M. TECH. (CHEMICAL ENGINEERING)
Harcourt Butler Technological Institute, Kanpur
Study and Evaluation Scheme
[Effective from the Session 2009-10]

M. Tech. (Chem. Engg)   **Year 1, Semester - I**

S. No.	Course Code	Subject	Periods			Evaluation Scheme				Subject Total	Credits
						Sessional Exam.			End Sem Exam		
			L	T	P	CT	TA	Total			
Theory Subjects											
1	CH-11	Advanced Separation Processes	3	1	0	30	20	50	100	150	4
2	CH-12	Advanced Chemical Engineering Thermodynamics	3	1	0	30	20	50	100	150	4
3	CH-13	Modeling and Simulation of Chemical Engineering Systems	3	1	0	30	20	50	100	150	4
4	CH 14-17	Elective - I	3	1	0	30	20	50	100	150	4

Elective - I
CH-14 Pollution Abatement and Control Equipments
CH-15 Safety Hazard and Risk Analysis
CH-16 Design of piping systems for chemical process plant
CH-17 Advanced Petroleum Refining

M. Tech. (Chem. Engg.)   **Year 1, Semester - II**

S. No.	Course Code	Subject	Periods			Evaluation Scheme				Subject Total	Credits
						Sessional Exam.			End Sem Exam		
			L	T	P	CT	TA	Total			
Theory Subjects											
1	CH-21	Advanced Chemical Reaction Engineering & Heterogeneous Catalysis	3	1	0	30	20	50	100	150	4
2	CH-22	Advanced Transport Phenomena	3	1	0	30	20	50	100	150	4
3	CH-23	Advanced Mathematics & Statistical Design of experiments	3	1	0	30	20	50	100	150	4
4	CH 23-24	Elective - II	3	1	0	30	20	50	100	150	4

Elective - II
CH-24 Computer-aided design of chemical process plant
CH-25 Instrumental Methods of Analysis
CH-26 Optimization of Chemical Processes
CH-27 Design & Analysis of Biological reactors
CH-28 Advanced Process Dynamics & Control

M. Tech. (Chem. Engg.)   **Year 1I, Semester - I**

S. No.	Course Code	Subject	Periods			Evaluation Scheme				Subject Total	Credits
						Sessional Exam.			End Sem Exam		
			L	T	P	CT	TA	Total			
Theory Subjects											
1	CH-31	Project #					600	600	------	600	16

 # Project - : Each student will be assigned a guide who will give a two semester project to the student to work upon. The progress in the first semester would be evaluated by the project guide.

M. Tech. (Chem. Engg.)   **Year 1I, Semester –II**

S. No.	Course Code	Subject	Periods			Evaluation Scheme				Subject Total	Credits
						Sessional Exam.			Project Evaluation		
			L	T	P	CT	TA	Total			
Theory Subjects											
1	CH-41	Project #					400	400	200	600	16

 # Project - : Project given in the first semester of the II year will be continued in the second semester under the same guide. A research report would be submitted at the end of the II semester.

<u>**Syllabus**</u>

M. TECH CHEMICAL ENGINEERING

<u>**SEMESTER-I**</u>

CH-11: Advanced Separation Processes

Multicomponent distillation – Bubble point and dew point calculations, Lewis and Matheson calculation, Method of Thiele and Geddes; Azeotropic distillation; Extractive distillation; Molecular distillation; Reactive distillation Classification of membrane processes; Liquid permeation membrane processes or dialysis – Series resistance in membrane processes, Dialysis processes, Types of equipment for dialysis; Gas permeation membrane processes – Types of membranes and permeability for separation of gases, Types of equipment for gas permeation membrane processes (flat membranes, spiral-wound membranes, hollow-fibre membranes); Types of flow in gas permeation; Complete-mixing model, cross-flow model and countercurrent flow model for gas separation by membranes; Effect of processing variables on gas separation by membranes Reverse osmosis membrane processes – Osmotic pressure of solution, flux equation, Types of equipment and Complete mixing model; Effect of operating variables; Concentration polarization; Permeability constants Ultra-filtration membrane processes – Types of equipment, flux equation, effects of processing variables Supercritical fluid extraction – Supercritical fluids, Phase equilibria, Industrial applications; Important supercritical processes – Decaffination of coffee, Extraction of oil from seeds, Residuum oil supercritical extraction (ROSE), Supercritical fluid chromatography, Supercritical fluid reactions etc.

