M. Tech. (Chemical Engineering)

First Semester:

Course Title	Course Code	Hours per week			Credits	Evaluation (Marks)						
						Theory			P/T			**Grand**
		Lectures (L)	Tutorials (T)	Practicals (P)		Int.	Ext.	Total	Int.	Ext.	Total	**Total**
Numerical methods and optimization in Chemical Engineering	CH 601	3	1	0	4	50	50	100	25	-	25	125
Advanced Chemical engineering Thermodynamics	CH 603	3	1	0	4	50	50	100	25	-	25	125
Advanced Transport Phenomena	CH 605	3	1	0	4	50	50	100	25	-	25	125
Chemic Engineering Lab-I	CH 607	0	0	4	2	-	-	-	20	30	50	50
Elective –I*		3	0	0	3	50	50	100	-	-	-	100
Elective – II*		3	0	0	3	50	50	100	-	-	-	100
	TOTAL	**15**	**3**	**4**	**20**	**250**	**250**	**500**	**95**	**30**	**125**	**625**

Total Contact Hours/Week=23 Total Credits = 20

Second Semester:

Course Title	Course Code	Hours per week			Credits	Evaluation (Marks)						
						Theory			P/T			**Grand**
		Lectures	Tutorials	Practicals		Int.	Ext.	Total	Int.	Ext.	Total	**Total**
Advanced Chemical Reaction Engineering	CH 602	3	0	0	3	50	50	100	-	-	-	100
Advanced Separation Methods	CH 604	3	1	0	4	50	50	100	25	-	25	125
Advanced Process Control	CH 606	3	1	0	4	50	50	100	25	-	25	125
Safety Health & Environment	CH 608	3	0	0	3	50	50	100	-	-	-	100
Chemical Engineering Lab-II	CH 612	0	0	4	2	-	-	-	20	30	50	50
Elective – III*		3	0	0	3	50	50	100	-	-	-	100
Seminar	CH 614	0	0	2	1	-	-	-	20	30	50	50
	TOTAL	**15**	**2**	**6**	**20**	**250**	**250**	**500**	**90**	**60**	**150**	**650**

Total Contact Hours/Week=23 Total Credits = 20

Third Semester:

Course Title	Course Code	Hours per week			Credit	Evaluation (Marks)						
						Theory			P/T			**Grand**
		Lectures	Tutorials	Practicals		Int.	Ext.	Total	Int.	Ext.	Total	**Total**
Dissertation Preliminaries	CH 701	-	-	16	8	-	-	-	100	150	250	250
Assignment	CH 703	-	-	4	-	-	-	-	-	-		
	TOTAL	**-**	**-**	**20**	**8**	**-**	**-**		**100**	**150**	**250**	**250**

Total Contact Hours/Week=20 Total Credits = 8

Fourth Semester:

Course Title	Course Code	Hours per week			Credit	Evaluation (Marks)						
						Theory			P/T			**Grand**
		Lectures	Tutorials	Practicals		Int.	Ext.	Total	Int.	Ext.	Total	**Total**
Dissertation	CH 702	-	-	24	12	-	-	-	160	240	400	400
	TOTAL	**-**	**-**	**24**	**12**	**-**	**-**	**-**	**160**	**240**	**400**	**400**

Total Contact Hours/Week=24 Total Credits = 12

Overall Contact Hours for M.Tech. = 90 and Overall Credits for M.Tech. = 60

List of Electives*

Sr. No.	Course Title	Hours per week			Credits
		L	T	P	
CH 610	Heterogeneous Catalysis	3	0	0	3
CH 620	Petroleum Refinery Engineering	3	0	0	3
CH 630	Non-conventional Energy	3	0	0	3
CH 650	Fluidization Engineering	3	0	0	3
CH 660	Nanotechnology	3	0	0	3
CH 670	Corrosion Engineering	3	0	0	3
CH 680	Computational Flow Modeling for Chemical Reactor Engineering	3	0	0	3
CH 690	Industrial Biotechnology	3	0	0	3
CH 700	Multiphase Reactor Design	3	0	0	3
CH 710	Polymer Engineering	3	0	0	3
CH 720	Electrochemical Reaction Engineering	3	0	0	3
CH 730	Process Intensification	3	0	0	3
CH 740	Rheology of Complex Fluids	3	0	0	3
CH 750	Interfacial Science and Engineering	3	0	0	3
CH 760	Computational Fluid Dynamics	3	0	0	3
CH 770	Nanomaterials Synthesis by Chemical Methods	3	0	0	3
CH 780	Multiphase Flow	3	0	0	3

