BIRLA INSTITUTE OF TECHNOLOGY
MESRA, RANCHI
DEPARTMENT OF CHEMICAL AND POLYMER ENGINEERING
COURSE STRUCTURE

BE (CHEMICAL ENGINEERING)

	Course No	Subjects	L	T	P	CP
	GROUP-A					
	I- SEMESTER					
	HU-1101	Technical English	3	0	0	3
	PH1201	Physics	3	1	0	4
	MA1201	Engg. Mathematics	3	1	0	4
	EE2201	Principles of Electrical Engg	3	1	0	4
	CH1401	Engg. Chemistry	3	0	0	3
	ME1202	Engg. Graphics	1	0	3	3
	CS1302	Fundamental of Unix & C Programming	1	0	3	3
	PE1202	Workshop Practice	0	0	3	2
	PH1202	Physics lab	0	0	3	2
	GA1002/ GA1004 GA1006/GA1008	NCC / NSS / PT & Games / C. Arts	0	0	2	1
						Total 29
	II- SEMESTER					
	EC2001	Principle of Electronics Engg	3	0	0	3
	MA2201	Advance Engg Mathematics	3	1	0	4
	CH2203	Environmental Science	3	0	0	3
	CS2301	Fundamentals of Data Structure	3	1	0	4
	ME2001	Principles of Mechanical Engg	3	0	0	3
	AM1201	Engineering Mechanics	3	1	0	4
	CH1402	Chemistry Lab	0	0	3	2
	EE3202	Basic Electrical Engg Lab	0	0	3	2
	EC2002	Basic Electronics Engg Lab	0	0	3	2
	CS2302	Data Structure Lab	0	0	3	2
	GA2002/ GA2004 GA2006/GA2008	NCC / NSS / PT & Games / C. Arts	0	0	2	1
						Total 30
	GROUP-B					
	I- SEMESTER					
	EC2001	Principle of Electronics Engg	3	0	0	3
	PH1201	Physics	3	1	0	4
	CH1401	Engg. Chemistry	3	0	0	3
	MA1201	Engg. Mathematics	3	1	0	4
	AM1201	Engineering Mechanics	3	1	0	4
	ME1202	Engg. Graphics	1	0	3	3
	CS1302	Fundamental of Unix & C Programming	1	0	3	3
	CH1402	Chemistry Lab	0	0	3	2
	EC2002	Basic Electronics Engg Lab	0	0	3	2
	GA1002/ GA1004 GA1006/GA1008	NCC / NSS / PT & Games / C. Arts	0	0	2	1
						Total 29

II-SEMESTER						
	HU1101	Technical English	3	0	0	3
	MA2201	Advance Engg Mathematics	3	1	0	4
	CH2203	Environmental Science	3	0	0	3
	CS2301	Fundamentals of Data Structure	3	1	0	4
	ME2001	Principles of Mechanical Engg	3	0	0	3
	EE2201	Principles of Electrical Engg	3	1	0	4
	PH1202	Physics lab	0	0	3	2
	PE1202	Workshop Practice	0	0	3	2
	AM2202	Engineering Mechanics Lab	0	0	3	2
	CS2302	Data Structure Lab	0	0	3	2
	GA2002/ GA2004 GA2006/GA2008	NCC / NSS / PT & Games / C. Arts	0	0	2	1
						Total 30
III- SEMESTER						
	BT3001/HU4001	**Biological Science/Language *(Breadth Paper)***	3	0	0	3
	CL3001	Fluid Mechanics	3	0	0	3
	CL3003	Chemical Engg Thermodynamics	3	1	0	4
	CL3005	Process Calculations and Mechanical Operations In Chemical Engg	3	1	0	4
	ME 3007	Strength of Materials	3	0	0	3
	EE3202/AM2202	Basic Electrical Engg. lab/Engg. Mechanics lab	0	0	3	2
	ME 3008	Strength of Materials Laboratory	0	0	3	2
	CL3004	Instrumental Analysis	0	0	3	2
	GA3002/ GA3004 GA3006/GA3008	NCC / NSS / PT & Games / C. Arts	0	0	2	1
						Total 24
IV- SEMESTER						
	BT3001/HU4001	**Biological Science/Language *(Breadth Paper)***	3	0	0	3
	CL4001	Heat Transfer Operations	3	1	0	4
	CL4003	Petrochemicals and Refinery Engineering	3	0	0	3
	CL4005	Numerical Methods For Chemical Engineers	3	0	0	3
	CL4007	Transport Phenomena	3	0	0	3
	CL4002	Chemical Engineering Lab- I	0	0	3	2
	CL4004	Numerical Methods For Chemical Engg. lab	0	0	3	2
	CL4006	Energy Engg lab	0	0	3	2
	GA4002/ GA4004 GA4006/GA4008	NCC / NSS / PT & Games / C. Arts	0	0	2	1
						Total 23
V-SEMESTER						
		Breadth Paper-I	3	0	0	3
	CL5001	Mass Transfer Operations	3	1	0	4
	CL5003	Energy Engg	3	0	0	3
	CL5005	Reaction Engg	3	0	0	3
	CL5007	Computer Aided Process Engineering	3	0	0	3
	CL5002	Chemical Engineering lab II	0	0	3	2
	CL5004	Computer Aided Process Engineering Lab I	0	0	3	2
	CL5006	Reaction Engg lab	0	0	3	2

VI-SEMESTER						
	CL6001	Biochemical Engg	3	0	0	3
	CL6003	Industrial Chemical Processes	3	0	0	3
	CL6005	Modern Separation Processes	3	0	0	3
	CL6007	Polymer Science and Engineering	3	0	0	3
	CL6009	Advances in Reaction Engineering	3	0	0	3
	CL6002	Chemical Engineering Lab III	0	0	3	2
	CL6004	Polymer Engg lab.	0	0	3	2
	CL6006	Chemical Engg Equipment Design Lab	0	0	3	2
						Total 21
VII- SEMESTER						
	CL7001	Process Control and Instrumentation	3	0	0	3
	CL 7003	Process Modelling, Simulation & Optimization	3	0	0	3
	CL7005	Project Engg& Economics for Chemical	3	0	0	3
		ELECTIVE I	3	0	0	3
		ELECTIVE II	3	0	0	3
	CL7002	Process Control and Instrumentation lab	0	0	3	2
	CL7004	Computer Aided Processes Engineering lab-II	0	0	3	2
	CL7006	Chemical Technology Lab	0	0	3	2
						Total 21
VIII-SEMESTER						
	CL8002	Project & Comprehensive viva	0	0	0	8
	CL8004	Entrepreneurship and Business Plan	0	0	0	1
						Total 9
						Grand Total 179

Elective-I	**3-0-0**	Elective – II	
CL7007	Safety & Hazards in Chemical Industry	CL 7029	Rocket Propulsion and Explosives
CL7009	Molecular simulation in chemical Engg.	CL 7031	Pollution Control Equipment Design
CL7011	Fertilizer Technology	CL 7033	Pulp & Paper technology
CL7013	Food Science and Technology	CL 7035	Colloid & Interfacial Engg
CL7015	Nanotechnology	CL 7037	Renewable & non-renewable energy
CL7017	Computational fluid dynamics	CL 7039	Multiphase flow
CL 7019	Mineral Processing	CL 7041	Process integration
CL 7021	Fuel Cell Technology	CL 7043	Combustion Engineering
CL 7023	Introduction to Petroleum Reservoir	CL 7045	Pharmaceutical Technology
CL 7025	Manufacturing of Pharmaceuticals	CL 7047	Non Newtonian flow
CL 7027	Introduction to microelectronics	CL 7049	Microfluidics
PC 7001	Fibre Science and Technology	PC 7009	Polymer Composite
PC 7003	Biomaterials	PC 7011	Plastic Product Design
PC 7005	Plastics and Environment	PC 7013	Surface Coating and Adhesion
PC 7007	Polymer Manufacture Technology	PC 7015	Rubber Product Technology

THIRD SEMESTER
CL 3001 FLUID MECHANICS

Module 1

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. (3)

Module 2

Fluid flow phenomena: Fluid as a continuum, Terminologies of fluid flow, velocity – local, average, maximum, flow rate – mass, volumetric, velocity field; dimensionality of flow; flow visualization – streamline, path line, streak line, stress field; viscosity; Newtonian fluid; Non-Newtonian fluid; Reynolds number—its significance, laminar, transition and turbulent flows: Prandtl boundary layer, compressible and incompressible. Momentum equation for integral control volume, momentum correction factor. (4)

Module 3

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. (5)

Module 4

Flow past 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, Fluidization: Introduction; different types of fluidization; fluidized bed assembly; governing equation; industrial use. Agitation and mixing of liquids: agitated vessel, blending & mixing, suspension of solid particles. Dispersion operation. Turbine Design/scale up, Flow number, Power Requirement. (7)

Module 5

Flow of compressible fluids: processes of compressible flow, Flow through variable area conduits, adiabatic frictional flow, isothermal frictional flow, stagnation point and stagnation pressure, motion of particles through fluids.

