market analysis, Business plan concepts, Development of financial projections

References:

1. Koontz D. *Essentials of Management* Mc Graw Hill, New York, 2004
2. Peter Drucker *Management, Task and Responsibility* Allied Publishers, 2006
3. Peter Drucker *The practice of management* Butterworth Hein Mann, 2003

CHE 3202: CHEMICAL REACTION ENGINEERING – II [2 1 0 3]

Isothermal non-ideal flow reactors – RTD in chemical reactors –distribution functions– Conversion in non-ideal flow reactors – Single and multi-parameter models for non-ideal flow – Concepts of mixing –Micro and macro mixing.

Non isothermal homogeneous reactions – Temperature effects – Principles of stability – Design procedures for adiabatic and non-isothermal conditions for batch semi-batch and flow reactors – Optimum temperature progression – Multiple reactions and effect of temperature on product distribution.

Heterogeneous reactions – Rate equation for heterogeneous systems – Contacting patterns for two phase systems – Fluid particle non-catalytic reactions – Different models – Derivation of rate equations – Application to design – Fluid-fluid non- catalytic reactions – Overall expression – Kinetic regimes – Rate equations - Application to design of towers for slow reactions - Mixer settlers – Slurry reaction kinetics – Reactive distillation and extractive reactions. Introduction to slurry and trickle bed reactors – Fluidized bed Reactors – Design.

Heterogeneous catalysis – Types and classification of catalysts – Desirable characteristics and the method of determination – Selection and preparation of catalysts for industrial reactions – Kinetics of heterogeneous solid catalysed gas reactions - Mechanisms – Derivation of mathematical models based on different mechanism - Rate controlling step – Analysis of external transport processes – Intrapellet mass transfer– Effectiveness factors

References:

1. Scott Fogler H, *Elements of Chemical Reaction Engineering, (4e)*, PHI, 2005
2. Octave Levenspiel, *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

CHE 3203: PROCESS DYNAMICS AND CONTROL [3 1 0 4]

Introduction –Laplace transforms-- Process models – Degrees of freedom analysis– Control degrees of freedom – Linearization –Process dynamics – Processes with complex dynamics – Time delay and Inverse response – Control Valve characteristics – Elements of feed-back control system – Block diagram algebra – Transient response – Stability – Routh criterion – Root locus diagram – Frequency response analysis – Bode and Nyquist plots – Design of feed-back controllers – Introduction to advanced process control

References:

1. Stephanopoulos G, *Chemical Process Control – An Introduction to Theory and Practice*, Prentice Hall of India, New Delhi, 2008
2. Donald R Coughanowr, *Process Systems Analysis and Control, (3e)*, McGraw-Hill, 2009
3. Carlos A Smith, Armando B Corripio, *Principles and Practice of Automatic Process Control*, John Wiley, 2006
4. Jairath A K, *Problems and solutions of Control Systems*, CBS Publishers, 2004

CHE 3211: MASS TRANSFER LAB [0 1 3 2]

Applicability of Rayleigh's equation for 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 in a three stage cross flow cascade operation – studies in simple and cross flow leaching – experimental determination of liquid-liquid equilibrium data – drying of solids in fluidized bed dryer – extraction of solute in packed bed column – crystallization process in an batch crystallizer – tray efficiency of bubble cap distillation column – VLE data.

CHE 3212 COMPUTATIONAL METHODS IN CHEMICAL ENGINEERING LAB

[0 0 3 1]

Chemical engineering problems related to Process Calculations, Momentum Transfer, Heat Transfer and Mass Transfer-I will be solved using numerical concepts discussed in Computational Methods in Chemical Engineering coursework with the help of computer software such as MAT LAB, POLYMATH, and EXCEL

SEVENTH SEMESTER

HUM 4002: ENGINEERING ECONOMICS AND FINANCIAL MANAGEMENT [2 1 0 3]

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, Break even 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, Costing and its types – Job costing and Process costing, 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. Blank Leland T. Tarquin Anthony J (2002), “*Engineering Economy*”, McGraw Hill, New Delhi.
2. Chan S. Park (2010), “*Contemporary Engineering Economics*”, Pearson Education, Inc
3. Raman B.S (1993), “*Advanced accountancy*”, United publications, Bangalore
4. T. Ramachandran (2001), “*Accounting and Financial Management*”, Scitech Publications Pvt. Ltd. India.
5. Thuesen G. J & Thuesen H. G (2005), “*Engineering Economics*”, Prentice Hall of India, New Delhi

CHE 4101: PROCESS MODELING AND SIMULATION [3 1 0 4]

Introduction- Models and model building, principles of model formulation , precautions in model building, fundamental laws- continuity equation, energy equation, equation of motion, transport equations equation of state, equilibrium kinetics, classification of models.

Numerical solutions of mathematical equations –Algebraic equation in one and two variables; simultaneous linear equations; ordinary differential equation in one variables and more than one variable, stiff differential equations.

Lumped parameter Models- steady and unsteady state- Formulation and solution techniques to be discussed for vapor equilibrium models – multi-component dew point and flash calculations, boiling operation, batch and continuous distillation, tank model- tank with flow rate as function of level, mixing tank, stirred tank with heating jacket, CSTR- with multiple, series and parallel reaction, chlorination of benzene, autocatalytic reaction. Non- isothermal CSTR, Non-ideal CSTR- models with dead space and passing estimation of model parameter, methods of moments.

Distributed parameter models (steady state)- solution of split boundary value problems – shooting technique, quasi-linearization solution; counter –current heat exchanger, tubular reactor with axial dispersion, counter current gas absorber, pipe line gas flow, permeation process, pipe line flasher, spray tower humidifier, packed bed catalytic reactor.

Distributed parameter models (unsteady state, one dimension): solution to partial differential equations using finite difference method –convection problems, explicit and implicit centered difference methods; diffusive problems, Crank Nicolson finite difference scheme , combined convective and diffusive problems.- unsteady state conduction and diffusion ,heat exchanger, gas absorbers and dynamics of tubular reactor with dispersion.

Introduction to population balance models

References:

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

CHE 4102: DESIGN AND DRAWING OF CHEMICAL EQUIPMENTS [3 1 0 4]

Introduction to equipment design - piping design and economic pipe diameter, design information and data, equipment selection and specification

Design of Heat Transfer equipment's - heat exchangers, condensers. Design of Mass Transfer equipment's - distillation columns, absorption columns, extraction columns

Introduction to mechanical design - classification of vessels, design codes, general design considerations, design of cylindrical and spherical vessels under internal pressure, design of heads and closures, standard flanges, design of cylindrical and spherical vessels under external pressures, use of stiffeners, compensation for openings and pipes, design of vessels subjected to combined loading, design of tall vessels, design of storage vessels, design of mixing equipment, heat exchangers, high pressure vessels, design of vessel supports.

References:

1. Coulson and Richardson's, *Chemical Engineering design, Volume 6*, BH publishers.
2. D Q Kern, *Process heat transfer*, McGraw-Hill publishers.
3. Badger, Walter L Banchemo, Julius T, *Introduction to Chemical Engineering*, McGraw-Hill publishers.
4. Coulson and Richardson's, *Chemical Engineering design, Volume 6*, BH publishers.
5. *Indian Standard Code for unfired pressure vessel, BIS 2825-1969*
6. *Indian Standard Code for Heat Exchangers, BIS 4503-1967*
7. M V Joshi, V VMahajani, *Process Equipment Design*, MacMillan Publishers

CHE 4111: PROCESS MODELING AND SIMULATION LAB [0 0 3 1]

Experiments based on a) simulation of steady state – flash drum, reactors, distillation column, absorber and chemical plants b) Simulation of unsteady state operation of chemical plants.