Books:
1. C.J.Geankoplis, Transport Processes and Unit Operations, Prentice-Hall of India Pvt. Ltd., New Delhi (2000).
2. T.K.Sherwood, R.L.Pigford and C.R.Wilke, Mass Transfer, McGraw-Hill, New York (1975).
3. R.E.Treybal, Mass-Transfer Operations, McGraw-Hill, New York (1980).

CH-12: Advanced Chemical Engineering Thermodynamics

Postulation Thermodynamics: Postulates; Equilibrium criteria ; Gibbs Duhem relation; Energy minimum principle ; Thermodynamics potentials ; Stability and phase Transition . Statistical Thermodynamics: Statistical mechanics of ensembles ; Estimation of Thermodynamics properties in ideal gases .Equations of state and intermolecular forces . Principles of corresponding state . Thermodynamic Relation .Fugacity in Gas and Liquid Phases . fugacity in the solid phase. Application of equilibrium criteria of chemical reactions . The standard Gibbs energy change and equilibrium constant. Minimization of Gibbs energy . Estimation of equilibrium constant in reacting system . Gas phase and Liquid –phase reaction. Single phase reactions . reaction in heterogeneous systems . Multireaction equilibrium . Fuel cells.   Topics in Phase Equilibrium Roles of Gibbs

energy and Entropy in Phase Equilibria.The gamma/phi formulation of VLE . VLE from cubic equations of state . Equilibrium and stability . Liquid-liquid equilibrium . Vapor-liquid-liquid equilibrium . Solid-liquid Equilibrium . Osmotic equilibrium and osmotic pressure . Equilibrium in Electrochemical System . Reaction equilibrium of Point Defects in Crystalline solids , Brouwer Diagram.

Books:
1. J M Prausnitz, R N Lichtenthaler, E G de Azevedo, Molecular Thermodynamics of Fluid Phase Equilibrium, 3rd Edition., Prentice-Hall, 1999.
2. V P Carey, Statistical Thermodynamics and Microscale Thermophysics, Cambridge University Press, 1999.
3. T L Hill, An Introduction to Statistical Thermodynamics, Dover Publications, New York.
4. J M Haile, Molecular Dynamics Simulations-Elementary Methods, J Wiley & Sons.
5. Introduction to Chemical Engineering Thermodynamics, Smith J.M, Van Ness H.C., Abbott M.M. The McGraw Hill Companies, Inc., USA, 5th Edition, 1996.
6. Chemical and Engineering Thermodynamics, Sandler S.I. John Wiley and Sons, Inc., New York, 3rd Edition, 1999.
7. Introductory Chemical Engineering Thermodynamics, Elliot J.R and Lira C.T., Prentice Hall, 1999.

CH-13: Modeling and Simulation of Chemical Engineering Systems

Fundamentals of mathematical modeling-Principles of formulations, Fundamental laws: Continuity equations, energy equation, equation of motion, transport equations, equation of state, equilibrium, chemical kinetics; Advantages and limitations of models and applications of process models of stand-alone unit operations and unit processes; Classification of models-Simple vs. rigorous, lumped parameter vs. distributed parameter, Steady state vs. dynamic, Transport phenomena based vs. Statistical; Concept of degree of freedom for steady state and unsteady state systems. Mathematical models of heat-transfer equipments: Shell & tube heat exchangers, Evaporators, Fired heaters, Partial condensers Mathematical models of mass-transfer equipments: Batch and continuous distillation columns, Reactive distillation columns, Packed absorption columns, Dehumidifiers Mathematical models of reactors: Batch reactors, Continuous-stirred tank reactors, Plug-flow reactors, Industrial reactors-Ammonia converter, Sulphuric acid converter, Methanol reactor, FCC reactor, Claus reactor, etc. Numerical methods: Linear and non-linear simultaneous algebraic equations, Ordinary-differential equations-Initial-value problems & boundary-value problems, Partial-differential equations Different approaches to flow sheet simulation- Sequential modular approach, Simultaneous modular approach, Equation oriented approach; Review of thermodynamic procedures and physical property data banks.
Books:
1. W.L.Luyben, Process Modeling, Simulation and Control for Chemical Engineers, McGraw-Hill, New York (1990).
2. M.M.Denn, Process Modeling,

