M. TECH. (CHEMICAL ENGINEERING)
Harcourt Butler Technological Institute, Kanpur
Study and Evaluation Scheme
[Effective from the Session 2014-15]

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

S. No.	Course Code	Subject	Periods			Evaluation Scheme			End Sem Exam	Subject Total	Credits
						Sessional Exam.					
			L	T	P	CT	TA	Total	Exam		
Theory Subjects											
1	QCH101	Advanced Mathematical Methods in Chemical Engg.	3	1	0	30	20	50	100	150	4
2	QCH102	Advanced Chemical Engineering Thermodynamics	3	1	0	30	20	50	100	150	4
3	QCH103	Advanced Chemical Reaction Engineering	3	1	0	30	20	50	100	150	4
4	QCH104-107	Elective - I	3	1	0	30	20	50	100	150	4
		Total								600	16

Elective - I
QCH104 Air Pollution Monitoring and Control
QCH105 Safety Hazard and Risk Analysis
QCH106 Instrumental Methods of Analysis
QCH107 Advanced Petroleum Refining

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

S. No.	Course Code	Subject	Periods			Evaluation Scheme			End Sem Exam	Subject Total	Credits
						Sessional Exam.					
			L	T	P	CT	TA	Total	Exam		
Theory Subjects											
1	QCH201	Advanced Transport Phenomena	3	1	0	30	20	50	100	150	4
2	QCH202	Advanced Separation Processes	3	1	0	30	20	50	100	150	4
3	QCH203	Optimization of Chemical Processes	3	1	0	30	20	50	100	150	4
4	QCH204-207	Elective - II	3	1	0	30	20	50	100	150	4
		Total								600	16

Elective - II
QCH204 Advanced Process Control
QCH205 Statistical Design of Experiments
QCH206 Design of Piping System for Chemical Plants
 QCH207 Water Pollution Monitoring and Control

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

S. No.	Course Code	Subject	Periods			Evaluation Scheme			End Sem Exam	Subject Total	Credits
						Sessional Exam.					
			L	T	P	CT	TA	Total			
Theory Subjects											
1	QCH301	Modeling and Simulation of Chemical Processes	3	1	0	30	20	50	100	150	4
2	QCH302-305	Elective-III	3	1	0	30	20	50	100	150	4
3	QCH306	Seminar	-	-	2	-	-	100	-	100	4
4	QCH307	Dissertation	-	-	8	-	50	50	-	50	4
		Total								450	16

Elective – III
QCH302 Principles of Polymer Engineering
QCH303 Solar Thermal Energy Storage
QCH304 Nano Technology
QCH305 Natural Gas Engineering

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

S. No.	Course Code	Subject	Periods			Evaluation Scheme			Project Evaluation	Subject Total	Credits
						Sessional Exam.					
			L	T	P	CT	TA	Total			
Theory Subjects											
1	QCH401	Dissertation	18			150	150	200		350	16
		Total								350	16

M. TECH. (CHEMICAL ENGINEERING) (Part Time)
Harcourt Butler Technological Institute, Kanpur
Study and Evaluation Scheme
[Effective from the Session 2014-15]

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

S. No.	Course Code	Subject	L	T	P	CT	TA	Total	End Sem Exam	Subject Total	Credits
Theory Subjects											
1	QCH101	Advanced Mathematical Methods in Chemical Engg.	3	1	0	30	20	50	100	150	4
2	QCH102	Advanced Chemical Engineering Thermodynamics	3	1	0	30	20	50	100	150	4
3	QCH103	Advanced Chemical Reaction Engineering	3	1	0	30	20	50	100	150	4
		Total								450	12

(Periods = L, T, P; Evaluation Scheme — Sessional Exam. = CT, TA, Total; End Sem Exam)

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

S. No.	Course Code	Subject	L	T	P	CT	TA	Total	End Sem Exam	Subject Total	Credits
Theory Subjects											
1	QCH201	Advanced Transport Phenomena	3	1	0	30	20	50	100	150	4
2	QCH202	Advanced Separation Processes	3	1	0	30	20	50	100	150	4
3	QCH203	Optimization of Chemical Processes	3	1	0	30	20	50	100	150	4
		Total								450	12

(Periods = L, T, P; Evaluation Scheme — Sessional Exam. = CT, TA, Total; End Sem Exam)

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

S. No.	Course Code	Subject	Periods			Evaluation Scheme			End Sem Exam	Subject Total	Credits
						Sessional Exam.					
			L	T	P	CT	TA	Total	Exam		
Theory Subjects											
1	QCH301	Modeling and Simulation of Chemical Processes	3	1	0	30	20	50	100	150	4
2	QCH308-311	Elective – I	3	1	0	30	20	50	100	150	4
		Total								300	8