CHE 4112: REACTION ENGINEERING AND PROCESS CONTROL LAB [0 1 3 2]

Experiments based on the following topics:

Kinetic studies under isothermal conditions using batch, semi-batch, PFR and CSTR - Concept of Recycle and kinetic studies on catalyzed liquid phase reaction employing varying recycle rates - RTD studies to determine the mixing pattern and non-ideal behaviour 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 – Valve characteristics of linear, equal percentage and quick opening valves – Studies on Proportional, Proportional-Integral, and Proportional-Integral-Derivative controllers – Control of systems with cascading and ratio effects

EIGHTH SEMESTER

CHE 4297: SEMINAR

- Each student has to present a seminar individually, on any technical topic of current interest / latest advancement / topics not covered in the syllabus.
- The topic has to be approved by the Department and a report of the same has to be submitted a week before the day of the presentation.

CHE 4298: INDUSTRIAL TRAINING

- Each student has to undergo industrial training for a minimum period of 4 weeks. This may be taken in a phased manner during the vacation starting from the end of third semester.

- Student has to submit to the department a training report in the prescribed format and also make a presentation of the same. The report should include the certificate issued by the industry.

CHE 4299: PROJECT WORK/PRACTICE SCHOOL

- The project work may be carried out in the institution/industry/research laboratory or any other competent institutions.
- The duration of the project work shall be a minimum of 16 weeks which may be extended up to 24 weeks.
- A mid-semester evaluation of the project work shall be done after about 8 weeks.
- An interim project report on the progress of the work shall be submitted to the department during the mid-semester evaluation.
- The final evaluation and viva-voce will be conducted after submission of the final project report in the prescribed form.
- Student has to make a presentation on the work carried out, before the department committee as part of project evaluation.

MINOR SPECIALIZATIONS

I. ENVIRONMENTAL BIOTECHNOLOGY

BIO 4001: BIOREMEDIATION [3 0 0 3]

Introduction, Advantages and Disadvantages of Bioremediation; Factors influencing Bioremediation; Microbial ecology and metabolism; Biodegradation of common contaminant compounds; Bioremediation processes; Biological Filtration Processes for Decontamination of Air Stream; Biotreatment of Metals; Phytoextraction; Rhizofiltration; Phytostabilization; Biomonitoring; Biomembrane Reactors; Successful and Unsuccessful Case Studies in Bioremediation Process

References:

1. Martin Alexander, *Biodegradation and Bioremediation*, Academic press, 1999
2. John. T. Cookson, Jr, *Bioremediation engineering; design and application*, McGraw Hill, Inc., 1995
3. Eweis, Ergas, Chang Schroeder, *Bioremediation Principles*, McGraw-Hill Series in Water Resources and Environmental Engineering, 1998

BIO 4002: DESIGN OF BIOLOGICAL TREATMENT PROCESSES [3 0 0 3]

Flow and Mass loading for treatment plants; Various Physical units operations equalization tank design, sedimentation tank design by solid flux and batch data, dissolved air flotation; Filtration mechanism in water treatment and design of filters, Chemical treatment and precipitation;

Activated sludge process and different types of active sludge processes; Mathematical model development for active sludge process, and design, Sequencing batch reactors (SBR), Plug flow aerobic treatment, Rotating Biological contactor and model, Trickling filters and roughing filters and various design parameters, Various pond processes, Disinfection-Mechanisms, Mathematical Models for disinfection, Breakpoint chlorination and calculations; Design considerations in anaerobic processes; Water reuse and reclamation technologies, Risk assessment.

References:

1. Metcalf and Eddy, *Wastewater Engineering - Treatment, Disposal and Reuse*, Tata McGraw Hill Publishing Co. Ltd, 1991
2. C.S.Rao, *Environmental Pollution Control Engineering*, New Age International (P) Ltd. Publishers, 1991
3. H.J. Jordening, and J.Winter, *Environmental Biotechnology: Concepts and Applications*, Wiley-VCH Verlag GmbH & Co, 2005

BIO 4003: MICROBIAL TREATMENT OF WASTEWATER [3 0 0 3]

Need for wastewater treatment; Characterization of wastewater- Biological- BOD, COD, TOC, MPN, Bacterial count, BOD kinetic parameter fitting by Least square, Fujimoto, Daily difference, Thomas and Moments-Methods; Physical characterization such as solids, Turbidity, and Chemical characterizations. Bacterial metabolism in treatment, Decomposition of organic compounds in Ecosystem, Biology, Mass energy balance for Aerobic respiration, and Anaerobic respiration, General considerations for Aerobic Vs. Anaerobic treatment, Kinetic aspects, Hydrolysis of cellulose-biological aspects, Anaerobic degradation of lignocellulose and cellulose, proteins, fats; Various types of anaerobic treatment reactors-UASB and its variations, calculation of biogas by Buswell equation, Nitrification and denitrification processes, and Anammox process, Biological Phosphorus removal processes.

References:

1. Metcalf and Eddy, *Wastewater Engineering - Treatment, Disposal and Reuse*, Tata McGraw Hill Publishing Co. Ltd, 1991
2. C.S.Rao, *Environmental Pollution Control Engineering*, New Age International (P) Ltd. Publishers, 1991
3. H.J. Jordening, and J.Winter, *Environmental Biotechnology: Concepts and Applications*, Wiley-VCH Verlag GmbH & Co, 2005

BIO 4004: SOLID WASTE MANAGEMENT [3 0 0 3]

Integrated solid waste management, operation of waste management systems. Legislative Trends and Impacts; Composition of municipal solid wastes, Properties of MSW; transformations of solid waste; Properties, classification and transformation of Hazardous wastes and its management; Collection of solid waste, Separation, processing and Transformation of solid

waste, Transfer and Transport, Disposal; Landfill methods & its design; Biological principles, aerobic composting, Anaerobic digestion, Biological transformation processes. Energy production from biological conversion products, Fermentation and compost processes: design parameters & Applications; Meeting federal and state mandated diversion goals; Recycling, Implementation of solid waste management options; planning, siting and permitting of waste management facilities.

References:

1. George Tchobanoglous, *Integrated solid waste management: Engineering principles and management issues*, McGraw Hill, 1993
2. William D Robinson, *The solid waste handbook: A practical guide*, John Willy & sons, 1986

II. PETROLEUM ENGINEERING

CHE 4001: NATURAL GAS ENGINEERING [3 0 0 3]

Determination of natural gas properties such as specific gravity, pseudo-critical properties, viscosity, compressibility factor, gas density, formation and expansion volume, and compressibility; Gas reservoir deliverability: analytical and empirical methods, construction of IPR curve, Well bore performance for both single and mist gas wells; Choke performance: Dry and wet gas flow in chokes; Well deliverability using nodal analysis; Natural gas processing: dehydration, gas treating, gas to liquids processing, compression and cooling; Natural gas transportation and measurement; advanced natural gas production engineering: Liquid loading, hydrate cleaning and pipeline cleaning.