3. C.D.Holland, Fundamentals and Modeling of Separation Processes,

Elective 1

CH-14: Pollution Abatement & Control Equipments

Waste water treatment and disposal, Elements of plant analysis and design, Facilities for physical and chemical treatment of wastewater, screening, comminuting, flow equalization, sedimentation, chemical precipitation, filtration, chlorination and odour control,Biological treatment of wastewater: activated sludge process, aerated lagoons, trickling filter, and stabilization ponds treatment and disposal of sludge, advanced astewater treatment processes,Air pollution control techniques, particulate emission control by inertial impaction, interception, stacks and chimneys, exhaust systems, dispersion heights and plume characteristics, gravity settling chambers, centrifugal collectors, wet collectors, bag filters, electrostatic precipitators, Pollution control by absorption, adsorption, combustion, condensation, oxidation and catalytic conversion, automotive emission control devicesSolid waste management, pyrolysis, combustion, biodegradation, land fills.Noise pollution control techniques.

Books

1. K.B.Schnelle & C.A.Brown, Air Pollution Control Technology Handbook, CRC Press
2. H.S. Peavy, Donald R Rowe &George Tchobanoglous, "Environmental Engineering", McGraw-Hill
3. R .K.Trivedy& P.K.Goel,An Introduction to Air Pollution, Technoscience Pub.

CH-15: Safety Hazards and Risk Analysis

Safety legislations: Safety programmes, Public perceptions, Engineering ethics, Government policy on safety hazard identification, preliminary hazard analysis, hazard and operability (HAZOP) analysis, event tree, fault tree analysis.Toxic releases, to phase phenomenon, emission and dispersion models, estimation and prevention.Fire and explosions, chemistry of fire, fire triangle, fire and explosion index (FEI), estimation, heat effects, vapor cloud explosion (VCE), boiling liquid expanding vapor explosions (BLEVE) and prevention.Industrial hygiene, health hazards, evaluation of worker's exposure to toxicants, control methods.Hazard management safety system, relief systems, risk management routines, emergency plans, and disaster control ergonomics.Case histories of some major accidents.Nuclear radiation hazards and safety from these.

Books:
1. G.L.Wells,Safety in Process Plant Design
2. Sanjoy Banerjee, Industrial Hazard & Plant Safety (8)
3. Daniel A. Crowl, Joseph F. Louvar, Chemical Process Safety: Fundamentals with Applications, Prentice Hall
4. Frank P. Lees, Loss Prevention in the Process Industries, Butterworths ,London

CH-16: Design Of Piping Systems For Chemical Plants

Fundaments of fluid flow through pipes-Calculation of pressure drop for Newtonian & non-Newtonian fluids, incompressible & compressible fluids and two-phase flow, Calculation of Economic pipe diameter, insulation thickness, equivalent length, Slurry transport and pipelines Engineering flow diagram, nomenclature and equipment elevation Piping layout, line pressure drop, piping analysis, stress analysis of curved pipelines, yard piping Piping codes, standards and specifications-ASME, ASTM, API Piping components-pipes, pipe ends, pipe fittings, end fittings, flanged joints, valves, valve codes and standards, valve classification, valve components, bolts, gaskets (fasteners and sealing elements)Piping materials-selection, cost and installation Design of heat exchanger piping, Thermosyphon reboiler piping, Pressure relief piping Steam tracing design, Thermowell design, Expansion loops and expansion joints Design of pipeline network-Pinch analysisPipeline operation and maintenance-friction reduction, cleaning, coating, wear, leak detection, water hammer

Books:
1. Peter Smith, Fundamentals of piping design, Gulf Publishing House
2. Kellog, Design of pipeline systems

