West Bengal University of Technology

BF-142, Salt Lake City, Kolkata-700064

Revised Syllabus of B.Tech in CHE(To be followed from the academic session,July 2006 ,i.e. for the students who were admitted in Academic Session 2005-2006).The syllabi of other semesters will be published soon.

Semester - III

Subject Code	Theory	Period/Week			Credit
		L	T	P	
CHE 301	Industrial Stoichiometry	3	1	0	4
CS 312	Data Structure and Database Concepts	3	1	0	4
CH 313	Chemistry	3	1	0	4
EE 314	Electrical Machines	3	1	0	4
M 315	Mathematics-III	3	1	0	4
	Total Theory	**15**	**5**	**0**	**20**

Practical

CHE 391	Instrumental Methods of Analysis Lab	0	0	4	2
CS 382	Data Structure and DBMS Lab	0	0	3	2
EE 383	Electrical Machines Lab	0	0	4	2
	Total of Practicals	**0**	**0**	**11**	**6**

		Period/Week	Credit
	Total of Semester	**31**	**26**

West Bengal University of Technology

BF-142, Salt Lake City, Kolkata-700064

Revised Syllabus of B.Tech in CHE(To be followed from the academic session,July 2006 ,i.e. for the students who were admitted in Academic Session 2005-2006).The syllabi of other semesters will be published soon.

Chemical Engineering					
Semester – IV					
Subject Code	**Theory**	**Period/Week**			**Credit**
		L	**T**	**P**	
CHE 401	Chemical Engg. Thermodynamics	3	1	0	4
CHE 402	Mechanical Operations	3	1	0	4
CHE 403	Material Science & Technology	3	0	0	3
CHE 404	Energy Sources and Their Utilization	3	1	0	4
CHE 405	Fluid Mechanics	3	1	0	4
	Total Theory	**15**	**4**	**0**	**19**
	Practical				
CHE 491	Mechanical Operations Lab	0	0	4*	2
CHE 492	Energy Lab	0	0	4	2
CHE 493	Fluid Mechanics Lab	0	0	4*	2
	Total of Practical	**0**	**0**	**12**	**6**
	Sessional				
HU 481	**Report Writing & Technical Language Practice Laboratory**	0	0	2	1
CHE 494	**Chemical Engineering Drawing**	0	0	3	2
		Period/Week			**Credit**
	Total of Semester	**36**			**28**

West Bengal University of Technology

BF-142, Salt Lake City, Kolkata-700064

Revised Syllabus of B.Tech in CHE(To be followed from the academic session,July 2006 ,i.e. for the students who were admitted in Academic Session 2005-2006).The syllabi of other semesters will be published soon.

Chemical Engineering

Semester – V

Subject Code	Theory	Period/Week			Credit
		L	T	P	
CHE 501	Machine Design	3	0	0	3
CHE 502	Process Heat Transfer	3	1	0	4
CHE 503	Chemical Process Technology-I	4	0	0	4
CHE 504	Chemical Reaction Engineering	3	1	0	4
CHE 505	Separation Processes-I	3	1	0	4
	Total Theory	**16**	**3**	**0**	**19**
	Practical				
CHE 591	Heat Transfer Lab	0	0	5	3
CHE 592	Process Equipment Design and Drawing -I	0	0	5	3
CHE 593	Chemical Reaction Engineering Lab	0	0	5	3
	Total of Practical	**0**	**0**	**15**	**9**
		Period/Week			**Credit**
	Total of Semester	**34**			**28**

West Bengal University of Technology

BF-142, Salt Lake City, Kolkata-700064

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Chemical Engineering

Semester – VI

Subject Code	Theory	Period/Week			Credit
		L	T	P	
CHE 601	Separation Processes-II	3	1	0	4
CHE 602	Chemical Process Technology-II	4	0	0	4
CHE 603	Instrumentation and Process Control	3	1	0	4
CHE 604	Numerical Methods in Chemical Engineering	3	1	0	4
CHE 605	Elective-I	3	0	0	3
	Total Theory	**16**	**3**	**0**	**19**
	Practical				
CHE 691	Numerical Computations Lab	0	0	5	3
CHE 692	Process Equipment Design and Drawing -II	0	0	5	3
CHE 693	Mass Transfer Lab	0	0	5	3
	Total of Practical	**0**	**0**	**15**	**9**
		Period/Week			**Credit**
	Total of Semester	**34**			**28**

West Bengal University of Technology
BF-142, Salt Lake City, Kolkata-700064

Revised Syllabus of B.Tech in CHE(To be followed from the academic session,July 2006 ,i.e. for the students who were admitted in Academic Session 2005-2006).The syllabi of other semesters will be published soon.

Chemical Engineering

Semester - VII

Subject Code	Theory	Period/Week			Credit
		L	T	P	
CHE 701	Mathematical Methods in Chemical Enginering	3	1	0	4
CHE 702	Modeling, Simulation and Optimization	3	1	0	4
CHE 703	Project Engineering	3	1	0	4
CHE 704	Elective-II	3	0	0	3
HU 715	Industrial Management	4	0	0	4
	Total Theory	**16**	**3**	**0**	**19**
	Practical				
CHE 791	Project Work / Plant Design	0	0	3	2
CHE 792	Process Instrumentation and Control Lab	0	0	5	3
CHE 793	Process Equipment Design and Drawing –III	0	0	5	3
	Total of Practical	**0**	**0**	**13**	**8**
	Sessional				
CHE 794	Report and Viva Voce on In-plant Training	0	0	0	4
CHE 795	Seminar	0	0	2	2
	Total of Sessional	**0**	**0**	**2**	**6**
		Period/Week			**Credit**
	Total of Semester	**34**			**33**

West Bengal University of Technology
BF-142, Salt Lake City, Kolkata-700064

Revised Syllabus of B.Tech in CHE(To be followed from the academic session,July 2006 ,i.e. for the students who were admitted in Academic Session 2005-2006).The syllabi of other semesters will be published soon.

Chemical Engineering

Semester - VIII

Subject Code	Theory	Period/Week			Credit
		L	T	P	
CHE 801	Transport Phenomena	3	1	0	4
CHE 802	Biotechnology & Biochemical Engineering	3	0	0	3
CHE 803	Environmental Engineering	3	1	0	4
CHE 804	Elective-III	3	0	0	3
	Total Theory	**12**	**2**	**0**	**14**
	Practical				
CHE 891	Project Work/Plant Design	0	0	12	6
CHE 892	Report and Viva Voce on Project Work / Plant Design	0	0	0	8
CHE 893	Comprehensive Viva Voce	0	0	0	8
	Total of Practical	**0**	**0**	**12**	**22**
		Period/Week			**Credit**
	Total of Semester	**25**			**36**

West Bengal University of Technology
BF-142, Salt Lake City, Kolkata-700064

Revised Syllabus of B.Tech in CHE(To be followed from the academic session,July 2006 ,i.e. for the students who were admitted in Academic Session 2005-2006).The syllabi of other semesters will be published soon.

CHE 605: ELECTIVE –I	CHE 704: ELECTIVE - II	CHE 804: ELECTIVE -III
CHE 605 A Pulp & Paper Technology	**CHE 704 A** Polymer Science & Engineering	**CHE 804 A** Nanotechnology
CHE 605 B Catalysis & Catalytic Reactor Design	**CHE 704 B** Petroleum Refinery Engineering	**CHE 804 B** Operation Research
CHE 605 C Food Processing Engineering	**CHE 704 C** Tea Processing Technology	**CHE 804 C** Computational Fluid Dynamics
CHE 605 D Ceramic Technology	**CHE 704 D** Fertilizer Technology	**CHE 804 D** Safety in Chemical Process Industries
CHE 605 E Petrochemical Technology	**CHE 704 E** Advanced Separation Processes	**CHE 804 E** Total Quality Management
CHE 605 F Shellac Processing Technology		

Total Credits

1st Semester – 30

2nd Semester – 30

3rd Semester – 26

4th Semester – 28

5th Semester – 28

6th Semester – 28

7th Semester – 33

8th Semester – 36

Total: 239

West Bengal University of Technology
BF-142, Salt Lake City, Kolkata-700064

Revised Syllabus of B.Tech in CHE(To be followed from the academic session,July 2006 ,i.e. for the students who were admitted in Academic Session 2005-2006).The syllabi of other semesters will be published soon.

3rd Semester

Industrial Stoichiometry (CHE 301)

Module I: **10L**

Units and Dimensions: Buckingham Pi-theorem, Dimensionless groups, Conversion of equations.

Introduction to Chemical Engineering Calculations: Basis, Mole Fraction and Mole Percent, Roult's Law, Henry's law, Dalton's law, Amagat's law, Behavior of ideal gases. Real gas relationships, Vapor Pressure.

Module II: **10L**

Mathematical Requisites: Solution of simultaneous equations, use of log-log and semi-log graph paper, triangular diagram, Graphical differentiation and graphical integration, least square method, curve fitting, Method of Regression, use of standard numerical software.

Material Balance: Without Chemical Reaction, Solubility and crystallization, With Chemical Reaction, Recycle, By-pass and Purge Calculations.

Module III: **10L**

Energy Balance: Without Chemical Reaction, With Chemical Reaction, Enthalpy Changes, Heats of Solution and Mixing, Adiabatic Flame temperature, Use of Humidity Charts.

Module IV: **10L**

Combined Material and Energy Balances: Simultaneous Material and Energy Balances: Industrial process calculations for Distillation, Combustion, Crystallization, Drying and Evaporation etc.

Revision: 5L

Text Books / References:

1. Chemical Process Principles (Part one): Hougen, Watson & Ragatz, John Wiley (Asian Edn.)2nd Ed.
2. Basic Principles and Calculations: Himmelblau: Prentice Hall, 6th Ed. in Chemical Engineering
3. Stoichiometry: Bhatt & Vora, 3rd Ed.

CS-312-- Data Structure and database concepts

Module I: **10L**

Linear Data structure: Sequential Representation, Arrays, Lists, Stacks, Queues, Strings, Linked List Representations: Linear Linked List, Circular Linked List, Doubly Linked List and their Application.

Module II: **10L**

Introduction to Graphs (undirected and directed) & Different Representation; Trees (Basic concepts and representations), Breadh first search (BFS) and Depth first search (DFS) algorithms, Spanning Trees, Minimum Spanning Tree (Prim's, Kruskal's algorithms), Dijkstra's Shortest Path Algorithm.

Module III: **10L**

Shorting and Searching Algorithms: Linear search, Binary search; Bubble sort, Insertion sort, Selection sort, Quick sort.
Introduction: Database System and Concept Architecture, Data Model, scheme & instances, Data Independence, Database Languages, Database Manager, Database Administrator, Database User, Relational Model & ED Diagram.

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Module IV: **10L**

Database Language: SQL, definition, manipulation, control, DBA function; Distributed Database Concepts.
Basic Concept of Computer Networking, LAN, MAN, WAN, Protocols, Web help for Chemical Engineering Application.

Text Book

1. Aho Alfred V., Hopperoft John E., Ullman Jeffrey D., "Data Structure and Algorithms", Pearson Education
2. Henry F. Korth and Silberschatz Abraham, "Database System Concepts", McGraw Hill
3. Corman, Introduction to algorithms, PHI
4. Elmasri Ramez and Novathe Shamkant, "Fundamentals of Database Systems", Pearson Education
5. Date C. J., "Introduction to Database Management", Vol-I,II,III, Pearson Education
6. Ullman J.D., "Principles of database systems", Galgottia Publication.
7. Tennenbaum- "Computer Networks", Pearson Education/PHI
8. W. Stallings – Data Communication & Network", Pearson Education/PHI

Reference:

1. Horowitz Ellis & Sartaj Sahani, "Fundamentals of Data Structures", Galgottia Publication.
2. Tennenbaum- "Data Structures using C", Pearson Education/PHI
3. N. Deo., Graph Theory - PHI

Chemistry (CH 313)

Module I: **10L**

Colloids: Introduction; Classification of colloids; Size and shape; preparation of sols; Origin of charge in Colloidal particles; Stability of Colloids; Kinetic, Optical & electrical properties; Electrokinetic phenomena; Electrical Double Layer; Ultracentrifuge and Molecular weight determination of Macromolecules.

Viscosity: Definition of a liquid; Determination of Viscosity; Shear Viscosity; Intrinsic Viscosity; Molecular weight from Viscosity measurement; Newtonian and non Newtonian Fluids (Pseudoplastic, Dilatant, Bingham Plastic fluids).

Module II: **10L**

Surface Tension: Introduction; Origin of Surface Tension; Surface energy; Laplace & Young-Laplace Equation, Capillarity; Contact Angle; Measurement of Surface Tension by Capillary rise method; Variation of Surface Tension of a liquid with Temperature and Concentration.

