Punjab Technical University
M.Tech - Chemical Engg. (Part Time)
Scheme of Syllabi (Ist Semester)

Course Code	Course Name	Load Allocated				Marks Distribution		
		L	T	P	Contact Hours	Internal Marks	External Marks	Total Marks
PGRM	Research Methodology	4	--	---	4	50	100	150
MTCH101	Advanced Fluid Mechanics	4	--	---	4	50	100	150
MTCH102	Advanced Mass Transfer	4	--	---	4	50	100	150

Punjab Technical University
M.Tech - Chemical Engg. (Part Time)
Scheme of Syllabi (2nd Semester)

Course Code	Course Name	Load Allocated				Marks Distribution		
		L	T	P	Contact Hours	Internal Marks	External Marks	Total Marks
MTCH201	Mathematical Methods in Chemical Engineering	4	--	---	4	50	100	150
MTCH202	Chemical Engineering Thermodynamics	4	--	---	4	50	100	150

Punjab Technical University
M.Tech - Chemical Engg. (Part Time)
Scheme of Syllabi (3rd Semester)

Course Code	Course Name	Load Allocated				Marks Distribution		
		L	T	P	Contact Hours	Internal Marks	External Marks	Total Marks
MTCH301	Advanced Heat Transfer	4	--	---	4	50	100	150
MTCH302	Chemical Reaction Engineering	4	--	---	4	50	100	150
MTCH	Elective - I	4	--	---	4	50	100	150

Punjab Technical University
M.Tech - Chemical Engg. (Part Time)
Scheme of Syllabi (4th Semester)

Course Code	Course Name	Load Allocated				Marks Distribution		
		L	T	P	Contact Hours	Internal Marks	External Marks	Total Marks
MTCH401	Advanced Process Dynamics & Control	4	--	---	4	50	100	150
MTCH	Elective - II	4	--	---	4	50	100	150

Punjab Technical University
M.Tech - Chemical Engg. (Part Time)
Scheme of Syllabi (5th Semester)

Course Code	Course Name	Load Allocated				Marks Distribution		
		L	T	P	Contact Hours	Internal Marks	External Marks	Total Marks
MTCH501	Environmental Engineering	4	--	---	4	50	100	150
MTCH502	Process Modelling & Simulation	4	--	---	4	50	100	150
MTCH503	Research Project Identification & Presentation	---	---	---	---	100	---	100

Punjab Technical University
M.Tech - Chemical Engg. (Part Time)
Scheme of Syllabi (6th Semester)

Course Code	Course Name	Load Allocated				Marks Distribution		
		L	T	P	Contact Hours	Internal Marks	External Marks	Total Marks
MTCH601	Dissertation	---	---	---	---	Satisfactory / Non-Satisfactory		

LIST OF ELECTIVES

Elective - I		
Sr. No	Course Code	Course Name
1	MTCH311	Multi Component Distillation
2	MTCH312	Adsorption Engineering
3	MTCH313	Refrigeration Engineering
4	MTCH314	Advanced Polymer Science and Engineering

Elective - II		
Sr. No	Course Code	Course Name
1	MTCH411	Petrochemical Technology
2	MTCH412	Corrosion Engineering
3	MTCH413	Analytical Techniques
4	MTCH414	Advanced Energy Technology

MT CH101 ADVANCED FLUID MECHANICS

Objective: The course introduces the students to the principles of advanced fluid mechanics which are of fundamental importance to chemical engineers. The students are also acquainted with its applications to analysis of a given flow situation.

Differential equations of fluid flow: (5 hrs)
Continuity equation for one dimensional and three dimensional flows. Derivation of momentum equation for three dimensional flow in Cartesian coordinates. Conversion of equations to spherical and cylindrical coordinates

Flow of non-viscous fluids: (5 hrs)
Equation of motion (Euler equation) and its integration to obtain Bernoulli equation, velocity potential and irrotational flow. Streamlines and stream functions for two dimensional incompressible flow and two dimensional irrotational flow.

Laminar flow of viscous fluids: (6 hrs)
Effects of viscosity on flow, pressure gradient in steady uniform flow, use of momentum equations in cylindrical coordinates, velocity profiles in isothermal and non-isothermal flow conditions in circular tubes and annuli, friction factor and shear stress relations. Flow between infinite parallel plates.

Turbulent flow of viscous fluids: (6 hrs)
Prandtl's mixing length theory, Reynolds equation for incompressible turbulent flow. Reynolds stresses, statistical theory of turbulence, intensity of turbulence, scale of turbulence, techniques for measurement of turbulence, isotropic and homogeneous turbulence.

Turbulent flow in closed conduits: (6 hrs)
Prandtl's power law of velocity distribution, logarithmic and universal velocity distribution equations for turbulent flow in smooth tubes. Friction factor for rough and smooth tubes, relationship of u^+ and y^+ to the friction factor and Reynolds number.

Flow of incompressible fluids past immersed bodies: (5 hrs)
Von-Karman integral momentum equation, boundary layer on immersed bodies, equation of two dimensional flow in the boundary layer, local and total drag coefficients. Transition from laminar to turbulent flow on the flat plate and bluff body.

Flow of compressible fluids: (6 hrs)
Mach number, acoustic velocity and their values for ideal gases, continuity equation, mechanical energy balance and total energy balance for steady state one-dimensional flow, asterisk condition and stagnation temperature, velocity distribution, pressure ratio and effect of cross sectional area for isentropic flow of ideal gas in convergent-divergent nozzle, equations for adiabatic and isothermal frictional flow

General topics: (2 hrs)
High velocity measurement techniques for fluids
Scale up techniques.