Elective - I
QCH308 Air Pollution Monitoring and Control
QCH309 Safety Hazard and Risk Analysis
QCH310 Instrumental Methods of Analysis
QCH311 Advanced Petroleum Refining

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

S. No.	Course Code	Subject	Periods			Evaluation Scheme			End Sem Exam	Subject Total	Credits
						Sessional Exam.					
			L	T	P	CT	TA	Total	Exam		
Theory Subjects											
1	QCH402-405	Elective-II	3	1	0	30	20	50	100	150	4
2	QCH 406	Seminar						150		150	4
		Total								300	8

Elective - II
QCH402 Advanced Process Control
QCH403 Statistical Design of Experiments
QCH404 Design of Piping System for Chemical Plants
QCH405 Water Pollution Monitoring and Control

M. Tech. (Chem. Engg.)   **Year III, Semester - V**

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	QCH501-504	Elective-III	3	1	0	30	20	50	100	150	4
2	QCH 505	Dissertation			6		50	50		50	8
		Total								200	

Elective – III
QCH501 Principles of Polymer Engineering
QCH502 Solar Thermal Energy Storage
QCH503 Nano Technology
QCH504 Natural Gas Engineering

M. Tech. (Chem. Engg.)   **Year III, Semester –VI**

S. No.	Course Code	Subject	Periods			Evaluation Scheme				Subject Total	Credits
						Sessional Exam.			Project Evaluation		
			L	T	P	CT	TA	Total			
Theory Subjects											
1	QCH 601	Dissertation	12				150	150	150	300	12
		Total								300	12

SYLLABUS
M. TECH CHEMICAL ENGINEERING

QCH 101   ADVANCED MATHEMATICAL METHODS IN CHEMICAL ENGINEERING

UNIT I
Ordinary Differential Equations, Separable equations, Equations made separable by change of variables, Homogeneous Equations, Equations with first order and first degree with linear coefficients, Exact equations, Linear equation of first order, Bernoulli's equation, Other integrating factors, Integration of Exact equations, Equations of first order and higher degree, Clairaut's equation, Singular solutions, Equations with missing terms, General properties of Linear equations, Linear equations with constant coefficients, Determination of the complementary function, exponential functions, Determination of the particular integral, the Euler equation, Simultaneous Linear Differential equations.

UNIT II
Power series method, theory of the power series method, Legendre's equation, Legendre's Polynomials, Frobenius Method.

UNIT III
Bessel's equation, Bessel Functions $J_v(x)$, Bessel Functions $J_v(x)$ for any $v \geq 0$. Gamma Function, Solution $J_{-v}(x)$ of the Bessel Equation, Backbones of Bessel's Theory, $J_v(x)$ with $v = \pm 1/2, \pm 3/2, \pm 5/2$.

UNIT IV
Definition of matrix, Some special definitions and operations involving matrices, Determinants, Theorems on determinants, Inverse of a matrix, Orthogonal and unitary matrix. Orthogonal vectors, System of linear equations, Systems on n equations with n unknowns, Cramer's Rule, Eigen values and eigen vectors.

UNIT V
Partial Differential equations, some definitions involving partial differential equations, Linear partial differential equations, some important partial differential equations, Method of solving boundary-value problems, General solutions, Separation of variables, Laplace transform nethods.

BOOKS:
1. Mickley, Reid and Sherwood, "Applied Mathematics in Chemical Engineering", Tata McGraw Hill, New Delhi (1981).
2. E. Kreyszig, "Advanced Engineering Mathematics", 8th edition, John Wiley and Sons (1999).
3. M. R. Spiegel, "Advanced Mathematics for Engineers and Scientists", Schaum Outline Series, McGraw Hill, (1971).

QCH 102   ADVANCED CHEMICAL ENGINEERING THERMODYNAMICS

UNIT 1
Introduction to Thermodynamics and statistical mechanics, Internal energy, First law of thermodynamics, Intensive and extensive properties Concept of entropy, Second law of thermodynamics : Extremum principles of Energy and Entropy., Legendre transforms of energy and reformulation of second law in terms of the Legendre transforms, Maxwell relations, Maximum work theorem

UNIT II
Conditions of phase equilibrium and its applications, Gibbs Duhem relations, Gibbs phase rule, Conjugate variables, Criteria for stability and its implications.
 Chemical reactions: condition of equilibrium for a reaction mixture, Equilibrium constants, Heat of reaction Thermodynamics of fluid-fluid interfaces: Dividing surface, surface excess quantities, condition of equilibrium at interfaces, Kelvin equation, Gibbs adsorption isotherm, Thermodynamics of fluid-solid interfaces: condition of equilibrium with respect to dissolution and growth of solids