CH-17: Advanced Petroleum Refining

Composition and properties of crude oil. Distillation methods: Atmospheric distillation, Vacuum distillation. Thermal cracking processes: Burton cracking processes, Visbreaking and different type of coking. Catalytic Conversion Processes: Fluid Bed and Orthoflow Catalytic Cracking, Catalytic Hydro cracking: Two stage and H-oil hydrocracker, Different type of catalysts used. Reforming-type of catalysts, hydro treating processes, hydrodesulphurization,Alkylation, Polymerization and isomerizationSupporting processes: solvent Extraction processes for deasphalting of Gasoline, Kerosene and Diesel oil. Wax separation and preparation as a finished product.
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Books & References:
1. Petroleum Refining Technology and Economics, J.H. Gary, G.E. Handiwerk, Marcl and Dekker Inc., New York.
2. The chemistry and Technology of Petroleum, J.G. Speight, Marcel Dekker, 1991
3. Modern Petroleum Refining Processes, B.K. Bhaskar Rao Oxford and IBM Pub. Co. Pvt Ltd, New Delhi, 1990

CH-21 : Advanced Chemical Reaction Engineering & Heterogeneous Catalysis

Reaction rates: Theory and application, Chemical Aspects of Heterogeneous catalysis, Physical aspects of Solid, Various methods of catalysis preparation, Characterization of Catalysts using Surface area estimation, X-Ray diffraction, Electron Microscopy and Magnetic Moment studies etc., Idealized models, Practical Rate Forms and analytical solutions, Catalysis and catalytic process, catalyst formation, adsorption on solid surfaces, Physical - chemical adsorption model, multiplayer adsorption theory; catalytic reaction kinetic model, real and ideal surface models; various models for data analysis, adsorption enhancement, multi step rate control, significances of rate– determining step, kinetic models, kinetics of catalyst deactivation. Fixed bed catalytic reactor; adiabatic and non adiabatic fixed bed reactor, design and modeling of fixed bed reactors. Fluidized bed catalytic reactor; fluid bed reactor modeling; Davidson Harrison model, Kunii - Levenspiel model, Olsons's fluid bed reactor analysis. Introduction and performance of catalytic gaze reactor, trickle bed reactor, catalyst deactivation in fixed bed, batch fluid bed, moving bed and continuous fluid bed reactors, comparison of fixed moving and fluid beds; reactor poisoning in terms of spm, thermal waves in fixed bed regeneration, optimization of regeneration cycles.

Books & References:
1. James J. Carberry: Chemical and catalytic reaction engineering McGraw Hill.
2. J.M.Smith, " Chemical Engineering Kinetics", McHill.
3. O.Levenspiel, "Chemical Reaction Engineering", Wiley Eastern, 2nd ed, 1972
4. Froment G.F., Bischoff K.B.; Chemical Reactor Analyser and design, John Wiley & Sons.

CH-22 : Advanced Transport Phenomena

Philosophy and fundamentals of three transport phenomena : Importance of transport phenomena; analogous nature of transfer process; basic concepts, conservation laws. Molecular transport of momentum, Heat and mass, laws of molecular transport, Newton's law of viscosity, Fourier law of heat conduction, and Fick's law of diffusion. Transport coefficients – viscosity, thermal conductivity and mass diffusivity. Estimation of transport coefficients and temperature / pressure dependence. one dimensional transport in laminar flow (shell balance) :Newtonian and non-Newtonian fluids, General method of shell balance approach to transfer problems; Choosing the shape of the shell; most common boundary conditions; momentum flux and velocity distribution for flow of Newtonian fluids in pipes, for flow of Newtonian fluids in planes, slits and annulus, heat flux and temperature distribution for heat sources such as electrical, nuclear, viscous and chemical; forced and free convection; mass flux and concentration profile for diffusion in stagnant gas, systems involving reaction and forced convection. equations of change and their applications : Conservation law sand equations of change; development of equations of continuity, motion and energy in single component systems in rectangular coordinates and the forms in curvilinear coordinates; simplified forms of equations for special cases,

solutions of momentum, mass and heat transfer problems discussed under shell balance by applications of equation of change. transport in turbulent and boundary layer flow : Introduction to turbulent flows, comparisons of laminar and turbulent flows in simple systems such as circular tube, flat plate. Concept of Boundary Layer Flow.