* Electives will be offered depending on the teacher's availability and his/her current research interest. Students will opt for a given elective only once.

M. Tech. I (CH) Semester – I **L T P C**

CH 601: NUMERICAL METHODS AND OPTIMIZATION IN CHEMICAL ENGINEERING **3 1 0 4**

- **INTRODUCTION (3 hours)**
  Maximization and minimization problems- examples, Basic concept of optimization – Convex and concave functions, Necessary and sufficient conditions for stationary points, Degree of freedom.

- **FORMULATION (04 hours)**
  Economic objective function, Formulation of various process optimization problems and their classification.

- **OPTIMIZATION OF UNCONSTRAINED AND CONSTRAINED SEARCH (16 hours)**
  Numerical methods for optimization of one dimensional function, Unconstrained multivariable optimization direct search methods, Indirect first order and second order methods, Constrained multivariable optimization - necessary and sufficient conditions for constrained optimum.

- **NUMERICAL METHODS IN LINEAR PROGRAMMING AND APPLICATIONS (8 hours)**
  Geometry of linear programs, Basic solution methods, Simplex algorithm and its applications,

- **NUMERICAL METHODS IN NON- LINEAR PROGRAMMING WITH CONSTRAINTS AND ITS APPLICATIONS (6 hours)**
  Quadratic programming, Generalized reduced gradients methods, Successive linear and successive quadratic programming, Dynamic programming, Integer and mixed integer programming.

- **APPLICATION OF OPTIMIZATION IN CHEMICAL ENGINEERING (6 hours)**
  Optimization of staged and discrete processes, Optimal shell-tube heat exchanger design, Optimal pipe diameter, Optimal design of an Ammonia reactor.

- **NONTRADITIONAL OPTIMIZATION TECHNIQUES (2 hours)**
  Introduction and application areas.

(Total Contact Time: 45 Hours)

BOOKS RECOMMENDED

1. Edger T. F. and Himmelblau D. M., "Optimization of Chemical Process", McGraw-Hill, New York, 2001.
2. Beveridge G. S. and Schechter R. S., "Optimization Theory and Practice", McGraw-Hill, New York, 1970.
3. Rekllaities F. V., Ravindan A. and Ragsdell K. M., "Engineering Optimization Methods and Applications", John Willy, New York, 1983.
4. Rao S., "Engineering Optimization", New Age International, New Delhi, 1996.
5. Deb K., "Optimization for Engineering Design: Algorithms and Examples," Prentice-Hall of India, 1995.
6. Gupta S. K., "Numerical Methods for Engineers", New Age International, New Delhi, 1995.
7. Pushpavanam S., "Mathematical Methods in Chemical Engineering", Prentice-Hall of India Pvt. Ltd., New Delhi, 1998.

M.Tech. I (CH), Semester - I L T P C

CH 603: ADVANCED CHEMICAL ENGINEERING THERMODYNAMICS 3 1 0 4

- **REVIEW OF CLASSICAL THERMODYNAMICS (3 HOURS)**

1ST Law, 2nd Law, Maxwell relations, Gibbs energy as a generating function, Residual Properties

- **PROPERTIES OF PURE FLUIDS (4 HOURS)**

Thermo Properties from Volumetric Data, Equations of State, Generalized correlations.