UNIT III
Classical mechanics: Lagrangian formulation, Constants of motion, Hamilton's principle, and phase space, concept of statistical ensemble, Statistical independence of macroscopic bodies, Liouville equation, Measurements and ensemble averages Micro   canonical, canonical and Grand-canonical ensembles. Gibbs entropy formula and Boltzmann entropy formula, Partition functions, Fluctuations and stability

UNIT IV
Ideal gas: Analytical derivations of the partition functions of ideal gas in various ensembles and thermodynamic properties,Ideal solid: Analytical derivation of partition function, heat capacity, Non-ideal gases, Virial equation of state, Second virial coefficient, Liquids: Distribution functions, pair correlation function $g(r)$ and experimental measurement of $g(r)$ by diffraction, Mean-field theory and perturbation theory.

.**UNIT V**
Dilute solutions and colligative properties: Derivation of Raoults law, Henry's law, Van't Hoff's formula for osmotic pressure. Boiling point elevation, freezing point depression Introductory Quantum Statistical mechanics: Schrödinger Wave equation, Degeneracy, Partition functions. Ideal gas of polyatomic particles, Molecular partition functions, Einstein and Debye theory of perfect crystals
BOOKS:
   1. Herbert B. Callen, "Thermodynamics and an Introduction to thermo statistics", John Wiley and Sons, 1985.
   2. D. A. McQuarrie and J. D. Simon, "Molecular Thermodynamics", Viva Books Pvt. Ltd., 2004
   3. David Chandler, "Introduction to modern statistical mechanics", Oxford University Press, 1987.

QCH 103   ADVANCED CHEMICAL REACTION ENGINEERING

UNIT I
Kinetics of heterogeneous catalytic reactions, rate equations, model discrimination and parameter estimation.

UNIT II
Deactivating catalysts, mechanisms of catalyst deactivation, the rate and performance equations, design.

UNIT III
Mass Transfer and Reaction in a Packed bed, Stoichiometric table, Pressure drop in a Reactor, Ergun's equation, Flow through a packed bed.

UNIT IV
Types of multiphase reactors, mass transfer reactors, mass transfer equations, Interfacial surface area, mass transfer between phases, multiphase reactor equations, equilibrium between phases, membrane reactors, falling film reactors, bubble column reactors.

UNIT V
Falling film catalytic wall reactor, trickle bed reactors, multiphase reactors with catalysts, other multiphase reactors, reactor-separator integration, catalytic distillation, chromatographic reactors, iron ore refining, petroleum refinery.

BOOKS:

1. O. Levenspiel, "Chemical Reaction Engineering, Wiley India, (1998).
2. G. F. Froment and K. B. Bischoff, "Chemical Reactor Analysis and Design", John Wiley and Sons, (1979).
3. H. S. Fogler, "Elements of Chemical Reaction Engineering", 2nd edition, Prentice-Hall, (2000).
4. Lanny D. Schmidt, "The Engineering of Chemical Reactions", 2nd edition, Oxford University Press, (2010).

QCH 104/308   AIR POLLUTION MONITORING AND CONTROL

UNIT –I

Air Pollutants - Sources and Classification, Effects of air pollutants on physical environment and living systems, Air pollution – Standards and acts, Global consideration of air pollution: Green house effect, Chemical reactions in a contaminated atmosphere, urban air pollution, acid rain.

UNIT –II

Air pollution monitoring, Sampling and analysis of gaseous and particulate air pollutants, Air pollution control by dilution of contaminants in atmosphere, Atmospheric stability, Lapse rate and Inversion, Meteorological aspects of air pollution: Dispersion models-Gaussian dispersion model, Plume behavior, Stack design.

UNIT –III

Air Pollution Control at Source - Source Correction methods - Particulate emission control: Dry techniques industrial dust collectors, cyclone and multiclone separators, bag filters, electrostatic precipitators, relative merits and demerits, choice of equipments, design aspects and economics.

UNIT –IV

Wet techniques for controlling particulate pollutants: wet dust collection, wet cyclone, empty scrubber, column (packed) scrubber, venturi scrubber, suitability, merits and demerits, design aspects and economics.

UNIT –V

Techniques for Controlling Gaseous Pollutants: Absorption - absorbents and absorbers (plate towers and packed towers), Adsorption, Condensation - direct and contact, Combustion - Thermal, flare and catalytic. Pollution control from automobiles - three way catalyst and catalytic converters.