Books Recommended:

1. Knudsen & Katz, Fluid Dynamics and Heat Transfer, McGraw Hill Book Co., 1974.
2. McCabe, Warren L., Smith, Julian C. and Harriot, P., Unit Operations of Chemical Engg., 7th Ed., McGraw Hill, 2005
3. Gupta, Santosh K., Momentum Transfer Operations, Tata McGraw Hill, 1984.
4. Sissom, L. E. & Pitts, D.R., Elements of Transport Phenomenon, McGraw Hill, 1972.

5. Nevers Noel De., Fluid Mechanics for Chemical Engineering, 2nd Edition, McGraw Hill Inc., 1991.
6. Backhurst J.R., Harker J.H., Coulson J.F., Richardson J.M., Chemical Engineering – Volume 1, 6th Ed., Butterworth Heinemann, 1999

MT CH102 ADVANCED MASS TRANSFER

Objective: The objective of this course is to present the principles of mass transfer and its advanced applications. The concept and mathematical treatment of turbulent diffusion, analogies and mass transfer with chemical reaction is developed.

Unsteady state diffusion: (12 hrs)
General methods of solution of problem in unsteady state molecular diffusion in isotropic media. Derivation of equations of unsteady-state diffusion for typical cases of mass transfer in infinite, semi-infinite and finite plane media and in spherical and cylindrical media.

Interphase diffusional phenomena: (8 hrs)
Steady state and unsteady state theories of diffusion in two phase systems, significance of hydrodynamic factor in mass transfer between two phases in relative motion.

Turbulent diffusion and analogies: (12 hrs)
Mechanism of turbulent diffusion in fluids. Application of the concept of the boundary layer theory and of analogies of momentum heat and mass transfer to turbulent range diffusional phenomena. A theoretical treatment of inter relationship of mass transfer co-efficient and heat transfer – co-efficient.

Mass transfer with chemical reactions: (8 hrs)
Diffusion reaction equations, slow reactions, fast reactions, transition from low to fast reaction, problems in practice.

Books Recommended:

1. Crank, J., The Mathematics of Diffusion, Oxford University Press, London, 1956.
2. Skelland, A. H. P., Diffusional Mass Transfer, John Wiley & Sons, 1974.
3. Sherwood, T. K., Pigford, R. L. & Wilke, C. R., Mass Transfer, McGraw Hill, Chemical Engineering Series, 1975.
4. Bird R.B., Stewart, W.E. and Lightfoot, E.N., Transport Phenomena, 2nd Ed., John Wiley& Sons, 2005.

MT CH201 MATHEMATICAL METHODS IN CHEMICAL ENGINEERING

Objective: This course is aimed at providing the knowledge about the numerical solutions and other techniques to solve various mathematical expressions; which are not easily solvable by conventional techniques.

Numerical solutions of simultaneous and higher order differential equations: (6 hrs)
Runge-Kutta method, Picard's method.

Approximate methods for B.V. problems: (10 hrs)
Finite difference method. Approximate and numerical solutions of PDE's: Finite difference approximation to derivatives. Numerical solutions of elliptic equations (Laplace and Poisson's equations), Parabolic equations and Hyperbolic equations. Finite Volume Method of Approximation

Integral functions: (8 hrs)
Gamma functions, Beta functions, Elliptic integrals and functions and error functions.
Solution methods for linear difference equations, complementary solutions and particular solutions. Nonlinear equations (Riccatic equations)

Z-Transforms: (8 hrs)
Introduction, some standard Z-transforms, linearity property damping rule, some standard results, shifting rules, initial and final value theorems, convolution theorem, evaluation of inverse transforms, applications to difference equations.

Fourier transforms: (8 hrs)
Introduction, Fourier integrals, properties of Fourier transforms, convolution theorem, Parseval's identity for F-transform, relation between Fourier and Laplace transforms, Fourier transforms of the derivatives of a function. Applications to boundary value problems.

Books Recommended:

1. Jain, R. K. & Iyengar, S., Advanced Engineering Mathematics, 2^{nd} Edition, Narosa Publishing House, New Delhi, 2003.
2. Grewal, B. S., Higher Engineering Mathematics, Khanna Publishers, New Delhi, 41^{st} Edition.
3. Rice, Richard G., Do, Duong, D., Applied Mathematics and Modeling for Chemical Engineers, John Wiley & Sons, 1995
4. Kreyszig, Erwin, Advanced Engineering Mathematics, 8^{th} Edition, Wiley Eastern, New Delhi, 2002.
5. Jain, R.K., Numerical Solution of Differential Equations, 2^{nd} Edition, Prentice Hall, 1987.
7. Mickley, H.S., Sherwood, T.K. and Reed, C.E., Applied Mathematics in Chemical Engineering, McGraw Hill
8. Sastry, S.S., Introductory Methods of Numerical Analysis, 4^{th} Ed., PHI

MT CH202 CHEMICAL ENGINEERING THERMODYNAMICS

Objective: This course covers the thermodynamic analysis of chemical engineering problems, using its principles to phase and chemical equilibrium with emphasis on vapor/liquid systems.

Review & applications of basic concepts: (10 hrs)
Inter-relationship of properties, Equations of States, Law of corresponding states, Maxwell's relations, Jacobian Method.
Equilibrium and Stability, Chemical potential, Gibbs Duhem equation & its applications, fugacity & activity, standard states, thermodynamic properties from volumetric data.