References:

1. B Guo, A Ghalambor, *Natural Gas Engineering Handbook*, Gulf Publishing Company, 2005
2. D L Katz, R L Lee, *Natural Gas Engineering*, McGraw-Hill, 1990
3. B Guo, W C Lyons, A Ghalambor, *Petroleum Production Engineering: A Computer Assisted Approach*, Elsevier, 2007
4. T Ahmed, P D McKinney, *Advanced Reservoir Engineering*, Elsevier, 2005

CHE 4002: OIL AND GAS RESERVOIR ENGINEERING [3 0 0 3]

Basic concepts of reservoir engineering: Calculation of hydrocarbon volume, Fluid pressure regimes, Recovery factor, Hydrocarbon phase behavior.

PVT analysis for oil, gas and water: 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.

Flow through porous media: Darcy's law, Flow regimes, Real gas potential, Flow geometry and pressure distribution, Radial flow equation, Multiphase flow: effective and relative permeability, solution of radial flow equation; transient flow analysis, stabilized deliverability, calculation of water influx.

Oil Well Testing: The constant terminal rate solution for transient and steady state flow, Superposition theories, Pressure build-up theory and analysis, Well-completion.

Gas Well Testing: Radial flow of a real gas, Solution techniques of radial flow equation, Theory of gas well testing, Pressure build-up and analysis techniques

Natural Water Influx and Immiscible Displacement: Water influx theory and prediction of water influx, Oil recovery calculations, Displacement under different conditions.

Reservoir Simulation: Classical reservoir engineering and reservoir simulation, Effects of variable properties, Capillary pressure and flow.

References:

1. Dake L P, *Fundamental of Reservoir Engineering*, Elsevier.1978.
2. Smith H C, Tracy G W, Farrar R L, *Applied Reservoir Engineering: VolI and II*, OGCI. 1999
3. Tarek Ahmed, *Reservoir Engineering Handbook, (2e)*, Gulf Professional Publishing, 2001
4. Salter A, Baldwin J, Jespersen R, *Computer-Aided Reservoir Management*, Pennwell. 2000

CHE 4003: PETROCHEMICALS [3 0 0 3]

General introduction – Economics and future prospects of petrochemicals – Energy crisis and petrochemical industry – Sources and classification of petrochemicals

First generation petrochemicals – Alkanes – Alkenes and alkynes – BTX aromatics – Diene base petrochemicals

Second generation petrochemicals – Synthesis gas – Methanol – Formaldehyde – Chloromethanes – Ethanol – Acetaldehyde – Acetic acid – Acetic anhydride – Isopropyl alcohol – Ethylene oxide – Propylene oxide – Acetone – Vinyl chloride – Phenol – Aniline – Styrene

Third generation petrochemicals – Plastics – Rubber – fibres – olefinic polymers – Polyethylene – Polypropylene – Poly-isobutylene – Diene polymers – Polybutadiene – Neoprene – Polyisoprene – SBR – Synthetic fibres

References:

1. Maiti, S., *Introduction to Petrochemicals*, Oxford and IBH Publishing Co. Ltd., 1992
2. Chem Tech IV, *Chemical Engineering Education Development Centre*, IIT Madras, 1978
3. Austin, G., *Shreve's Chemical Process Industries, (5e)*, McGraw-Hill, NY, 1986

CHE 4004: PETROLEUM REFINERY ENGINEERING [3 0 0 3]

Origin, Formation, Migration & Accumulation of petroleum, Exploration, Drilling, Well completion, Recovery (primary, secondary & tertiary), Separation and Transportation; Indian refining scenario, OPEC and WPC; Crude oil composition, Characterization and classification; Atmospheric and vacuum distillation, Design of crude oil distillation columns; Thermal Cracking, Visbreaking, Coking; Catalytic cracking and hydro cracking: principles, feedstocks, technologies, catalyst, operational conditions, products etc.; Catalytic reforming: principles, feedstocks, technologies, catalysts, operational conditions, products etc.; Isomerization, Alkylation and Polymerization; Refinery Products, Tests and specifications, Treatment of petroleum products, Hydro desulfurization, Product blending; Lube oil processing: De asphaltting, solvent extraction and de-waxing; Energy conservation in petroleum refineries; Environmental issues and New Trends in petroleum refinery operations

Reference Books:

1. James G Speight, *The chemistry and technology of petroleum, (4e)*, CRC Press, 2006
2. R A Meyers, *Handbook of petroleum refining processes, (3e)*, McGraw-Hill, 2004
3. B K BhaskaraRao, *Modern petroleum refining processes, (5e)*, Oxford& IBH, 1984
4. Nelson, *Petroleum refining engineering*, McGraw-Hill, 1949
5. R N Watkins, *Petroleum refinery distillation*, Gulf publication, 1979

III. POLLUTION CONTROL ENGINEERING

CHE 4005: ENVIRONMENTAL IMPACT ASSESSMENT AND MANAGEMENT PLAN [3 0 0 3]

Environmental impact assessment (EIA), definitions and concepts, rationale and historical development of EIA, EIA in Civil Engineering, Initial environmental examination, environmental impact statement, environmental appraisal, environmental impact factors and areas of consideration, measurement of environmental impact, organization, scope and methodologies of EIA, status of EIA in India; Environmental management - principles, problems and strategies; Review of political, ecological and remedial actions; future strategies; multidisciplinary environmental strategies, the human, planning, decision-making and management dimensions; Environmental audit, definitions and concepts, partial audit, compliance audit, methodologies and regulations; introduction to ISO and ISO 14000; Life cycle assessment; Triple bottom line approach; Industrial Ecology; Ecological foot printing; Carbon trading; Sustainable development

Reference Books:

1. L. W. Canter, *Environmental Impact Assessment, (2e)*, McGraw-Hill, 1997
2. P. Judith, G. Eduljee, *Environmental Impact Assessment for Waste Treatment and Disposal Facilities*, John Wiley & Sons, 1994

3. G. Burke, B. R. Singh, L. Theodore, *Handbook of Environmental Management and Technology*, (2e), John Wiley & Sons, 2000
4. C. H. Eccleston, *Environment Impact Statements: A Comprehensive Guide to Project and Strategic Planning*, John Wiley & Sons, 2000
5. R. Welford, *Corporate Environmental Management - Systems and Strategies*, Universities Press, 1996
6. K. Whitelaw, Butterworth, *ISO 14001: Environmental System Handbook*, 1997
7. The Economist Intelligence Unit, *Best Practices - Environment*, Universities Press, 1993
8. R. Therivel, John Glasson, Andrew Chadwick, *Introduction to Environmental Impact Assessment (Natural and Built Environment)*, Routledge, 2005

CHE 4006: INDUSTRIAL WASTE WATER ENGINEERING [3 0 0 3]

Introduction to waste water engineering, Standards for treated waters, Algae, Control measures, quality of underground Waters. Nature and source of impurities. Examination of waters. Requirements of water treatment facilities. Purpose of advanced wastewater treatment, Physical treatment, pre-treatment, solids removal by setting and sedimentation, filtration centrifugation, coagulation and flocculation. Kinetics of biological growth, introduction to suspended and fixed film reactors. Concepts of gas transfer and solids separation, Nitrogen and Phosphorus removal from waste water. Concepts of aerobic and anaerobic treatment of waste water. Design of Activated Sludge system using biological process dynamics. Complete design details of Activated Sludge Process. Modifications of ASP. Process concepts and design aspects of Trickling Filters, Rotating Biological Contactors (RBC), Fluidized bed reactor/treatment. Anaerobic and aerobic treatment biochemical kinetics, trickling filter, activated sludge and lagoons, aeration systems, sludge separation and drying. Advance waste water treatment processes, sludge treatment and disposal