BOOKS:
1. Peavy H.S., Rowe D.R. and Tchobanoglous G., Environmental Engineering, McGraw-Hill edition, 1985
2. M.N. Rao and H.V.N. Rao, "Air Pollution", Tata McGraw Hill, New Delhi, 1993.
3. Rao C.S. "Environmental Pollution Control Engineering," 2nd Edition, New Age International Publishers, 2006.
4. P. Sincero and G.A. Sincero Environmental Engineering: A Design Approach, PrenticeHall of India pvt Ltd, N.Delhi.1996
5. Y.B.G. Verma, H. Brauer," Air Pollution Control Equipments", Springer, Berlin, 1981

QCH105/309   SAFETY HAZARD AND RISK ANALYSIS

UNIT I
Industrial safety, Industrial hygiene and safety aspects related to toxicity, noise, pressure, temperature, vibrations, radiation etc. Explosions including dust, vapor, cloud and mist explosion.

UNIT II
Elements of safety, safety aspects related to site, plant layout, process development and design stages, identification of hazards and its estimation, risk, risk analysis and assessment methods; fault free method, event free method, scope of risk assessment, controlling toxic chemicals and flammable materials.

UNIT III
Toxic substances and degree of toxicity, its estimation, their entry routes into human system, their doses and responses, control techniques for toxic substances exposure, use of respirators, ventilation systems.

UNIT IV
Prevention of losses, pressure relief, provision for fire fighting, release of hazardous materials from tanks, pipes through holes and cracks, relief systems : types and location of relief's.

UNIT V
Handling, transportation and storage of flammable liquids, gases, and toxic materials and wastes, regulation and legislation, government role, risk management routines, emergency preparedness, disaster planning and management.

BOOKS:
1. Daniel A. Crowl and Joseph F. Louvar, Chemical Process Safety: Fundamentals with applications, Prentice Hall, Inc, 1990.
2. F. P. Lee's, Loss prevention in the process Industries, Volume 1 and 2 Butterworth, 1983.
3. Hoboken, N. J., Guidelines for Chemical Process Quantitative Risk Analysis, Wiley-Interscience, 2000.
4. R. W. King and J. Magid, Industrial Hazards and Safety Handbook, Butterworth, 1982.
5. G. L. Wells, Safety in Process Plant Design, John Wiley and Sons Inc., 1980.
6. Fawcett, H.H. and W.S. Wood, Safety and Accident Prevention in Chemical Operations, 2nd Edition, Wiley-Interscience, New York, 1982.

QCH106/310   INSTRUMENTAL METHODS OF ANALYSIS

UNIT I
Introduction to spectroscopic techniques, UV - Vis Spectrophotometry, Nephelometry, Turbidimetry, Reflectance Spectrometry, Fluorescence, Phosphorescence Spectrometry.

UNIT II
Flame Emission and Atomic Absorption Spectrometry, Electro thermal AAS, Hydride generation AAS and Flameless mercury analysis. Inductively Coupled Plasma Atomic Emission Analysis

UNIT III
Infrared spectrometry, Introduction to X-Ray techniques, XRF. Introduction to NMR spectroscopy and mass spectrometry.

UNIT IV
Electro analytical techniques: Potentiometry, Voltametry, Polarography Chromatographic analysis: GC, LC

UNIT V
Chromatographic analysis, HPLC, Hyphenated techniques. Errors, statistical methods of data handling

BOOKS:
1. H.Willard, L.L Meritt, J.A Dean and F.A.Settle: Instrumental Methods of Analysis, 6th Edition, CBS.
2. A.I.Vogel: Quantitative Inorganic Analysis, 5th Edition, ELBS.
3. G.W. Ewing: Analytical Instrumentation Hand book, Marcell Dekker, New York, 1990

QCH107/311   ADVANCED PETROLEUM REFINING

UNIT I
Petroleum Exploration Production and Refining of Crude oils, Crude oils: Characteristics and constituents of crude oils, Classification of crude oils.

UNIT II
Quality Control of Petroleum Products. Classification of laboratory tests, distillation, vapour pressure, flash and fire points, octane number, performance number, cetane number, aniline point, viscosity index, calorific value, smoke point, char value, viscosity, viscosity index, penetration tests, cloud and pour points, drop point of grease, melting and settling points of wax, softening point of Bitumen, induction period of gasoline, thermal stability of jet fuels, gum content, Total Sulphur, Acidity and Alkalinity,, Copper Strip Corrosion Test, Silver – Strip Corrosion Test for ATF, Ash, Carbon Residue (Conradson method, Ramsbottom method) Colour, Density and Specific gravity, Refractive index of hydrocarbon liquids, water separation index (modified) (WSIM), ductility.