(5)

Module 6

Flow measurement: Introduction; general equation for internal flow meters; Orifice meter; Venturimeter; concept of area meters: rotameter; Local velocity measurement: Pitot tube. (5)

Module 7

Fluid moving machines: Introduction; Basic classification of pumps: Non-Mechanical Pumps—acid egg, steam jet ejector, airlift 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. (6)

Text Nooks:

1. Unit operations of Chemical Engineering: McCabe, Smith and Harriot,TMH, 5th Edn.
2. Transport Process and Unit Operations: Geankoplis, 3rd Edn. PH**I**

Reference:

5. Chemical Engineering, vol. 1, Coulson & Richardson, Butterworth Heinemann

CL 3003 CHEMICAL ENGINEERING THERMODYNAMICS

Module 1

Review of 1st and 2nd laws of thermodynamics. Volumetric properties of fluids and Equation of state. (5)

Module 2

Entropy concept, entropy and lost work calculations. Microscopic interpretation of entropy. Criteria for irreversibility, Clausius inequality, Principle of entropy increase. 2nd law of thermodynamics for a control volume. (5)

Module 3

Third law of thermodynamics and its applications, criteria for equilibrium, Euler relation, Gibbs-Duhem relation, Helmholtz free energy, Gibbs free energy, energy minimum principle. Clapeyron equation and some important correlation for estimating vapour pressures. (5)

Module 4

Thermodynamic property relations: mathematical preliminaries, Maxwell relations, partial derivatives method, Jacobian method, Bridgman table. Thermodynamic properties of real gases using tables and diagrams: Edmister chart, Lee-Kesler data, Peng-Robinson equation of state. (5)

Module 5

Solution Thermodynamics: 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. Excess Gibbs free energy model: Margules equation, Redlich-Kister equation, van-Laar equation, Wilson and NRTL. Prediction of activity coeficients-group contribution methods, UNIQUAC and UNIFAC methods. Henry‘s Law. (5)

Module 6

Vapor / liquid equilibrium, bubble pressure, dew pressure, bubble temperature, dew temperature and flash calculations. Modified Raoults‘ law, k-value correlations, Excess properties, reduction of VLE data. (5)

Module 7

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. (5)

Text books:

1. Chemical Engineering Thermodynamics, Y.V.C. Rao, University Prress
2. Introduction to Chemical Engineering Thermodynamics: Smith, J.M., Van ness, H.C. and Abbot, M.M., 6th Edn. MGH., 2001.
3. A Text Book of Chemical Engineering Thermodynamics, Narayanan, PHI

CL3005 PROCESS CALCULATION & MECHANICAL OPERATIONS IN CHEMICAL ENGG.

Module I

Introduction to Chemical Engineering Calculations; Unit & Dimensions, Dimensional analysis, Conversion of units, Mole concept, Basic Concept, Stoichiometric and composition relationship, limiting-excess reactant, conversion yield. Energy Balance: a. review: Thermo-physics, Thermo-chemistry-law of constant heat, summation, Hess's Law, standard heat of reaction, combustion and formation problems using Hess Law. (5)

Module 2

Material Balance (Without Chemical reaction) Ideal gas-law calculations, real-gas relationships, vapour pressure of immiscible liquids, solutions and problems based on Raoults, Henry & Dalton's Law. Humidity, Saturation & use of psychometric Chart. Material Balance (With Chemical Reaction) Combustion, gas-synthesis, acid-alkali production and the like. Recycle, purge, bypass in batch, stage wise and continuous operations in systems with or without chemical reaction. (5)

Module 3

Characterization of solid particles :Particle Shape. Particle size analysis Differential and cumulative analysis. Properties of particulate masses: Bulk density, coefficient of Internal Friction, Storage of solids, Pressure distribution in hopper. Janssen Equation. Transportation of Solids: Studies on performance and operation of different conveyors eg. Belt, Screw, Apron, Flight etc. and elevators. (5)

Module 4

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. Dry and wet griding, open and closed circuit. Simulation of Milling operation grinding rate function, breakage function. (5)

Module 5

Solid Liquid separation : Gravity Settling process – Clarifiers and Thickeners, Flocculation Design of Gravity Thickner,**. Centrifugal Settling:** principle, Centrifuges for solid liquid and liquid liquid separation. (5)

Module 6

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. (5)

Module 7

Solid Solid Separation : Industrial Screening equipment : Screen effectiveness and Capacity.**Wet Classification:** Differential settling, Liquid cyclones,Drag, Rake and Spiral, Bowl, Hydroseparator, Hydaulic classifiers, Tabling, Jigging, Froth floatation, Dense media separation etc.Magnetic separation, Electrostating Separation. **Gas-solid separation** : Settling chambers, centrifugal settling, Cyclones, ESP, Scrubbers, Filters. (5)

Text Books:

1. Haugen, P.A. Watson, K.M., Ragatz R.A Chemical Process Principles Part - I
2. Himmelblau, D.M Basic Principles and Calculation in chemical engineering, Prentice Hall
3. Bhatt B.L.Vora, S.M Stoichiometry, Tata McGraw Hill Publishing Co. Ltd., New Delhi.
4. Unit Operations of Chemical Engineering By Mc Cabe Smith and Harriot TMH, 5th Edn.

ME 3007 STRENGTH OF MATERIALS

MODULE-1

Two dimensional state at a point. Complementary shears, Principal stresses graphical representation of state of stress.

(6 Lectures)

MODULE-2

Two dimensional state of strain at a point, principal strains ,Graphical representation of state of strain, strain rosettes.

(6 Lectures)

MODULE-3

Distribution of bending stress and shear stress in the cross-section of beams.

(6Lectures)

MODULE-4

Differential equation of the elastic curve-Deflection of beams by double integration method-Area moment theorems-Application to simply supported, Cantilever and overhanging beams.

MODULE-5 (8 Lectures)

Statically indeterminate beams: propped cantilevers, built in beam, fixed beams and continuous beams.

MODULE-6 (7Lectures)

Strain energy for axial load, bending and torsion,Castigliano's theorem-Application. Deflection due to shear.

(6Lectures)

MODULE-7

Torsion of circular shaft and power transmitted by the shaft. Combined bending and twisting of circular shaft-EquitantB/ M. and Twisting moment.

(6Lectures)

Recommended Books:

1. Strength of Material- F.L Singer.
2. Strength of materials by Ryder.
3. Strength of materials by S.S. Rattan

FOURTH SEMESTER

CL 4001 HEAT TRANSFER OPEARATIONS

MODULE– I

Conduction: Derivation of basic heat conduction equation in rectangular co-ordinates, expression in cylindrical and spherical co-ordinates. Steady state conduction in one dimension for plane wall, cylinders, hollow spheres. Shape factor. Solving two-dimensional steady-state heat transfer equations.

(5)

MODULE– II

Unsteady state conduction: general solution of unsteady state differential heat conduction equation, lumped heat capacity systems, Infinite plate, semi-infinite solid, charts for transient heat transfer and their uses.

(5)

MODULE– III

Convection: Natural and forced convection, heat transfer coefficient, empirical equations to calculate heat transfer coefficient, **(5)**

MODULE– IV

Radiation: Stefan Boltzmann law, Kirchoff's law, Radiant heat exchange between black and gray bodies. Radiation from gas and vapour (preliminary). Heat loss to atmosphere.
Lagging of pipes, Optimum lagging thickness. **(5)**

MODULE– V

Heat exchanger: concept LMTD and effectiveness. Types of heat exchangers, double pipe, shell and tube. Extended Surface Heat Exchangers, Plate type, Spiral heat exchangers etc. Heat transfer in batch and continuous Agitated vessels.

(5)

MODULE– VI

Design of double pipe heat exchanger, shell & tube heat exchanger and Extended surface heat exchanger.

(5)

MODULE– VII

Heat transfer with phase change: boiling and condensation. Condenser design.
Evaporator: Classification and design of multiple effect evaporators. Steam economy.

(5)

Text Books:

1. Holman, J.P., Heat Transfer, Mc Graw Hill
2. Process Heat Transfer: Kern D.Q., McGraw Hill.
3. Unit Operations of Chemical Engineering: McCabe, W.L., Smith, J.C., Harriot, P., McGraw Hill, 1993.
4. Kothandaraman, C.P. and S. Subramanyan, Heat and Mass Transfer Data Book. New Age International

CL4003 PETROCHEMICALS AND REFINERY ENGINEERING

Module I

Exploration and Refining of Crude Oil: Introduction, Indian and world reserve of crude oil and its processing. Capacity, Market demand & supply of petroleum Fractions. methods for evaluation of crude & fractions. TBP, ASTM, EFV, and their inter-convertibility, yield Curve etc. (5)

Module 2

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. (5)

Module 3

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. (5)

Module 4

Polymerization, Isomerization processes, Alkylation, Hydrocracking, Catalytic Polymerization for gasoline stock preparation. Finishing & Treatment processes : Different Hydrotreatment (eg. Hydro desulfurization) processes. (5)

Module 5

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.

Petrochemicals based on methane, ethylene, acetylene, propylene and butane (5)

Module 6

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. (5)

Module 7

Production of styrene, cumene and phenol, Isomerization of O and m xylene into p-xylene.Production of pthalic Anhydride etc. (5)

Text Books / References:

1. Petroleum Refinery Engineering – W.L. Nelson, Mc Graw Hill.
2. Modern Petroleum Refining Processes – B.K.B Rao. Oxford & IBM.
3. Petroleum Refining Technology – Dr. Ram Prasad, Khanna Publishers.
4. Advanced Petroleum Refining: Dr. G. N. Sarkar, Khanna Publishers.
5. A Text on Petrochemicals: B.K.B. Rao, Khanna Publishers.
6. Petrochemical processes :Chauvel ,Gulf Publishing.
7. Advanced Petrochemicals: Dr. G. N. Sarkar, Khanna Publishers

CL 4005 NUMERICAL METHODS FOR CHEMICAL ENGINEERS

Module I

Computational Errors & Approximations:

Numbers & their accuracy, Errors & their Analysis, Errors in a series approximation.

Solution of Algebraic & Transcendental Equations with Algorithms:

Graphical Method, The bisection method, the method of false position, Newton-Raphson Method & its rate of convergence. Solution of Non-linear equations in two variables by Newton-Raphson method & Bairstow's method for complex roots. (5)

Module 2

Solutions of System of Linear Algebraic Equations with Algorithm:

Direct Methods: Gaussian Elimination method. Gauss-Jordan Method & Decomposition method, Iteration methods: Jacobi & Gauss-Seidal Methods. (5)

Module 3

Interpolation:

Finite differences, Newton's forward and backward interpolation formula, Gauss's Central Difference formula Sterling's & Bassel's interpolation for unevenly spaced points, Newton's general interpolation formula with divided differences. (5)

Module4

Curve Fitting Cubic Splines and Approximation:

Principal of least squares, Curve fitting: Fitting a straight line. Polynomial of second degree, Data fitting with cubic splines. (7)

Module 5

Numerical Differentiation & Integration:

Differentiation by using Newton's forward. Backward and central difference formulas, Differentiation by cubic spline method. Integration by Trapezoidal Rule, Simpson's 1/3' rd Rule. 3/8th Rule. (5)

Module6

Computational Algorithm:

Solution of initial value problems of first order: Picard's method Taylor's series, Euler's method, Runge-Kutta method, Milne-Simpson method, Finite Difference algorithms for solutions of a two point, Second order boundary value problem. (8)

Module 7

Finite Difference:

Analogues of Partial Differential equations, Use of standard five point algorithms and diagonal five point algorithms in solution of Laplace equation & Parabolic equations. (5)

References:

1. Introductory method of Numerical analysis – Prentice – Hall of India New Delhi, S.S. Sastry
2. Computer Oriented Numerical Methods – Prentice-Hall of India – V. Rajaraman.
3. Finite Differences & Numerical Analysis – S. Chand & Co. Ltd. New Delhji – H.C. Saxena.
4. Introduction to Numerical Analysis – Addision – Wesley Publishing Company – Froberg.)