Adsorption: Introduction; Gibb's adsorption equation; Surface Excess; Adsorption isotherms: Freundlich, Langmuir, BET adsorption equations; Surface Films; Langmuir Balance; two-dimensional equation of state.

Module III: **10L**

General Organic Chemistry: Common organic reactions: nucleophilic; electrophilic; addition and substitution; Different types of conversion; important reactions of carbonyl compounds; Markownikof's rule; peroxide effect.

Preparation and synthetic application of Acetoacetic ester, Malonic ester and Grignard's reagent;

Module IV: **10L**

Aminoacids: Classification; General methods of preparation and properties of amino acids, polypeptide synthesis, General properties of proteins, colour tests, enzymes.

Carbohydrate: Classification, Glucose and fructose, Mutarotation, epimerisation, Inter–conversion of aldose and Ketose; Methods of ascending and decending sugar series; Disaccharides: Surcose, maltose, cellobiose (brief properties and mention of structures).

Revision: 5L

Text Books / References:

1. Physical Chemistry: P. W. Atkins: Oxford
2. Physical Chemistry: G.W.Castellan, Narosa
2. A Text book of Physical Chemistry: K. L. Kapoor: Macmillan
3. A guide Book to Mechanism in Organic Chemistry: Peter Sykes
4. Organic Chemistry: Finar; I.L. – Vol – I & II, Pearson Education

Revised Syllabus of B.Tech in CHE(To be followed from the academic session,July 2006 ,i.e. for the students who were admitted in Academic Session 2005-2006).The syllabi of other semesters will be published soon.

5. Organic Chemistry: Morrison & Boyd; PHI/Pearson Education.
6. Organic Chemistry: Loudon: Oxford.

Electrical Machines (EE 314)

Module-I: 10 L

D.C. Machines--Generators and Motors: Constructional features and principles of operation of shunt, Series and compound generators and motors. Performance characteristics, starting speed controls and breaking of motors.

Module-II: 10 L

Application of Static and Rotating Machines: Two quadrant and four quadrant operation of motors. Choice of D.C. motors for different applications.
Constructional features and principles of operation of 1-phase transformers, Open Circuit Test and Short Circuit Test, Equivalent Circuit, Typical applications of transformers and A.C. motors.

Module-III: 10 L

Induction motors: Principles of operations, Equivalent circuit and diagram, Torque speed characteristics, Methods of improving starting torque speed control. Starting and breaking of induction motors, Single phase induction motors and methods of starting.

Module-IV: 10 L

Synchronous Machines: Synchronous generators and motors, Principles of operations and simple equivalent circuit, Method of synchronization of synchronous generator, Application of synchronous machines and 3-phase transformer.

Revision: 5L

Text Books / References:

1. Electrical Technology: Edward Hughes. Pearson Education

2.Hubert, Electrical Machines, Pearson Education

3. Applied Electricity: H. Cotton. CBS Distributors, New Delhi

4. A Text Book of Electrical Technology: Theraja and Theraja – Vol –

4. Electrical Machinery: Bhimra,

5. Electrical Machines: P.K.Mukherjee and S.Chakraborty.

Mathematics – III (M 315)

Code: M 315
Contact: 3L + IT
Credit: 4
Allotted Hrs.: 48L

Fourier Series:

Introduction; Euler's formula; Problems related to Fourier series; Conditions for Fourier expansion; Functions having points of discontinuity; Change of Interval; Even and Odd function; Half Range series; Typical Waveforms (square, saw-toothed, triangular, half wave rectifier, full wave rectifier) *12L*

Series Solution of Ordinary Differential Equation (ODE); Special Functions:

Introduction, validity of series solution of an ordinary differential equation, general method to solve equation of the type: $P_o y'' + P_1 y' + P_2 y = 0$; Problems; Bessel's equation; Properties of Bessel's function; Recurrence formula for Bessel's function of first kind ($J_n(x)$); Equation reducible to Bessel's equation; Legendre's equation, Legendre function, Recurrence formula for Legendre function ($P_n(x)$); Orthogonality relation. *14L*

Revised Syllabus of B.Tech in CHE(To be followed from the academic session,July 2006 ,i.e. for the students who were admitted in Academic Session 2005-2006).The syllabi of other semesters will be published soon.

Partial Differential Equations (PDE) and its Applications:

Introduction, linear and nonlinear PDE of first order; Examples; Homogeneous Linear PDE of 2nd Order with constant coefficients and variable coefficients; Separation of variables, Formulation and solution of wave equation (1D); One Dimensional heat flow equation and solution; Two Dimensional heat flow equation and solution. *12L*

Statistics:

Mean, median; mode; Standard Deviation, Variance, Random Variable; Discrete and Continuous Probability Distributions: Distribution and Density Function, Mathematical Expectation; Standard Probability Distributions: Binomial, Poisson, and Normal; Correlation and Regression; Linear Curve Fitting—Least Square Method. *10L*

Total 48L

Text Books / References:

1. Advanced Engineering Mathematics: E. Kreyszig, Wily, 5th Edn.
2. Higher Engineering Mathematics: B. S. Grewal, 1997
3. Engineering Mathematics, Vol. 1 & 2, Shastri, PHI
4. Fundamental Concepts of Mathematical Statistics: Gupta and Kapoor, S.Chand.
5. Advanced Engineering Mathematics, GreenBerg, Pearson Education
4. Statistical Methods: N.G.Das
6. Elements of partial Differential Equation: Sneddon, MGH

CHE 391 – Instrumental methods of analysis Lab

1. Determination of Sulfur in coal by Turbidity Meter.
2. Preparation of standard curve (Absorbance vs. concentration) of a standard protein by Folin's Method using visual Spectrophotometer.
3. Determination of Fe^{3+}/Cu^{2+} by Colorimeter Method.
4. Determination of carbon monoxide in a combustion process by IR method.
5. Analysis of gaseous mixture using TCD/FID.
6. Separation of Proteins by Paper Chromatography.
7. Determination of Molecular Weight by UV Spectrophotometer.
8. Calibration and analysis of an organic mixture (benzene & toluene) by a refractometer.
9. Determination of any optically active substance in the presence of non-active species by a polarimeter.

CS 382—Data Structure & data base Lab

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1. Study of CAD and Graphics Packages for Chemical Process.
2. Study of AutoCAD Packages w.r.t. 2D and 3D objects---drawing, dimensioning, resizing, multiplicity aspects, connections; Block diagram representation of Chemical process, drawing/Editing of special blocks; integration of blocks/units for a complete flow diagram.
3. Dynamic and Static Data Exchange between Database and Auto CAD
4. Data Structure using C++ - Linked-List
5. Interface between C language and SQL Server
6. Data Exchange between VB and MS Access
7. Study of Access Package: Data storage, retrieval, data classification using SQL/DML; graphic representation of stored data (in database) using Excel Package facility.

EE 383 – Electrical Machines Lab

1. To study the open circuit and short circuit tests of a single-phase transformer.
2. To study the speed control characteristics of a D. C. shunt motor.
3. To study the saturation characteristics of a D. C. generator.
4. To study the external load characteristics of a D. C. shunt generator.
5. To study the speed-torque characteristics of an induction motor.
6. To study the open and short circuit characteristics of an alternator.

4th Semester

Chemical Engineering Thermodynamics (CHE-401)

Module I: **10 L**

Basic concepts and definitions: What is thermodynamics? Macroscopic and microscopic view. The scope of thermodynamics. Thermodynamic systems and surroundings. Concepts of force, properties, energy, temperature, pressure, heat work, equilibrium, phase, process etc.

Volumetric properties of pure fluids: Graphical representation of P-V-T behaviour. Mathematical representation of P-V-T behaviour: ideal gas law, cubic equations of state, virial equation of state and its application, Law of corresponding states, Generalised correlations for gases and liquids, acentric factor, compressibility factor.

First law of thermodynamics and its applications: First law of thermodynamics, Energy balance for closed system. Thermodynamic state and state functions. The reversible process. The adiabatic process. The constant volume and constant pressure process. Enthalpy, heat capacity. Mass and energy balance for open systems.

Module II: **10 L**

Second law of thermodynamics and its application: Limitations of the first law of thermodynamics, statements of the law. Heat engine and heat pump / refrigerator. Mathematical statement of second law. Carnot cycle and Carnot

Theorems. Refrigeration cycle, criterion of irreversibility, clausius inequality, entropy and its change calculation for ideal gases. Absorption refrigeration, choice of refrigerant, Liquefaction process. The third law of Thermodynamics.

Thermodynamic property relations: Maxwell relations. Joule – Thomson coefficient, Clapeyron equation and enthalpy of vaporization.

Module III: **13 L**

Solution Thermodynamics: Theory:
Partial molar properties, partial properties in binary solution, chemical potential, Gibbs Duhem relation, fugacity, fugacity coefficient for pure species and solution. Generalized correlations for fugacity coefficient, Fugacity of liquid and solid. Ideal solution, Residual properties, phase equilibria, Lewis – Randall rule, simple models for low pressure vapor / liquid equilibrium, bubble pressure, dew pressure, bubble temperature, dew temperature and flash calculations. Modified Raoults' law, k-value correlations, Excess properties,

Solution Thermodynamics: Applications:
activity & activity coefficient, Excess Gibbs free energy models – Margules, Redlick – Kister, Whol's, Van Laar, Wilson & NRTL, UNIQUAC, Group Contribution methods, Henrys law. Retrograde condensation, VLE at law to moderate pressures, Calculate the VLE data for a binary mixture from azeotropic conditions, VLE at high pressures. Thermodynamic consistency.

Module IV: **7 L**

Chemical Reaction Equilibria: Criterion of chemical reaction equilibrium, Application of Equilibrium Criteria to Chemical Reactions, the standard Gibbs Energy Change and the Equilibrium Constant, Effect of Temperature on the Equilibrium Constant, Evaluation and Relation of Equilibrium Constants, Equilibrium Conversions for single Reactions, Phase Rule and Duhem's Theorem for Reacting Systems, Fuel Cells.

Text Books / References:

1. Introduction to Chemical Engineering Thermodynamics: Smith, J.M., Van ness, H.C. and Abbot, M.M., 6th Edn. MGH., 2001.
2. Chemical Engineering Thermodynamics: Y.V.C. Rao.
3. A Text Book of Chemical Engineering Thermodynamics, Narayanan, PHI
4. Chemical Process Principles (Vol-2): O.A.Hougen, K.M. Watson and R.A.Ragatz.
5. Chemical and Process Thermodynamics: Kyle PHI.

Mechanical Operation (CHE 402)

Module I: **10 L**
Screen Analysis: Mixed particle sizes, Differential and cumulative analysis, Screen effectiveness, Ideal and Actual Screening, Types of screen, commercial screening equipment
Transportation & Storage of Solids: Studies on performance and operation of different conveyors eg. Belt, Screw, Apron, Flight etc. and elevators. Centrifugal discharge, continuous, positive discharge: storage bin for solid and feeders.

Module 2: **10 L**
Principles of Commination (Size Reduction): Rittinger's law, Kick's law, Bond's law, Work index, Types of comminuting equipment – Jaw Crushers, Gyratory Crusher, Roll crushers; Grinders-hammer Mill, Ball Mill, Rod Mill etc.; Ultrafine Grinders – Fluid Energy Mill etc. Charactristics of comminuted products. Open circuit and closed circuit grinding.

Module 3: **10 L**
Principles of particle Mechanics: free and Hindered settling, terminal velocity, Stock's law & Newton's law regimes of settling, Batch sedimentation, Design of continuous clarifier, classification, froth flotation. Cyclone separator, electrostatic precipitator.
Mixing: Mechanism of mixing, power consumption in mixing, power number, flow number, froud number, various types of agitator, solid-solid mixing equipment. Mixing effectiveness and mixing index.

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Module 4: **10 L**

Filtration: Theory of solid-liquid filtration, principle of filtration, constant pressure and constant rate filtration, compressible and incompressible cakes, Filter aids, Equipment of liquid solid filtration, Batch and continuous pressure filters. Theory of centrifugal filtration, Equipment for centrifugal filtration, filtration of solid from gases- bag filter.

Text Books/ References:

1 Unit Operations of Chemical Engineering By Mc Cabe Smith and Harriot TMH, 5th Edn.
2 Introduction to Chemical Engineering 2nd Vol. By Badger & Banchero
3 Mechanical Operations by B. C. Bhattacharya & Narayanan.

Material Science & Technology (CHE 403)

Module - I: **10L**

Structure of materials-Various types of bonds. Crystalline Structure of Solids- concepts of unit cell and space lattice, packing factor. X-ray diffraction for determining crystal structure. Mechanical properties-Elastic, anelastic and viscoelastic behaviour of material. Strength, hardness toughness, ductility, brittleness in engineering materials. Optical fibers.