Solution thermodynamics applications: (14 hrs)
Models for the Excess Gibbs Energy: Wilson equation, Van-Laar equations, NRTL equation, UNIQUAC equation
The Phase Rule, The Gamma/ Phi Formulation of VLE, Dew point and Bubble point Calculations, Flash Calculations for binary systems
Equilibrium adsorption of pure gas on solid: Gibb's, Langmuir and Freundlich adsorption isotherms, heat of adsorption

Thermodynamic properties and VLE from equations of state: (8 hrs)
Properties of fluids from the various equations of state – viral equations, R-K equation, Lee/Kesler equation
VLE from cubic equations of state

Chemical reaction equilibrium: (10 hrs)
Effect of Temperature on the Equilibrium Constant, Relation of equilibrium constants to composition, Equilibrium Conversions for single reactions
Phase rule & Duhem's Theorem for reacting systems, multi-reaction equilibria, multi-phase reaction equilibria

Books Recommended:

1. Smith J.M. and Van Ness, H.C, Introduction to Chemical Engineering Thermodynamics, 7th Ed., McGraw Hill Book Co., 2005
2. Narayanan, K. V., A Textbook of Chemical Engineering Thermodynamics, 2nd Edition, Prentice Hall India, 2001.
3. Balzhiser R., Samuels M., Eliassen J., Chemical Engineering Thermodynamics, Prentice Hall, 1972
4. Prausnitz, T.Z., Lichtonthaler R.N. and de Azevedro E.G., Molecular Dynamics of Fluid Phase Equilibria, Englewood Cliff, N.Z. Prentice Hall, 2nd Ed., 1986.
5. Kennethenbigh, The Principles of Chemical Equilibrium, Cambridge University press, 4th Edition,1981
6. Kyle, B. G., Chemical and Process Thermodynamics, 3rd Edition, Prentice Hall of India, 1999.
7. Chao,K.C.& Greenkorn, R.A., Thermodynamics of Fluids, Marcel Dekker, 1975

MT CH301 ADVANCED HEAT TRANSFER

Objective: The objective of the course is to impart the knowledge of heat transfer mechanisms and its advanced applications to chemical engineering. The students are also exposed to the analysis of heat transfer phenomenon in beds of solids.

Heat transfer in closed conduits: (6 hrs)
Heat Transfer in Laminar and Turbulent flows and in High Speed Flow.
Natural convection: (8 hrs)
Free Convection heat transfer from

- a vertical flat plate, empirical relations for free convection
- vertical planes and cylinders
- horizontal cylinders
- inclined surfaces
- spheres
- in enclosed spaces

Non- Newtonian Fluids, Simplified Equations for Air
Forced convection: (10 hrs)
Analysis of laminar forced convection in long tube, correlations for laminar and turbulent flow conditions, forced convection in noncircular sections.
Flow over bluff bodies, local heat transfer coefficient distribution around cylinders, effect of various parameters on local heat transfer coefficient, heat transfer from tube bundles in cross-flow, heat transfer from non-circular sections.
Combined Free and Forced Convection

Analogies between momentum, heat and mass transfer (4 hrs)
Reynolds analogy, Prandtl analogy, Colburn analogy, Chilton Colburn analogy, Linton Sherwood analogy
Heat transfer with phase change: (4hrs)
Condensation Heat Transfer, Condensation Number, Film Condensation inside horizontal tubes,
Boiling Heat Transfer, Simplified relations for boiling heat transfer with water.

Heat transfer in fixed bed and fluidized bed: (4 hrs)
Resistance due to solid phase, conduction and convection effects in packed and fluidized beds, various correlations for heat transfer in packed and fluidized beds

Heat transfer by combined conduction, convection and radiation: (4 hrs)
Thermocouple lead error in surface temperature measurements, heat transfer from radiating fins, the flat plate solar collector, the heat pipe.

Books Recommended:

1. Holman, J.P., Heat Transfer, 10th Ed., McGraw Hill, 2010.
2. McAdams W.H., Heat Transmission, 3rd Ed., Kreiger Publishing Co, 1985
3. Kays, W. M. & Crawford, M. E., Convective Heat and Mass Transfer, 3rd Edition, McGraw Hill International Editions, 1993.

4. Backhurst J.R., Harker J.H., Coulson J.F., Richardson J.M., Chemical Engineering – Volume 1, 6th Ed., Butterworth Heinemann, 1999
5. Kreith F., Manglik R.M., Bohn M.S., Principles of Heat Transfer, 7th Ed., Brooks Cole Thomson Learning Publication, 2010
6. Incopera F.P., DeWitt D.P., Bergman T.L., Lavine A.S., Fundamentals of Heat and Mass Transfer, 7th Ed., John Wiley, 2011

MT CH302 CHEMICAL REACTION ENGINEERING

Objective: The course is aimed at imparting the knowledge about the various types of reactor systems especially homogeneous reactors operating under non-isothermal and non-ideal conditions and the detailed study of catalytic reactors is also included.

Review: (6 hrs)
Fundamental concepts in kinetics, design equation for single and multiple reactions in isothermal batch, semi - batch, stirred tank and plug-flow reactors, Kinetics of catalytic reactions.

Non-isothermal reactors: (8 hrs)
Temperature and pressure effects on the reaction rates. Optimum temperature progression Design Equation for Non- isothermal Reactors.
Reactor stability with special reference to C.S.T.R.