CL 4007 TRANSPORT PHENOMENA

Module I
Transport by molecular motion: Newton‘s law and viscosity, Fourier‘s law of Heat conduction. Fick‘s law of Diffusion. (5)

Module 2
Transport in laminar flow or in solid in one dimension: Development of continuity (conservation) equation Velocity, temperature and concentration profiles Momentum, energy and mass flux (5)

Module 3
Transport in an arbitrary continuum: Stream function, rotational and irrotational flow, vorticity. Equation of change for isothermal, non-isothermal and multicomponent systems. Navier-Stokes Equation, Eular Equation, Bernoulli Equation. Use of the equation of change to solve flow problem. Equation of energy, Equation of motion for free and forced convection(Heat/ Mass) (5)

Module 4
Momentum, energy and mass transport in boundary layer with relevant analogy, Unsteady viscous flow, heat conduction and diffusion. (5)

Module 5
Transport in turbulent flow: Velocity, temperature and concentration profiles interphase momentum, heat and mass transfer. Concepts and relation of friction factor, heat transfer coefficient, mass transfer coefficient. (5)

Module 6
Nature of materials pseudoplastics, dilatants, Bingham plastic, Rheopexy and thixotropy. Rheology of Polymer melts. Shear flow. Viscosity models. Dependence of viscosity on Temperature, Pressure, molecular weight etc. Viscous dissipation. (5)

Module 7
Flow through circular, annulus and slit cross section. Flow of falling film, flow of two adjacent immiscible fluids, creeping flow around a sphere. Techniques of measurement of shear in Capillary viscometer, rotational viscometers, Torque Rheometer. Measurement of die swell. Extensional flow and measurement of extensional viscosity. Measurement of normal stress (5)

Text Books:

1. R. B. Bird, W. E. Stewart, and E. N. Lightfoot *Transport phenomena,* John Wiley & Sons; Revised 2nd Edition, 2007

Reference:

1. Bennett and Myers, *Mass, Heat and Momentum transport*.
2. J. Welty, C. E. Wicks, G. L. Rorrer, and R. E. Wilson *Fundamentals of Momentum Heat and Mass Transfer*, John Wiley & Sons; 5th Edition, 2008
3. R. S. Brodkey & H. C. Hershey, *Transport Phenomena*.
4. J.L. Plawsky, *Transport Phenomena Fundamentals*, Marcel Dekker, New York, 2001.

FIFTH SEMESTER

CL5001 MASS TRANSFER OPERATIONS

Module-1

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. (5)

Module-2

ABSORPTION:

Introduction, The mechanism of absorption, Equipment for Gas Liquid contact. 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. tray hydraulics. Humidification and dehumidification operations, Psychometric chart, Adiabatic saturation curves etc. Design of cooling towers (Natural draft, forced draft and induced draft cooling towers. (5)

Module-3

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. Steam distillation,Azeotropic & Extractive Distillations, Introduction to multicomponent distillation. (5)

Module-4

LIQUID-LIQUID EXTRACTION and 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. **LEACHING:** 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. (5)

Module-5

DRYING:

Introduction to drying, Rate of drying, Batch drying mechanism, the mechanism of moisture movement during drying, classification and design of dryer. (5)

CRYSTALLIZATION:

Introduction to crystallization, Theory of Crystallization, Formation and growth of crystals, crystal yield, Rate of crystallization. (5)

Module - 6
ADSORPTION
Introduction, nature of adsorbents, batch adsorption, Adsorption isotherms. Adsorption equipment, pressure swing, thermal-swing, breakthrough curves, design of fixed bed adsorption column**.** . (5)

Module-7
Membrane Processes: for Gases: Polymer membranes, Membrane structure, Flow patterns in membrane separators,Separator arrangements, product purity and yield, Membrane area determination. Membrane Separation processes for liquids, Principles, Equipment and Design principles for Dialysis, Reverse osmosis, ultra filtration, etc. (5)

Text Books:
1. Mass Transfer Operations: Treybal R.E., Mc Graw Hill, 1981
2. Unit Operations of Chemical Engineering: Mc Cabe W.L.and Smith J.C., Mc Graw Hill.5th Ed. 1993
3. Transport proceses and Separation Process Principles, C.J.Geankoplis, Prentice Hall
of India, 4th Ed. 2004

CL5003 ENERGY ENGINEERING

Module 1

Introduction to Energy Science and Energy Technology; Energy sources and their availability. Prospects of Renewable energy sources; Energy conservation : Principle of energy conservation and Energy audit. Energy conservation Technologies – Co generation, waste heat utilization, Heat recuperators, Heat regenerators, Heat pipes,, Heat pumps Energy storage. (5)

Module 2

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. Fluidized bed combustion boilers for burning coal; fuels; 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. (5)

Module 3

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. (4)

Module 4

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. Mechanism and principle of combustion. Laminar flame propagation, theory & structure of flame. Burning velocity & its determination. Diffusion of flame & Flame stabilization. (5)

Module 5

Nuclear energy: Nuclear reactions, Nuclear Fuels and reactors, power generation.global, Indian Scenario. (3)

Module 6

[Alternate Engergy – I]

Geothermal energy: Introduction, Resources and Utilization of Geothermal energy, Different types of Geothermal Electric power plant and their operations for Geothermal Energy systems in India; **Wind energy:** Fundamentals and application, Wind Energy conversion system, Performance of wind machines, Electricity generation for wind; **Biomass Energy Resources:** Introduction, Biomass Conversion Process. Biogas from plant/animal wastes, community biogas plants. Biochemical conversion, Fermentation, liquid fuels from biomass; BioDiesel from oil producing seeds/algae; .Energy from waste : Incinerators for Agricultural / urban wastes.Environmental Considerations. **Energy from the oceans:** Introduction Ocean Energy conversion Technologies. Types of Ocean Thermal Electric Power Generation system and their operation. Tidal power plant; **Hydro Energy:** Introduction, types hydroelectric plants and energy conversion scheme, Impulse turbine and Reaction turbine. Classification of Hydro-Energy plants; (7)

Module 7 [Alternate Energy – II]

Solar energy: Solar radiation & its measurement, different types of solar collectors. Solar energy storage system & application of solar energy in water heating, space heating/cooling, solar distillation, solar pumping, solar cooking, solar furnace, solar green houses, electric power generation etc.Solar Photovoltaic. Recent Advances **Fuel cell:** Introduction, design & principle operation of fuel cell, classification of fuel cells- Alkaline Fuel Cell, Solid Oxide Fuel Cell, ProtonExchange Fuel Cell, Direct Methanol Fuel Cell – Applications and recent advanes. . Conversion efficiency, type of electrode, catalyst, flow fields current collectors, fuel cell stack. Basic battery theory, characteristics and advantages for bulk energy storage. **Hydrogen energy :**Introduction, production of hydrogen energy: electrolysis, thermo-chemical, Biotechnology methods etc. Hydrogen storage & transportations. Safety & management. Hydrogen technology development in India. (6)

References

1. S. Sarkar, *Fuels and Combustion*. Sangam books Ltd
2. Himus, *Elements of Fuel technology.*
3. J. Brame and King, *Fuels: Solid, liquid and gaseous fuels,* Kessinger Publishing, LLC, 2007.
4. S. Rao and Dr. B.B. Parulekar, *Energy Technology, Non-convential, Renewable and Conventional*, Khanna Publishers.
5. G.D. Rai, *Non-conventional Energy Sources,* Khanna Publishers
6.D.S. Chauhan and S.K. Srivastava, *Non- Conventional Energy Resources,* New Age International Pvt Ltd.
7.G.N. Tiwari, *Fundamentals of Renewable Energy Sources*, Narosa Publishing House.

CL 5005 REACTION ENGINEERING

Module- 1Chemical reaction kinetics: basic features, interpretation of kinetic data in batch and flow systems and
effect of process variables on rate of reaction. (5)

Module- 2

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; 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, (5)

Module- 3

Reactors of Different Types in Series, Recycle Reactor: Definition of Recycle Ratio, Design Equation, Optimum Recycle ratio. 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 (5)

Module- 4

Introduction to homogeneous and heterogeneous catalysis; Rate equation; Factors affecting heterogeneous catalytic reaction; Types of catalytic Reactor and their performance equations; Related Problems. Determination of Catalyst surface area and particle size; Pore volume Distribution; Design of Fixed Bed and Fluidized Bed Reactors; (5)

Module- 5

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 (5)

Module- 6

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. (5)

Module- 7

Kinetic mechanism of Polymerization Reaction. Kinetic analysis and Mathematical Modeling of Polymerization reaction. Polymerization Techniques, solution, emulsion and suspension polymerization, merits and limitations. Effect of reactor types on MW and MWD of polymers. Polymerization Reactor design of industrially important polymers, such as polystyrene, PVC etc. (5)

Text Books:

1. Chemical Reaction Engineering, O Levenspiel, Wiley, 3rd Ed., 1999
2. Elements of Chemical Reaction Engineering, H. S. Foglar, 3rd Ed., Prentice Hall of India, 2000
3. Chemical Engineering, vol. 3, Coulson & Richardson, Butterworth Heinemann
4. Fundamentals of Polymer Science and Engineering, Anil Kumar and R. P. Gupta, McGraw Hill, 1998
5. Reaction Engineering of Step Growth Polymerization, S. K. Gupta and Anil Kumar, Plenum Press, 1987

CL 5007 COMPUTER AIDED PROCESS ENGINEERING

Module - I

Review of numerical methods - convergence techniques, solution of linear and non-linear algebraic equations, solution of coupled ordinary differential equations. (5)