- **INTERMOLECULAR INTERACTIONS AND CORRESPONDING STATE THEORY (HOURS 5)**

Origin of interactions (Permanent, induced and instantaneous dipoles), Intermolecular forces and potential energy functions, Corresponding states theory

- **THERMODYNAMIC PROPERTIES OF MIXTURES (15 HOURS)**

Mixtures, partial molar properties, Chemical potential, Gibbs Duhems equations, Property changes on mixing, Fugacity in gas mixtures-Virial and Cubic EOS, corresponding states, fugacities in liquid mixures, fugacities in liquid mixures(electrolyte solution) Excess Functions in Liquid Mixtures, Models for Excess Gibbs energy

- **PHASE EQUILIBRIA (8 HOURS)**

Multiphase Multicomponent phase equilibrium, VLE/SLE/LLE/VLLE, Solubility of gases in liquids, solubility of solids in liquids.

- **CHEMICAL EQUILIBRIUM**

Combined phase and Reaction equilibrium **(5 HOURS)**

- **STATISTICAL MECHANICS AND MOLECULAR SIMULATION (5 HOURS)**

BOOKS RECOMMENDED:

1. J.M. Prausnitz, R.M. Lichtenthaler and E.G. Azevedo, Molecular Thermodynamics of Fluid-Phase Equilibria,3rd edition, Prentice Hall Inc., New Jersey,1996.
2. J.M. Smith. H.C. Van Ness and M.M.Abott, Introduction to Chemical Engineering Thermodynamics, 6th edition, McGraw Hill International edition, 2005.
3. S. I. Sandler, Chemical, Biochemical, and Engineering Thermodynamics, 4th Edition, John Wiley & Sons, Inc.,2006.
4. B. E. Poling, J. M., Prausnitz, J. P. O'Connell, The Properties of Gases and Liquids, 5th edition, McGraw Hill, 2001.
5. J.W. Tester and M. Modell, Thermodynamics and Its Applications, 3rd ed.,Prentice Hall, NJ (1997).
6. D. Chandler, Introduction to Modern Statistical Mechanics,Oxford university press, New york, 1987

M. Tech. I (CH), Semester –I	L	T	P	C
CH 605: ADVANCED TRANSPORT PHENOMENA	**3**	**1**	**-**	**4**

- **INTRODUCTION** **(01 Hour)**

- **TRANSPORT BY MOLECULAR MOTION** **(12 Hours)**
  Momentum transport by viscosity and momentum-flux. Energy transport by thermal conductivity and heat-flux. Mass transport by diffusivity and mass-flux.

- **TRANSPORT IN ONE DIMENSION (SHELL BALANCE METHODS)** **(15 Hours)**
  Shell momentum balances and velocity distributions. Shell energy balances and temperature distributions. Shell mass balances and concentration distributions.

- **USE OF GENERAL TRANSPORT EQUATIONS** **(06 Hours)**
  Equations of change and their use in momentum transport (isothermal). Equations of change and their use in energy transport (nonisothermal). Equations of change and their use in mass transport (mixtures).

- **TRANSPORT WITH TWO INDEPENDENT VARIABLES** **(03 Hours)**

- **VELOCITY DISTRIBUTION IN TURBULENT FLOW** **(02 Hours)**

- **INTERPHASE TRANSPORT IN ISOTHERMAL SYSTEMS** **(04 Hours)**
  Friction factors for flow in tubes, flow around spheres, and packed columns.

- **MACROSCOPIC BALANCES FOR ISOTHERMAL FLOW SYSTEMS** **(02 Hours)**
  Macroscopic mass balance for steady and unsteady-state problems.

(Total contact hours : 45)

BOOKS RECOMMENDED:

1. Bird R.B., Stewart W.E. and Lightfoot E.N., "Transport Phenomena" 2nd Ed., John Wiley & Sons, Singapore, 2002.
2. Thomson, W.J. "Introduction to Transport Phenomena" Pearson Education Asia, Singapore, 2000.
3. Brodkey R.S. and Hershey H.C., "Transport Phenomena: A Unified Approach" McGraw-Hill, 1989.
4. Plawsky J.L., "Tranport Phenomena Fundamentals", Marcel Dekker, New York, 2001.
5. Slattery J.C., Sagis L.,and Oh E-S., "Interfacial Transport Phenomena", 2nd Ed., Springer, 2007.