UNIT III
Petroleum Products: Composition, Properties & Specification of LPG, Naphthas, motor spirit, Kerosine, Aviation Turbine Fuels, Diesel Fuels, Fuel Oils, Petroleum Hydrocarbon Solvents, Lubricating oils (automotive engine oils, industrial lubricating oils electrical insulating oils, Jute Batching oils, white oils, steam turbine oils, metal working oils, etc.) Petroleum Waxes Bitumens, Petroleum coke. **Crude Oil Distillation**: Desalting of crude oils, Atmospheric distillation of crude oil, Vacuum distillation ofatmospheric residue.Thermal Conversion Process: Thermal Cracking Reactions, Thermal Cracking, Visbreaking, (Conventional Visbreaking and Soaker Visbreaking) Coking (Delayed Coking, Fluid Coking, Flexicoking), Calcination of Green Coke.
UNIT IV
Catalytic Converson Process: Fluid catalytic cracking; Catalytic reforming; Hydrocracking Catalytic Alkylation, Catalytic Isomerization; Catalytic Polymerization.
Finishing Process: Hydrogen sulphide removal processes; Sulphur conversion processes; Sweetening processes (Caustic treatment, Solutizer process; Doctor treating process; Copper chloride sweetening,; Hypochlorite sweetening ;Air and inhibitor treating process; Merox processes;Sulphuric acid treatment; Clay treatment); Solvent extraction processes (Edeleanu process, Udex process, Sulfolane process), Hydrotreating processes.
Unit V
Lube Oil Manufacturing Process: Evaluation of crude oils for lube oil base stocks, Vacuum distillation, Solvent deasphalting Solvent extraction of lube oil fractions (Furfural, NMP and Phenol), Solvent dewaxing, Hydrofinshing, Manufacture of petroleum waxes (Wax sweating, Solvent deoiling)
Manufacture of Bitumens: Selection of crude oil, Methods of manufacture of bitumens, (Distillation, Solvent precipitation, Air blowing).
BOOKS:
1. Ram Prasad, Petroleum Refining Technology, Khanna Publishers, Delhi (2000)
2. Nelson, W.L., Petroleum Refining Engineering, McGraw Hill

QCH 201   **ADVANCED TRANSPORT PHENOMENA**

UNIT 1
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.

UNIT II
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, Time derivatives, The equation of continuity, the equation of motion, the equations of change in curvilinear, co-ordinates, use of the equations of change to set up steady flow problems.

UNIT III
Unsteady state momentum transport, Flow near a wall suddenly set in motion, Momentum transport phenomena in turbulent flow. Definitions of friction factors, friction factor for flow in tubes, for flow around spheres, for packed bed column.

UNIT IV
shell energy balance, boundary conditions, Heat conduction with an electrical heat source, Heat conduction in a cooling fins, heat conduction with exothermic reactions. Temperature distributions with more than one independent variables: Unsteady state heat conduction in solids, Boundary layer theory.

UNIT V

Definitions of concentrations, velocities & mass fluxes, Fick's law of diffusion, Temperature & pressure dependence of mass diffusivity, Maxwell's law of diffusion.shell mass balance, boundary conditions, diffusion through a stagnant gas film. Diffusion with heterogeneous chemical reaction, Diffusion with homogeneous chemical reaction, Diffusion in to a falling liquid film.

 BOOKS:
 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

QCH 202 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

Absorption with chemical reaction; Enhancement factor; Simultaneous diffusion and chemical reaction near an interface – Film theory, Penetration theory, Surface renewal theory for a first-order irreversible reaction; Effect of reversibility of the chemical reaction on the mass-transfer rate; Computation of reaction effect for a few chemical situations – absorption of CO_2 and H_2S from a gas stream into aqueous solution of KOH etc.

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.

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 permeabilities 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

Ultrafiltration membrane processes – Types of equipment, flux equation, effects of processing variables

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).

QCH 203   OPTIMIZATION OF CHEMICAL PROCESSES

UNIT I
Introduction to process optimization; formulation of various process optimization problems and their classification, Basic concepts of optimization-convex and concave functions, necessary and sufficient conditions for stationary points.

UNIT II
Optimization of one dimensional functions, unconstrained multivariable optimization-direct search methods. Bracketing methods: Exhaustive search method, Bounding phase method Region elimination methods: Interval halving method, Fibonacci search method, Golden section search method. Point-Estimation method: Successive quadratic estimation method. Indirect first order and second order method. Gradient-based methods: Newton-Raphson method, Bisection method, Secant method, Cubic search method. Root-finding using optimization techniques.

UNIT III
Multivariable Optimization Algorithms: Optimality criteria, Unidirectional search, direct search methods: Evolutionary optimization method, simplex search method, Powell's conjugate direction method. Gradient-based methods: Cauchy's (steepest descent) method, Newton's method. Constrained Optimization Algorithms: Kuhn-Tucker conditions, Transformation methods: Penalty function method, method of multipliers, Direct search for constraint minimization: Variable elimination method, complex search method.