Module – II

Application of MATLAB various toolboxes. Use of MATLAB functions for performing integration and differentiation and solving algebraic equations, ordinary and partial differential equations with initial and boundary conditions. (5)

Module – III

Importance of VLE/LLE calculations for process simulation. Algorithms for VLE / LLE calculation methods for non-ideal systems. (5)

Module – IV

Excel VBA as a problem solving tool for chemical engineering. (5)

Module - V

Modeling / simulation of different process equipment - heat exchangers, furnaces, flash drum, distillation, absorption, other staged / differential contacting processes, reactors etc. Techniques of process flowsheeting. (5)

Module – VI

Commercial steady state process simulators. Simulator components and structures. Salient features of simulators like ASPEN plus, DESIGN II etc. (5)

Module – VII

Use of AI and ANN in process engineering. (5)

Books:

1. Introduction to Chemical Engineering Computing, Bruce A Finlayson, JOHN WILEY & SONS, INC., PUBLICATION
2. N. L.Nilsson, "Problem Solving Methods in Artificial Intelligence", McGraw Hill, 1971.
3. T.E.Quantrille and Y.A.Liu, "Artificial Intelligence in Chemical Engineering", Academic Press, 1991
4. J.ZUARDA, "Introduction to Artificial Neural Systems", West Pub. CO., St.Paul, MN, 1992.
5. J.F.Davis, G.Stephanopoulos and V.Venkatasubramanian, "Intelligent Systems in Process Engineering", ALChE Symposium Series, Volume 92, 1996.

SIXTH SEMESTER
CL 6001 BIO-CHEMICAL ENGG

Module 1

Introduction To Bioscience:Types of Microorganisms: Structure and function of microbial cells. Fundamentals of microbial growth, batch and continuous culture. Isolation and purification of Enzymes from cells. Assay of Enzymes. (5)

Module 2

Functioning Of Cells And Fundamental Molecular Biology: Metabolism and bioenergetics, Photosynthesis, carbon metabolism, EMP pathway, tricarbocyclic cycle and electron transport chain, aerobic and anaerobic metabolic pathways. Synthesis and regulation of biomolecules, fundamentals of microbial genetics, role of RNA and DNA. (5)

Module 3

Enzyme Technology And Kinetics: Applied Enzyme catalysis, Applications of enzymes in industry and medicine. Immobilization of enzymes. Kinetics of enzyme catalytic reactions involving isolated enzymes. Reversible inhibition. (5)

Module 4

Reactions Catalysed By Enzymes, Reactors, Analysis: Reactor Design and Analysis for soluble enzyme systems. Cofactor regeneration. Membrane reactor. Effect of mass transfer in immobilised enzyme particle systems. Reactors for immobilised enzyme systems. Sensors, Monitoring and control systems in Bioprocesses: Instrumentation and process control in Bioprocesses. (5)

Module 5

BioReactors, Effect Of Transport Processes: Introduction to Bioreactor design: Continuously Stirred aerated tank bioreactors. Mixing power correlation. Determination of volumetric mass transfer rate of oxygen from air bubbles and effect of mechanical mixing and aeration on oxygen transfer rate, heat transfer and power consumption. Multiphase bioreactors and their applications. Downstream processing and product recovery in bioprocesses. (6)

Module 6

Mixed microbial populations in applications and natural systems: uses of well-defined mixed populations, microbial participation in the natural cycles of matter, biological wastewater treatment. Simulation studies
of control strategies for anaerobic digesters. (5)

Moduce 7:

Fermentation industries: Industrial Alcohol, Absolute Alcohol; their production process with flow diagram (4)

TEXT BOOKS:

.

1. J.E. Bailey, D.F. Ollis, Biochemical Engineering Fundamentals, 2nd ed.,McGraw Hill, 1986. 20
2. Trevan, Boffey, Goulding and Stanbury," Biotechnology", Tata McGraw Hill Publishing Co., New Delhi, 1987.
3. Chemical Engineering, vol. 3, Coulson & Richardson, Butterworth Heinemann
4. "Bioprocess Engineering - Basic Concepts" by Michael L. Shuler and Fikret Kargi, 2nd edition, Prentice Hall, New Jersey, 2002.
5. "Bioprocess Engineering - Systems, Equipment and Facilities", edited by by Bjorn K. Lydersen, Nancy A. D'Elia and Kim L. Nelson, John Wiley & Sons, New York, 1994.

CL6003 INDUSTRIAL CHEMICAL PROCESSES

Module 1:

Hydrochloric Acid: Raw materials, principles of manufacture, flow sheet and sequence of operation, major engineering problems, uses. 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. (5)

Module 2

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. (5)

Module 3

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. (5)

Module 4

Oils & Fats: Methods of extracting vegetable oils (Process Description and Flow sheet). Hydrogenation of oils (Process description & flow shee t) 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. (5)

Module 5

Adhesive and Surface Coating Industries. (5)

Module 6

Brief outline of the following industries: Ceramic, Glass, Cement, Pulp and Paper. (5)

Module 7

Hazards, Safety measures and loss prevention in chemical process industry. (5)

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. Kirk & Othmer (Ed.), Encyclopedia of Chemical Technology.
4. Unit operation in organic systhesis : P.H. Groggins.
5. Sinnott, R.K., Coulson and Richardson's Chemical Engineering- 6th Volume, Chemical Engg Design, 2th Ed., Asian Book Pvt. Ltd.1996.

CL 6005 MODERN SEPARATION PROCESSES

Module 1

Fundamental concepts: separation processes, thermodynamics, masstransfer and diffusion. Membrane separation: fundamentals and terms, classification, membrane materials, membrane modules, membrane preparation, transportation in membranes, design aspects and their applicability, ultra filtration, microfiltration, nanofiltration.

Module 2

Dialysis, electrodialysis, reverse osmosis, pervaporation, gas separation, membrane distillation. Membrane fouling, remedial measures, design aspects.

Module 3

External field induced membrane separation processes for colloidal particles, fundamentals of various colloid separation, derivation of profile pf elecic fiels strength, coupling with membrane separation and electrophoresis.

Module 4

Bioseparations: overview bioprocesses, fermentation broths : characteristics, pretreatment, filter media, equipment, centrifugation, cell disruption.

Module 5

Chromatography: principles and practicem classification of chromatographic techniques, gel filtration, ion exchange chromatography anf chromatofocusing, reversed phase and hydrophobic interaction chromatography, affinity chromatography.

Module 6

Liquid liquid extraction, multi component absorption, stripping, distillation, extraction, super critical fluid extraction

Module 7

Enhanced distillation: extractive distillation, salt distillation, pressure swing distillation, reactive distillation, rate based models for distillation.

Common fouling factors, their removal and design aspects.

REFERENCES:

1. Handbook of separation processes and technology by R W Rousseau (John Wiley & Sons)
2. Super critical fluid extraction by M A Mchugh 7 V J Krukonis (Butterworth Heinmann)
3. Large scale adsorption and chromatopgraphy by W C Wankat (CRC Press)
4. Advanced membrane technology and applications by NN Li (Wiley)
5. Separation process principles by J D Seader and E J Henley (Wiley)
6. Bioseparations :principles and trechniques by B Sivasankar (PHI)

CL6007 POLYMER SCIENCE AND ENGINEERING

Module–1

Chemistry and classification of polymers. Compounding of polymer, effect of additives, filler, plasticizer, cross linker, stabilizers, blowing agents, coupling agents etc. Special application of polymer: conductive, magnetic, optical, photo responsive, smart polymer and polymeric gel. (5)

Module–2

Crystal structure and Morphology: Crystalline homopolymers, spherulitic microstructures, Amorphous polymers, Measurement of Crystallinity and orientation. Thermal transitions. Physical and chemical properties: Molecular weight averages, measurement of MW andMWD. (5)

Module–3

Thermal Analysis, Chemical Instrumental Analysis. Characterization of Polymers Thermal and chemical resistance, Electrical, optical Non Mechanical Properties. (5)

Module – 4

Mechanical properties of solid polymers. Viscoelasticity, Melt Rheology (5)

Module– 5

Thermoplastics – Commodity and Engineering plastics, Thermoset resins for mouldings and composites. Rubbers. (5)

Module - 6

Polymer Processing-I: Machinery, material property, process condition, simulation -Extrusion – pipe, film blowing, monofilament, Calendering, blow-moulding, (5)

Module– 7

Polymer Processing II – Machinery, material property, process condition, simulation -Injection Moulding, Rotomoulding, Thermoforming, Compression moulding, (5)

TEXT BOOKS:

1. Text book of Polymer Science: Billmeyer F.W., 3rd Ed. Willey Inter. Science, 1984.
2. **P**lastics Product Design and Process Engineering, H. Belofsky, Hanser, 1995.
3. Plastics Engineering, Crawford, R.J., Pergammon Press.
4. Polymer Processing Principles and Design, D. G. Baird and D. Collias, John Wiley and Sons.19981.
5. Plastic Extrusion Technology, Hensen, Hanser, 1997.
6. Polymer Extrusion, Chris Rauwendaal, Hanser, 1994.

CL 6009 ADVANCES IN REACTION ENGINEERING

MODULE 1

Design of non-isothermal reactor: steady and unsteady state tubular reactor with heat exchange, CSTR with heat effects, multiple steady states. Non-isothermal multiple chemical reactions. Reactor safety. Semi-batch reactors with heat exchangers.

MODULE 2

Review of heterogeneous catalytic reactions, porous catalyst particles, performance equations. Heterogeneous data analysis for reactor design Mechanism of catalyst deactivation, Rate and performance equations,Design.

MODULE 3

Non-catalytic systems: fluid-fluid reaction kinetics and reactor design. Kinetics Regimes for Two-Film Model, Fluid-particle reaction kinetics, Shrinking core model. Design of Fluid-particlereactors.

MODULE 4

Reactor design with suspended solid catalyst: bubbling fluidized bed, the K-L model for BFB, circulating fluidized bed and jet impact reactor.

Three phase fluidized bed reactors: trickle beds, slurry reactors.

MODULE 5

Statistical methods for experimental design and data analysis, parameter estimation.