Reference Books:

1. Templeton M R, Butler D, *Introduction to Wastewater Treatment (e-book)*
2. Metcalf, Eddy, *Wastewater Engineering - Treatment and Reuse*, (4e), McGraw-Hill, 2003
3. Viessman W, Hammer M J, *Water Supply and Pollution Control*, (6e), Addison Wesley, 1998
4. Hendricks D, *Fundamentals of Water Treatment Unit Processes*, CRC Press/IWAPublishing, 2011
5. Peavy H S, Rowe D R, Tchobanoglous G, *Environmental Engineering*, McGraw-Hill, 1985

CHE 4007: POLLUTION CONTROL ENGINEERING [3 0 0 3]

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 behavior – Meteorological factors affecting air pollution – Equipments 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

References:

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

CHE 4008: SOLID WASTE ENGINEERING & MANAGEMENT [3 0 0 3]

Sources, quantities generated, and physiochemical properties of municipal solid waste and hazardous waste, Solid Waste Management Pyramid – Key Technologies for SWM (collection, handling, transformation, landfills, incinerators, composting); Relevant environmental regulations for waste disposal, site investigations; Site Selection (NIMBY), Regulatory permitting process; Incineration, composting, Types of Landfills, basic geotechnical considerations, earthen liners for waste disposal, Clay mineralogy, factors controlling hydraulic conductivity, methods to measure k in the lab and field, compatibility of liner materials to chemicals in leachate, Operational aspects of MSW landfills (daily cover, leachate disposal, GW monitoring), Landfill Gas Collection System and Leachate Recirculation System Design, Landfill Final Cap Design and Water Balance Modeling

Reference Books:

1. Tchobanoglous, Getal, *Integrated Solid Waste Management, (2e)*, McGraw Hill New York, 2001
2. LaGrega, Mi, Buckingham P, Evans, J, *Hazardous Waste Management, (2e)*, McGraw Hill, 2001
3. McBean E, Rovers F, Farquhar G, *Solid Waste landfill Engineering and Design, (1e)*, PHI, New York, 1995

IV. BUSINESS MANAGEMENT

HUM 4011: FINANCIAL MANAGEMENT [2 1 0 3]

Introduction to financial management, Principle of accountancy, Sources of long term finance, Valuation of securities, Leverages, Working capital management, Capital budgeting, Cost of capital, Cash management, and Dividend decisions.

References:

1. Prasanna Chandra (2006), “Fundamentals of Financial Management”, Tata McGraw Hill, Delhi.
2. I M Pandey (2007), “Financial Management”, Vikas Publishing house, Delhi.
3. Subir Kumar Banerjee (1999), “Financial Management”, Sultan Chand & Co., Delhi.
4. ICFAI (2003), “Corporate Financial Management”, ICFAI, Hyderabad.
5. Maheshwari S.N (2002), “Financial Management”, Sultan Chand & Co., Delhi

HUM 4012: HUMAN RESOURCE MANAGEMENT [2 1 0 3]

Evolution and development, HRD Organization and responsibilities. Evolution of HRM, Theories of HRM. Human resource planning, Human Resources Inventory, Forecast, Job analysis, Job description, Job specification, Job evaluation, Employment stability. Human Resource Planning and Recruiting, Induction, & socialization, Training and development, Performance management and appraisal.

References:

1. T.V. Rao and Pereira D F (1986), “*Recent experiences in Human Resources Development*”, Oxford and IBH Publishing.
2. Subbrao A. (1999), “*Essentials of Human Resource Management and industrial Relations*”, Himalaya Publishing House.
3. N G Nair and Latha Nair (1995), “*Personnel Management and Industrial Relations*”, S. Chand Company.
4. Virmani B R; Rao Kala (1997), “*Economic restructuring technology transfer and human resource development*”, Response books.
5. Pareek Udai et al. (2002), “*Human Resource Development in Asia: Trends and Challenges*”, Oxford and IBH Publishing.

HUM 4013: MARKETING MANAGEMENT [2 1 0 3]

Understanding marketing management, Assessing market opportunities and customer value, Adapting marketing to the New Economy, Building Customer Satisfaction, Value, and Retention, Market Demand, Scanning the Marketing Environment, Consumer Markets, Business Markets, Dealing with the Competition, Market Segments, Product Life Cycle, New Market Offerings, Designing and Managing Services, Price Strategies, Retailing, Wholesaling, Integrated Marketing Communications.

References:

1. Philip Kotler (2000), “*Marketing Management – Analysis, Planning, Implementation and Control*”, Prentice Hall of India Private Limited, New Delhi.
2. ICFAI (2003) “*Marketing Management*”, ICFAI, Hyderabad.
3. Varshney R L and Gupta S L (2004), “*Marketing Management*”, Sultan Chand & Sons, New Delhi.
4. Adrian Palmer (2000), “*Principles of Marketing*”, Oxford University Press, New York.

HUM 4014: OPERATIONS AND SYSTEMS MANAGEMENT [2 1 0 3]

Types of production activities, Production consumption cycle, Functions of production and operations management, Importance and uses of forecasting, Product development and design: Product life cycle, Process design, Process charts, Flow diagrams and Man machine charts, Capacity planning, Aggregate planning, Scheduling, Operations strategy, Operation performance Frontier and productivity, Systems thinking, Systems engineering and its management, Systems decision process. Systems thinking, structure, classification, boundaries, visibility, System life cycle models, System dynamics and its importance in system thinking. System dynamics modeling process.

References:

1. Monks Joseph G (2004), “*Operations Management*”, Tata McGraw-Hill Publishing Co. Ltd., New Delhi.
2. Krajewski Lee J. and Ritzman Larry P (2005), “*Operations Management*”, Pearson Education (Singapore) Pte. Ltd., Delhi.
3. Mieghem J (2008), “*Operations Strategy: Principles and Practices, Dynamic Ideas*”, ISBN: 0-9759146-6-9.
4. Sterman J D (2004), “*Business Dynamics - Systems Thinking and Modeling for A Complex World*”, McGraw Hill, International Edition.
5. Senge Peter (1990), “*The Fifth Discipline*”, Currency Doubleday, New York.

OTHER PROGRAMME ELECTIVES

CHE 4009: ADVANCED BIO-CHEMICAL ENGINEERING [3 0 0 3]

Genetic engineering – aims, techniques, achievements and prospects of genetic engineering – Process of gene expression, split genes and MRNA modification in eukaryotes, post translational modifications of proteins – Induction and mutation

Alteration of cellular DNA: Virus and phages – cell fusion – Commercial applications of microbial genetics and mutant populations – Recombinant DNA technology

Transport phenomena in bioprocess systems – Gas liquid mass transfer in cellular systems – Determination of oxygen transfer rates – Power requirements for sparged and agitated fermentors – Scale up and scale down of bioreactors

Recovery and purification of fermentation products: Filtration – Centrifugation – coagulation and flocculation – separation of soluble products – Liquid –liquid extraction – adsorption-dialysis – reverse osmosis – ultrafiltration and microfiltration, chromatography, electrophoresis, electro dialysis

Design and analysis of biological reactors – Ideal bioreactors – Sterilisation of reactors – Batch and continuous – Immobilised biocatalysts – Formations – Characterisation and applications – multiple bioreactors – Packed, fluidized and trickling bed reactors

Alternate bioreactor configurations – animal and plant cell reactor technology

Analysis for mixed culture fermentation systems – Neutralism, mutation, commensalisms and amensalism – Classification of interaction between two species – Competition and survival of the fittest – Volterra's analysis of competition – competition and selection in a chemostat – Predation and parasitism – Model development via stability analysis – Effects of number of species and their interactions – definitions – Population dynamics in model of mass action form

Biological reactors in the mixed culture and with natural systems – uses of well defined mixed populations

Medical applications of bioprocessing Engineering - Tissue engineering – Commercial tissue culture process

References:

1. Bailey, J.S. and Ollis, D.F., *Biochemical Engineering Fundamentals*, McGraw-Hill, New York, 1986
2. Shuler, M.L. and Kargi, F., *Bioprocess Engineering Basic Concepts*, Prentice Hall of India, New Delhi, 1988
3. Blanch, H.W. and Clerk, D.S., *Biochemical engineering*, Marcel Dekker Inc., New York, 1996.