Non – ideality in reactors: (12 hrs)
Effects of non-ideality on conversion, one parameter models for non-ideal flow- tank in series model and dispersion model, Two parameter models for real reactors- real CSTR modelled with exchange volume and real CSTR modelled with bypassing dead space, Mixing of fluids in reactors and its effect on conversion, Characterization of micro and macro mixing.

Catalytic reactors: (14 hrs)
Application of kinetics to design of isothermal fixed bed and fluidized reactors for fluid-solid catalytic reactions, Catalyst deactivation, One dimensional and two dimensional models for non – isothermal, non- adiabatic fixed- bed reactors.
Fluidized reactors: information about suspended solid reactors, bubbling fluidized bed (BFB), K-L model for BFB and circulating fluidized beds (CFB).
Slurry reactors: rate of gas absorption, transport to catalyst pellet, diffusion and reaction in catalyst pellet, rate law and determining the rate limiting step, slurry reactor design.

Books Recommended:

1. Levenspiel O., Chemical Reaction Engineering, 3rd Ed., John Willey, 2004.
2. Smith J.M., Chemical Engineering Kinetics, 3rd Ed., McGraw Hill, 1981.
3. Peacock D.G., Richardson J.F., Chemical Engineering – Volume 3, 3rd Ed., Butterworth Heinemann, 1994
4. Fogler H. S., Elements of Chemical Reaction Engineering, 4th Ed., Prentice Hall, 2006
5. Walas S.M., Reaction Kinetics for Chemical Engineers, 3rd Ed., McGraw Hill Book Co, Inc.
6. Denbigh K.G. , Turner J.C.R., Chemical Reactor Theory –an Introduction, 3rd Ed., Cambridge Univ. Press London, 1984.

MT CH401 ADVANCED PROCESS DYNAMICS AND CONTROL

Objective: The objective of this course is to impart the knowledge about process control strategies that include controller settings based on frequency response, advanced control systems like feed forward control systems, ratio control etc.

Review of fundamental concepts: (3 hrs)
First Order and Higher Order Systems, Physical examples of systems of different order systems.
Concepts of control systems, controllers and Final Control Elements, Concepts of Block Diagrams.

Stability: (5 hrs)
Concept of Stability, Routh Test for Stability, Concepts of Root Locus & their plotting for feed back controllers.

Frequency response: (10 hrs)
Introduction to Frequency Response, Bode and Nyquist plots, Bode and Nyquist stability criteria, Control System Design by Frequency Response.

Process applications: (5 hrs)
Controller Tuning and Process identification, Theoretical analysis of Complex Processes.

Advanced control strategies: (6 hrs)
Logic of feed forward/ anticipatory control, designing of feed forward controllers, practical aspects on the design of feed forward controllers, feed forward-feed back control, Cascade control, ratio control.

State – Space methods: (5 hrs)
State-Space Representation of Physical Systems, Transfer Function Matrix, Multivariable Control.

Non-linear control: (4 hrs)
Examples of Non-linear Systems. Methods of Phase-plane Analysis, The Describing Function Technique.

Digital control: (2 hrs)
Introduction to direct digital control (DDC), sampling continuous signals and its reconstruction.

Books Recommended:

1. Coughanowr D. R., Leblanc S., Process System Analysis and Control, 3rd Ed., McGraw Hill, 2009
2. Stephanopoulos, G., Chemical Process Control - An Introduction to Theory and Practice, 1st Ed., Prentice Hall of India, 1990
3. Peacock D.G., Richardson J.F., Chemical Engineering – Volume 3, 3rd Ed., Butterworth Heinemann, 1994
4. Bequette B.W., Process Dynamics: Modeling, Analysis and Simulation, Prentice Hall, 1998
5. Bequette B. W., Process Control: Modeling, Design and Simulation, Prentice Hall, 2003
6. Luyben, W.L. & Luyben M. L., Essentials of Process Control, McGraw Hill, International Editions, Singapore, 1997.
7. Rice, Richard G., Do, Duong, D., Applied Mathematics and Modeling for Chemical Engineers, John Wiley & Sons, 1995

MTCH501 ENVIRONMENTAL ENGINEERING

Objective: The course is aimed at acquainting the students with environmental pollution; its agents, effects and abatement techniques.

Air pollution: (14hrs)

Inter- relation ship between energy and pollution, global warming. Effect of change in climate on eco- systems and world economy, clean and green technologies, pollution by automobiles and aircrafts.

Source of pollution and emission inventors, effects of air pollutants on human being and plant life, methods of reducing pollutants emissions.

Metrological aspects of air pollution, inversion, types of plumes and their behavior and different atmospheric stability conditions , plume dispersion, Gaussian model, buoyant plumes (Temperature profile of earth's atmosphere and its role in air pollution)

Types of smogs, photo- chemical and classical, fog, mist, aerosol diffusion coefficient, Air quality and emission standards.

Particulate matter as air pollutant, it's sources and effects

Equipments for removal: settling chambers, cyclone, electrostatic precipitators, filter bags, venturi scrubbers- their advantages and disadvantages and selection of equipments

Types of cyclones, Stairmand design of cyclones, grade efficiency curves, pressure drop measurement.

Removal of SO_x and NO_x from stack gases (mainly from thermal plants and chemical industries)

Water pollution: (10hrs)

Types of water pollutants, their sources and effects (mainly from chemical industry)

Primary, Secondary and Tertiary treatment of waste water, thickening of sludge, activated sludge process, sludge processes, sludge digester.

Treatment of low COD and BOD waste waters.

Trickling filters their working and design, some tertiary treatment methods.

Solid waste: (6hrs)

Nature and characterization of Solid waste.