MODULE 6

Introduction to population balance modeling, application to RTD of CSTR, application to gas solid reactions in rotary kiln and fluid beds, performance of reactor regenerator system from PBE modeling.

MODULE 7

Density functional theory, applications in reactor design

REFERENCES:

1. Elements of chemical reaction engineering, H.S. Fogler
2. Chemical Reactor Analysis and Design, G. F. Froment and K. B. Bischoff
3. Chemical Engineering Kinetics, J. M. Smith
4. Heterogeneous Catalysis in Industrial Practice, Satterfield, C. N.,

SEVENTH SEMESTER

CL7001 PROCESS CONTROL AND INSTRUMENTATION

Module- 1

Process control Instrumentation - Measuring elements (Temperature, Pressure, thickness, power, rotational speed, flow rate, liquid level etc.). Control valves and their characteristics. (5)

Module- 2

Concept of feed back and feed forward control system. Final control element. The controller, Proportional, PI, PID controller, construction of pneumatic and hydraulic controller. Servomotor technology in control. (5)

Module- 3

Control system dynamics: Transfer function of first order, second order systems. Response of control loop components to forcing functions. Transfer function of feed back control systems. Control system design. Tests for unstable systems (5)

Module- 4

Conventional control system and hardware. **Advanced control systems:** Multivariable control problem, Ratio control, Cascade control, Computed variable control, Feed forward control, Over ride control, Adaptive control etc, Sensors, LVDT, Strain gauge. (5)

Module- 5

Data processing for process plants, monitoring and data logging equipment for process control, process control computer equipment. Control based on computed functions. Methods of optimizing control and criteria for optimization, optimizing by computer control. (7)

Module- 6

Application of computer control, on line computer control, predetermined programme control, repetitive computer control, adaptive control, optimizing control of continuous process with significant dynamics. Brief idea about application of Dynamic Matrix Control, Predictive Control, PLC, Fuzzy logic control. (5)

Module- 7

Basic concepts of Control of Reactors, Unit operation equipments and polymer processing machineries.
(5)

TEXT BOOKS:

1. Stephenopolos, S., "Chemical process control", Prentice Hall of India, New Delhi, 1984
2. Luyben, W.L., "Process modelling, simulation, and control for Chemical Engineers", McGrawHill, 1989

Reference:

1. Coughanowr, Process Systen Analysis, MGH
2. Considine, D.M., "Process/Industrial Instruments and Controls Handbook", McGraw Hill, 1993
3. Oggunaika B.A. and Ray W.H., "Process Dynamics, Modeling and control". Oxford University Press, U.K. 1994
4. Alciatore D.G. and Histand M.B., ―Introduction to Mechatronics, Tata McGraw Hill

CL7003 PROCESS MODELLING, SIMULATION & OPTIMIZATION

Module 1

Simulation: Techniques of digital simulation – Information flow, from process to information flow diagram, From information flow diagram to numerical form, Recycles, Calculation of a recycle set, etc; Digital simulation of C.S.T.R.s in series, non-isothermal C.S.T.R, Binary distillation column, Batch reactor, Computer aided design. (5)

Module 2

Modeling: Fundamentals of mathematical models and formulation – Continuity equation, Equation of motion, Transport equations, Energy equation, Equations of state, Equilibrium, Chemical kinetics and their applications; Lumped and distributed parameter models – Fluid systems, C.S.T.R. (single, series, isothermal, constant hold up, variable hold up, gas phase pressurized and non-isothermal), Single component vaporizer, Multi-component flash drum, Batch reactor, Reactor with mass transfer, Ideal binary distillation column, Batch distillation, Heat exchanger,etc; (5)

Module 3

Formulation of Optimization Problems: Degree of Freedom, Objective Functions, Constraints, Continuity of Functions, Unimodal and multi-modal Functions, Concave and Convex Functions. (5)

Module 4

Single Variable Problems: Analytical and Numerical Methods, Search Techniques (interval halving, Fibonacci, Golden Section, Gradient Method) (5)

Module 5

Linear Programming: Simplex Method, Artificial variables and duel method (5)

Module 6

Multivariable problems without constraints (Direct Search Method: Simplex, Hooks-Jeeves and Powel‘s conjugate Method; Gradient Method: Steepest Descent, Newton, Marquardt and conjugate gradient method) (5)

Module 7

Multivariable problems with constraints: Kuhn-Tucker condition, Penalty method, Method of Multipliers, Direct Search Method, Generalized Reduced Gradient (GRG) Method.Calculus of variation, Pontryagin‘s maximum principle, Bellman,s Principle of Optimallity (5)

BOOKS:

1. Optimization Theory and Practice by G. S. G. Beveridge and R. S. Schechter, McGraw Hill, 1970.
2. Optimization Theory and Application by S S Rao, Wiley Eastern, 2006.
3. Optimization for Engineering Design: Algorithm and Examples by K Deb, PHI, 1995
4. Optimization Concepts and Applications in Engineering by A. D. Belegundu and T. R. Chandrupatla, Pearson Education Asia, 2002
5. Process Optimization by W. H. Ray and Szekely, Wiley, NY, 1973
6. Process Optimization by Edger and Himmelblau, McGraw Hill, 2002.
7. Optimization Theory and Practice by G. S. G. Beveridge and R. S. Schechter, McGraw Hill, 1970.

CL 7005 PROJECT ENGINEERING & ECONOMICS FOR CHEMICAL ENGINEERS

Module-1

Development and implementation of the project in the following steps: Initial conception; Preliminary design ideas and rough evaluation of market and economics using IPR; Procuring data for final design; Final economic evaluation and decision set up the project; Detailed design; Procurement; Construction work; Start up and trail runs; Commercial production.

Module-2

Safety consideration; health and safety hazards, loss prevention HAZOP, Consequence analysis Fault Tree, Event Tree, LEL, UEL, Safety Audits.etc. Event probability and failure frequency analysis. Environment protection. Chemical hazards: Classification of chemical hazards, Chemical as cause of occupational diseases – dust, fumes, gases and vapors; Industrial hygiene.

Module-3

process intensification;

Introduction to process intensification; Benefits and drawbacks; Techniques – passive and active techniques. Mixing, flow patterns, Scales of mixing; Flow patterns in reactors, Mixing in stirred tanks, Mixing in intensified equipment; Static mixers; Ejectors; heat transfer, Compact heat exchangers; Enhanced fields; green chemistry; Intensified separation. **Process Design;** Chemical process considerations; Qualitative block type process flow sheet; Selection of process equipment, Plant layout: Planning layout and methods of layout planning.

Module-4

Economic evaluation of the project; Capital Cost; Plant cost estimating. **Total product cost:** Manufacturing cost; Raw material cost; Miscellaneous cost (labour cost, repair cost and maintenance cost); Depreciation; Economic Analysis: Net earning profitability analysis; Introduction to optimization. **Accounting of Business Transactions:** Accounting principles, journal and ledger entries, balance sheet, profit and loss statement, ratio analysis.

Module-5

Cost and Cost Analysis: Cost structure, methods of allocating overhead costs, standard cost, concept of opportunity cost, sunk cost, fixed cost and variable cost. **Break Even Analysis:** Drawing of brake even charts, effect of different variable on break even point, cost comparison of two or three alternatives

Module-6

Time Value of Money: Single sum and series of cash flow, uniform and gradient series, multiple compounding periods in a year, continuous compounding, bonds. **Comparison of Alternative Proposals:** Bases of comparison-present worth amount, annual equivalent amount, future worth amount, rate return, defining mutually exclusive alternatives, decision criteria for selection of investment proposals, comparison of alternatives, with unequal service life, sensitivity analysis

Module-7

Replacement Analysis: Reasons for replacement, evaluation of replacement involving excessive maintenance cost, decline in efficiency inadequacy and obsolescence. **Depreciation and Decision Making Under Uncertainty:** Methods of depreciation and their comparison, decision making on the basis of expected value decision tree in the evaluation of alternatives

REFERENCES:

1. Peters – Timmerham (International Editions), *Plant Design and Economics for Chemical Engineers*, McGraw Hill Book Co.

2. F. C. Viberandt and C. E. Dryden (International Students Editions), *Chemical Engineering Plant Design*, McGraw Hill Book Co.

ELECTIVE-I

CL7007 SAFETY AND HAZARDS IN CHEMICAL INDUSTRY

Module I

Scientific principles, Engineering aspects of industrial safety in relation to economic and operational aspects, Safety regulations, Wind roses, Hazards due to fire, explosions, toxic chemicals and radiation, Procedure for systematic study of plants. Plant and equipment start up and shut downs, operations at steady state. Emergency response strategy for plants and equipment. Plant test runs and rating calculations for various equipment. Plant systems for utilities and auxiliary services. Handling of plant effluent. Safe commissioning of Plants. (5)

Module 2

Flammable liquids and gases. Fire Triangle, BLEVE, Runaway reaction, confined and unconfined vapor cloud explosion modeling , Deflagration, Detonation.etc. (5)

Module 3

Tools for hazards identification: Reliability and risk analysis, HAZOP, HAZAN Consequence analysis Fault Tree, Event Tree, LEL, UEL, Safety Audits.etc. Event probability and failure frequency analysis(5)

Module 4

Chemical hazards: Classification of chemical hazards, Chemical as cause of occupational diseases – dust, fumes, gases and vapors; Industrial hygiene, Hazard analysis and health management; (5)

Module 5

Engineering control of chemical plant hazards, Intensification and attenuation of hazardous materials, Industrial plant layout, Ventilation and lighting, Electrical system, Instrumentation etc, Fire prevention, (5)

Module 6

Safety training, emergency planning and disaster management Emergency safety and laboratory safety; Legal aspects of safety, Management information system and its application in monitoring disaster, safety, Hazop Analysis. Inherently safer design, process intensification, plant security. (5)

Module 7

Case studies on plant accidents. Engineering ethics, engineering ethics codes, professional responsibility, ethical dilemmas and engineering ethics threshold. (5)

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. Chemical Engineering, vol. 6, Coulson & Richardson, R. K. Sinnott.S Butterworth Heinemann
4. F.P. Lees, Loss Prevention in Process Industries, Vol. 1 and 2, Butterworth, 1983.
5. R.W. King and J. Magid, Industrial Hazards and Safety Handbook, Butterworth, 1982. A. Khulman, Introduction to Safety Science, TUV Rheinland, 1986.
6. W.E. Baker, Explosion Hazards and Evaluation, Elsevier, Amsterdam, 1983
7. O.P. Kharbanda and E.A. Stallworthy, Management of Disasters and How to Prevent them, Grower, 1986
8. Engineering, ethics and the environment: Susan B. Hodgson & Slobodan Perdan.