Module - II: **10 L**

Mechanism of plastic deformation, slip and dislocations, stain hardening and recrystallization. Elementary aspects of creep, fatigue, fracture. Phase Diagrams- Solidification and structure of metals. Grain boundaries. Phase equilibrium and phase diagrams of binary alloys. Phase diagram of ternary systems. Iron-Carbon diagram. Heat Treatment -Introduction and purposes of heat treatment. T-T-T Curve. Corrosion-Concepts and forms of corrosion. Corrosion Mechanism and prevention. Protective materials and coating.

Module – III: **10 L**

Basic principles of metal extraction: Pyrometallurgy: calcinations, roasting—oxidizing, predominance area diagrams, multiple hearth, flash and fluo-solid, sintering, smelting, slag and its classification.
Steelmaking process flow diagram: Iron making (Operation involved in Blast furnace)– Steel making (oxygen blown converter – LD) – Secondary steel making / refining (ladle processing, vacuum degassing, ladle furnace processing) – Continuous casting - with emphasis on application of the concepts of physicochemical principles involved, moving/packed bed reactor, gas-liquid two-phase flow, heat transfer with phase change (solidification).

Module - IV: **10 L**

Principles of Hydrometallurgy and Electrometallurgy, Extraction of Aluminum: Hall-Heroult process, Electrolytic refining; Sources of Zinc & Copper: Pyro & Hydro metallurgical extraction of copper & Zinc; Extraction of Lead, Recent development in Lead smelting. .

Text Books and References:

1. Lawrence, H. Vanvlack, Elements of Material Science and Engineering, Pearson Education.
2. Raghavan, V. Material Science and Engineering, Prentice Hall of India.
3. Lakhtin, Engineering Physical metallurgy; MIR publishers.
4. Ray, Sridhar & Abraham. Extraction of non ferrous metal, EWP
5. L. Von Bogdandy and H.J Engell: The Reduction of Iron Ores, Springer-Verlag, NY.
6. R.I.L Guthrie: Engineering in Process Metallurgy, Oxford University Press (Paperback edition 1992).

Energy Sources & Their Utilization (CHE 404)

Module I: **10L**

Introduction: Conventional and non-conventional energy resources, Global Energy consumption pattern.
Solid Fuels: Biomass, Wood and Charcoal, Peat, Coal, Classification & Rank of Coal, Lignite, Sub-Bituminus coal, Bituminus coal, Anthracite coal. Physical Properties of coal,Proximate & Ultimate Analysis of Coal, Cleaning & Storage of coal.
Coal Carbonization: Low Temperature Carbonization (LTC),High Temperature Carbonization(HTC),Horizontal & Vertical Gas Retorts, Coke Ovens-Beehive& Byproduct Slot Type_Details of Structural configuration and Operating principles_ Recovery of byproducts.

Module II: **10L**

Liquid Fuels: Constitution of petroleum, theory of formation of crude, characterization of crude oil & petroleum fuels, operation and flow-sheet of crude distillation, catalytic cracking, coking, visbreaking and reforming processes, Process of

a typical Indian refinery. Parameters and testing logistics of petroleum products—Octane no.; Cetane no.; Aviation fuel, Power no.; Pour point; Smoke point; Char point; Cloud point; Flash point; Fire point; Aniline point and Diesel index.
Liquid fuel from coal: Bergius and Fischer Tropsch process, Other Synthetic Liquid fuels.

Module III: **10L**

Gaseous Fuels: Physico-chemical principles, Calorific Value, Wobbes index, flow-sheet and burners and furnace operation of: Producer gas, Water gas, Carburetted water gas, oil gas, coke-oven gas, blast furnace gas, Natural Gas and LPG. Coal Bed Methane.
Bio Gas: Principles and Operation of Aerobic & Anaerobic Digestors, Biogas generation and management.

Module IV: **10 L**

Solar Energy : Devices for measurement of solar flux, Solar collectors, Utilization of Solar Energy- solar Pond, Photovoltaic cells, Chemical storage etc.
Geothermal Energy And Wind Energy: Utilization of Geo thermal Energy, Operating principles of different types of Wind Energy Mills.
Nuclear energy: Nuclear reactions and power generation.

Text/ Reference Books:

1. Fuels & Combustion: Dr. Samir Sarkar,Orient Longmans
2. Fuel and Combustion: Sharma S.P. and Chanra Mohan
3. Elements of Fuels. Furnace and Refractories: O.P .Gupta

Fluid Mechanics (CHE 405)

Module I: **10 L**

Fundamental Concepts: Fluid as a continuum, Terminologies of fluid flow, velocity – local, average, maximum, flow rate – mass, volumetric, velocity field; dimensionality of flow; flow visualization – streamline, pathline, streak line, stress field; viscosity; Newtonian fluid; Non-Newtonian fluid; Reynolds number—its significance, laminar, transition and turbulent flows: Pandtl boundary layer, compressible and incompressible flows.

Fluid Statics: Basic equation of fluid statics; pressure variation in a static field; pressure measuring devices–manometer, U-tube, inclined tube, well, diaphragm, hydraulic systems – force on submerged bodies (straight, inclined), pressure centre.

Basic equations in integral form: Basic laws for a system; relation of system derivatives to the control volume formulation; conservation of mass; momentum equation for integral control volume, momentum correction factor, differential control volume analysis; first law, Navier Stokes equation – specific applications.

Module II: **10 L**

Internal incompressible viscous flow: Introduction; flow of incompressible fluid in circular pipe; laminar flow for Newtonian fluid; Hagen-Poiseullie equation; flow of Non-Newtonian fluid, introduction to turbulent flow in a pipe; energy consideration in pipe flow, relation between average and maximum velocity, Bernoulli's equation–kinetic energy correction factor; head loss; friction factor; major and minor losses, Pipe fittings and valves.

Module III: **10 L**

Flow measurement: Introduction; general equation for internal flow meters; Orifice meter; Venturimeter; concept of area meters: rotameter; Local velocity measurement: Pitot tube. Anaemometer.

Resistance of immersed bodies: Introduction; concept of drag and lift;; variation of drag coefficient with Reynolds number; streamlining; packed bed; concept of equivalent diameter and sphericity; Ergun equation.

Revised Syllabus of B.Tech in CHE(To be followed from the academic session,July 2006 ,i.e. for the students who were admitted in Academic Session 2005-2006).The syllabi of other semesters will be published soon.

Module IV: **10 L**

Fluid moving machines: Introduction; Basic classification of pumps: Non-Mechanical Pumps—acid egg, steam jet ejector, air lift pump, Mechanical pump: Centrifugal and Positive displacement pumps (rotary, piston, plunger, diaphragm pumps); pump specification; basic characteristics curves for centrifugal pumps; fan, blower and compressor.

Fluidization: Introduction; different types of fluidization; fluidized bed assembly; governing equation; industrial use.

Revision: 5L

Text Books / References:

1. Introduction to Fluid Mechanics: Fox & McDonald, John wiley
2. Unit operations of Chemical Engineering: McCabe, Smith and Harriot,TMH, 5th Edn.
3. Mohanty, Fluid Mechanics, PHI
4. Fluidization: Kunii and Levenspiel.
5. Fluid Dynamics and Heat Transfer: Knudsen and Katz, MGH
6. Transport Process and Unit Operations: Geankoplis, 3rd Edn. PHI
7. Principles of Unit Operations: Foust and Wenzel, Wiley, 1980

Mechanical Operations Lab (CHE-491)

1. Verification of Rittinger's Law and determination of grindability index of a drop weight crusher for a given granular solid sample.
2. Determination of reduction ratio and capacity of a laboratory scale 'Ball Mill'.
3. Estimation of capacity and reduction ratio of a batch 'Hammer Mill'.
4. Determination of average particle size of a given solid sample using a sieve shaker by (i) Random Sampling (ii) Coning and quartering.
5. Determination of overall effectiveness of a sieve shaker for a given solid sample of unknown size.
6. Estimation of Mixing Index at different time and power consumption for fluid mixing for different rotational speed of the impeller.
7. Determination of rate of sedimentation for a given slurry by plotting interface height vs. time.
8. Design of a continuous thickener by conducting a batch sedimentation test for a given sedimentation duty.
9. Determination of specific cake resistance '$\propto$' and filter medium resistance 'R_m' by filtering a slurry using plate and frame filter press.
10. Estimation of '$\propto$' (specific cake resistance) and 'R_m' by filtering a slurry using a batch centrifugal filter.

Energy Lab (CHE 492)

1. Proximate analysis of Coal: a) Determination of moisture content of Coal.
   b) Determination of volatile matter and ash content of Coal.
3. Determination of carbon residue of fuel oil.
4. Determination of aniline point of a fuel oil.
5. Determination of moisture content of fuel oil by Dean & Stark apparatus.
6. Atmospheric Distillation of petroleum product.
7. Determination of Flash Point & Fire Point of an oil by ABLE apparatus.

8. Determination of Flash Point & Fire Point of an oil by closed-cup Pensky Martin apparatus.
9. Determination of kinematic viscosity of oil.
10. Determination of calorific value of gaseous fuel by Junker's apparatus.
11. Determination of calorific value of solid and liquid fuel by Bomb Calorimeter.
12. Determination of vapour pressure of petroleum product using Reid apparatus.
12. Experiments on Non-conventional Energy Source using Solar Cooker/Flat Plate Connector/Bio Gas Reactor
13.

Report Writing & Technical Language Practice Laboratory
(HU 484)

1. Introductory lecture is to be given to the students so that they get a clear idea of the syllabus and understand the need for having such a practice lab in the first place(3 hours)
2. Conversion practice is done on given situation topics. The students are also made to listen to pre-recorded cassettes produced by British Council and also by the Universities of Oxford and Cambridge (6 hours)
3. Group Discussions:- The students are made to understand the difference between the language of conversion and group discussion. Strategies of such discussions are to teach to them. It is also helpful to use videocassettes produced by the U.G.C. on topics like group-discussion. After wards the class is divided into groups and the students have to discuss on given topics on current socio-economic-political-educational importance(12 hours)
4. Interview sessions-students are taught the do's and don'ts of facing a successful interview. They then have to face rigorous practices of mock-interviews. There simulations of real life interview sessions where students have to face an interview panel(12 hours)
5. Presentations: The secrets of an effective presentation are taught to the students. Then each and every student has to make lab presentations with the help of the Overhead projector/ using power point presentation and other audio-visual aids in the laboratory. They also have to face the question answer sessions at the end of their presentation (12 hours)
6. Classes are also allotted to prepare the students for competitive examinations like the T.O.E.F.L. by making the students listen to specially produced C.D. cassettes of such examinations (3 hours)

The overall aim of this course is to inculcate a sense of confidence in the students and help them to become good communicators in their social as well as professional lives.

Text Books/References:

1. Sharma—Business Correspondence & Report Writing, TMH
2. Prasad—Group Discussion & Interview (With Audio Cassette) , TMH

Chemical Engineering Drawing (CHE 494)

Drawing of: (S. No. 8 and any three of the remaining items)

1. Flange Coupling
2. Hydraulic Pipe Joints
3. Valves
4. Stuffing Box
5. Belt-Pulley
6. Screw Jack
7. Cylinder heads & Cover plates.
8. Assembly Drawing of any Chemical Engineering equipment.

Text Book/ References:

1. Machine Drawing: N.D. Bhatt & V.M.Panchal: Anand India.

West Bengal University of Technology
BF-142, Salt Lake City, Kolkata-700064

Revised Syllabus of B.Tech in CHE(To be followed from the academic session,July 2006 ,i.e. for the students who were admitted in Academic Session 2005-2006).The syllabi of other semesters will be published soon.

5th Semester

Machine Design (CHE 501)

Module-I **10L**

Stress Analysis: Strain, Stress, Elasticity, Medullae of Elasticity, Simple stress, torsion, bending, stress analysis in beams and columns, Euler column formula, combined stresses (Normal and shear stress only), general notions of dynamic load and impact stresses.

Module-II **10L**

Designing for strength: stress-strain diagram, stress concentration (static load applied steadily, static load applied suddenly, variable load), types of failure, prevention of failure, factor of safety, design of combined loading, theories of failure: maximum normal stress theory, maximum shear stress theory, choice of theory of failure, impact loading and fatigue loading, endurance strength, endurance limit, design for fatigue loading; Soderberg criterion, Goodman criterion.

Module-III **10L**

Fasteners: Riveted joints: introduction, rivet heads and methods of riveting, rivet material and rivet test, types of riveted joints, failure of rivet joints and its design. Eccentric loading on rivet and bolted joints. cotter and Knuckle joints. Keys and couplings: Introduction to keys, types of keys, introduction to coupling, different types of coupling,. Pipe joints- different types of hydraulic pipe joints. Shaft-general use, causes of failure in shaft, designing of straight shaft, design for strength, design for rigidity and stiffness. Belt drives-Introduction to different types of belt drives, general design of belt drive.