CHE 4010: ADVANCED CHEMICAL REACTION ENGINEERING [3 0 0 3]

Homogeneous Reactor design and Analysis for ideal reactors. Review of isothermal design for batch, semi batch and flow reactors, multiple reactions and reaction networks, yield selectivity concepts. Analysis for first order networks, reaction networks of general order. Reactor energy balance and its applications to reactor design and analysis. Homogeneous reactor design and analysis for non ideal reactors. Review of basic concepts of residence time distributions (RTD). Single and Multiparameter models for real reactor behavior, macro mixing and micro mixing, segregated flow model and Zwietering's Analysis of maximum mixedness, IEM and other models for micro mixing.

Heterogeneous reactors-gas-solid systems-Reviews of kinetics of gas-solid catalytic reactions with and without diffusion limitations. Reactor design for fixed and fluidized bed reactors, selected case studies. Non catalysis gas solid reactions review of kinetics reactor design case studies. Gas-liquid systems-Basic theories of mass transfer with chemical reaction model

systems and model reactors. Reactor design for mechanically agitated and bubble column reactors selected case studies.

References:

1. Octave Levenspiel, *Chemical Reaction Engineering*, (3e), Wiley & Sons, 2003.
2. Rawlings J.B, Ekerdt, J.G., *Chemical Reactor Analysis and Design Fundamentals*, (1e), Nob Hill Publishing Co., 2002.
3. Scot Fogler, H, *Elements of Chemical Reaction Engineering*, (4e), PHI, 2005.
4. CarberrY J J, *Chemical and Catalytic reaction engineering*, (1e), Doven Publishers, 2001
5. Froment G F, Bischoff K B, *Chemical Reactor Design and Analysis*, (2e), John Wiley and Sons NY, 1997

CHE 4011: ADVANCED PROCESS CONTROL [3 0 0 3]

Laplace domain analysis of advanced control systems – Cascade control – Feed forward control – Open loop unstable processes – Processes with inverse response – Adaptive control – Model based control – Introduction to multivariable control – Matrix properties – State variable – Solution of state equations – Controllability and observability – Analysis of multivariable systems stability – Resiliency – Interaction – RGA – Robustness – Design of controllers for multivariable processes – Selection of controlled variables – SVD-BLT tuning of multivariable controllers – Multivariable DMC – Multivariable IMC – Model predictive control – Introduction to sampled data control system – Sampling – Hold element – z transforms – Stability analysis and design of digital compensators

References:

1. W.L. Luyben, *Process Modelling, Simulation and Control for Chemical Engineers*, McGraw Hill, 1990.
2. Donald R Coughanowr, *Process Systems Analysis and Control*, (3e), McGraw-Hill, 2009
3. D.W. Seborg, T.F. Edgar and D.A. Millichamp, *Process Dynamics and Control*, John Wiley & Sons, 1989
4. Stephanopoulos G, *Chemical Process Control – An Introduction to Theory and Practice*, Prentice Hall of India, New Delhi, 2008

CHE 4012: ADVANCED SEPARATION PROCESS [3 0 0 3]

Thermodynamics of separation operations-Energy entropy and availability balances-Review of ideal gas and ideal solution Models-Non ideal thermodynamic property Models, P-V-T – equations of state, Models of activity coefficients-Margules-Van Laar. Wilson-NRTL UNI QUAC and UNI FAC Models Liquid-liquid equilibria, Review of equilibrium based methods for binary systems. Equilibrium based methods for Multi component Absorption stripping Distillation and Extraction. Equation tearing procedures-Simultaneous correction procedures Inside out methods, Enhanced Distillation and super critical Extraction – Residue curve Maps-Heterogeneous Azeotropic Distillation, Reactive Distillation – usage of software Super critical

fluid extraction – Rate Based Models for Distillation – Thermodynamic properties and transport rate expressions – Methods of calculation – Multi component batch distillation Rapid Solution Methods – Membrane separations Dialysis and Electro dialysis. Adsorption, ion exchange and chromatography.

References:

1. J. D. Seader, Ernest J. Henley, *Separation process principles, (2e)*, John Wiley & Sons, 2006
2. Wanket P C, *Separation Process Engineering, (2e)*, PHC, NJ 2007
3. C. Judson King, *Separation Processes, (1e)*, TMH, New Delhi 1974

CHE 4013: ADVANCED THERMODYNAMICS [3 0 0 3]

Thermodynamic Analysis of Chemical engineering systems. Minimum energy requirements Estimation of properties in multicomponent multiphase systems. Analysis of high pressure and low temperature phase equilibria, intermolecular force, potential energy functions and virial coefficients and excess functions; Thermodynamic models and data reduction procedures for estimation of the interaction parameters; Theories of solutions; Phase instability and partially miscible systems; Estimation procedures for solubility of gases in pure and mixed solvents, computations methods for generation of Multicomponent phase equilibrium data for process design; Review of chemical equilibria in complex reacting systems and computational methods for optimum process conditions for maximum conversion, statistical thermodynamics. Schrodinger's equation, microcanonical and canonical ensembles, partition function, expressions for thermodynamic quantities, perfect gases. Analysis of problems in irreversible thermodynamics.

References:

1. J.M.Prausnitz, Lichtenthal R.M., Edmundo G. De Azevedo, *Molecular thermodynamics of fluid phase equilibria, (3e)*, PHI, 1998
2. Tester J.W., Modell, M., *Thermodynamics and its applications, (3e)*, PHI, 1997
3. Bejan, *Advanced Thermodynamics, (1e)*, Wiley, 1988
4. Y.V.C.Rao, *Chemical Engineering Thermodynamics*, Universities Press, 1997

CHE 4014: AIR POLLUTION CONTROL & EQUIPMENT DESIGN [3 0 0 3]

Meteorological aspects of air pollution dispersion; Air pollution sampling and measurements; Air pollution control methods and design of Equipments: Settling chambers, laminar and turbulent flow – Filtration, Collection of particles by cylindrical fibers and granular beds – Electrostatic precipitation – Cyclones – Wet collectors; Efficiency and dimensions of particle control devices; Gas absorption in tray and packed towers, Stage efficiency, Equilibrium number of stages/packed height; Absorption with/without chemical reaction. Advanced techniques for Removal of SO₂ and CO₂; Removal of HCs/VOCs; NO_x removal from effluent streams.