CL7009 MOLECULAR SIMULATION IN CHEMICAL ENGINEERING

Module 1

Fundamentals of molecular simulations -Ab-initio Methods, Basis Sets, Hartree-Fock Theory, Density Functional Theory, Geometry Optimization, Vibrational Analysis. 5

Module 2

Classical statistical mechanics, elementary concepts of temperature, ensembles and fluctuations, partition function, ensemble averaging, ergodicity. 6

Module 3

Molecular Dynamics Methodology - Force Field, Integrating Algorithms, Periodic Box and Minimum Image Convention, Long Range Forces, Non Bonded Interaction.

Module 4

Temperature Control, Pressure Control, Estimation of Pure Component Properties, Radial Distribution Function; Molecular Dynamics Packages. 5

Module 5

Monte Carlo simulation - Monte Carlo integration, simple biasing methods, importance sampling, Markov chain, transition-probability matrix, detailed balance. 5

Module 6

Metropolis algorithm. 6

Module 7

Monte Carlo simulation in different ensembles. Monte Carlo simulation for polymer; Advanced applications. 5

TEXT BOOKS:

1. Daan Frenkel and Berend Smit, Understanding Molecular Simulation: From Algorithms to Applications, 2e, Academic Press, New York, 2002.
2. M.P. Allen and D.J. Tildesley, Computer Simulation of Liquids, Clarendon Press, Oxford, 1987.

References:

1. K. Binder, The Monte-Carlo Method in Condensed Matter Physics, Berlin : Springer-verlag, 1992.
2. D. A. McQuarrie, Statistical Mechanics, Harper and Row, New York, 1976.
3. Andrew R. Leach, Molecular modelling: principles and applications, 2e,
Pearson, New Delhi, 2001.

CL7011 FERTILIZER TECHNOLOGY

Module 1

Introduction to Chemical Fertilizers: Chemical inorganic Fertilizers and Organic manures. Types of fertilizers: Mixed, complex and Granulated, plant nutrients. (5)

Module 2

Nitrogenous fertilizers: Feedstock for production of Ammonia gas, Associated gas, Coke oven gas, Naphtha, Fuel oil, Petroleum heavy stock, Coal, Lignite, Water, Coke, methods of production, Characteristics, Specification and storage of ammonium sulphate, nitrate, urea, calcium ammonium nitrate and ammonium chloride; (5)

Module 3

Phosphatic fertilizers: Raw materials – Phosphate rock, Sulphur, Pyrirites. Methods of production, Characteristics, Specification and storage of single super phosphate, triple super phosphate; (5)

Module 4

Potassic fertilizers: Methods of production, Characteristics, Specification and storage of potassium chloride, potassium sulphate and potassium schoenite; (5)

Module 5

Complex and NPK fertilizers: Methods of production, Characteristics, Specification and storage of ammonium phosphate sulphate, Diammonium phosphate, Nitrophosphates, Urea ammonium phosphate, Mono ammonium phosphate and various grades of NPK fertilizers; (5)

Module 6

Secondary nutrients, Micro nutrients, Fluid fertilizers, Controlled release fertilizers; Technology of compound fertilizers, Nitrogeneous fertilizers, Phosphate fertilizers, Potash and mixed fertilizers, Fertilizer applications and agronomical details, Technology of ammonia manufacture, Fertilizer raw materials and availability. (5)

Module 7

Indian Fertilizer Industry: Single and Triple Superphosphate, biofertilizer. Fertilizer Industry in India. (5)

TEXT BOOKS:

1. Nielssion, *Manual for Fertilizer Technology Series*
2. S. Lee, J. G. Speight, and S. K. Loyalka , *Handbook of Alternative Fuel Technology,* CRC, 2007

CL 7013 FOOD SCIENCE AND TECHNOLOGY

Module 1

Food quality characteristics; Composition and nutritive value of common foods, Structure, properties and metabolic function of food constituents viz. water, carbohydrates, lipids, proteins, enzymes, vitamins, minerals, pigments, colours and flavouring substances; Undesirable constituents in foods; Changes in food constituents during processing and storage. (5)

Module 2

Food Microbiology: Microbial groupings and identification; Nutrient requirements for bacterial culture; Growth and inactivation kinetics; Harmful and beneficial effects of microbes, microbes in food industry; Food spoilage, poisoning and intoxication . (5)

Module 3

Unit operations in Food industries : Fluid flow, thermal process calculations, refrigeration, evaporation and dehydration Size reduction and screening of solids, mixing and emulsification, filtration and membrane separation, centrifugation, crystallization, extraction. (5)

Module 4

Food canning technology: Fundamentals of food canning technology. Heat sterilization of canned food, containers - metal, glass and flexible packaging. Canning procedures for fruits, vegetables, meats, poultry, marine products. (5)

Module 5

Baking Roasting Frying. Applications. Equipment. Engineering problems (5)

Module 6

Low Temperature and Non Thermal Processing of foods : Applications. Equipment. Engineering problems. Dairy Processing Technology. (5)

Module 7

Post harvest Technology for cereals, pulses and oil seeds. Food Laws and Standards : good packaing Quality control in food industry. (5)

BOOKS:

1. R.P.Singh and D.R.Heldman, Introduction to Food Engineering, II Edition, Academic Press, 1993
2. E. L.Watson and J.C.Harper, Elements of Food Engineering, II Edition, Van Nostrand Reinhold Co., 1987.
3. R.Macral, R.K.Robinson and M.J.Sadler (Editors),Encyclopaedia of Food Science, Technology and Nutrition, 8 volumes, Academic Press, 1993.
4. McKenna,Engineering and Food 2 Volumes, Elsevier Applied Science Publication, 1984.
5. T.Kadiya (Editor),Food Packaging, Academic Press Inc., 1990. Bourivert, Food Microbiology; IV Edition, 1986.
6. R.T. Toledo, "Fundamentals of Food Process Engineering", AVI Publishing Co., 1980.
7. R. Angold,G.Beech and J.Taggart, " Food Biotechnology", Cambridge University Press, 1989.
8. J. M. Jackson and B. M. Shinn, "Fundamentals of Food Canning Technology", AVI Publishing Co., 1978.
9. J. G. Bernnan, J. R. Butters, N. D. Cowell and A.E.V.Lilley, "Food Engineering Operations", 2nd Edn., Applied Science, 1976.

CL7015 NANOTECHNOLOGY

Module 1 :
Nanotechnology and definition, classification of nanomaterials. Top-down versus bottom up approach in manufacturing. [5]

Module 2 :
Novel physics and chemistry of nanodimensions. Unique chemical, electronic, magnetic, optical, thermal and mechanical properties. Metals, ceramics & semiconductors. [5]

Module 3 :
Dendrimers – synthesis, properties & structure Fullerenes – synthesis, properties & structure Carbon Nanotube - synthesis, properties & structure [5]

Module 4 :
Conducting polymers – synthesis & properties of Polyacetylenes, Polyanilines, polyphenylene, polythiophene & polypyrrole. Charge transfer polymers, Ionically conducting polymers, Conductively filled polymers [5]

Module 5 :
Polymer dopant interaction. Diffusion of dopants, chemistry of doping. Doping level. Marphology of pristine polymers, doped polymers. Mechanism of conduction, Applications [5]

Module 6 :
Stimuli responsive Polymers – Solvent, Temperature, pH responsive, Ions, Electrical energy, Photons – Applications. [5]

Module 7 :
Principles of molecular self assembly and self organization, surfactant solutions, polymers. Self assembled monolayers, thiol and silane monolayers, Langmnir – Blodgett films, Topological substrate Patterning. Polymer surfaces and interfaces, structure and properties. [5]

BOOKS:
1. Nanotechnology, T. Pradeep

CL7025 COMPUTATIONAL FLUID DYNAMICS

Module 1

Philosophy of computational fluid dynamics (CFD), review of equations governing fluid flow and heat transfer, simplified flow models such as incompressible, inviscid, potential and creeping flow (5)

Module 2

Classification of partial differential equations, initial and boundary conditions, review of applied numerical methods (3)

Module 3

Finite difference method: introduction, discretization method, consistency, error and stability analysis, fundamentals of fluid flow modeling (5)

Module 4

Finite difference applications in heat conduction and convection: steady and transient heat conduction in rectangular and cylindrical geometries, convective heat transfer (6)

Module 5

Solution of viscous incompressible flows by stream function-vorticity formulation; Solution of Navier-Stokes equation for incompressible flows using SIMPLE algorithm (6)

Module 6

Finite Volume Method: Discretization methods, approximations of surface integrals and volume integrals, interpolation and differential practices, implementation of boundary conditions, application to the engineering problems (8)

Module 7

Solution of chemical engineering problems; Introduction to multiphase and turbulence modeling (5)

TEXT BOOK:

1. K. Muralidhar and T. Sundararajan, Computational fluid flow and heat transfer, 2nd edition, Narosa Publishinh House, 2003.

References books:

1. S.V. Patankar, Numerical Heat Transfer & Fluid Flow, Hemisphere Publishing Co-operation, McGraw-Hill, 1980.
2. P.S. Ghoshdastidar, Computer Simulation of Flow and Heat Transfer, Tata McGraw Hill, 1998.
3. J.D. Anderson, Computational Fluid Dynamics, McGraw Hill, 1995.

CL 7019 MINERAL PROCESSING

Module 1

Exploitable characteristics of minerals. Economics of mineral processing. Particle technology, , Rheology of suspension, porosity, pore size distribution, Storage and transportation of ores and minerals.

Module 2

Power laws. Principles of crushing and grinding. Shear strength of particulate matter. Grindability Evaluation of particle size. Size distribution curves and their significance Mechanism of breakage of material. Classification, design and application of crushers and grinders. Autogenous Grinding Industrial screening , classification and performance of screens. Dry and wet classifiers. Thickeners, hydro cyclones, filtration,

Module 3

Tabling, jigging, magnetic and electrostatic separation.