Module-IV **10L**

Design of Pressure vessel: thin and thick cylinder design, design of cylinder head, cover plate, selection of gasket, design of bolt and flange.

Text Book

1. Process Equipment Design – Brownell and Young, John Wiely and sons
2. Machine Design, Norton, Pearson Education
3. Design of Machine Elements, Sharma & Purohit, PHI
4. Design of Process Equipment – Hesse and Rushton

Revised Syllabus of B.Tech in CHE(To be followed from the academic session,July 2006 ,i.e. for the students who were admitted in Academic Session 2005-2006).The syllabi of other semesters will be published soon.

5. Process Equipment Design – M.V. Joshi, Macmillan India Ltd.

Process Heat Transfer (CHE 502)

Module I **10L**

Heat Transfer by Conduction:

Classification of different Modes; Concept of heat diffusion (conduction), Fourier's Law; Thermal Conductivity – constant and variable; Thermal Diffusivity; Steady State Conduction – Rectangular (Cartesian), Cylindrical and Spherical coordinates; Compound Resistance in Series; Critical thickness of insulation, One dimensional unsteady state heat conduction, Lumped system analysis, Slab – use of transient temperature chart.

Module II **10L**

Heat Transfer by Convection:

Concept of convection, General Heat Transfer Equation (Convection-Diffusion), Flow over a body – Hydrodynamic boundary layer, Drag coefficient, Drag force, Thermal boundary layer, Heat Transfer coefficient. Flow inside duct – Thermal boundary layer, Heat Transfer coefficient.

Heat Transfer in Turbulent Region: Dittus-Boelter Equation; Correction for temperature variation over pipe cross section; Physical Interpretation of different Dimensionless groups; Reynolds analogy, Colburn Analogy; Wilson Equation;

Natural Convection; Correction of Laminar flow equation for Natural Convection.

Module III **10L**

Heat Transfer of Fluids with Phase Change:

Introduction; Dropwise and Film-Type Condensation; Coefficients for Film-Type Condensation: Nusselt Equation for Vertical and Horizontal Tubes; Condensation of Superheated Vapors; Heat Transfer to Boiling Liquids: Pool boiling of Saturated Liquid; Film Boiling.

Radiation Heat transfer:

Introduction; Monochromatic emissive power; Weins displacement law; Plank's law of radiation; Kirchoff's Law; Emissivity of Solids; Absorption of Radiation; Lambert-Beer's law; Absorption by gases. Radiation between surfaces, Concept of View Factor.

Module IV **10L**

Heat Exchange Equipments:

Typical Heat Exchange Equipment; Parallel Flow, Countercurrent Flow, and Cross Flow; General Design of Heat-Exchange Equipment; Different types of Heat Exchanger: Double Pipe Heat; Shell and Tube (1-1, 1-2, 2-4); Introduction to Plate Type; Condensers: Shell and Tube;

Evaporation:

Introduction; Liquid Characteristics; Types of Evaporator; Performance of tubular evaporator: Capacity, Steam economy; Boiling Point Elevation (Dühring Rule); Outside Heat Transfer Coefficients; Enthalpy Balance for a Single Effect Evaporator; Introduction to Multiple Effect Evaporator: Forward feed, Backward feed, Mixed feed, Parallel feed; Design concept of Multiple Effect Evaporator.

Text Books:

1. Heat Transfer – A Basic Approach: M. Necati Ozisik, McGraw-Hill International Edition, Singapore (1985)
2. Fundamentals of Heat and Mass Transfer: Frank. P. Incropera and David. P. Dewitt, Wiley, 4th Ed.
3. Units Operations of Chemical Engineering: McCabe & Smith and Harriot, MGH, 5th Edn.
4. Heat Transfer, B. K. Dutta, PHI
5. Process Heat Transfer: D. C. Kern : MGH.
6. Heat Transfer,Long,Pearson Education

References:

1. Coulson & Richardson: Chemical Engineering (IV)
2. Process Heat Transfer: Y.V.C. Rao

West Bengal University of Technology
BF-142, Salt Lake City, Kolkata-700064

Revised Syllabus of B.Tech in CHE(To be followed from the academic session,July 2006 ,i.e. for the students who were admitted in Academic Session 2005-2006).The syllabi of other semesters will be published soon.

Chemical Process Technology – I (CHE 503)

Module I: **10 L**

Chlor-alkali industries: Production and consumption pattern, manufacture of Chlorine-caustic soda: Raw materials, principles of manufacture, Mercury-cathode & Membrane process: flow-sheet and sequence of operation, other processes, advancement of process technology and major engineering problems, uses.

Hydrochloric Acid: Raw materials, principles of manufacture, flow-sheet and sequence of operation, major engineering problems, uses.

Soda-ash : Production and consumption pattern, Raw materials, Solvey process Physico-chemical principles of manufacture, carbonation and ammonia recovery step, flow-sheet and sequence of operation, other processes, advancement of process technology and modified Solvey process, major engineering problems, uses.

Module II: **8 L**

Sulfur and sulfuric acid: Sulfur and sulfuric acid production process, Production and consumption pattern, Contact process, Physico-chemical principles and general theory of contact reaction with thermodynamic and reaction engineering aspects, different types of catalyst – preparation methodology and relative merits, flow-sheet and sequence of operation, details of major equipments, advancement of process technology and major engineering problems, DCDA process, uses.

Module III: **11 L**

Fertilizer Industries: Production and consumption pattern, Different grades of fertilizer.

Raw materials, Physico-chemical principles of manufacture, flow-sheet and sequence of operation, details of major equipments, advancement of process technology and major engineering problems, uses of the following: **Nitrogen industries:** Ammonia, Nitric acid, Urea and ammonium nitrate. **Phosphorus industries:** phosphorus, phosphoric acid, Calcium phosphate, Triple super phosphate, Ammonium phosphate.

Module IV: **11 L**

Ceramic and ceramic materials: Cement: dry and wet process, setting of cement. Glass: tank and pot furnace method, annealing, manufacture of glass-wool Enameling. Ceramic: white-wares and their forming operations. Refractories: acid, base and neutral, silica and fireclay.

Paints, pigment and surface coating industries: Raw materials, methods of production and uses.

Pulp and Paper industries: Raw materials, Method of production, sequence of operation, Major engineering problems

Nuclear materials: Uranium, Thorium, Heavy water – Raw materials, manufacturing processes.

Text Books / References:

1. Dryden, C. E., and Rao, M.G. (Ed.), Outlines of Chemical Technology Affiliated East West Press
2. Austins, G.T., Sherve's Chemical Process Industries, MGH 5th Edn.
3. Venkateswarlu, S. (Ed.) Chemtech (II) Chemical Engineering Development Centre, IIT, Madras
4. Kirk & Othmer (Ed.), Encyclopedia of Chemical Technology.

Chemical Reaction Engineering (CHE 504)

West Bengal University of Technology
BF-142, Salt Lake City, Kolkata-700064

Revised Syllabus of B.Tech in CHE(To be followed from the academic session,July 2006 ,i.e. for the students who were admitted in Academic Session 2005-2006).The syllabi of other semesters will be published soon.

Module: I **10L**

Introduction; Definition of reaction rate;

Kinetics of homogeneous reaction: Concentration-dependent term of a rate equation, single and multiple reaction, Elementary & Nonelementary reactions, kinetic view of equilibrium for elementary reactions, Molecularity and order of reaction, Representation of reaction rate, Kinetics for non elementary reactions, related problems, Temperature-dependent term of a rate equation: Arrhenius law, Collision theory, Transition-state Theory, related problems;

Interpretation of batch reactor data: Constant-volume batch reactor, Integral method of analysis of data: General Procedure, Irreversible unimolecular-type First-order Reaction, Irreversible Bimolecular-type Second-order Reactions, Empirical Rate Equations of nth Order, Zero-order Reactions, Over-all Order of Irreversible Reactions from the Half-life, Irreversible Reactions in Parallel, Autocatalytic reactions, Irreversible reactions in series, First-order Reversible Reactions, Differential method of Analysis of data: Analysis of the Complete Rate Equation, Partial analysis of rate equation, Variable-Volume Batch Reactor: Differential method of analysis, Integral method of Analysis: Zero-order Reactions, First-order Reaction, Second-order Reactions;

Enzymatic Reaction: Definition and Mechanisms, Michaelis-Menten kinetics.

Module: II **10L**

Single Ideal Reactors: Introduction; Basic division of ideal reactors, Ideal Batch Reactor, Space-time and Space-velocity, Steady-state Mixed Flow Reactor: Design Equation, Graphical Representation of Design Equation, related problem; Steady-state Plug Flow Reactor: Design equation, graphical representation, related problem; Stoichemetric Table, Elementary idea and design equations for Bioreactor: Mass Balance for Cell, Substrate and Product;

Design for Single Reactions: Size and comparison of single reactors: Batch Reactor, PFR, MFR, General Graphical Comparison; Multiple-Reactor Systems: PFRs in Series and/or in Parallel, Equal-size MFRs in Series, MFRs of different sizes in Series, Determining the best size combination of reactor size for a given combination, Reactors of Different Types in Series, Recycle Reactor: Definition of Recycle Ratio, Design Equation, Optimum Recycle ratio.

Module III: **10L**

Design for Multiple Reactions: Introduction, Reactions in Parallel, Qualitative aspects of Product Distribution, Quantitative Treatment of Product Distribution and of Reactor Size: Definition of Instantaneous and Overall fractional yield, graphical representation; Reactions in Series: Successive First-Order Reactions, Product Distribution, Quantitative Treatment of PFR, MFR and Batch Reactor.

Solid-Catalyzed Reaction: Introduction; Basic idea of catalysis, Catalyst properties, Steps in catalytic reaction: Qualitative discussion on Pore Diffusion, Adsorption, Surface reaction and Desorption, Concept of Rate limiting step; Design of reactors for gas-solid reactions: Design equation and data analysis of heterogeneous system; Quantitative aspects of Pore diffusion controlled reactions (single cylindrical pore, first-order reaction): Material balance for the elementary slice of catalyst pore, Definition of Thiele Modulus and Effectiveness Factor.

Fluid-Particle Reactions: Introduction; Different behavior of reacting solid particles; Selection of a Model; Qualitative discussion on Progressive-Conversion Model & Unreacted-Core Model; Comparison of Models with Real Solution.

Module IV: **10L**

Distribution of Residence Times for Chemical Reactors: General Characteristics; Residence-Time Distribution (RTD) Function; Measurement of the RTD: Pulse Input; Related problems; Characteristics of RTD: Integral Relationships, Mean Residence Time, Different Moments od RTD; RTD in Ideal Reactor: RTD in Batch and PFR, Single CSTR, PFR/CSTR series RTD; Reactor Modeling with the RTD: Introduction, Concept of Macromixing & Micromixing, Zero Parameter Model: Segregation Model & Maximum Mixedness Model

Models for Nonideal Reactors: Introduction; One-Parameter Models: Tanks in Series Model, Dispersion Model: Basic Formulation, Definition of Peclet Number & Vessel Dispersion Coefficient, Boundary Conditions (Closed-Closed & Open-Open), Correction for Sloppy Tracer Input, Relation between Flow, Reaction and Dispersion.

Text Books / References:

1. Chemical Reaction Engineering – Levenspiel. O.: Wiley Eastern Ltd. 3rd Edn.
2. Elements of Chemical Reaction Engineering, Fogler, PHI
3. Chemical Engineering Kinetics – Smith J.M. MGH 2nd Edn.
4. Principles of Reaction Engineering – S.D. Dawande, Central Techno Publications.

Revised Syllabus of B.Tech in CHE(To be followed from the academic session,July 2006 ,i.e. for the students who were admitted in Academic Session 2005-2006).The syllabi of other semesters will be published soon.

Separation Processes-I (CHE 505)

Module-I **10L**

FUNDAMENTALS OF MASS TRANSFER:

Principles of molecular diffusion and diffusion between phases, Fick's Law, Diffusivity, Equation of continuity, Diffusion in solids. A definition of Mass transfer coefficient, other definitions of mass transfer coefficient, correlation of mass transfer coefficients, Theories of Mass Transfer, mass transfer across interfaces, Analogy between momentum, heat and mass transfer, Concept of stage wise processes.

Module-II **10L**

ABSORPTION:

Introduction, The mechanism of absorption, Absorption equipment, Diameter and height calculations for packed columns, Kremser equation, H. E. T. P. , H. T. U. , and N. T. U. concepts, Packed tower design, height of column based on conditions in the gas film, height of column based on conditions in the liquid film, height of column based on overall coefficients, plate type towers, number of plates by use of absorption factor.