UNIT IV
Linear Programming: Graphical solution, Primal Simplex method, Artificial starting solution, Dual Simplex method, Primal-Dual relationship, Duality, Sensitivity analysis. Revised Simplex method.

UNIT V
Transportation Problem, Optimization of staged and discrete processes. Dynamic programming, Specialized & 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   T.F.Edgar and D.M.Himmelblau, "Optimization of Chemical Processes", Mc Graw Hill, International editions, chemical engineering series, 1989.
2   G.S. Beveridge and R.S. Schechter, "Optimization theory and practice", Mc Graw Hill, Newyork, 1970.
3.   Hamdy A. Taha, " Operation Research", Pearson, 2008
4.   Rekllitis, G.V., Ravindran, A., and Ragdell, K.M., Engineering Optimization-Methods and Applications, John Wiley, New York, 1983.

QCH204/402   **ADVANCED PROCESS CONTROL**

UNIT I
Introduction to process dynamics (first and second order process), Block diagram preparation of control system, various modes of control action, Stability, Characteristic equation, Routh-Hurwitz criterion for stability. Root locus Analysis, Frequency response, Bode stability criterion, Bode diagrams, Nyquist stability criterion, Nyquist plots, Frequency response of closed loop systems

UNIT II
Outline of the design problems. Simple Performance criteria, Time-integral performance criteria, Selection of the type of feedback controllers. Designing of Feedback Controllers by Frequency Response Techniques. Gain and Phase margins, Controller tuning, Zeigler – Nichols Tuning technique, Cohen and Coon tuning method, Smith Predictor for dead-time compensation

UNIT III
Cascade control, Design of Cascade controllers, Various types of selective control-Autioneering and Override control, Split range control, Feed forward control, Ratio control

UNIT IV
Adaptive and inferential control, Concept of discretization and Z-transforms, Introduction to digital control

UNIT V
Control configuration for multi-input and multi-output processes, State space representation of physical systems, Interaction and decoupling

BOOKS:
1. Coughnower, "Process Systems Analysis and Control". McGraw Hill, Singapore, Second Edition, 1991.
2. George Stephanopoulose, **"**Chemical Process Control, An Introduction to Theory and Practice", Prentice Hall of India, New Delhi 1999.
3. W. L. Luyben, "Process Modeling, Simulation and Control for Chemical Engineers", McGraw Hill Singapore, 1990.

QCH205/403   STATISTICAL DESIGN OF EXPERIMENTS

UNIT I
Introduction to statistics for engineers: 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)

UNIT II
Design and analysis of experiments: 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).

UNIT III
Orthogonal second order design (Box Benken design), D-optimality, B_k-designs and Hartleys second order design.
Statistical analysis: Determination of experimental error, Significance of the regression coefficients, Lack of fit of regression models

UNIT IV
Experimental optimization of research subject: Problem of optimization, Gradient optimization method, canonical analysis of response surface.

UNIT V
**Mixture design `composition-property:** Screening design `composition-property', Simplex lattice design, Scheffe simplex lattice design, Simplex centroid design, Extreme vertices design, D-optimal design, Draper-Lawrence design, Factorial experiments with mixture, Full factorial combined with mixture design

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

QCH206/404   DESIGN OF PIPING SYSTEM FOR CHEMICAL PLANTS

UNIT I
Fundaments of fluid flow through pipes-Calculation of pressure drop for Newtonian & non-Newtonian fluids, incompressible & compressible fluids and two-phase flow,

UNIT II
Calculation of Economic pipe diameter, insulation thickness, equivalent length, Slurry transport and pipelines

UNIT III
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

UNIT IV
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

UNIT V
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

QCH207/405   WATER POLLUTION MONITORING AND CONTROL

UNIT I
Water Pollutants, Effects, Monitoring and Quality standards: Pollution of water and soil, effect of pollutants on environment and health, monitoring water, pollution, water pollution laws and minimum national standards, monitoring, compliance with standards, Latest norms for effluent treatment.

UNIT II
Water Pollution Sources, Analysis and Methods of control: Water pollution sources and classification of water pollutants - Wastewater sampling and analysis. Treatment of water-pollution: BOD, COD of wastewater and its reduction – Fundamentals of Anaerobic digestion and Aerobic digestion.

UNIT III
Wastewater Treatment Plant Design: Physical unit operations: Screening, Flow equalization, sedimentation etc., Chemical Unit Processes: chemical precipitation, dis-infection, color removal by adsorption Biological unit processes: Aerobic suspended - growth treatment processes, aerobic attached growth treatment processes, anaerobic suspended - growth treatment processes,Anaerobic attached-growth treatment processes.