Books & Reference :

1. Transport Phenomena,R.B. Bird, W.E. Stewart and E.W. Lighfoot, 2nd Edition. John Wiley, 2002
2. Fundamentals of Momentum Heat and Mass Transfer, J.R. Wilty, R.W. Wilson, and C.W. Wicks, 4th Edition, John Wiley, New York, 2001
3. Transport Processes and Separation Process Principles, Christie J. Geankopolis, 4th Edition. Printice-Hall, 2003
4. "Transport Phenomena – A Unified Approach", R.S. Brodkey, and H.C. Hershey, McGraw Hill, 1988

CH-23 : Advanced Mathematics & Statistical Design of Experiments

Formulation of linear and non-linear first and second order ordinary differential equations, higher order linear, differential equations for systems involving momentum, heat and mass transfer with and without chemical reactions and their analytical solutions. Principal types of matrix, Introduction to eigen values, bilinear forms and positive-definiteness, Cholesky decomposition, Gershorgin's theorem eigen values of diagonal and triangular matrices, similarity, transforms, decomposition, iteratively, estimating the leading eigen value, Linear transformations and linear operators, eigenvector expansion, matrices as representations of linear operators Zero eigen values, null spaces, and operator inversion, singular value decomposition. Applications of series in chemical engineering, Simple series solutions, Method of Frobenius, Bessel's equation, Diffusion/convection form of PDE's in chemical engineering, characteristics and PDE types (elliptic, parabolic, and hyperbolic) and their analytical solution. Formulation of linear and non-linear finite difference equations, differential - difference equations for multistage separation units and chemical reactors in series and their analytical solution. Simplest discrete and continuous distributions, Statistical inference, Statistical estimation, tests and estimates on statistical variance, Analysis of variance, Regression analysis (Simple linear, multiple, polynomial, nonlinear), Correlation analysis (Correlation in linear regression, correlation in multiple linear regression), Determination of experimental error, Significance of the regression coefficients, Lack of fit of regression models. Introduction to design of experiments, Preliminary examination of subject of research, Screening experiments. Basic Experiment - Mathematical Modeling: Full factorial experiments and fractional factorial experiments, Second-order rotatable design (Box-Wilson design), Orthogonal second order design (Box Benken design), D-optimality, Bk-designs and Hartleys second order design
Books:

1. Jenson and Jeffery, Mathematical Methods in Chemical Engineering,
2. Mickley, Reid and Sherwood, Applied Mathematics in Chemical Engineering, Tata-McGraw-Hill, New Delhi

3. Z.R.Lazic, Design of experiments in chemical engineering: A practical guide, Wiley (2005).

Elective II

CH-24 : Computer-Aided Design of Chemical Process Plants

Elements of computer-aided system design, Interactive methods, Computer graphics, Database technology, Application to property estimation.Steady state and dynamic simulation, process synthesis and flow sheeting, executed programs for plants like sulphuric acid, ammonia etc.Introduction to computer aided chemical processes analysis, modeling concepts and system analysis, software architectures, network decomposition mathematical algorithms, design criteria in process design, decision and state variables, control functions, information and data structure.Modular programs for design of pressure vessel, shell and tube heat exchanger, multiple effect evaporators, plate and packed towers, fixed and fluidized bed reactor.Costing and project evaluation.
Books:

1. M.S Peter and K.D. Timmer haus, R.E West , Plant design and economics for chemical engineers Mc Graw Hill (2002)
2. M.E. Leesley , Computer aided process plant design, Gulf Pub. Co.(1982)