Module-IV **14L**

DISTILLATION:

Introduction, Vapor -liquid equilibria, Relative volatility, Ideal and non -ideal solutions, Batch, differential and equilibrium distillation, Enthalpy concentration diagram, Rectification of binary systems, Design of rectification column, calculation of number of plates in a distillation column by McCabe-Thiele method, importance of reflux ratio, calculation of number of plates by Ponchon and Savarit method, Azeotropic & Extractive Distillations, Introduction to multicomponent distillation.

Module-IV **6L**

ADSORPTION:

Introduction, nature of adsorbents, batch adsorption, Adsorption isotherms, Adsorption equipment, breakthrough curves, design of fixed bed adsorption column.

Text Books / References:

1. Mass Transfer Operations: Robert E. Treybal, MGH, International student Edition.
2. Transport process and Unit Operations: Geankoplis. 3rd Edn., PHI.
3. Unit Operations in Chemical Engfueering : McCabe, Smith, and Harriot. MGH, Sth Edn.
4. Multicomponent Distillation: Holland, C. D., PHI.
5. The Elements of Fractional Distillation: Robinson, C. S. and Gilliland, E. R. MGH.
6. Mass Transfer: Sherwood, Pigford, and Wilke, MGH.
7. Separation Processes: King, C. J. MGH.
8. Design of Equilibrium Stage Processes: Smith, B. D. MGH.
9. Distillation: van Winkle, M., MGH.

Heat Transfer Lab (CHE- 591)

1. Determination of thermal conductivity of metal bar using Fourier's Equation.
2. Heat loss through lagged pipe and determination of thermal conductivity of insulating material.
3. Determination of thermal conductivity of insulating powder in a spherical vessel.
4. Determination of heat transfer coefficient of air in forced convection and to study the effect of velocities on heat transfer coefficient.
5. Determination of over all heat transfer coefficient in Counter current double pipe heat exchangers.
6. Determination of over all heat transfer coefficient in Parallel flow double pipe heat exchangers.
7. Determination of over all heat transfer coefficient and efficiency of Shell & Tube heat exchanger.

8. Determination of over all heat transfer coefficients in film wise and drop wise condensation.
9. Determination of emissivity of an unknown surface.
10. Determination of Stefan's Boltzman constant using ($dTe/d\theta$) from temperature vs. time plot.
11. Determination of capacity and economy for single /double effect evaporator.
12. Determination of Biot Number and Fourier number in unsteady state heat transfer process

Process Equipment Design and Drawing-I (CHE 592)

1. Flow sheeting: Plan and Space layout of Chemical Processes
2. Design of Orificemeter, Venturimeter, Rotameter.
3. Pipeline design, valve and fittings.
4. Design of shell & tube heat exchanger.

Chemical Reaction Engineering Lab (CHE-593)

1. Determination of rate constant $\Re$, effect of temperature on $\Re$ and activation energy for a non-catalytic liquid phase homogenous reaction (ethyl acetate and aqueous sodium hydroxide solution) carried out in an isothermal batch reactor.
2. To predict the degree of conversion from time temperature data for the reaction: hydrolysis of acetic anhydride with water in presence of an acid catalyst (sulfuric acid) carried out in an adiabatic batch reactor.
3. Determination of rate constant $\Re$ and variation of the concentration of NaOH with time for the saponification reaction between ethyl acetate and caustic soda carried out in an isothermal semi-batch reactor.
4. Determination of rate constant $\Re$ for saponification of ethyl acetate with NaOH, a non-catalytic homogenous liquid phase reaction at ambient condition in a plug Row reactor (straight tube type).
5. Determination of rate constant $\Re$, effect of temperature on $\Re$ and activation energy for a non-catalytic homogenous reaction (ethyl acetate and NaOH) carried out in an isothermal continuous stirred tank reactor (CSTR).
6. Study of RTD in a packed bed reactor using a pulse input of the tracer to measure the axial dispersion co-efficient.
7. Determination of rate constant $\Re$ for saponification of ethyl acetate with NaOH, a non-catalytic homogenous liquid phase reaction at ambient condition in a coil type plug flow reactor.
8. Study of RTD in a straight tube PFR using a pulse input of the tracer to measure the axial dispersion coefficient.

West Bengal University of Technology
BF-142, Salt Lake City, Kolkata-700064

Revised Syllabus of B.Tech in CHE(To be followed from the academic session,July 2006 ,i.e. for the students who were admitted in Academic Session 2005-2006).The syllabi of other semesters will be published soon.

6th Semester

Separation Processes-II (CHE 601)

Module-I **10L**

HUMIDIFICATION & DEHUMIDIFICATION PROCESSES:

Humidification and dehumidification operations, Characteristics of saturated and unsaturated vapor gas mixtures, Dry and wet bulb thermometry, Psychometric chart, Adiabatic saturation curves, Gas liquid contact, Design of humidifiers, Dehumidification operation, Principle and design of cooling towers (Natural draft, forced draft and induced draft cooling towers).

Module-II **15L**

LIQUID-LIQUID EXTRACTION & LEACHING:

Introduction to Extraction, Liquid- liquid equilibria, Triangular diagram, Selectivity and choice of solvents, Stage wise contact, co-current & countercurrent extractor, Stage type extractors and differential extractors, Determination of number of equilibrium stages by graphical method for multistage extraction, Extraction efficiency.

Introduction to leaching, general principle, factors affecting the rate of extraction, Liquid -solid equilibria, calculation of number of stages, batch processes, countercurrent washing, stage calculation methods.

Module-III **8L**

DRYING & CRYSTALLIZATION:

Introduction to drying, Rate of drying, Batch drying mechanism, the mechanism of moisture movement during drying, classification and selection of dryer.

Introduction to crystallization, Theory of Crystallization, Formation and growth of crystals, crystal yield, Rate of crystallization.

Module-IV **7L**

MEMBRANE SEPATION PROCESSES:

Introduction to advance separation processes, classification of membrane processes, Dialysis, Ultra filtration, Reverse Osmosis, reverse osmosis in water treatment plant, Pervaporation, Electro dialysis, membrane fouling, liquid membrane.

Text Books / References:

1. Separation Processes: King, C. J., MGH.
2. Unit Operation Handbook (Vol. I): John J. Mcketta.
3. Transport Process and Unit Operations: Geankoplis. 3rd Edn., PHI.
4.Unit Operations in Chemical Engineering: McCabe, Smith, and Harriot. MGH, Sth Edn.
5. Mass Transfer Operations: Robert E. Treybal, MGH, International Student Edition.
6. Chemical Engineers.s Handbook: Perry, J. H. MGH, 6th Edn.

Chemical Process Technology – II (CHE 602)

Module I: **10L**

Oils & Fats: Methods of extracting vegetable oils (Process Description and Flow sheet). Hydrogenation of oils (Process description & flow sheet) and major engineering problems.

Soaps, Detergents & Glycerin: Classification of cleansing compounds, uses, Methods of soap production, Methods of detergent manufacture, Methods of production of Glycerin. Process description & flow sheet of each process.

Module II: **10L**

Sugar and starch industries: Manufacturing process with flow diagram, Sugar refining, manufacturing process of starch and their different by-products.

Fermentation industries: Industrial Alcohol, Absolute Alcohol; their production process with flow diagram.

Agrichemical industries: Pesticides: Insecticides, Fungicides, Herbicides– Varieties of insecticides and methods of preparation and uses, Classification of herbicides and methods of preparation, DDT manufacturing process and flow sheet.

Module III: **12L**

Unit operation in organic synthesis: nitration, sulfonation, amination, Halogenation, Hydrolysis with examples.

Petrochemicals : Methanol, Vinyl chloride, Ethylene oxide, Isopropanol, Butadiene, Phenol and Pthalic anhydride – their manufacturing process with flow diagram and engineering problems.

Synthetic Fibre industry: Rayon, Nylon, Terelyne – Methods of production and flow diagrams.

Module IV: **8L**

Polymerisation: Principles of polymerization, Different methods of polymerization, manufacturing process and flow diagram for Polyethylene, PVC and Phenol formaldehyde.

Rubber industry: Natural and synthetic rubber (SBR, Butyl rubber).

Text Books / References:

1. Dryden, C. E., and Rao, M.G. (Ed.), Outlines of Chemical Technology Affiliated East West Press
2. Austins, G.T., Sherve's Chemical Process Industries, MGH 5th Edn.
3. Venkateswarlu, S. (Ed.) Chemtech (II) Chemical Engineering Development Centre, IIT, Madras
4. Kirk & Othmer (Ed.), Encyclopedia of Chemical Technology
5. A Text on Petrochemicals: B.K.B. Rao, Khanna Publisers.
6. Unit operation in organic systhesis : P.H. Groggins.

Instrumentation and Process Control (CHE 603)

Module I: **10 L**

Introduction: Principles of measurement. Error Analysis, Static and dynamic characteristics of instruments; Temperature measurement: Filled system Thermometer, Thermocouples, resistance thermometers, radiation and optical pyrometers; Pressure: Manometers, elastic deformation and electrical type gauges. Vacuum gauges: mechanical, electrical and ionization types; Flow: Head flow meters, area flow meters, positive displacement flow meters, mass and magnetic flow meters; Level: Direct and inferential type; composition. Analytical principles involving emission spectrometry, I R, spectroscopy, gas chromatography, Polarography, x-ray and p_H

Module II: **10L**

Simple Process Model: Stirred Tank Heater, CSTR, Shell &Tube Heat exchanger, I/O model, Linearization and concept of deviation variable, Laplace Transform, Block Diagram, Different forcing function: step, pulse, impulse, ramp, sinusoid: Transfer function: both for SISO & MIMO systems, Transient response of first, second and higher order systems, Transportation lag; Pade' approximation, Lumped and distributed parameter system, Control valve: Characteristics curves and transfer function.

Module III **10L**

Control loop and its components: Measuring device, Controller, Final Control Element (FCE), transmission line; Servo and Regulator control, closed loop response, Different type of analog controller: P, PI, PD, PID, On-Off. Concept of Stability: BIBO, characteristics equation, Routh– Hurwitz method, root locus method

Module IV **10L**

Frequency Response Analysis: Amplitude Ratio and Phase Lag calculation for: General, first, second and higher order systems, Dead time, P, PI, PD, PID controllers and their respective Bode plot & Nyquist plot; Bode & Nyquist stability criteria; Controller design: Empirical tuning criteria: one quarter decay ratio, ISE, IAE, ITAE; Controller tuning: Cohen-Coon, Zeigler-Nichols method; Elementary idea of feed forward, cascade, ratio, adaptive and digital computer control.

Text Books / References:

1. Intrumentation, measurement and Analysis – B. C. Nakra & K. K. Chaudhury (TMH)
2. Process system analysis & Control – D. R. Coughanowr MGH.
3. Chemical Process Control – G. Stephanopoulus PHI.

Numerical Methods in Chemical Engineering (CHE 604)

Module I: **10L**

Error Analysis: Taylor series expansion, Truncation error. Round-off error vs. Chopping-off error. Propagation of Error
Solution of simultaneous linear equations: Gauss elimination Method, Gauss-Jordon Method -Pivoting and ill-conditioning. Iterative method - Jacobi iteration, Gauss-Seidel Method. SOR method, Application in steady-state solution of isothermal CSTR in Series in which a first-order reaction is taking place and multiple reactions in CSTR. Tri-Diagonal Matrix Algorithm (TDMA).

Module II: **10L**

Solution of Non-linear equations:
Bisection method, Newton-Rapson method, Secant method, Modified Newton-Rapson methodfor multiple roots - Application in thermodynamic property calculation, buble point and dew point calculation. Finding of multiple roots of a polynomial. Solution of a set of non-linear equations - Newton's method, Jacobian matrix, charactertics equations and stability analysis of solution. Steady-state solution of a non-isothermal CSTR in which a first-order reaction is taking place.

Module III: **10L**

Curve-fitting : Linear least-square method for straight line and polynomial. Lagrange interpolation.
Numerical Solution of ODE: Initial and boundary value prolem- Euler's Method, Runge-Kutta Method(2^{nd}, 3^{rd} and 4^{th} order), Euler's predictor-corrector method (Heun' method)- finite difference method (forward, backward and central differences). Solution of a set of ODEs. Application in chemical and bio-chemical reaction.

Module IV: **10L**

Numerical Integration: Trapezoidal rule, Simpson's 1/3rule.
Numerical Solution of PDE: Explicit, Implicit and Crank-Nicholson method for elliptical and parabolic equation. Convergence and stability criteria of these methods. Application in unsteady-state heat transfer through a slab and unsteady-state tubular reaction problem.

Text Book and references

1. Mathematical Methods in Chemical Engineering : V. G. Jenson and Jeffrey
2. Applied Mathematics in Chemical Engineering: Mickley TMH
3. Mathematical Methods in Chemical Engineering: S. Pushpavanam, PHI
4. Numerical methods for Mathematics, Science and Engineering: John H. Mathews , PHI
5. Applied Numerical Methods: Carnahan, H.A.Luther and J.O.Wilkes, Wiley

Elective–I (CHE 605)

Pulp & Paper Technology (CHE 605 A)

Classification of pulp, Pulp making process, Treatment, Bleaching and testing of pulp, By product utilization and chemical recovery processes in the paper industry, Methods of production of paper from pulp. Different paper products. Pollution control problems in paper industries, Recovery of different chemical from the waste.