References:

1. Martin Crawford, *Pollution Control Theory*, McGraw Hill, NY. 1976.
2. Joe Ledbetter, *Air Pollution Part A&B*, Marcel Dekker, NY, 1972.
3. A.C Perkin, *Air Pollution*, McGraw-Hill 1974.
4. S.M. Khopkar, *Environmental pollution Monitoring and control*, New Age Int. ND, 2004.

CHE 4015: BIO ENERGY ENGINEERING [3 0 0 3]

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, Thermo chemical 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 equipments. 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. VenkataRamana, S. N. Srinivas, *Biomass energy systems, (1e)*, Tata energy Research Institute New Delhi, 1996.

CHE 4016: ENERGY ENGINEERING [3 0 0 3]

Energy scenario in India – Renewable sources of energy – Availability – Generation and utilization of solar, wind, geothermal and tidal, ocean thermal energies and Nuclear Energy

Solid fuels: Testing methods – Proximate and ultimate analysis – Calorific value – Weathering and grindability index of coal – Theories of origin and stages of formation – Coal washing techniques – Carbonisation – Gasification – Briquetted and pulverized fuels

Liquid fuels: Testing methods – Aniline point – Viscosity index – ASTM distillation – Flash and fire point – Carbon residue – Moisture – Smoke point and char value – Calorific value – Origin, composition and classification of petroleum – Distillation of crude and purification of petroleum products

Gaseous fuels: Fuel gas and flue gas analysis – Calorific value – Production and utilization of Natural gas, producer gas, water gas and carbonated water gas

Combustion: Terminology – Calculation of air requirement – Grates, burners and stokers

Furnaces: Classification – Construction – Thermal efficiency – Fuel economy – Types of furnaces used in process industries

Energy audit: Energy conservation and auditing – Guidelines and procedures for energy audit – Domestic, industrial and transportation sectors

References:

1. Sharma, S.P, Chander Mohan, *Fuels and Combustion*, Tata McGraw-Hill, 1982
2. Saha, A.K., *Combustion Engineering and Fuel technology*, Oxford Press
3. Gilchrist, J.D., *Fuels, Furnaces and Refractories*, Pergamon Press, 1977
4. Manson L. Smith, Keri W. Stinson, *Fuels and Combustion*, McGraw-Hill, 1952

CHE 4017: APPLIED INTERFACIAL ENGINEERING [3 0 0 3]

General introduction of colloids and interfaces.

The role of mixing and entropy: Brownian motion and Brownian flocculation

Colloid stability: what the attractive forces and repulsive forces which exist and why the colloidal (nano) domain is different from molecular scale. Van der Waals forces, Electrical phenomena at interfaces (Electrical double layer).

What happens at surfaces: Surface and interfacial tension/free energy, planar and curved interfaces. Spreading of droplets. Application: non-stick frying pans and EOR (without chemicals)

Experimental interrogation of colloids and surfaces: Measurement of surface tension, contact angle, zeta potential, particle size

Understanding adsorption at surfaces (Thermodynamics of interfaces): The surface excess and the Gibbs equation. Application: Spreading or roll-up of droplets. cEOR.

Self –assembly of Amphiphiles(surfactants): Micelle formation and surfactant adsorption. The hydrophobic effect.The effect of counter ions.Phospholipids and cell membranes. Application: General applications (builders and sequestrants; anti-corrosion agents; anti-stripping agents, micro-emulsions)

Particles at interfaces: emulsions. Applications: foods (pickering) emulsions and froth flotation for ore extraction

Novel fabrication of nanostructured particles: Self-assembled & nanostructured / biomimetic interfaces. Application: gecko adherence to walls and catalysts

Electron transfer across interfaces: electrode kinetics. Application: GlucoWatch: non-invasive blood glucose monitoring for diabetics.

Latest trends in interfacial science and latest innovation in interfacial engineering applications

Reference Books:

1. Hiemenz, P. C, Rajagopalan, R., *Principles of Colloid and Surface Chemistry, (3e)*, Marcel Dekker, New York, 1997.
2. M. J. Rosen, *Surfactants and Interfacial Phenomena, (1e)*, Wiley-Interscience Publication, New York, 1978.
3. Adamson, A. W. Gast, A. P., *Physical Chemistry of Surfaces, (1e)*, Wiley-Interscience, New York, 1997.
4. D. Fennell Evans, Kakan Wennerstrom, *The Colloidal Domain: Where Physics, Chemistry, Biology, and Technology Meet (Advances in Interfacial Engineering)*, Wiley-VCH, 1999
5. J. Israechvili, *Intermolecular & Surface Forces, (2e)*, Academic Press, 1992

CHE 4018: INTRODUCTION TO BIOCHEMICAL ENGINEERING [3 0 0 3]

Introduction – Principles of microbiology – Structure of cells – Microbes – Bacteria – Fungi – Actinomycetes – Algae – Chemicals of life – Lipids – Sugars and polysaccharides of cellular organization – cell nutrients – Macronutrients – Growth media

Kinetics of enzymes – Catalysed reactions – Enzyme substrate complex and enzyme action – Simple enzyme kinetics with one and two substrates – Determination of elementary step rate constants – Isolation and utilization of enzymes – Production of crude enzyme extracts – Enzyme purification – enzyme immobilization – Application of hydrolytic enzymes – Immobilised enzyme technology – Methods of immobilization – Enzyme production – Intracellular and extracellular enzymes

Metabolic pathways and energetic of the cell – Glucose metabolism – Glycolysis and TCA cycle – Respiration – Control sites of aerobic glucose metabolism – Metabolism of nitrogenous compounds – Nitrogen fixation – Metabolism of hydrocarbons – Overview of biosynthesis – Anaerobic metabolism – Photosynthesis - Autotropic metabolism – transport across cell membranes

Cell growth – Batch growth – Determining cell mass concentration – Growth patterns and kinetics in batch culture – Factors affecting growth kinetics-Quantification of growth kinetics – Unstructured non-segregated models to predict specific growth rate – Models with growth inhibitors – Logistic equation – Growth models for filamentous organisms – Models for transient behaviour – Models with time delay – Chemically structured models

References:

1. J.S.Bailey and D.F. Ollis, *Biochemical Engineering Fundamentals*, McGraw-Hill, NY, 1986

2. M.L.Shuler and F.Kargi, *Bioprocess Engineering Basic Concepts*, Prentice Hall of India, New Delhi, 1998
3. H.W. Blanch and D.S.Clerk, *Biochemical Engineering*, Mercel Dekker Inc., 1996

CHE 4019: MEMBRANE SCIENCE AND TECHNOLOGY [3 0 0 3]

Membrane preparation and structure, membrane permeability, flow pattern and classification: micro filtration, ultra filtration, nano filtration, reverse osmosis, electro dialysis, 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 Chapman & Hall, Glasgow, 1996

CHE 4020: OPTIMIZATION OF CHEMICAL PROCESSES [3 0 0 3]

The nature and organization of optimization – the essential features of optimization problems- Review of fitting models to data formulation of objective functions. Optimization theory and methods – Basic concepts of optimization-Convex and concave functions-optimization of un-constrained functions: one dimensional search, uni-dimensional and Multidimensional problems. Un-constrained Multivariable optimization.Simplex, conjugate search.PowellsMethod.Indirect and Secant Methods.Linear programming and applications – Non-linear programming with constraints. Diagnosis of the failure of optimization codes to solve problems. Optimization of staged and Discrete processes Dynamic programming, integer and Mixed Integer programming-nonlinear. mixed integer programming algorithms. Application of optimization in Heat transfer and Energy conservation, separation processes, fluid flow systems chemical reactor Design and operation and optimization in large-scale plant Design and Operation.