Module 4

Surface behavior and floatation principles. Floatation machines, differential floatation and floatation circuit design

Module 5

Elements of hydrometallurgy, microbial leaching et

Module 6

Important beneficiation circuits of coal and minerals like chalcopyrite, sphalerite, galena, magnetite and Hematite, . bauxite, Steel alloying oreetc. Handling of Aggregates for roads, concrete, lime, cement and other binders, masonry light weight concrete, aerated concrete, class insulators and other construction materials, Ceramics, Refractories, Pigments and fillers.

Module 7 Environmental issues: Handling of solid waste from mineral processing plants. Legislation. Process water.

BOOKS:

1.B.A.Wills, Mineral Processing Technology, 6th Edition, ButterworthHeinemann, Boston, MA, ISBN 0-7506-2838-3, 1997

2. J.W.Leonard III, Coal Preparation, 5th Edition, SME Inc., 1992
3. R.P.King, Principles of Flotation, South African Institute of Mining and Metallurgy, 1982
4. .L.Khoury, Coal Cleaning Technology, Noyes Data Corporation, 1981
5. A.J.Lynch, N.W.Johnson, E.V.Manlapig, C.G.Thorne, Mineral and Coal Floation circuits 1981

CL 7021 FUEL CELL TECHNOLOGY

Module 1
Introduction and overview of fuel cell: Why we need fuel cell?, History; Principle and overview of fuel cell, Basic electrochemistry for all the fuel cells

Module 2
Thermodynamics of the fuel cell: Gibb's free energy; reversible andirreversible losses; Fuel cell efficiency; Nernst equation; Effect of temperature, pressure, concentration on Nernst potential, Concept of electrochemical potential

Module 3
Irreversible losses in fuel cell: Activation polarization Concept of electrochemical kinetics; reaction rate; Surface coverage, Activation polarization for charge transfer reaction; Butler-Volmer equation; Tafel equation, How to improve kinetic performance, **Concentration polarization** Diffusion transport in electrodes – limiting current density Concentration polarization – derivation Transport through flow channels (bipolar plate) **Ohmic polarization** Ionic Conductivity Electronic Conductivity, **Modelling of fuel cell: current-voltage predictions**

Module 4
Components of fuel cell: Electrolytes, Catalysts, Current collector/ bipolar plate

Module 5
Fuel cell characterization: Why characterization needed? Possible ways of characterization, In-situ characterization especially I-V characteristics and electrochemical impedance spectroscopy; Cyclic voltammetry; Current interruption technique, Ex-situ characterization especially electrolyte and bipolar plate

Module 6
High temperature fuel cell: Comparison of low and high temperature fuel cells

Module 7
Balance of plant and commercialization issues
Power electronics and system integration, Hydrogen production and storage,Endurance analysis; Safety issues; Cost issues

REFERENCES:
1. O 'Hayre, R. P., S. Cha, W. Colella, F. B. Prinz, Fuel Cell Fundamentals,
Wiley, NY (2006).
2. Bard, A. J. , L. R., Faulkner, Electrochemical Methods, Wiley, N.Y. (2004)
Ref Book.
3. Basu, S. (Ed) Fuel Cell Science and Technology, Springer, N.Y. (2007).
4. Liu, H., Principles of fuel cells, Taylor & Francis, N.Y. (2006).

CL7023 INTRODUCTION TO PETROLEUM RESERVIOR ENGG

Module 1	Petrophysical properties of Reservoir Rock Properties: Porosity, permeability, fluid saturation, effective and relative permeability, wettability and capillary pressure.	5
Module 2	Reservoir Fluids: Reservoir fluid characteristics, reservoir fluid sampling, PVT properties determination, different correlations and laboratory measurements. Phase behavior of hydrocarbon system.	5
Module 3	Flow of Fluids through Porous Media: Darcy's law, single and multiphase flow, linear, radial& spherical flow, steady state & unsteady state flow, flow through fractures, GOR, WOR equations.	5
Module 4	Reservoir Pressure Measurements and Significance: Techniques of pressuremeasurement. Reservoir Drives: Reservoir drive mechanics, Drive indices and recovery factors.	5
Module 5	Reserve estimation: Estimation of petroleum reserve, resource & reserve concept, latest SPE/ WPC/ IS classification, volumetric material balance. Generalized MBE & Gas MBE.	5
Module 6	Production behavior of gas, gas condensate and oil reservoirs. Rock and fluid compressibility effect. Water influx in reservoir, Performance prediction of depletion, gas cap, water and combination drive, reservoir pressure maintenance.	5
Module 7	Displacement process, Immiscible, Buckeley&Leverett treatment of fractional flow & frontal advance equations. Water flood performance.	5

REFERENCES:

1. Reservoir Engineering Handbook – Tarek Ahmed –
2. Petroleum reservoir engineering: Petrophysical properties: J. W. Amyx; D. M. bass, Jr, R. L. Whiting-TEX
3. Fundamentals of Reservoir Engineering: J. C. Calhoun Jr.T-
4. Oil reservoir Engineering: S. J. Pirson-
5. Reservoir engineering Mannual: F. W. Cole
6. Basics of Reservoir Engineering: R. Cosse
7. Fundamentals of Reservoir Engineering : L. P. Dake.-
8. Oil reservoir engg by Muscat

CL 7025 MANUFACTURE OF PHARMACEUTICALS

Module 1: Historical background of pharmaceutical industry; pharmaceutical industries-indian scenario; Profile of a pharmaceutical industry- raw materials, production of bulk pharmaceuticals, formulation, mixing & compounding; Good Manufacturing Practice (GMP) (4)

Module 2: Pharmaceutical industry equipment: GMP reactors: Batch, semi-batch, continuous reactors, Bioreactors, Fermenters, Mixing & melting tanks, Homogenizers; Storage tanks, agitator vessels, CIP/SIP vessels, S&T heat exchangers, preparation and transportation vessels (5)

Module 3: Alkylation : Fundamental concepts on mechanistic approaches to alkylation with reference to substitution (SN_1 and SN_2) and elimination reactions.Commercial manufacture of marketed anticonvulsants (Phenobarbital USP, Barbital, Procaine Hydrochloride USP), Analgesics (Codeine NF and Coneine phosphate USP), Antihistaminics (Cimetidine), etc. (6)

Module 4: Carboxylation and acetylation – Fundamental concepts on mechanistic approaches to carboxylation and acylation with reference to nucleophilic substitution - alkyl vs. acyl, kinetics of hydrolysis of esters by alkali and acids and Transesterification reactions . Commercial manufacture of marketed analgesics (Salicyclic acid, and derivatives USP, Acetaminophen USP).
(6)

Module 5: Halogenation, Dehydration, Oxidation and Reduction, Sulphonation and Amination : Fundamental concepts on mechanistic approaches to these reactions with a few examples of manufacture of pharmaceuticals using these reactions. (5)

Module 6: Fermentation and life processing for antibiotics, biologoicals, hormones and vitamins and manufacture of β lactam antibiotics, cephalosporins, aminoglycosides, macrolides, polypeptides and unclassified antibiotics (5)

Module 7: Manufacture of steroid hormones with particular reference to antifertility agents, vitamins, insulin preparations (Lente, Semilente Protamine Zinc Insulin and other official products) and diagnostic agents.
(5)

BOOKS RECOMMENDED **:**

1. Morrison & Boyd: "Organic Chemistry," 6th ed.(20th Indian Reprint), Prentice-Hall, 1999.
2. B. K. Razdan: "Medicinal Chemistry", 1st edition, CBS Publishers, 2011.
3. M.g.Gopala Rao, & Marshall Sitting Dryden's Outlines of chemical Technology, EWP
4. G.T. Austin, Shreve"s Chemical Process Industries, McGraw Hill
5. Groggins, Unit Processes in Organic Synthesis, 5th edition, Tata McGraw Hill

CL 7027 INTRODUCTION TO MICROELECTRONICS FABRICATION

Module 1: Introduction: Review of Chip Manufacturing Process, Front-End-Of-Line (FEOL) and Back-End-Of-Line (BEOL) concepts (3)

Module 2: Patterning: Introduction; Patterning techniques classification- Top down, bottom up, combined, serial, parallel techniques, introduction-polymer thin films, Lithography (4)

Module 3: Lithography: Lithography basics, Types – Photolithography, Microcontact printing, Nano-imprint lithography, Hot embossing, Replica Molding (REM), Mircomolding in capillaries (MIMIC), Capillary Force Lithography, Polymer bonding lithography, Elastic contact lithography, Lithography induced self-assembly (7)

Module 4: Deposition: Physical and Chemical Vapor Deposition (PVD & CVD) basics, Electrochemical deposition, Electro-migration Vs grain size, Implantation basics, Constant source and limited source diffusion, Mask making, Phase shift mask (7)

Module 5: Material Removal: Plasma and wet etching, Aluminum and Oxide etching, Chemical Mechanical Polishing (CMP) basics, Dishing, Erosion, Issues in Shallow Trench Isolation, Oxide Polish and Copper Polish, Dummy fill (6)

Module 6: Process Integration: BEOL Issues, Cu Vs Al metallization, oxide Vs low-k integration (3)

Module 7: Testing, Process Control and Yield: Scribeline Test (for process evaluation), Functional Test (for product evaluation), Process stability and control, Yield Models, process and design modifications for yield optimization (5)

TEXT BOOK:

1. The Science and Engineering of Microelectronic Fabrication (2nd Edition) by S.A. Campbell, Oxford Univ Press, 2001

Reference Books:

1. ULSI Technology by C.Y. Chang and S.M.Sze, McGraw Hill, 1996
2. Introduction to Microelectronic Fabrication, Vol 5 of Modular Series on Solid State Devices (2nd Edition) by Richard C. Jaeger, Prentice Hall, 2001
3. Microchip Fabrication: A Practical Guide to Semiconductor Processing (2nd Edition) by Peter Van Zant, Carol Rose (Editor), Daniel Gonneau (Editor), Semiconductor devices, 1990