Text Books / References:

1. Hand Book of Pulp and Paper Technology: K. W. Britt, Van Nostrand, Reinhold, N. V., 2nd Edn.

2. Pulp and paper, Vols I, II, III and IV: J. P. Casey, Wiley – Interscience, 3rd Edn.

3. Pulp Technology and Treatment for Paper: J. Clark, Miller, Freeman, S. F.

Catalysis & Catalytic Reactor Design (CHE 605 B)

Module I: **10L**
Introduction to homogeneous and heterogeneous catalysis; Rate equation; Factors affecting heterogeneous catalytic reaction; Types of catalytic Reactor and their performance equations; Related Problems.

Module II: **10L**
Catalyst Preparation; Concept of Promoter & Inhibitor; Catalysis mechanism; Langmuir-Hiselwood model.

Module III: **10L**
Determination of Catalyst surface area and particle size; Pore volume Distribution; Design of Fixed Bed and Fluidized Bed Reactors; Two Dimensional Model.

Module IV: **10L**
Catalyst deactivation mechanism; Related Problems; Cocept of Nanotechnology in Catalyst.

Text Books/ References:

1. Chemical Reaction Engineering – Levenspiel. O.: Wiley Eastern Ltd. 3rd Edn.
2. Elements of Chemical Reaction Engineering, Fogler, PHI
3. Chemical Engineering Kinetics – Smith J.M. MGH 2nd Edn.

Food Processing Engineering (CHE 605 C)

Basic principles of food preservation, Dehydration, thermal processing, Freezing, Fermentation etc. Classification of foods, Processing of fruits–vegetables–cereals–pulses– oil seeds–poultry–meat and fish, effects of processing on acceptability and nutritive value of foods, Food additives–Preservatives and food packaging.

Text Books / References:

1. Fundamentals of food processing Engineering: Toledo, R. T. Avi Westport Conn.
2.Food Processing & Preservation, Sivashankar, PHI

3. Food Processing Engineering: Heldman, D, Rand R. P. Singh, Avi Westport Conn., 1981.

Ceramic Technology (CHE 605 D)

Module-I: **10L**

Revised Syllabus of B.Tech in CHE(To be followed from the academic session,July 2006 ,i.e. for the students who were admitted in Academic Session 2005-2006).The syllabi of other semesters will be published soon.

General: Concepts of Materials Science, Definition & scope of ceramics, Classification of Ceramic materials-conventional & advanced, silicate structures, Principal ceramic raw materials-general idea about their mining & purification, physical & chemical properties, availability & uses.

Module-II: **10L**

White ware & ceramic coatings: Manufacturing process technology of white ware bodies specially high voltage & high tension insulators, bone china crockeries etc, basic properties & testing. Definition of glaze & enamel, their types & adherence mechanism, elementary ideas on their process technologies & properties.

Module-III: **10L**

Glass & cement: Classification of different types of glasses, manufacture of glass- its melting reactions & annealing, defects & their remedies, properties & testing of glass. Concept of hydraulic materials, types of cement & concrete, manufacturing processes, cement compounds & their functions, setting & hardening mechanisms, fly ash & B. F. slag cements, properties & testing of cement & concrete.

Module-IV: **10L**

Refractories & kilns: Classification of refractories-conventional & monolithies, phase diagrams of simple refractory systems like silica-alumina, magnesia-silica, magnesia-alumina, etc. manufacture, basic properties, testing & applications. Various types of kiln & furnaces used in ceramic industries with heat economy systems.

Text Books / References:

1. Elements of Ceramics: F. H. Narton, Pearson Education
2. Fine Ceramics: F. H. Norton, MGH.
3. Source book of ceramics, Part I & II, S. Kumar

Petrochemical Technology (CHE 605E)

Module I: **10 L**

Petrochemical Industries & their feed stocks: Survey of Petrochemical industry.Resources and generation of different feedstocks – their purification, separation of individual components by adsorption, low temperature fractionation and crystallization.

Production and Utilization of Synthesis gas: Generation of synthesis gas by steam reforming of naptha & Natural gas, fuel oil partial oxidation. Chemicals from synthesis gas eg. methanol, Oxosynthesis etc. Fischer – Tropsch process.

Module II: **10 L**

Petrochemicals based on methane, ethylene, acetylene, propylene and butane: Acetylene & methanol from methane ,VCM, VAM, ethylene oxide and ethylene glycol, ethanol amines from ethylene.VCM, VAM, acrylonitile etc. from acetylene. Isopropanol, propylene oxide, glycerine, acrylonitile, acrylic acid, acrolien etc. from propylene. Production of Butadiene by dehydrogenation of Butane.

Module III: **10 L**

Separation and Utilization of Aromatics: Catalytic Reforming operation – Separation of BTX from reformate. Isolation of Benzene, Toluene, Xylene. Aromatics derived from thermal cracking of naptha, pyrolysis gasoline hydrogenation process. Alkylation of Benzene. Production of styrene, cumene and phenol, Isomerization of O and m xylene into p-xylene. Production of pthalic Anhydride etc.

Synthetic Detergents: Classification of detergents, Production of Keryl Benzene sulphonate etc., filter, binders, dyes, perfumes etc. for detergents. Hard and soft detergents.

Revised Syllabus of B.Tech in CHE(To be followed from the academic session,July 2006 ,i.e. for the students who were admitted in Academic Session 2005-2006).The syllabi of other semesters will be published soon.

Module IV: **10 L**

Synthetic fibres, rubbers, plastics, resins : Method, mechanism & types of polymerization, production of HDPE, LDPE, PP, PVC, Polystyrene, Polybutadiene etc. Manufacture of Polyesters, nylons, aerylic fibres etc. Production of phenol formaldehyde resin, Epoxy resin Production principle of ABS plastic, polycarbonates etc. Manufacturing techniques of Butyl rubber, SBR, Isoprene rubber etc.

Text Books / References:

1. A Text on Petrochemicals: B.K.B. Rao, Khanna Publishers
2. Petrochemical processes :Chauvel ,Gulf Publishing
3. The Petroleum chemicals Industry: R. F. Goldstein and A. L. Waddams.
4. Advanced Petrochemicals: Dr. G. N. Sarkar, Khanna Publishers

Shellac Processing Technology (CHE 605 F)

Syllabus to be designed

Numerical Computations Lab (CHE 691)

Module- I: Numerical Methods (Programming language: C/FORTRAN)

1.0 Solution of Linear System by Gauss Elimination method and Gauss-Seidel iterative method: Steady-state solution of isothermal CSTR in Series in which a first-order reaction is taking place.
2.0 Solution of a non-linear equation by Newton-Raphson method.
3.0 Solution of a set of non-linear equations by Newton method: steady-state solution of a non-isothermal CSTR in which a first-order reaction is taking place.
4.0 Solution of one-dimensional unsteady state heat conduction problem using Taylor series based Finite Difference Method – Explicit scheme, Implicit scheme using Tri-diagonal Matrix Algorithm (TDMA).
5.0 Numerical solution of ODEs by Runge-Kutta method : Unsteady-state solution of Multiple reactions in a CSTR or Binary distillation column

Module-II: Use of MATLAB / POLYMATH software to solve following problems:

6.0 Solution of Linear System: Steady-state solution of isothermal CSTR in Series in which a first-order reaction is taking place.
7.0 Solution of a set of non-linear equations: Steady-state solution of a non-isothermal CSTR in which a first-order reaction is taking place.

Process Equipment Design and Drawing-II (CHE 692)

1. Design and Drawing of Evaporator.

2. Design and Drawing of Reactor.

3. Design and Drawing of Dryer.

Mass Transfer Lab (CHE-693)

1. Determination of diffusivity of volatile liquids in air using Stefan tube.
2. Study of simple batch distillation to verify of Rayleigh's equation.
3. To draw vapor liquid equilibrium diagram using Othmer still.
4. Experiment on wetted wall column to determine k_L (liquid phase mass transfer co-efficient).
5. To study the performance of a rectification column (plate type).
6. To study the absorption CO_2 in NaOH solution in a packed tower.

7. To study the drying characteristics curve under constant drying condition in a rotary vacuum or tray dryer.

8. Experiment on batch adsorption (to verify adsorption isotherms).

9. Experiment on liquid-liquid extraction (to determine overall efficiency for a three stage counter current and cross current system).

10. Determination of dry bulb temperature, wet bulb temperature, barometric pressure and psychometric properties of air.

7th Semester

Mathematical Methods in Chemical Engineering (CHE 701)

Module I **10L**

Mathematical statement of Chemical Engineering problems: Introduction; Representation of the problems: Solvent extraction in two stages, Solvent extraction in N stages, Simple water still with preheated feed, unsteady state operations; Dependent and Independent variables and parameters; boundary conditions.
Matrix: Introduction; Matrix algebra; Determinant of square matrix and matrix products; Transpose, Adjoint & Inverse of a matrix; Rank & degeneracy of a matrix; Sub matrix; Solution of linear algebraic equations; Matrix series; Differentiation & Integration of matrix; Lamda matrix; Characteristics equation; Sylvester's theorem; Solution of systems of linear differential equations by matrix.

Module II **10L**

Ordinary Differential Equations: Introduction; Order & Degree; First order differential equations: Characteristics, General method of solution, related problems; Second order differential equations: Linear & simultaneous differential equations, related problems.

Solution by series: Introduction; Infinite series; Power series; Method of Frobenius and Related problems: Temperature distribution in a transverse fin of triangular cross section, Tubular gas preheater; Bessel's Equation, Problem of heat loss through pipe flanges, properties of Bessel function.

Module III: **10L**

Partial differentiation & Partial Differential Equations: Introduction; Interpretation of partial derivatives, Formulation of partial differential equations; Boundary conditions; Particular solutions of partial differential equations; Orthogonal functions; Method of separation of variables; Laplace transform method.

Module IV: **10L**

Finite Differences: Introduction; The Difference Operator (Δ); other difference operators; Interpolation & Extrapolation; Finite Difference Equations: Linear Finite Difference Equations & Nonlinear Finite Difference Equations; Differential-Difference Equations; Related Chemical Engineering Problems.

Text Book/ References:

1. Mathematical Methods in Chemical Engineering: V. G. Jenson & G.V. Jeffreys: Academic Press.
2. Mathematical Methods in Chemical Engineering: S. Pushpavanam: Prentice Hall of India

Modeling, Simulation and Optimization (CHE 702)

Module I: **10L**

Introduction to mathematical Model and Simulation: Concept of Mathematical model, simulation and process analysis. Lumped and distributed parameters models- hydraulic tank, mixing vessel, simultaneous mass and energy balance.

Modeling of Batch and Continuous Process: Batch heating of multi-component flash drum, Steady-state flow processes involving non-reactive systems-Extraction column (plate type), Continuous heating in a stirred tank using jacket and using coil, Mixing in flow processes.

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Module II: **10L**

Modeling of Heat and Mass Transfer: Concentration gradient across a bubble plate, Simultaneous heat and mass transfer in packed bed, Start-up of double pipe heat exchangers, Shell and tube heat exchanger, Simulation of multi-component distillation column: Wanke-Henke bubble method, sum-rate method and simultaneous correction method.

Module III: **10L**

Chemical Reactor Simulation: Modeling and simulation of isothermal and non-isothermal operation of batch reactor, CSTR and Semi-batch reactor, Steady-state multiplicities in CSTR, Thermal stability analysis of CSTR, Non-isothermal operation of a single-homogeneous gas phase reaction in PFR, Diffusion and chemical reaction-catalytic reaction in packed bed reactor.

Module IV: **10L**

Introduction to Flow sheeting: Concept of flow sheeting,Various methods of flow sheeting-equation oriented approach and modular approach.

Process Optimization: Concept and utility of process optimization one variable optimization (Newton's method, Secant methods, dichotomous search, Fibonacci, golden search method), Constrained Optimization: Simplex method, Unconstrained optimization: Direct search technique and gradient search technique.

Text Book/ References:

1. Luyben, W.L., Process modeling simulation and Control, MGH

2. Edger, T.F. and Himmelblau, D.M., D.M., Optimization of Chemical Process, MGH

3. Henley and Seader, Multistage separation

4. Froment and Bischoff, Chemical reactor analysis and design, Weiley.

5. Westerberg, A.W., Hutchinson, H.P., Motard, R.L., and Winter,P., Process Flowsheeting, CUP(1979)

6. Systematic method of Chemical Process Design- L.T. Biegler, I.E. Grossmann, and A.W. Westerberg, Prentice-Hall International, Inc.