Disposal of solid waste and threats. Landfills for solid wastes, advantages and disadvantages

Solid waste management: Reuse and recycle of Solid waste materials, Recovery of materials & metals, Conversion into useful products

Environmental auditing: (4hrs)

Environmental auditing, introduction to ISO-14000 and its impact on auditing

Miscellaneous topics: (4hrs)

Noise pollution, e-waste- problem and management

Books Recommended:

1. Perkins H. C., Air Pollution, McGraw Hill, N.Y., 1974
2. Liptak B.G., Liu D. H. F., Environmental Engineers Handbook, 2nd Ed., CRC Press, 1999
3. Williamson S.J., Fundamentals of Air Pollution, Addison Wesley Co. N.Y.,1973
4. Nemerow N.L., Liquid Wastes of Industry: Theory, Practices and Treatment, Addison Wesley Co. N.Y., 1971
5. Rao C.S., Environmental Pollution Control Engineering, 2nd Edition, New Age International Pvt. Ltd., 2006

6. Metcalf and Eddy, Waste-Water Engineering, 4th Edition, Tata McGraw Hill, 2007.
7. Peavy H. S, Rowe D. R., Tchobanoglous G., Environmental Engineering, McGraw Hill, 1985
8. Mahajan S. P., Pollution Control in Process Industries, Tata McGraw Hill, 2008.
9. Sincero, A.P., Sincero, G.A., Environmental Engineering, Prentice-Hall of India, 1999.

MT CH502 PROCESS MODELLING AND SIMULATION

Objective: The objective of this course is to impart the knowledge of developing different types of mathematical models for various systems in chemical engineering.

Review: (4 hrs)
Review of numerical methods used for solution of linear and non linear equations, ODE's and PDE's.

Introduction to mathematical modeling: (6 hrs)
Advantages and limitations of models; Classification of models – Simple and rigorous. Lumped parameter and distributed parameter; Steady state and dynamic, Transport phenomena based and Statistical, empirical and analytical.
Concept of degree of freedom, parametric sensitivity.

Process models:

Steady state models (6 hrs)

- model of flash vessels
- model of equilibrium staged processes distillation columns, absorbers, strippers
- model of CSTR
- model of heat exchangers
- model of evaporators

Unsteady state models

- ***Lumped parameter systems*** (12 hrs)
- model for liquid level tank
- model of gravity flow tank
- model of jacketed stirred tank heater
- model of jacketed stirred tank reactor
- model of flash separation column
- model of multistage batch and continuous distillation column, Absorption and Extraction columns.
- ***Distributed parameter systems:*** (12 hrs)
- model of laminar flow in pipe, heat exchanger
- model of packed columns
- model of plug flow reactor
- model of packed bed reactor

Books Recommended:

1. Luyben, W.L., Process Modeling Simulation and Control for Chemical Engineers, 2^{nd} Edition, McGraw Hill Book Co., 1990.
2. Franks, R.G.E., Mathematical Modeling in Chemical Engineering, John Wiley, 1967.
3. Ramirez F. W., Computational Methods in Process Simulation, 2^{nd} Ed., Butterworth Heinemann, 1998
4. Bequette B.W., Process Control: Modeling, Design and Simulation, Prentice Hall, 2003

MT CH503 RESEARCH PROJECT IDENTIFICATION & PRESENTATION

Each student will have to prepare and deliver a seminar based on literature survey and course of action for the work to be undertaken for thesis. Depending on his/her performance in seminar he/she will be evaluated. The main aim is to develop an understanding of literature survey, its analysis and presentation skills in the students.

ELECTIVE – I
MT CH311 MULTI-COMPONENT DISTILLATION

Objective: The objective of this course is to acquaint the students with the concepts and techniques of separating the constituents in a multi-component mixtures by distillation.

Binary vapour – liquid equilibria:
P-x- y diagram, T-x-y diagram, x-y diagram, H-x-y diagram
Nonideal vapour – liquid equilibrium:
Activity Coefficient (various correlations), K- Factor, Relative Volatility.
Multi-component distillation:
Different methods of flash vaporization calculations including empirical co-relations, Analytical (Fensky, Underwood & Smoker equations) and graphical methods for calculation of stage requirement for binary and multi-component systems for constant and varying flow rates for varying relative volatilities for complex columns involving multiple feeds , side streams , open stream and like , for other special cases.
Methods for estimation of minimum reflux requirements, optimum, feed stage locations and minimum number of stages.
Unsteady state distillation, single and multistage processes, effect of column hold up
Contacting efficiencies in distillation, different methods for estimation of efficiencies, effect of liquid mixing.
Distillation trays, Hydraulic and other design considerations.
Extractive and Azeotropic distillations, general considerations for the choice of separating agents and methods of calculations.

Books Recommended:

1. Treybal Robert E., Mass Transfer Operations, 3rd Ed., McGraw Hill, 2001
2. Backhurst J.R., Harker J.H., Coulson J.F., Richardson J.M., Chemical Engineering – Volume 1, 6th Ed., Butterworth Heinemann, 1999
3. McCabe, Warren L., Smith, Julian C. and Harriot, P., Unit Operations of Chemical Engg., 7th Ed., McGraw Hill, 2005
4. Harker J. H., Richardson, J. F., Backhurst J. R., Chemical Engineering Vol. 2, 5th Ed., Butterworth-Heinemann, 2003.

ELECTIVE – I
MT CH312 ADSORPTION ENGG.