UNIT IV

Advanced Wastewater and Water Treatment: Carbon adsorption - Ion exchange- Membrane processes - Nutrient (nitrogen and phosphorus) removal - Design of plant for treatment and disposal of sludge

UNIT V

Water pollution legislation and regulation. Schemes for treatment of some typical industrial wastes – pulp and paper, sugar, distillery, dairy, fertilizer, refinery etc.

BOOKS:

1. C.S. Rao, "Environmental Pollution Control Engineering", Wiley 2nd Edition, New Age International Publishers, 2006.
2. S.P. Mahajan, "Pollution Control in Process Industries", Tata McGraw Hill, New Delhi, 1985
3. P. Sincero and G.A. Sincero, Environmental Engineering: A Design Approach Prentice Hall of India pvt Ltd, N.Delhi.1996
4. Tchbanoglous and F.L. Burton, Metcalf and Eddy's Wastewater Treatment- Disposal And Reuse (Third Ed.), TMH publishing Co Ltd, N. Delhi

QCH 301 MODELING AND SIMULATION OF CHEMICAL PROCESSES

UNIT I
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.

UNIT II
Mathematical models of heat-transfer equipments: Double pipe heat exchanger, Shell & tube heat exchangers, Evaporators, Fired heaters, Partial condensers

UNIT III
Mathematical models of mass-transfer equipments: Batch and continuous distillation columns, Reactive distillation columns, packed absorption columns, Dehumidifiers

UNIT IV
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.

UNIT V
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. Luyben, W.L., "Process Modeling, Simulation, and Control for Chemical Engineering", Wiley.
2. M.M. Denn, "Process Modelling", Wiley, New York, (1990).
3. Hussain Asghar, "Chemical Process Simulation", Wiley Eastern Ltd., New Delhi, (1986)
4. C.D. Holland and A.I. Liapis, "Computer Methods for Solving Dynamic Separation Problems", McGraw Hill, (1983).
5. C.D. Holland, "Fundamentals of Modelling Separation Processes", Prentice Hall, (1975)
6. S.M. Walas, "Modelling with Differential Equations in Chemical Engineering", Butterworth, (1991)

QCH302/501   PRINCIPLES OF POLYMER ENGINEERING

UNIT I
Addition polymers, Condensation polymers, Copolymers, Cross-linked polymers, Molecular symmetry and the tendency to form crystals, Distribution of relative molecular mass, Structure of the crystal, Crystal shape, Crystallinity, Crystallization and melting, the glass transition temperature, Molecular conformation in the amorphous polymer, the freely jointe chain, the Gaussian chain, Molecular orientation.

UNIT II
Structure of an ideal rubber, Entropy elasticity, elasticity of a network, Stress-strain relationship, Engineering rubbers, The nature of viscoelasticty, Creep, Stress relaxation, Dynamic properties, Theory of linear viscoelasticity, Polymer selection:stiffness.

UNIT III
Yielding, Crazing, Linear elastic fracture mechanics, Elastic-plastic fracture mechanics, Brittle fracture of polymer, rubber toughening, Reinforced plastics, Forming of reinforced plastics, the mechanics of fibre reinforcement, Reinforced rubbers.

UNIT IV
The flow properties of polymer melts, Cooling and solidification, Extrusion, Injection moulding, Compression and transfer moulding.

UNIT V
Materials selection, Designing for manufacture, Designing for stiffness, Designing for strength, Case Histories.

BOOKS:
1. N. G. McCrum, C. P. Buckley and C. B. Bucknall, Principles of Polymer Engineering, 2nd Edition, Oxford University Press, (1997).

QCH303/502   SOLAR THERMAL ENERGY STORAGE

UNIT I
Importance and modes of energy storage; Size and duration of storage; Applications-Stationary, transport; Quality of energy and modes of energy storage; Thermal energy storage, Mechanical energy storage, Electrical and magnetic energy storage, Chemical energy storage

UNIT II
Sensible heat storage: Basics, Sensible heat storage media; Well-mixed liquid storage; Stratified liquid storage; Containers for water storage; Packed bed storage system

UNIT III
Latent heat or phase change thermal energy storage: Basics of latent heat storage-Heat of fusion, Employment of latent heat storage system; Liquid-solid transformation; Phase change materials (PCM); Selection of PCM; Storage in salt hydrates, Prevention of incongruent melting and thermal cycling; Storage in paraffins; Heat transfer in PCM; Heat exchange arrangement and containment of PCM; Storage in PCM undergoing solid-solid transition; Heat of solution storage and heat exchangers.

UNIT IV
Chemical Energy Storage: Selection criterion-Thermodynamic considerations, Reversibility, Reaction rates, Controllability, Ease of storage, Safety, Availability and cost, Product separation, Catalyst availability and lifetime; Energy storage in thermal dissociation type of reactions; Methane based reactions; Heat transformations and chemical heat pumps; Three step approach; Energy storage by adsorption

UNIT V
Long-term energy storage; Solar ponds-Construction, Working, Applications; Energy storage in aquifers; High temperature heat storage; Testing of thermal energy storage systems.