7. Chemical Process Simulation : Wiley Eastern Ltd., New Delhi, *Asghar Hussain*

Project Engineering (CHE 703)

Module I: **10 L**

Basis of chemical plant design: Steps in process development, feasibility survey, pilot and semi commercial plant design, scale up and scale down techniques, plant location and plant lay out, plant utilities, environment and safety clearances.

Mathematical tools for analysis in design: Basic statistical techniques, testing of hypothesis, t-test, F-test, chi-square test, basic concepts of ANOVA, one way and two way classification models.

Module II: **10 L**

Depreciation: Types of depreciation, Depletion, concepts of service life, salvage value, and book value, straight-line method, text book and double declining balance method, sum of the years digit method and sinking fund method for determination of depreciation.

Interest, annuities, costing and project evaluation: simple, compound and continuous interest, annuity, fixed and working capital, factorial method of cost estimation for plants, present worth, cash flow and discounted cash flow and rate of return, pay-back period, perpetuity and capitalized costs, pay out period, sensitivity analysis, alternative investments and replacements.

Module III: **10 L**

Optimum Design and Design strategy: Basic principle of Optimum Design, general procedure for determining optimum conditions, Breakeven analysis, Optimum production rate in plant, determination of optimum economic pipe diameter and optimum flow rate in condenser, optimum design in separation columns.

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Module IV: **10 L**

Bar chart, Gantt chart, Milestone Chart, Concepts of Network Analysis: PERT, CPM, Numbering a network, Statistical distribution associated with PERT network, Earliest Expected time and Latest allowable occurrence time calculation, Slack, determination of critical path, concepts of Float.

Revision: 5L

Text Book/ References:

1. Peter and Timmerhaus, Plant Design and Economics for Chemical Engineers.
2. Himmelblau, Chemical Engineering Plant Design.
3. Sinnott, R.K., Coulson and Richardson's Chemical Engineering- Vol. 6 (Chemical Engineering Design)
4. Montogomery, Design of Experiments

Elective-II (CHE 704)

Polymer Science & Engineering (CHE 704 A)

Definitions and concepts of terms used in polymer engineering, Polymerization reactions, Polymer structures functionality and Degradation, Characterization of polymers, Molecular weight, Physical, Chemical and Mechanical properties and their determination, Classification of polymers, Methods of polymerization, Mechanism and Kinetics of polymerization, Analysis of polymerization reactions, Polymer processing, molding, Cold and hot compression, Transfer injection and jet types extruding, Calendening, Skiving, Sheet forming, Atmospheric and fluid pressure forming, Lamination and impregnating, Coating, Expanding, Casting, Embedding, Spinning and finishing.

Text Books / References:

1. Introduction to Polymer Science & Technology: Herman S. Kaufman and J. J. Falcetta: Wiley.

2. Polymer Science & Engineering: David J Williams, Prentice Hall Inc.
3. Outlines of Polymer Technology, Sinha, PHI

Petroleum Refinery Engineering (CHE 704 B)

Module I: **10 L**

Exploration and Refining of Crude Oil : Introduction, Indian and world reserve of crude oil and its processing capacity, Market demand & supply of petroleum Fractions. Exploration, Drilling and Production of crude oil; engineering data of crude and fractions. Characterization factor, Key Fraction Number and correlaton index methods for evaluation of crude & fractions. TBP, ASTM, EFV, and their inter-convertibility, yield Curve etc.

Module II: **10 L**

Desalting of crude, pipe still furnaces, preflashing operation, Atmospheric and vacuum distillation units, different types of Reflux arrangements, Calculation of tray requirement for ADU column. Test methods and specifications: Distillation, Aniline point, Reid vapour pressure, Smoke point, flash point fire point, Carbon residue, viscosity and viscosity index, refractive index, Copper & silver strip corrosion, Octane No, cetane No, sulphur content, calorific value, Total acid number, oxidation stability, cloud point, pour point etc.

Module III: **10 L**

Thermal conversion Processes: Thermal cracking processes – mechanism, applications e.g. visbreaking, thermal cracking, coking operations, Catalytic Conversion Processes : Catalytic cracking processes, Different FCC operating modes, Catalytic reforming operations, Hydro cracking, Simple process calculations.

Module IV: **10 L**

Thermal Polymerization, Isomerization processes, Alkylation, Catalytic Polymerization for gasoline stock preparation.

Finishing & Treatment processes : Different Hydrotreatment (eg. Hydro desulfurization) processes, Merox process, Doctor's sweetening, Smoke point improvement, etc. Simple process calculations
Alternative fuels, Production and Specifications: Synthetic gasoline, Bio Diesel, Ethanol, Automotive LPG

Text Books / References:

1. Petroleum Refinery Engineering – W.L. Nelson, Mc Graw Hill.
2. Modern Petroleum Refining Processes – B.K. Rao. Oxford & IBM.
3. Petroleum Refining Technology – Dr. Ram Prasad, Khanna Publishers.
4. Advanced Petroleum Refining: Dr. G. N. Sarkar, Khanna Publishers.

Tea Processing Technology (CHE 704C)

Syllabus to be designed

Fertilizer Technology (CHE 704 D)

Types of fertilizers and their uses, Production and consumption pattern, Raw materials, Mini and large plants their merits and demerits, Symbiosis, Different nitrogen fixation Processes, Nitrogen cycle in the nature, Different nutrient of the soil and their removal, Status of ammonia production, Synthesis gas by reforming hydrocarbons from natural gas and naptha. Consideration for primary reformer design, Secondary reforming design and operation, Synthesis gas by partial Oxidation of hydro-carbons, Reactor volume calculation, Sources of hydrogen, Gas purification, Shift reactor design, Methods for removal of carbon dioxide, Carbon dioxide absorber design, ammonia synthesis, Kinetics and catalysis, Urea superphosphate and other fertilizers.

Text Books / References:

1. A Text Book of Chemical Technology: S. O. Shukla and G. N. Pandey.

2. Chemistry and Technology of Fertilizer: Sanchilli, V. Reinhot Pub. Co.

3. Encyclopedia of Chemical Technology: Kirk and Othmer, Wiley.

Advanced Separation Processes (CHE 704 E)

Module I: **10 L**

Membrane Separation Process: Types of membranes, structural properties of membranes, Mechanical properties of membranes. Organic & Inorganic membranes, advantages & disadvantages and applications of various membranes, membrane modules, transport mechanism in membrane process, formation of liquid membrane, operational aspects of liquid membrane, effect of various operating conditions on the performance of LSM, advantages & disadvantages of liquid membrane.

Module II: **10 L**

Ultrafiltration: UF modules, applicability, concentration polarization.
Reverse Osmosis: Fundamentals of RO, Osmotic pressure, relation between chemical potential & osmotic pressure, factors affecting the performance of RO plant, RO membrane module, membrane age, advantages, disadvantages and application of RO process.

Module III: **10 L**

Pervaporation: Theory of Pervaporation, separation factor, factors affecting pervaporation – Classical Pervaporation, Air heated pervaporation, Osmotic Distillation, Thermopervaporation, Reactive pervaporation, advantages of pervaporation, application of pervaporation.
Chromatographic Separation: Theory of Chromatographic separation, selectivity or separation factor, Efficiency of Chromatographic system, types of Chromatography, Liquid Chromatography, Liquid-Solid Chromatography, Advantages & Disadvantages of Chromatographic Separation.

Revised Syllabus of B.Tech in CHE(To be followed from the academic session,July 2006 ,i.e. for the students who were admitted in Academic Session 2005-2006).The syllabi of other semesters will be published soon.

Module IV: **10 L**

Gas Separation: Theory of gas separation and permeability, permeability ratio and Knudsen diffusivity, factors affecting permeability, separation factors, application of gas separation process.
Dialysis: Theory of Dialysis, separation factor in Dialysis, Fluid film resistance in dialysis, dialysis membrane, application of dialysis process.

Revision: 5 L

Text Book/ References:

1. J.D. Seader and Ernet J. Henlay; Separation Process Principles.
2. C.J. King; Hand Book of Mass Transfer.
3. John J. Meketta; Unit Operation.
4. Perry's Chemical Engineers Hand Book, MGH

Industrial Management (HU 715)

Module I: **10L**

Principles of Management: Taylor and Fayol, Concept of production and productivity. Types of production system. Inventory control-EOQ Model, Model with price discount. MRP. Quality control: SQC (Acceptance sampling and control charts)

Module II: **10L**

Financial statement and analysis: Basic Financial concepts, Risk and Return, liabilities, Importance of ratio analysis, types of ratios, liquidity ratio, current ratio, profitability ratio, Debt-equity ratio, expenses ratio, activity ratio, return on asset, Du-Pont chart.

Module III: **10L**

Fund and cash flow analysis, Budgetary control, Different types of audit, Problem of allocation of limited resources in an optimal way.

Module IV: **10L**

Formulation of linear programming problem, Graphical methods, Simplex techniques, Transportation and assignment models.
Introduction to game theory, Equivalence of matrix game (2×2, m×2,m×m, 2×m) games.

Text Books/References:

1. H.B. Maynard- Handbook of Industrial Engineering.
2. Billy E.Gillet- Operations Research: A computer oriented algorithmic approach. Tata McGraw Hill.
3. Financial Management : Prasanna Chandra, Tata McGraw Hill
4. Production and operation Management: S.N.Chary, Tata McGraw Hill

References:

a. Operation Research-an introduction: H. Taha. Pearson.
b. Operation Research : Hiller and Lieberman, Tata McGraw Hill
c. Modern Production and Operation Management:Buffa and Sarin, John Wiley.
d. Finantial Management: I.M.Pandey, Vikas

Project Work/ Plant Design (CHE 791)

Revised Syllabus of B.Tech in CHE(To be followed from the academic session,July 2006 ,i.e. for the students who were admitted in Academic Session 2005-2006).The syllabi of other semesters will be published soon.

Each student shall be required under the supervision of a faculty to prepare a project work on a topic of design or to carry out investigation on an industrial research problem; the design / research work has to be carried out by the student himself occasionally consulting his supervisor. The work has to be allotted at the beginning of the seventh semester indicating the items to be carried out by the student. The report in duplicate has to be submitted in typed and bound from before the commencement of the VIIIth (final) semester examination. The examination shall include presentation of the research/ design report and a viva-voce.

Processes Instrumentation and Control Lab (CHE 792)

1.0 Temperature Measurement using Resistance Temperature Detector (RTD), Thermocouple.
2.0 Pressure gauge calibration using Dead Weight Tester
3.0 Liquid-Level Measurement using Air-Purge Method
4.0 Measurement using Load Cell
5.0 Study on Responses of First and second-Order Interacting and non-interacting Systems

6.0 Studies on Characteristics of Control Valve
7.0 Studies on the Stability and tuning of a Flow Controller
8.0 Response of a P & PI Controller
9.0 Demonstration of Bourdon tube, diaphragm gauge, etc

Process Equipment Design and Drawing-III (CHE 793)

Design and Drawing of the followings:

1. Absorption/ Stripping Column.

2. Rectification Column

3. Induced Draft Cooling Towers.

Report and Viva-Voce on In-plant Training (CHE 794)

Report should consist of:

1. A general overview of the Plant.

2. The products and raw material sources of the Plant.

3. Details of different equipments like valve, pump, heat exchanger, furnace, storage vessel, piping, basic control configurations etc.

4. Scheduling and Optimization of plant operations.

Seminar (CHE 795)

A Seminar topic will be allotted to individual student according to his/her subject of interest (students are also suggested to propose topics with relevant research papers during the time of allotment). A thorough report should be prepared based on which seminar presentation and question-answer session will be conducted

8th Semester

West Bengal University of Technology
BF-142, Salt Lake City, Kolkata-700064

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Transport Phenomena (CHE 801)

Module I **10L**

Introduction:

Concept of unified approach to Momentum, Heat and Mass Transport through Transport Phenomena - Assumptions of Transport phenomena; Similarity of Mass, Momentum and Energy transfer, Diffusivities, Transport Theorem.

Vectors & Tensors:

Geometric representation of vectors; Einstein summation convention; Basic review of vector algebra; Representation using Kronecker delta and alternating unit tensor; Review of vector calculus. Tensors: dyadic products with another tensor, vector etc; tensor operations required for stress analysis.

Module II **10L**

Momentum Transport:

Viscosity, Newton's law of viscosity, calculation of momentum flux, Non-Newtonian fluids – Bingham model, Ostwald-de Waele model, Eyring model, Reiner-Philippoff model.

Shell momentum balance and boundary conditions – Flow of a falling film with constant/variable viscosity, Flow through a circular tube, Flow through annulus, Flow of two adjacent immiscible fluids, Creeping flow around a sphere.