References:

1. T.F.Edgar, D.M.Himmelblau, L.S. Ladson, *Optimization of chemical processes, (2e)*, McGraw Hill international Editions, 2003
2. S.S. Rao, *Engineering Optimization-theory and practice, (4e)*, John wile and sons, 2009
3. M.C. Joshi, K.M. Moudagalya, *Optimizations, Theory and practice, (1e)*, Narosa Pub, New Delhi, 2008

CHE 4021: PINCH TECHNOLOGY [3 0 0 3]

Need of Pinch Technology, Types of Pinch, Problem addressed by Pinch technology. Key Steps of Pinch Technology: Data extraction, Targeting, Designing, Optimization.

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, Shell targeting, cost targeting.

Designing of HEN: Pinch design methods, Heuristic rules, Stream splitting, Design of maximum energy recovery (MER)

Heat Integration of Equipments: Heat engine, Heat pump, Distillation column, Reactor, Evaporator, Drier, Refrigeration systems.

“HINT” Software – Practice of software for HEN using Pinch Technology

References:

1. Ian C Kemp, *Pinch Analysis and Process Integration: A User Guide on Process Integration for the efficient use of energy, (2e)*, Butterworth-Heinemann(Elsevier) publisher, 2007
2. Stanislaw Sieniutycz, JacekJezowski, *Energy Optimization in Process Systems, (1e)*, Elsevier, 2009
3. Robin M. Smith, *Chemical Process: Design and Integration*, John Wiley & Sons, 2005
4. RK Sinnott, Richardson & Coulson’s *Chemical Engineering* volume 6, Chemical Engineering Design, (4e), Elsevier, 2005
5. Angel Martin, Fidel A. Mato, *Hint: An educational software for heat exchanger network design with the pinch method, Education for Chemical Engineers*, Elsevier, Volume 3, 2008, e6-e14

CHE 4022: PROCESS INSTRUMENTATION [3 0 0 3]

Functions and Elements of measuring instruments: Static and Dynamic characteristics, Errors in measuring instruments.

Temperature measurement: Filled system thermometers, Metallic expansion thermometers, Resistance thermometers, Thermistors, Thermocouples, Radiation pyrometers, Temperature transducers.

Pressure measurement: Mechanical pressure instruments – Manometers, Elastic type pressure gauge; Electrical methods of pressure measurements; Strain gauge, Capacitance pressure transducer, Potentiometric, Piezoelectric, Magnetic, Optical pressure transducers.

Vacuum sensors: Mechanical vacuum gauges, Thermal vacuum gauges, Ionization gauges.

Flow measurement: Variable Head type flow meters: Orifice meters, Venture meters, Flow nozzle, Pilot tube, Variable area flow meters, Differential pressure transmitters, Quantity meters, Mass flow meters, Electrical flow meters: Electro-magnetic, Ultrasonic, Laser Doppler, Vortex shedding flow meter, Anemometer.

Level measurement: Gauge glass, Float, Displace and Torque type, Air purge/bubbler type, Level measurements by electric methods: Resistance, Capacitance, Radiation, Ultrasonic, Microwave, Optical, Radar, and Laser.

Density measurement: Displacement & float type, Hydrometers, Ultrasonic and Sonic, Radiation densitometers, Gas densitometers.

Viscosity measurement: Capillary, Efflux cup, Falling ball, Float, Rotational, Gyration, Vibrating rod, Plastometers

Humidity measurement: Dry & wet bulb Psychrometer, Hair Hydrometers, Thin film capacitance, Humidity sensor, Dew-point Hydrometers.

References:

1. KKrishnaswamy, SVijayachitra, *Industrial Instrumentation*, New Age International (P) Limited, 2005.
2. Donald Eckman, *Industrial Instrumentation*, Wiley Eastern Limited.
3. S K Singh, *Industrial Instrumentation & control*, Tata McGraw Hill Educational Private Limited, 2009.
4. Bela G Liptak, *Instrument Engineers' Handbook, (4e), Process Measurement and Analysis – Volume I*, CRC Press, 2003

CHE 4023: PROJECT ENGINEERING [3 0 0 3]

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, plant utilities, insulation, instrumentation, safety in chemical plant, Project engineering management, Project scheduling and its importance, PERT and CPM techniques, 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, 1957
2. Warren Sieder, J.D. Seader, Daniel Lewin, *Product and Process Design Principles*, John Wiley, 2004
3. Gael D. Ulrich, *A Guide to Chemical Engineering Process Design and Economics*, John Wiley, 1984
4. Max S Peters, Klaus D. Timmerhaus, Ronald E. West, *Plant Design and Economics for Chemical Engineers*, McGraw-Hill, 2003
5. E.E. Ludwig, *Applied Project Engineering*, Gulf Publishing Co., Houston, 1988
6. J.Modes, Philips, *Project Engineering with CPM & PERT*, Renhold Publishing Co.

7. *Coulson and Richardson's Chemical Engineering Series Chemical Engineering Volume 6, Chemical Engineering Design, (3e), 2003*

CHE 4024: RISK AND SAFETY MANAGEMENT IN PROCESS INDUSTRIES [3 0 0 3]

Safety in process plants: Hazard analysis, damage minimisation, and control, fires, types of fire, fire extinguishers, types and handling, contamination removal, reduction methods, personal protective devices, Plant and personal safety. Pressure vessels, storage, handling and transportations of liquids and gases under high pressure, material of construction, safety precautions, explosive chemicals and handling. Safety administration, types of organisation, safety committee, safety council, safety education. First aid principles and methods, first aid training, plant inspection, safety specialist jobs. Engineering design for safety considerations, plant layout for safety. Hazards in work places: nature and type of work places, types of hazards, hazards in industries, workers exposure to hazardous chemicals, threshold limit values of chemicals, Engineering control of hazards and accidents due to fire and explosives and natural causes in different industries.

Safety management: Fundamental safety aspects, costs of industrial injuries, accountability of personnel and managers. Measuring safety performance, measuring companywide safety performance, measuring national safety performance, national safety council. Motivating safety performance, motivation of employees, supervisors, managers and management, legal aspects of safety

References:

1. Roland P.Blake, *Industrial safety, (2e)*, Prentice Hall Inc, New York, 1953
2. G.D, Muir, *Hazards in Chemical Laboratory, (2e)*, The Chemical Society, London, 1980
3. Judson and Brown, *Occupational Accident Prevention*, John Wiley, New York, 1980
4. Handling, *Industrial Safety Hand Book*, McGraw Hill, London, 1969

CHE 4025: UPSTREAM AND DOWNSTREAM BIOPROCESSING [3 0 0 3]

Substrate processing (milling, grinding and extraction etc), Sterilization of air and medium in batch and continuous mode, the development of inocula for industrial fermentation, the development of inocula for yeast, bacterial and mycelia processes, the aseptic inoculation of plant fermenters.