CH- 25 : Instrumental Methods of Analysis

Analog and digital signals, concepts of signal noise sensitivity, detection limit, resolution, dynamic range and selectivity to an instrumental analysis, calibration of an instrumental method, electromagnetic sources and detection systems used in instrumental method of chemical analysis, selection of suitable instrumental method for a given analysis.Basic principles of Instrumental methods- IR, UV, Visible, Fluorescence spectroscopy, mass spectrometry, Nuclear magnetic resonance, gas and liquid chromatography, X-ray analysis and electron spectroscopy (surface analysis).Physical characteristic of the analytical Instruments- UV-Visible, IR, Fluorescence, Atomic Absorption, NMR Spectrophotometers, Gas chromatograph, High performance liquid chromatograph, Electrochemistry- Glucose sensors, HPTLC, SEM, GCMS, Mass spectrometer.
Books: H. Williard, L. Merrlt, J. Dean,F. Settle, Instrumental Methods of Analysis

CH- 26 : Optimization Of Chemical Processes

Introduction to optimization; formulation of objective function; Basic concept-function, regions, necessary and sufficient conditions for an extremum of an unconstrained function.One dimensional search: Scanning and breaking; Newton, quasi-Newton and secant method; Region elimination method; Polynomial approximation method.Unconstrained multivariable optimization: Direct methods- random search, grid search, univariate search, simplex method, conjugate search direction and Powell's method; indirect method-gradient and conjugate gradient method, Newton's method, movement in search direction, secant method.Linear programming: Basic concepts in linear programming; Graphical solution, simplex method, Standard LP form; obtaining first feasible solution; sensitivity analysis.Non linear programming: Lagrange multiplier method; Quadratic programming; Penalty function and augmented Lagrangian method; Successive quadratic programming; Optimization of dynamic processes.Optimization of staged and discrete processes: Dynamic programming; integer and mixed integer programming.Non traditional optimization techniques: Simulated annealing; Genetic algorithms; Differential evolution.Application of optimization in the design of separation process, chemical reactor and large scale process plant.

Books:
1. Edgar and Himmelblau, Optimization of Chemical Processes, McGraw-Hill

CH-27 : Design & Analysis of Biological reactors

Ideal Bioreactors: Fed-Batch Reactor, Enzyme-catalysed reactions in CSTRs, CSTR reactors with recycle and wall growth, The ideal plug-flow tubular reactor.
Reactor Dynamics: Dynamics model, StabilityReactors with non-ideal mixing: Mixing time in agitated tanks, Resident time distributions, Models for no-ideal reactors, Mixing-Bio reaction interactions.Sterilization Reactors: Batch Sterilization, Continuous terilization Immobilized Bio Catalysits: Formulation and characterization of immobilized cell bio catalysts, Application of immobilized cell bio catalysts Multiphase Bio reactors: Conversion of heterogeneous substrates, Packed bed reactors, Bubble column Bio-reactors, Fluidised bed Bio-reactors, Trickle bed reactors Fermentation Technology: Medium formulation, Design and operation of a typical aseptic, alrobic fermentation process, Alternate bio reactor configuration.Animal & Plant Cell Reactor Technology: Environmental requirements for animal cell cultivation, Reactor for large-scale production using animal cells, Plant cellcultivation.
Books & References:
1. Biochemical Engineering Fundamentals by James E.Bailey & David F.Ollis, Publishers: McGrew-Hill.
2. Bioprocess Engineering by Shuler & Kargi, Prentice Hall

CH-28 : Advanced Process Dynamics & Control

Complex control system: Multiple loop control systems; Cascade control; Ratio control; Feed forward control Multivariable process control: Design of controllers for nteractions, Loop interaction, Decoupling of interacting loops.Tuning of feed back controllers ☐ Quarter Decay Ratio Response, Minimum error Integral Criterion, IAE, ISE, ITAE, ITSE

Design strategies for common industrial processes such distillation, heat exchangers,etc.Batch Process: Introduction to advanced control strategies, use of microprocessors in process control.

Books & References:
1. Industrial Instrumentation, Eckman. D.P,Wiley Eastern Ltd.
2. Process Instrumentation and Controls Handbook, Considine,D.N., McGraw Hill.
3. Process System Analysis and Control, Coughanowr, D.R. and Koppel, L.B.,McGraw Hill.
4. Chemical Process Control- An introduction theory and practice, Stephanopolous, G., Prentice Hall of India.
5. Principals and Practice of Automatic Process Control, Carlos A. Smith and Armando