Objective: The course is aimed at providing the detailed knowledge about adsorption as an operation for separations on industrial scale.

Adsorption vs distillation, Selectivity, Practical Adsorbents, Zeolites, Commercial Molecular Sieve Adsorbent.

Physical adsorption and the characterization of process adsorbents:
Forces and Energies of Adsorption Theoretical calculation of Heat of adsorption at low coverage, Monolayer and multilayer adsorption, Capillary condensation, Mercury porosimetry, Characterization of Zeolites

Thermodynamics of adsorption:
Classical Equilibrium Relationship, Thermodynamics of an adsorbed phase, Derivation of isotherm equations from the Gibbs Equation, Adsorption of mixtures, Statistical thermodynamic approach.

Correlation, analysis and prediction of adsorption equilibrium:
Localized adsorption, Mobile adsorption, General thermodynamic correlation - Heat of adsorption, Entropy and heat capacities, Adsorption of mixture, Adsorption from the liquid phase.

Pressure Swing Adsorption:
Pressure swing adsorption, pressurization and blowdown, drying of gases

Books Recommended:

1. Ruthven Douglas M., Adsorption & Adsorption Processes, Wiley- Inter Science Publication, 1985
2. Ruthven Douglas M., Farooq S., Knaebel K. S., Pressure Swing Adsorption, VCH Publication, 1994
3. Treybal Robert E., Mass Transfer Operations, 3rd Ed., McGraw Hill, 2001
4. Hill, T.L. Introduction to Statistical Thermodynamics, Addison Weslay, Reading Mass, 1960.
5. Young, D.M. and Crowell , A.D. , Physical Adsorption of Gases , Butterworths, London, 1962.
6. Holland, C. D. and Lrapis A.I. Computer Methods for solving Dynamic Separation Problems, McGraw- Hill, New York, 1983.

ELECTIVE - I
MT CH313 REFRIGERATION ENGINEERING

Objective: The objective of this course is to impart the knowledge of fundamentals and concepts of refrigeration process as applicable to industrial practice.

Introduction and basic concepts:
Introduction; Various Methods of Refrigeration; Unit of Refrigeration and Coefficient of Performance; Carnot Refrigeration Cycle; Difference between Heat Engine, Refrigerator and Heat Pump
Vapour compression refrigeration systems:
Carnot Vapour Compression Cycle; Simple Vapour Compression System; Wet Compression Versus Dry Compression; Expansion Process; Simple Vapour Compression Cycle; Ewing's Method for Suction State with respect to Maximum COP; Use of p-h Chart; Effect of Condenser Pressure, Evaporator Pressure, Super Heating of Refrigerant Vapour before Suction and Sub cooling of Refrigerant before Expansion on Performance of Vapour Compression Cycle; Actual Vapour Compression Cycle
Multi-pressure vapour compression systems:
Multi-Pressure Vapour Compression Systems in Industrial Refrigeration; Multistage Vapour Compression Systems; Necessity of Multistage Vapour Compression System; Optimum Inter-stage Pressure; Removal of Flash Gas; Inter-cooling; Multistage Vapour Compression Systems with Multi-Evaporators, Multi-Compressors with or without Flash Gas Removal and Flash Gas Inter-cooling; Cascade Refrigeration System
Vapour absorption refrigeration system:
Principle of Vapour Absorption Refrigeration System; Comparison of Vapour Absorption Refrigeration System with Vapour Compression Refrigeration System; Aqua-Ammonia Vapour Absorption Refrigeration System; Temperature-Concentration Diagram; Temperature-Enthalpy Diagram; Lithium-Bromide Water-Vapour Absorption Refrigeration System; Three Fluid Absorption Refrigeration System; Multi-Stage Vapour Absorption System
Refrigerants:
Primary and Secondary Refrigerants; Halocarbon Compounds; Inorganic Compounds; Hydrocarbons; Azeotropes; Nomenclature of Refrigerants; Thermodynamic, Chemical and Physical Properties of Refrigerants; Common Refrigerants; Environmental Aspects of Refrigerants; Alternative Refrigerants; Comparative Study of Refrigerants
Refrigeration equipments:
Compressors; Condensers; Evaporators; Expansion Devices; Selection of Capillary Tube; Drier, Receiver, Oil Separator and Electric Controls
Low temperature refrigeration:
Applications; Joule-Thomson Coefficient and Irreversible Expansion of Gases; Liquefaction of Gases, Linde or Linde-Hampson System; Claude Liquefaction System; Helium Liquefaction; Refrigeration System for Solid CO2; Magnetic Cooling
Non-conventional methods of refrigeration:
Steam Jet Refrigeration; Vortex Tube Refrigeration; Pulse Tube Refrigeration; Thermo-Electric Refrigeration

Books Recommended:

1. Dossat R. J., Horan T.J., Principles of Refrigeration, 5th Ed., Prentice Hall, 2002
2. Sparks & Dillo, Mechanical Refrigeration, McGraw Hill
3. Stoecker W.P., Refrigeration & Air-Conditioning, Tata McG

4. Jordan R.C., Priester G. B., Refrigeration & Air-Conditioning, Prentice Hall, 1956
5. Jennings & Lewis, Air-Conditioning & Refrigeration, International Text Book Company
6. Arora C. P., Refrigeration & Air-Conditioning, Tata McGraw Hill, 2008
7. Prasad M., Refrigeration & Air-Conditioning, 2nd Ed., New Age Publishers, 2002
8. Arora S. C., Domkundwar S., Refrigeration & Air-Conditioning, Dhanpat Rai & Company, 2002
9. Ballaney P.L., Refrigeration & Air-Conditioning, 15th Ed., Khanna Publisher

ELECTIVE - I

MT CH314 ADVANCED POLYMER SCIENCE & ENGINEERING

Objective: The objective of this course is to impart the knowledge of polymer science that includes advanced analysis, types and techniques of polymerization

Introductory survey:
Definition and Concept of polymers, Classification of polymers, Structure- Properties relationship, configuration and conformation, solubility parameter, intrinsic viscosity, diffusion and permeability in polymers, crystallization from melt, Kinetics of crystallization, Theory of glass transition.