BOOKS:
1. H.P.Garg, S.C.Mullick and A.K.Bhargava, Solar Thermal Energy Storage, D.Reidel Publishing Company, Dordrecht ((1985).

QCH304/503   NANO TECHNOLOGY

UNIT I
Introduction: Introduction to Nanotechnology - its emergence and challenges, Nanomaterials and its classification, Properties of individual nanoparticles, Methods of synthesis, Reactivity of nanoparticles, List of stable carbon allotropes extended, Synthesis of carbon buckyballs, fullerenes, metallofullerenes, solid C60, bucky onions, nanotubes, nanowires, nanocones, Carbon nanostructures

UNIT II
Synthesis procedures of nanomaterials: Methods of Synthesis of Nanomaterials: Bottom-up (building from molecular level) and top-down (breakdown of microcrystalline materials) approaches. Manufacturing of nanoscale materials: Chemical vapor deposition of carbon nano tubes, Plasma deposition of ultra thin functional films on nano materials, Solution based Synthesis of Nanoparticles, Vapour Phase Synthesis & Synthesis with framework, Nanolithography, Dip Pen Lithography. Artificially Layered Materials: Quantum Well, Quantum Dots, Super lattices & Layered Structures.

UNIT III
Characterizations of nanomaterials : Top down approach vs Bottom up approach, Optical Microscopy, Electron Microscopy, Secondary electron scattering, back scattering, Scanning Probe Microscopes, Focussed Ion Beam Technique, X-ray imaging, Transmission Electron Microscope (TEM), Scanning Probe Microscope (SPM)-Atomic Force Microscope (AFM), Scanning Tunneling Microscope (STM).

UNIT IV
Nano colloids and Chemistry : Surface Tension and Interfacial Tension, Surfaces at Equilibrium, Surface Tension Measurement, Contact Angles, Colloidal Stability, Electrical Phenomena at Interfaces, Vander Waals Forces between Colloidal Particles, Photocatalysis Nanostructured materials, Self-assembly and Catalysis.

UNIT V
Commercial Processes for Nanotechnology and Chemical Engineering Applications:
Nanobiotechnology : Drug Delivery, Nanoclay, Nanocomposites, Surface coatings, Self cleaning Materials, Hydrophobic Nanoparticles, Biological nanomaterials, Nanoelectronics, Nanomachines & nanodevices, Nanohydrogel, Photocatalytic reactors, Nanoclay Synthesis, Polymer nanocomposite, Waste Water Treatment, Societal, Health and Environmental Impacts, Introduction to industries which produces commercial nanomaterials.
BOOKS:
1. G. Louis Hornyak, Joydeep Dutta, Harry F. Tibbals and Anil K. Rao, Introduction to NanoScience, CRC Press of Taylor and Francis Group, 2008
2. Pools C.P. and Owens F.J., Introduction to Nanotechnology, Wiley-Interscience, 2003
3. Bhusan B., Springer Handbook of Nanotechnology

QCH305/504   **NATURAL GAS ENGINEERING**

UNIT I
Introduction: Estimation of gas reserves and non-associated gas reserves.
Properties: Phase behaviour fundamentals, properties of natural gas, gas and liquid separation.

UNIT II
Natural Gas Hydrates: Natural gas hydrates, hydrate thermodynamics and formation kinetics, hydrate exploitation.

UNIT III
Gas Dehydration: Gas-water system, water content determination, glycol dehydration, solid bed dehydration.
Acid Gas Treating: Gas sweetening processes, solid bed adsorption, chemical and physical solvent processes, desulphurization, membrane separation.

UNIT IV
Gas Processing: Absorption, refrigeration, fractionation and design consideration, design procedures for absorbtion, adsorption and membrane separation .
UNIT V
Gas Hydrates: Determination of hydrate formation temperature/ pressure, condensation of water vapor, temperature drop due to gas expansion, thermodynamic inhibitors, kinetic inhibitors and anti agglomerates.
Gas Engineering: Steady state flow of gas through pipes,

Books:
1. William C. L., "Standard Handbook of Petroleum and Natural Gas Engineering", Vol. 2, 6th Ed., Gulf Publishing Company. 2001
2. Arnold K. and Steward M., "Surface Production Operations: Design of Gas Handling Systems and Functions", Butter Worth Heinemann. 1999
3. Molhatab S., Poe W. A. and Speight J. G., "Handbook of Natural Gas Processing and Transmission", Gulf Publishing Company2006
4. Kidney A. J. and Prvish W. R., "Fundamentals of Natural Gas Possessing", CRC. 2006