M. Tech. I (CH), Semester-II	L	T	P	C
CH 602: ADVANCED CHEMICAL REACTION ENGG.	3	-	-	3

- **RTD STUDIES (03 Hours)**
  Non ideal flow in reactors, RTD of fluid in reactors, Age distribution, F curve, C curve and E curve, Intensity Function, Effects of RTD on performance of Chemical Process Equipment

- **CATALYTIC REACTORS (06 Hours)**
  Adsorption kinetics, External and Internal Diffusional Resistances, Effects of Heat Generation/Absorption, Effectiveness Factors, Fixed Bed, Fluid Bed, Trickle bed, Slurry Reactors,

- **CATALYSIS (08 Hours)**
  Typical Catalysts used in chemical processes, Catalyst Characterizations, Catalyst Deactivation and Regeneration, Metal recovery from the Spent Catalysts

- **ZEOLITE CATALYSTS (06 Hours)**
  Applications, Rise of Acidity, Modifications, Shape Selectivity

- **ENVIRONMENTAL CATALYSIS (06 Hours)**
  Importance, Applications

- **BIOCHEMICAL REACTION ENGINEERING (04Hours)**
  Types of bio-reactors, Design, scale-up, operation and control of bio-reactors, Kinetics of biochemical reactions

- **MONOLITHIC REACTORS (05 Hours)**
  Configurations, Preparation, Hydrodynamics and Applications, Accelerated Deactivation of catalysts, Laboratory reactors, Oscillatory motion of reactants in catalyst pores, Microreactors.

- **INDUSTRIAL CASE STUDIES ON CATALYSIS AND CATALYTIC REACTORS (04Hours)**

- **CATALYSIS IN IONIC LIQUIDS (03 Hours)**

(Total Contact Time: 45 Hours)

BOOKS RECOMMENDED:

1. Fogler H.S., "Elements of Chemical Reaction Engineering", 4th Edition, Prentice Hall, NJ, 2006
2. Levenspiel O., "Chemical Reaction Engineering", 3rd Edition**,** John Wiley & Sons, Singapore, 1998.
3. Smith J. M., "Chemical Engineering Kinetics", 3rd Edition, McGraw Hill, N Y, 1981.
4. Inamdar S.T.A., "Biochemical Engineering – Principles and concepts", Prentice-Hall of India, New Delhi, 2007.
5. Shuler M.L. and Kargi F., "Bioprocess Engineering – Basic Concepts", 2nd Edition, Prentice-Hall of India, New Delhi, 2006.
6. Hand-outs from recent publications

M.Tech. I (CH), Semester – II	L	T	P	C
CH 604: ADVANCED SEPARATION METHODS	**3**	**1**	**0**	**4**

- **MEMBRANE SEPARATION PROCESSES** **(30 Hours)**
  Reverse Osmosis, Ultrafiltration, Microfiltration, Electro-Dialysis, Pervaporation, Gas Permeation, Membrane Distillation, Liquid Membranes.
- **SUPERCRITICAL FLUID EXTRACTION** **(04 Hours)**
- **REACTIVE SEPARATIONS** **(04 Hours)**
- **CHROMATOGRAPHY,** etc. **(07 Hours)**

BOOKS RECOMMENDED:

1. Wanket P. C., "Rate-Controlled Separations", Elsevier Applied Science, New York, 1990.
2. Bungay P.M., Lonsdale H.K. & de Pinho M.N. (Eds.), "Synthetic Membranes: Science, Engineering and Applications", NATO ASI Series, Vol.181, D.Reidel Publishing Company, Dordrecht, Holland, 1986.
3. Schweitzer P.A. (Ed.), "Handbook of Separation Techniques for Chemical Engineers", 3rd Edition, McGraw-Hill, New York, 1997.
4. Kulprathipanja S. "Reactive Separation Processes", Taylor and Francis, New York, 2002.
5. Sundmacher K. & Kienly A., "Reactive Distillation", John Wiley & Sons, New York, 2000.
6. Recent literature from Journals on Separations.