Polymerization:
Step polymerization (Carothers equation, reactivity of functional groups, kinetics of step polymerization), accessibility of functional groups in polymerization reaction, cross linking technology, distribution of molecular weight in bi-function polymerization, prediction & practical consideration of gel point;
Free Radical polymerization (Kinetics rate & nature), Determination of absolute rate constant; Nature of termination and its effect on distribution on molecular weight; auto-acceleration & its kinetic study; Process condition; Relation between chain length & D.P.; Thermodynamic Consideration; Living Polymers; Ionic Chain Polymer; comparison between Radical and ionic polymerization ; Cationic copolymerization of C-C bond; Anionic polymers of C-C double bond; copolymerization; kinetics of copolymers; monomers reactivity ratio; significance of copolymerization; block & graft copolymers; copolymer composition ; kinetics of stereo regular polymerization ; detailed study of kinetics & mechanism of polymerization involving Ziegler Natta catalysts & metallocene catalysts ; ring opening polymerization
Group transfer polymerization: detailed study of kinetics & mechanism of formation of inorganic polymers .

Techniques of polymers:
Design criterion of polymerization system; brief introduction & comparison of various techniques of polymerization; bulk polymerization; solution polymerization (description of process, effect of process, parameter of polymerization kinetics and distribution on molecular weight of polymers) emulsion polymerization; (description of process, effect of process parameter on polymerization kinetics and distribution on molecular weight of polymers); inverse emulsion polymerization (description of process , effect of process parameter on polymerization kinetics and distribution on molecular weight of polymers) ; suspension polymerization (description of process , effect of process parameter on polymerization kinetics and distribution on molecular weight of polymers).

Books Recommended:

1. Gowariker V.L., Viswanathan N.V., Sreedhar J., Polymer Science, 1st Ed., New Age International
2. Ghosh P., Polymer Science & Technology of Plastics & Rubber, 3rd edition, Tata McGraw Hill New Delhi, 2010
3. Billmeyer F.W., Text Book of Polymer Science, 3rd edition, John Wiley
4. Sinha R., Outlines of Polymer Technology - Manufacture of Polymers, PHI
5. Kumar A., Gupta R.K., Fundamentals of Polymers, McGraw Hill, 1998
6. Kumar A., Gupta R.K. ,Fundamentals of Polymer Science and Engineering, Tata McGraw Hill New Delhi, 1978

ELECTIVE-II
MT CH411 PETROCHEMICAL TECHNOLOGY

Objective: The course is aimed at imparting to the students the knowledge of petrochemical technologies and processes used in petrochemical industry

Petrochemicals:
An overview, growth of global and indian petrochemical industry, petrochemical feed stock, resources and generation of different feedstocks-their purification, separation of individual components by adsorption, low temperature fractionation and crystallization.
Processes and technologies in petrochemical industry:
Steam reforming, syn gas manufacture, steam cracking, olefin separation, separation of ethyl benzene, benzene, toluene and xylene, Polymerization and their types
Aromatic conversion process:
Xylene isomerization: isomerization of o-xylene and m-xylene into p-xylene
Major downstream products:
Manufacture, properties and uses of:

- Methanol, Formaldehyde, Ethylene oxide, Ethylene glycol, Ethylene amines from ethylene, acrylonitrile from acetylene, Isopropanol, Acrylic acid, butadiene by dehydrogenation of butane, , Acetic acid, 1,4 Butanediol
- Monomers and polymers-, Poly-vinyl chloride, Vinyl acetate monomer, LDPE and HDPE, Polystyrene, Polybutadiene, Phenol formaldehyde resin, Styrene, Cumene, Propylene oxide, Phthalic anhydride, Iso-phthalic acid, Iso-Propyl Alcohol, Butadiene, isobutylene, Maleic anhydride, Nylon 6, Nylon 66, Polyethylene terepthalate, Formaldehyde resins, Styrene Butadiene Rubber

Synthetic detergents:
Classification of detergents, production of Alkyl Benzene Sulfonate, keryl benzene sulphonate etc, hard and soft detergents.

Books Recommended:

1. Chauvel A Lefebvre G, Petrochemical Process Vol. I & II, Gulf Publishing Company, 1989
2. Rao M.G., Sittig M, Dryden's Outlines of Chemical Technology, Affiliated East West Press Pvt. Ltd., New Delhi
3. Maiti Sukumar, Introduction to Petrochemicals, Oxford & IBH Publishing Co., 1992
4. Hatch L F, Matar S., From Hydrocarbons to Petrochemicals, Gulf Publishing Company, 1981
5. Lee S, Methane and its Derivatives, Marcel Dekker, 1997

ELECTIVE-II
MT CH412 CORROSION ENGINEERING

Objective: The course will provide an overview of corrosion effects, the various processes and applications where corrosion is dominant and mitigation strategies.