An overview of bioseparations, Characteristics of bioseparators, Removal of insolubles. Filtration and micro filtration, Equipments for conventional filtration. General theory-continuous equipments, Laboratory tests, Centrifugation scale-up of centrifugation, Cell disruption chemical methods, Mechanical methods, Isolation, extraction, Batch, staged operation, Differential extractions and fractional extractions with a stationary phase. Fractional extractions with two mixing phases, Adsorption-Batch and continuous operation, Product purification- Elution, chromatography-yield and purity-scaling-up chromatography, precipitation, ultrafiltration and

electrophoresis, Polishing crystallization, batch crystallization, Drying-basic concepts-ancillary operations, water quality, solvent recovery, waste disposal. Biosafety.

References:

1. Paul A. Belter, E. L. Cussler, Wei-Shan Hu, *Bioseparations, Downstream processing for biotechnology, (1e)*, John Wiley and Sons. 1988
2. Pauline M. Doran, *Bioprocess engineering principles, (1e)*, Academic press. 1995
3. H.J. Rehm, G. Reed, G. Stephanopoulos (ED), *Biotechnology, (2e)*, *Bio Processing, Vol. 3*, John Wiley, 1993
4. Stanbury P.F., A. Whitakar, S.J. Hall, *Principles of Fermentation Technology, (2e)*, Elsevier Publishers, 2005

CHM 4001: ANALYTICAL TECHNIQUES AND INSTRUMENTATION [3 0 0 3]

Spectroscopic methods of analysis: Introduction, Energy concepts, Properties of EMR, Types of molecular spectra, Interaction of EMR with matter, Instrumentation, Applications.

Microwave spectroscopy: Introduction, Diatomic rigid rotor and non-rigid models, Instrumentation, Applications, Advantages and disadvantages.

Raman spectroscopy: Basic principles, Properties of Raman lines, Classical and quantum theories, Techniques and instrumentation, Applications.

Infrared spectroscopy: Theory, Diatomic molecules as harmonic & anharmonic oscillators, Diatomic vibrating rotator, Vibrations of polyatomic molecules, Instrumentation of dispersive and FT-IR, Double beam IR spectrometer, Uses of IR, Advantages, Limitations.

UV-visible spectroscopy: Theory, Types of transitions, Instrumentation, Double beam spectrophotometer, Applications, Spectrophotometry, Beer's law, Deviations,

NMR spectroscopy: Basic principles, Chemical shift, Spin-spin coupling, Instrumentation, Applications of proton NMR spectroscopy.

Chromatographic techniques: General concepts, Classification, Instrumentation, Experimental techniques, Applications, Advantages & disadvantages of CC, HPLC, TLC & GC.

Electroanalytical methods: Basic Principles of conductometric & potentiometric titrations, Applications.

References:

1. D.A. Skoog, J. Holler, F.T.A. Nieman, *Principles of Instrumental Analysis, (5e)*, Saunders, Philadelphia, 1992
2. GH Jeffery, *Vogel's Textbook of Quantitative Chemical Analysis, (5e)*, John Wiley & Sons Inc, 1989
3. G.W. Ewing, *Instrumental Methods of Chemical Analysis*, Mc-Graw-Hill, 1989

CHM 4002: CATALYSIS AND COLLOIDAL SYSTEMS [3 0 0 3]

Adsorption & catalysis: Adsorption of gases by solids, Adsorption isotherm, Physisorption & chemisorption, Theories of adsorption, Types of adsorption isotherm, Factors influencing

adsorption, Adsorption from solution, Gibb's adsorption isotherm for adsorption from solution, Catalytic properties, Classification, Industrial catalytic processes, Catalytic cycles, Energetics. **Solutions & solubility:** Introduction, Factors affecting solubility, Expressing concentrations, Solutions of liquids in liquids, Ideal and non-ideal solutions, Thermodynamics of ideal solutions, Free energy, volume, enthalpy & entropy changes of mixing for an ideal solution, Vapor pressure composition and boiling point composition curves, Distillation behavior, Azeotropes, Fractional distillation, Solubility of partially miscible liquid pairs, Lower and Upper critical solution temperature, Vapor pressure and distillation of immiscible liquids, Steam distillation, Solutions of gases in liquids, Factors influencing solubility of a gas.

Colligative properties: Introduction, Lowering of vapor pressure, Experimental measurement, Determination of molar masses, Osmosis, Osmotic pressure, Measurement; Laws of osmotic pressure, Van Hoff's theory of dilute solutions, Isotonic solutions, Relationship between osmotic pressure & vapor pressure lowering, Theories of semi-permeability, Effects of osmosis and semi-permeability, Concept of reverse osmosis, Boiling point elevation, Experimental measurement, Thermodynamic treatment, Molal elevation constant, Determination of molar masses, Depression of freezing point, Experimental measurement, Thermodynamic treatment, Molal depression constant, Determination of molar masses, Van Hoff's factor, Degree of association.

Colloidal state: Introduction, Types, Preparation & purification, General properties of sols, Dialysis, Electro-dialysis and ultra-filtration, Optical property of sols, Electro-osmosis, Determination of size & mass of colloidal particles, Kinetic properties of sols-diffusion, Brownian movement & sedimentation, Application of colloids, Emulsions, Types, Applications, Preparation, Properties and applications of gels.

References:

1. S. H. Maron, C. F. Prutton, *Principles of Physical Chemistry, (4e)*, IBH Publishing Co. New Delhi, 1985
2. D. A. Skoog, D. M. West, F. J. Holler, R. Crouch, *Fundamentals of Analytical Chemistry, (8e)*, Thomson-Brooks, 2007
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OPEN ELECTIVES

CHE 3281: INTRODUCTION TO CHEMICAL ENGINEERING [3 0 0 3]

Chemical engineering and chemical technology. Chemical engineering: Origin, growth and role in chemical process industries. **Chemical Process Industry:** Definition, origin, growth and the present scenario. Concepts of unit processes and unit operations, chemical kinetics and thermodynamics applied to reactions. **Systematic analysis of chemical processes:** Need and basic considerations. Chemical engineers, the diversity of employment opportunities for them. A successful chemical engineer. Professional ethics. Intimate connections with physico-chemical

sciences, biological and biomedical sciences and other engineering streams case studies. **Concerns of chemical engineering traditional areas:** environment, energy and petroleum refining, polymer, pharmaceutical and food processing, bioengineering and biotechnology, health and safety. Concepts of scale-up, modelling and simulation. Dimensional analysis. Computer in chemical engineering. Nanotechnology. Grand challenges of engineering in the 21st century.

References:

1. Himmelblau, David Mautner, and James B. Riggs., *Basic principles and calculations in chemical engineering. Vol. 1*, Prentice Hall PTR, 1996.
2. Morton M. Denn, *Chemical Engineering- an Introduction*, Cambridge University Press, NY, 2012.
3. Felder, Rousseau, *Basic Principles of Chemical Engineering, (3e)*, Prentice Hall, 2002.
4. Ghosal, S.K., Sanyal, S.K. and Datta, S. *Introduction to Chemical Engineering*, Tata McGraw-Hill Publishing Company Ltd., New Delhi 1997.
5. Badger, W.A., Banchero, J.T., *Introduction to Chemical Engineering*, McGraw-Hill Book Company.
6. Perry, R.H., Green, D.W., *Perry's Chemical Engineers' Handbook*, McGraw-Hill Book Company

CHE 3282: INDUSTRIAL POLLUTION CONTROL [3 0 0 3]

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 behavior – Meteorological factors affecting air pollution – Equipments for control and abatement of air pollution.

Pollution from automobiles – control mechanisms

E-waste – sources and effects, e-waste management.

References:

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