Equations of Continuity and Motion in rectangular (Cartesian) coordinate system, Expression of stress tensor for Newtonian and non-Newtonian fluids; Special forms of equation of Motion – Euler equation, Navier-Stokes equation. Transformation of equations of Continuity and Motion to cylindrical coordinate system by changing variables and using vector calculus.

Use of the above conservation equations – Steady incompressible flow through circular tube, Laminar flow between two flat stationary/moving plates, Shape of the surface of a rotating fluid.

Concept of Boundary layer and Boundary layer theory. Concept of turbulence, Time-smoothed quantities, Reynolds' decomposition, RANS (Reynolds Averaged Navier-Stokes equation).

Dimensional analysis of equations of Continuity and Motion.

Module III **10L**

Energy Transport:

Modes of heat transfer; concepts of (a) thermal conductivity – constant and temperature dependent, (b) thermal diffusivity and (c) heat transfer coefficient. Fourier's law of heat conduction.

Shell energy balance and boundary conditions – Heat conduction with electrical, nuclear, viscous and chemical heat source, Heat conduction through composite walls, Heat conduction in fins.

Free convection – flow between two vertical walls.

Equation of energy (general convection-diffusion equation) – rectangular coordinate system. Use of the Energy equation - Unsteady state conduction in finite and semi-infinite slabs.

Concept of thermal boundary layer vis-à-vis hydrodynamic boundary layer – effect of Prandtl number on thermal boundary layer thickness.

Dimensional analysis of equation of Energy.

Module IV **10L**

Mass Transport:

Concentrations, Velocities and Mass and Molar fluxes. Concept of Mass diffusivity and Mass transfer coefficient. Fick's law of diffusion.

Shell mass balance and boundary conditions – Diffusion through stagnant gas film, Diffusion in a falling film, Diffusion with heterogeneous chemical reaction, Simultaneous mass and heat transfer problem.

Equations of Continuity for binary mixture, simplification of general equation for special cases.

Dimensional analysis of the equations of Continuity – role of Schmidt number.

Generalized Transport Equation:
General Advection-Diffusion equation - conservation equations (Motion, Energy and Species concentration) in terms of general variable (Φ) and diffusivity. Concept of coupled equations.

Text Books:

1. Transport Phenomena: R. Byron Bird, Warren E. Stewart and Edwin N. Lightfoot. , John Wiley & Sons Inc. Asian Students Edition.

Biotechnology & Biochemical Engineering (CHE 802)

Module I: **10L**
Introduction to biochemical Process industries; interaction of chemical engineering principles with biological systems; Microbiology; Fermentation pathways; Reactions in living systems.

Module II: **10L**
Biocatalysts; enzymes and enzymatic reactions; Michaelis-Menten equation and its various forms; enzymatic immobilization and Kinetics of immobilized systems with diffusion.

Module III: **10L**
Fermentation; Mechanism and kinetics (Monod model); types of fermenters; chemostat; chemostat, PFR, fluidized bed reactor, Bubble column and air lift fermenter; Mass transfer in microbial reactors; mixing phenomenon in bioreactors (RTD); sterilization of air and media; design of sterilizers.

Module IV: **10L**
Downstream processing; separation process for cell mass and product, filtration, Centrifuging, membrane processes (Reverse osmosis, ultrafiltration, chromatographic separation,

Text/Reference Books:

1. Schule & Kargi: Bioprocess Engineering, Pearson, 2002.
2. J. E. Bailey and D.F. Ollis, Biochemical Engineering Fundamentals, 2nd Edition, 1986, McGraw Hill Book Co.
3. S.Siba and A.E. Humphrey and N.F. Mills- Biochemical Engineering, 2nd edition, 1973, Prentice Hall.

Environmental Engineering (CHE 803)

Module I: **10 L**
Types of environments and their pollutants. Classification of pollutants. Legislative aspects including water act. 1974, Air Act 1981 and efflument standards.
Air pollution : Sources and effects of different air pollutants, Sampling and analysis of air pollutants, Air pollution control methods and equipment, Cyclone Separator, Baghouse, ESP, Venturi Scrubber

Module II: **10 L**
Water pollution :Sources, sampling and classification of water pollutants, determination of basic parameters and computations associated with: BOD, COD, TS, TDS, SS;

Waste water treatment: primary, secondary, tertiary and advanced; aerobic treatment with special reference to activated sludge, trickling filter, RBDC and RBRC, EA; non conventional: WSP, anaerobic treatment with special reference to AFFR, UASB

Module III: **10 L**

Solid waste management, Sources and classification, public health aspects, Methods of collection and disposal methods: open dumping, landfill, incineration, composting, vermiculture; Solid waste management using bioremediation for specific pollutants like chromium. Mercury, ammonia / urea, phenolic sludges.

Module IV: **10 L**

Pollution control in selected process industries – fertilizer industries, petroleum refineries and petrochemical units, pulp and paper industries, Tanning industries, Sugar industries, Dairy, Alcohol industries, Electroplating and metal finishing industries, Radioactive wastes, ranking of wastewater treatment alternatives.

Text Books / References:

1. Pollution Control in process industries – S.P.Mahajon
2. Introduction to Environmental Engineering – Connwell & Devis. TMH.
3. Wastewater treatment for pollution control – S.J.Arceivala, TMH
4. Air Pollution – Rao,
5. Wastewater Engg. – Metcalf & Eddy, TMH
6. Environmental Pollution Control Engineering – C S Rao, New age
7. Standard Methods APHA /AWWA

Elective III (CHE 804)

Nanotechnology (CHE 804 A)

Introduction; Concept of miniaturization; Use of Microlithographic techniques to achieve dimensions less than 1000 nanometers; Sub-micron Lithography; Molecular Nanotechnology or Molecular Manufacturing; Concept of positional assembly and massive parallelism in Nanotechnology; Surface properties of fabricated Nanotechnological elements.

Text Book/ References:

1. Nanosystems: Molecular machinery, Manufacture & Computation: K. Eric. Dexler: Wiley

Operation Research (CHE 804 B)

Introduction, Decision making, Development of OR, Application of OR, Linear programming, Formulation of LP models, Graphical solution, Simplex method, Duality theory and application, Transportation problem, Assignment problem, Network models, CPM and PERT, Crashing of network, Waiting line models, Elements of queuing models, Poisson arrival and exponential service time distribution, M/ M/I Queue, Finite population models, Queuing cost models, Simulation modeling, Use of random numbers, Flow chart development, Inventory control, Deterministic and Stochastic models, Buffer stocks.

Text Books / References:

1. Introduction to Operations Research: Gillett. TMH
2. Operations Research, Panneerselvam, PHI

3. Operation Research: Gupta, P. K. and D. S. Hira

Computational Fluid Dynamics (CHE 804 C)

Introduction to Computational Fluid Mechanics and Heat Transfer – Modeling of Transport Phenomena
Transport Equations – Equations of Continuity, Motion, Energy in dimensional and non-dimensional forms – Lagrangian and Eulerian forms
Conservative and Non-conservative forms of transport equations
Equations – Elliptic, Parabolic and Hyperbolic
Understanding the convection and diffusion terms
Generalized Advection-Diffusion Equation with source term
Initial condition and Boundary conditions – three kinds

Concept of discretization – Taylor series FDM and CV based FVM – one-dimensional unsteady state heat diffusion equation - Treatment of boundary conditions
Numerical solution of PDE - Explicit method – Stability – Convergence – Consistency
Thomas (Tri-diagonal Matrix) Algorithm - Implicit method
Discretization of two-dimensional unsteady state heat diffusion equation – Numerical solution - ADI method – Line-by line solution for multi-dimensional problem
Vorticity-Stream function approach
Primitive variable approach - Staggered grid
Discretization of the convection term - Upwind scheme - Central Difference scheme - Hybrid scheme - Power law scheme
Evaluation of pressure from Equation of Continuity
Pressure correction - Velocity correction
SIMPLE Algorithm – Residues in solution – Relaxation
Iterative scheme – Over and under relaxation - quick updation
Discussion on SIMPLER, SIMPLE-C
Solution of coupled equations – Thermal buoyancy
Validation of code and results – Benchmarking - Benchmark cases - Lid driven cavity - Flow in pipe - Estimation of location of *vena contracta* in orifice flow – Rayleigh-Benard convection

Test Books/ References: :

1. *Numerical Heat Transfer and Fluid Flow*: S V Patankar. Taylor & Francis (Paperback Ed)
2. *Computational Fluid Mechanics and Heat Transfer*: J C Tannehill, D A Anderson and R H Pletcher. Taylor & Francis (1997)
3. *Computational Methods for Fluid Dynamics*: J H Ferziger and M Peric. Springer-Verlag (1999)
4. *Computational Fluid Dynamics*: P J Roache
5. *Applied Numerical Methods*: B Carnahan, H A Luther and J O Wilkes. John Wiley. NY.
6. *Handbook of Numerical Heat Transfer*: Ed. W J Minkowycz, E M Sparrow, G E Schneider and R H Pletcher. Wiley InterScience (Paperback Ed)
7. *Physical and Computational Aspects of Convective Heat Transfer*: Tuncer Cebecci and Peter Bradshaw. Springer (Paperback Ed)

Safety and Hazard management (CHE 804 D)

Module I: **10L**
Scientific principles, Engineering aspects of industrial safety in relation to economic and operational aspects, Safety regulations, Wind roses, Hazards due to fire, explosions and toxic chemicals, Fire Triangle, BLEVE, Runaway reaction, etc.

Module II: **10L**
Tools for hazards identification: HAZOP, Fault Tree, Event Tree, FMEA, Dow Fire and Explosion Index, Mond Index, Safety Audits.etc.

Module III: **10L**
Risk analysis concept and methodology: Risk concept and measure of risk, Risk acceptance criteria, Quantitative risk analysis, Probit number.

Module IV: **10L**
Engineering control of chemical plant hazards, Intensification and attenuation of hazardous materials, Industrial plant layout, Ventilation and lighting, Electrical system, Instrumentation etc, Fire prevention, Personnel protection devices, Laboratory safety, Emergency safety, Safety systems and disaster management.

Text Books & References:

1. Chemical Process Safety: Fundamentals with Applications: Daniel A. Crowl and J.F.Louvar
2. Safety in Chemical Process Industries: 0. P. Kharbanda
3. Hazardous Waste management: Wentz. C. A. MGH.
4.Environmental Risks & Hazards, Cutter, PHI

5. Chemical Engineering (vol-6): Coulson and Richardson

Total Quality Management (CHE 804 E)

Module: I **10L**

Basic concepts– Three paradigms of management and evolution of concept of quality management, Organization: its basic objectives and goal, Mission and Vision, customer and secondary customer, Deming's wheel, bottom line: profit vs quality, historical defilements: Juran, Deming, Ischikawa and Taguchi, Kaizen, JIT.

Basic statistical concepts associated with quality management, measurement of central tendency and dispersion, range versus variance, quality and process capability, probability distributions, concept of statistical quality control.

Module: II **10L**

Use of control charts and process engineering techniques for implementing the quality plan: X—R chart, moving average chart, p- chart, c-chart and control chart for continuous production

Acceptance sampling: single–double and multiple sampling, AOQ, AQL, LTPD, Chain sampling plan, Dodge-Romig plan.

Module :III **10L**

Tools and techniques for improvement in TQM: type A techniques with a special reference to FPC & FD, QFD, SWOT analysis; type B techniques with a special reference to brainstorming, stratification, Ischikawa diagram, check sheet, Pareto diagram

Philosophy and concept of quality circle: formation, steering committee, power and functions of leader, dy. Leader, coordinator, facilitator, case studies.

Module :IV **10L**

Different standards: ISO, BS and bureau of Indian standards, details of ISO 9000 series, ISO 14000 series and SA 8000 and the certification authorities

Text Books / References:

1. Total Quality Management- A Practical Approach: H. Lal, New Age International
Qualty Circle : S R Udpa,
2. Total Quality Management – A Primer: Sundara Raju S. M., TMH.
3. Fundamentals of Quality Control Improvement, Mitra, PHI
4. TQM -SK Ghosh, Oxford

Project Work/ Plant Design (CHE 891)

Each student shall be required under the supervision of a faculty to prepare a project work on a topic of design or to carry out investigation on an industrial research problem, The design / research work has to be carried out by the student himself occasionally consulting his supervisor. The work has to allotted at the beginning of the seventh semester indicating the items to be carried out by the student. The report in duplicate has to be submitted in typed and bound from before the commencement of the VIIIth (final) semester examination. The examination shall include presentation of the research/ design report and a viva-voce

Report and Viva Voce on Project Work/ Plant Design (CHE 892)

Defense of Project–Viva on the project in presence of external examiner along with internal teachers.

Comprehensive Viva Voce (CHE 893)

This is a Viva – Voce examination to ascertain the student's overall grasp of the principles of Chemical Engineering and allied subjects