Electrochemical basics:
Electrode sign conventions, potential/pH diagrams, Faraday's Law, mixed potential theory
Direct & two stage attack, electrochemical attack, environment conditioning,
Corrosion in engineering applications:
Corrosion in sulfur bearing solutions, soils, acids, and concrete. high temperature corrosion, Material transport, pumping, filtration, condensation, boiling, riveting, welding, high temperature environments etc.
Measurement of corrosion:
Tafel extrapolation & polarization resistance, instrumental methods and commercial corrosion monitoring devices
Methods and techniques for corrosion resistance:
Resistance to corrosion by

- proper selection of material
- isolation of corrosion prone materials from destructive environment by coating and inhibition.
- Technologies of anodization, enamelling, rubber lining, glass lining, refractory lining, painting and other surface protective measures.
- Use of materials like carbon, graphite and polymers for corrosion resistance

Economic considerations for competitive corrosion prevention/inhibition techniques.

Books Recommended:

1. Jones D.A., Principles and prevention of Corrosion, Prentice Hall Inc., 1996
2. Uhling, H.H., Corrosion Control, John Wiley & Sons, 1971
3. Roberge P. R., Handbook of Corrosion Engineering, McGraw Hill, 2000
4. Butler, G. & Ison, HCK, Corrosion & its Prevention in Waters, Leonard Hill - London, 1966
5. Maslow, P., Chemical Materials for Construction, Structures publishing co. 1974
6. Rajagopalan, K S., Corrosion and its Prevention, Chemical Engineering Education Development Centre, IIT Madras, 1975

ELECTIVE-II
MT CH413 ANALYTICAL TECHNIQUES

Objective: This course is aimed at imparting the information and knowledge about the advanced analytical techniques available for the analysis of any substance.

Complexometric titrations:
Complexes-formation constants; chelates – EDTA, Chelon Effect, EDTA equilibria, effect of pH on EDTA equilibria, EDTA titration curves, endpoint – detection and indicators; Importance of complexometric titrations.
Solvent extraction:
Distribution law, extraction process, factors effecting extraction, technique for extraction, quantitative treatment of solvent extraction equilibria, classification of solvent extraction systems. Advantages and applications of solvent extraction.
Chromatographic techniques:
Introduction to chromatography, principles, classification of chromatographic techniques, thin layer and paper chromatography – principle and technique.
Column Chromatography – Factors affecting column efficiency and applications.
Gas – liquid chromatography – theory, instrumentation and applications.
HPLC – instrumentation, method, column efficiency and applications.
Spectroscopic techniques:
IR spectroscopy:
Origin, rigid rotor model, harmonic oscillator model, principle, modes of vibrations of atoms in polyatomic molecules, instrumentation, selection rules, identification of organic compounds on the basis of infrared spectra.
UV-Vis spectroscopy:
Introduction, laws of absorption, origin of spectra, types of transitions, selection rules, identification of organic compounds using UV-VIS spectroscopy.
NMR:
Principle, chemical shift, spin-spin coupling shift reagents, instrumentation, spectra and molecular structure, identification of organic compounds on the basis of NMR.
Thermo-analytical techniques:
Principle, classification of methods.
TGA – Instrumentation, factors affecting results and analysis of data, applications.
DTG – Instrumentation, analysis of data and applications.
DTA – Principle, Instrumentation and applications.

Books Recommended:

1. Skoog, D. A. & West D. M., Principles of Instrumental Analysis, 5th Edition, Saunders College Publishers, USA.
2. Skoog, D. A. & West D. M., Fundamentals of Analytical Chemistry, 7th Edition, Saunders College Publishers, USA.
3. Willard H., Meritt L., Dean J. & Settle F., Industrial Methods of Analysis, 7th Edition, Wadsworth Publishing Company; 1988
4. Galen W. Ewing., Industrial Methods of Chemical Analysis, 5th Edition, McGraw Hill, 1985
5. Silverstein R. M. & Webster F.X., Spectrometric identification of Organic Compounds, 6th Edition, John Wiley and Sons, Inc., USA

ELECTIVE-II
MT CH414 ADVANCED ENERGY TECHNOLOGY

Objective: The objective of this course is to impart the knowledge of advances in energy sector and the technologies thereof.

Energy classification, sources, utilization, economics and terminology
Important sources of energy:
Biomass Fuels, Fossil Fuels, Nuclear Fuels, Solar Energy.
Production of thermal energy:
Conversion of Mechanical Energy, Electrical Energy, Electromagnetic Energy, Chemical Energy and Nuclear Energy.
Fossil fuel system:
Fluid Moving System, Combustion Methods and System, Stream Generation.
Nuclear power reactor system
Production of energy from biomass:
Gasification, Pyrolysis and Combustion Technology.
Energy storage:
Storage of Mechanical, Electrical, Chemical, Nuclear and Thermal Energy.

Books Recommended:

1. Archie W. C. Jr., Principles of Energy Conversion, 2nd Ed., McGraw Hill Inc. Publication, 1991.
2. Rai G. D., Non-Conventional Energy Sources, Khanna Publishers
3. Ramesh R., Kumar U. K., Anandakrishnan M., Renewable Energy Technologies: Ocean Thermal Conversion and Other Sustainable Energy Options, Narosa Pub., 1997
4. Desai Ashok V, Non-Conventional Energy, Wiley Eastern
5. Sarkar Samir, Fuels and Combustion, 2nd Ed., Orient Longman, 2003.
6. Rao, S., Parulekar, B.B., Energy Technology – Non-conventional, Renewable & Conventional, 3rd Edition, Khanna Publishers, 2007