M. Tech. I (CH), Semester-II	L	T	P	C
CH 606: ADVANCED PROCESS CONTROL	**3**	**1**	**0**	**4**

- **INTRODUCTION** **(04 Hours)**
  Control objectives and benefits, Importance of control engineering

- **PROCESS DYNAMICS** **(08 Hours)**
  Review of single Input Single Output (SISO) Control Mathematical modelling principles, modeling analysis for process control, dynamic behaviour of typical process systems, empirical model identification,

- **PID CONTROLLER TUNING** **(04 Hours)**
  Controlled variable performance(IAE), Manipulated- variable behavior, correlations for controller tuning constant

- **ADVANCED CONTROL SYSTEM** **(08 Hours)**
  Feedback, feedforward, ratio, cascade, adaptive, inferential control system

- **MULTIVARIABLE CONTROL** **(06 Hours)**
  Multivariable control Strategies, Effects of interaction, performance analysis, variable structure and constraint control, centralized multivariable control

- **PROCESS CONTROL DESIGN** **(15 Hours)**
  Steady state & unsteady state operations**,** methods of calculation, Identification of Non-Parametric Representations, Model Predictive Control, Analysis of Dynamic Matrix Control (DMC) and Generalized Predictive Control (GPC), Controller Tuning and Robustness Issues, Extensions to Constrained and Multivariable Cases, Process synthesis.

(Total Contact Time: 45 Hours)

BOOKS RECOMMENDED:

1. Marlin T.E." Process Control", ", 2nd Edition, McGraw-Hill, Singapore, 2000.
2. Coughanowr D. R. "Process Systems Analysis and Control", 2nd Edition, McGraw-Hill, New York, 1991.
3. Stephanopoulos G." Chemical Process Control", Prentice-Hall of India, New Delhi, 2001.

M. Tech. I (CH), Semester – II	L	T	P	C
CH 608: SAFETY HEALTH AND ENVIRONMENT	**3**	**0**	**0**	**3**

- **INTRODUCTION** **(02 Hours)**
  Environment, Environmental quality and degradation, description of environment setting

- **ENVIRONMENT IMPACT ASSESSMENT** **(05 Hours)**
  Principles and procedures for environment impact assessment policies and acts, prediction and assessment of impacts on specific environments. e.g. biological:

- **IMPACT ON BIOLOGICAL ENVIRONMENT** **(09 Hours)**
  Basics of Ecology, Biological setting, Critical impacts.

- **IMPACT ON WATER** **(10 Hours)**
  Identification of water pollutants, water quality and management criteria, wastewater characteristics, treatment and removal.

- **IMPACT ON AIR** **(10 Hours)**
  Identification of air pollutants, air quality, air pollution dispersion potential, mesoscale and macroscale impacts, abatement strategies, analysis and treatment of gaseous and particulate pollutants, recovery and recycling of effluents.

- **NOISE** **(03 Hours)**
  Noise standards and criteria, effects and control, Green chemical Processes, Global warming,

- **HAZOP & HAZAN** **(03 Hours)**

- **GREEN CHEMICAL PROCESSES, GLOBAL WARMING** **(03 Hours)**

(Total Contact Time: 45 Hours)

BOOKS RECOMMENDED:

1. Crowl D.A. & Louvar J.F., "Chemical Process Safety", 2nd Ed. Prentice-Hall, New Jersey, 2002.
2. Mahajan S.P., "Pollution Control in Process Industries", Tata McGraw Hill Inc., New Delhi, 1985.
3. Rao C.S., "Environmental Pollution Control Engineering", New Age International, New Delhi, 1991.
4. Bhatia S.C., "Environmental Pollution & Control in Chemical Process Industries", Khanna Publications, Delhi, 2001.
5. Sawyer C.N., McCarty P.L. & Perkin G.F., "Chemistry for Environmental Engineering and Science", McGraw-Hill, 5th ed., 2002.