PC7001 FIBRE SCIENCE AND TECHNOLOGY

Module-1: Natural fibre - Cotton, linen, jute, hemp, sisal, coir, wool, silk, asbestos etc, chemical structures, source, use and limitations. Quest for synthetic fibres.[5]

Module-2: Conventional man made fibres: Rayon, Polyethylene terephthalate , Nylon 6 and nylon 66, Acrylic fibres, Polyolefin‘s, Polyvinyl Chloride, Polyvinyl Alcohol, Elastomeric.[5]

Module-3: Fibres for high performance, industrial and non-conventional applications: Polymeric - Aramid-Nomex and Kevlar, Ordered polymeric fibre, Aromatic polyesters, PEK, PEEK, Misscellaneous fibres. Carbon fibre. Glass fibre, Boron fibre. Ceramic fibre. Alumina fibre. Metallic fibre. Conducting polymeric fibre. Optical fibre. [8]

Module-4: Fibre formation and Processing-Principles, machineries, influence of process parameters on structure and morphology of fibre : Spinning, Tow process, Post spinning operations, spin finish, Drawing, Heat setting, Spunbonding and melt-blowing processes. Brief idea about Auxiliary plants and Equipment. Reccycling of fibre waste. [7]

Module-5: Characterization of fibres - Fibre Morphology, Dye uptake, Thermal properties, Chemical stability, Fineness-Denier & Tex, crimping properties, length, twists and intermingling. [5]

Module-6: Mechanical Properties, Electrical properties, Shrinkage, uniformity, Frictional properties, Tactile and optical properties. [5]

Module-7: Brief outline of manufacture of textiles: Fibres to yarn, Yarns to Fabrics- weaving, knitting, braiding, Compound fabric constructions, Finishing processes, Dyeing and printing. [5]

BOOKS:-

1. Gupta, V.B., and Kothari, V.K., Manufactured Fibre Technology, Chapman & Hall, 1997.
2. Fourne,Franz, "Synthetic Fibres, Machines, and Equipment, Manufacture, Properties", Hanser Publishes, 1999.
3. Corbman, Bernard P, "TEXTILES fibre to fabric", Sixth Edition, McGraw Hill, 1983.

PC 7003 BIOMATERIALS

Module 1: Biomaterials-definition-classification-metal-ceramic-polymers, Source, application, advantage and limitations

Module 2: Metals and alloys-phase diagram, corrosion, imperfections and strengthening mechanisms, amorphous solids-pure metals-iron, cobalt, magnesium, copper, aluminum etc. and alloys

Module3: Ceramics- atomic bonding and arrangements, physical properties, deterioration of ceramics- carbon, glass

Module 4: Polymers- synthesis, structural modifications, molecular weight and MWD, properties of polymers, deterioration –chemical, thermal, radiation and others-polyolefins

Module 5: Structure and properties of biological materials-proteins, carbohydrates, application

Module 6: Soft tissue replacements-eye, ear, skin, maxillofacial

Module 7:Hard tissue replacements-bone and skeletal

BOOK REFERENCE:

1. Biomaterials - An introduction - J.B. Park, Plenum Press.
2. Plastics Materials – J.S. Brydson, 3rd Edn. Buthreoortle 1975.

PC 7005 PLASTICS AND ENVIRONMENT

Module 1: Waste statistics. Legislation and economic of plastic recycling. Waste management. Land filling. Few case studies on life cycle analysis: Household plastics packaging (PE, PP, PVC), PET bottles, tyres. (8)

Module 2: Pretreatment of polymer waste: Classification, washing drying, size reduction, special cleaning techniques, sorting techniques. Mechanical Recycling: Filtration system Additives blends technology in recycling problem encountered in extrusion, extrusion blow moulding, injection moulding in recyclates. Press processing of homogeneous recyclates. (8)

Module 3: Commercial recycling plants. Machineries for plastic recycling. Properties and application of recyclates PE, PP, PS EPS, PVC, PET, Polyamides Polyurethanes, FRP, Commingled plastics waste. (8)

Module 4: Feed stock recycling: Degradative Extrusion, Pyrolytic techniques, Hydrogenation, Gasification, Reduction in Blast Furnace, Depolymerization of polyamides, PMMA, solvolytical process for PET, Polyamides, polyoxymethylene. (5)

Module 5: Energy recovery from plastic waste in waste incineration plant. Waste Rubber Recycling. (8)

Module 6: Pollution control in petroleum Refining and petrochemical Industries. (4)

Module 7: Toxicity of plastics: Commodity plastics, toxicity of additives used in plastics Industrial hygiene, Toxicity due to plastics combustion, rules and regulation of plastic toxicity. (4)

BOOKS:

1. Bandrup, Dr. J. Ed. Recycling of plastics‖ Carl Hanser Verlag 1995.
2. Raymond D. Harbison Ed. ― Hamilton & Hardy‘s Industrial Toxicology‖ 5th edition. Mosby Publisher, 1998.
3. Rene Lefaux: ―Practical Toxicology of plastics‖ , CRC press, Cleveland, Ohio 1968.

PC 7007 POLYMER MANUFACTURE TECHNOLOGY

Module 1: Polymers classification, Raw materials, physico-chemical structure of polymers, General polymerization processes: bulk polymerization, solution polymerization, suspension polymerization, emulsion polymerization.

Module 2: Condensation polymerization: reaction mechanism, complexity, equilibrium considerations, kinetics Addition polymerization: step addition, chain addition, ionic addition, reaction kinetics, Alloying and blending, Natural products

Module 3: Ethenic polymer processes - LDPE, HDPE, polypropylene. Poly vinyl chloride and co-polymers Phenol-formaldehyde resins, polyurethanes

Module 4:Man made fiber and film industries: synthetic fibers-polyamides, polyesters,acrylics and modacrylics, vinyls and vinylidines, spandex, polyolefins, fluorocarbons, glass fibres,multicomponent fibres cellulosic fibres: viscose manufacture, cellulose acetate Films manufacture

Module 5:
Rubber industries : natural rubber, synthetic rubber, classification Styrene manufacture, Styrene butadiene (SBR) manufacture. Rubber compounding, rubber fabrication

Module 6: Additives for Plastics: Definition, classification, mechanism of action, method of incorporation of: fillers, plasticizer, stabilizers (antioxidants & antiozonants), coupling agents, cross linking agents, blowing agents.

Module 7: Nucleating agents, toughening agent, flow promoters, slip additives, flame retardants, antiblock agents, antistatic agents

REFERENCES:

1. Dryden's Outlines of chemical technology
2. Shreve's Chemical process industries
3. Plastics materials: Brydson J.A., 3rd Edn., Butter worth, Woburn 1975

ELECTIVES -II

CL 7029 Rocket Propulsion and Explosives

Module 1: Propulsion definition; Types-chemical, nuclear and solar propulsion, Duct jet propulsion, Rocket Propulsion; Fundamentals of Rocket Propulsion: Impulse, thrust, Energy efficiencies, and Effective exhaust velocity, typical Performance values (5)

Module 2: Nozzle theory and thermodynamic Relations; Heat Transfer aspects; Flight Performance; chemical rocket propellant performance analysis (5)

Module 3: Components of solid rockets; Propellant feed systems, Liquid propellant Rocket Engine systems, Rocket testing (5)

Module 4: Solid propellants-Classification and Ingredients: Fuels, Oxidizers, Binders, Burning rate modifiers, Hybrid Propellants, Gel Propellants. (5)

Module 5: Liquid propellant systems. Oxidizers, Fuels – Chemical compounds, Monopropellants, bio propellants, cryogenic propellants, storable propellants. (5)

Module 6: Explosives I - Aqueous compositions: Thickeners and gelling agents, Sensitizers, Foaming agents, Dispersants, other aqueous compositions (5)

Module 7: Explosives II - Ammonium nitrate based compositions; Nitromethane; Plastic bonded explosives; Explosive formulations; Manufacture – process description, flow sheet (5)

REFERENCE BOOKS:

1. Rocket Propulsion Elements, George P Sutton, Fifth Ed., John Wiley and Sons, USA
2. Propellants and Explosives, Ronald W. James, Chemical Tech. Review No.40, Noyes Data Corporation, USA
3. Chemistry & Technology of Explosives, Tadeusz Urbanski, Polish Scientific Publishers, Pergamon Press.

CL 7031 POLLUTION CONTROL EQUIPMENT DESIGN

Module I
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. (5)

Module 2
Design and working principle of Air pollution control equipments: gravitational settling chambers, Cyclone Separator, Baghouse, ESP, Venturi Scrubber, fabric filter. Selection criteria of particulate collector. Dispersion of air pollutants and solutions to the atmospheric dispersion equation. (5)

Module 3
Control of gaseous emission with special reference to Sulphur dioxide, Nitrogen oxide, carbon monoxide and hydrocarbons. Design of gaseous emission controlling equipments: Gas absorption, Adsorption, burners etc. (5)

Module 4
Water pollution: Sources, sampling. Classification of water pollutants & their effect. BOD, COD, SS, TS, TDS etc. Primary Treatment- Design of Sedimentation tank, Floatation (5)

Module 5
Biological Treatment of wastewater: Design of activated sludge treatment system, trickling filter. Facultative ponds, aerobic and anaerobic ponds, etc. Advanced Treatment: microstraining, coagulation and filtration, sonoluminiscence, adsorption, Ion exchange, solvent extraction, stripping, Membrane Separation techniques – ultrfiltration, Reverse osmosis, electrodialysis etc. (8)

Module 6
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 sludge. Incinerator Design. (5)

Module 7
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. (7)

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

CL7033 PULP AND PAPER TECHNOLOGY

Module-1

WOOD CHEMISTRY: Chemical composition- cellulose, hemi cellulose, lignin, wood extractives, raw material. Quality parameters under evaluation. Yield of raw material. (5)

Module – 2

PULPING: General principle of pulping. Types of pulping processes: mechanical, chemical, semichemical, sulphate process, Kraft process. Process calculations. Raw material utility requirements. Process flow sheet and description. Washing and bleaching. Common unit operation. Wood treatment, digestion, evaporation, drying with equipments used. (5)

Module – 3

TREATMENT OF PULP: Screening, washing, refining, thickening of pulp. Bleaching- conventional and non-conventional bleaching techniques. (5)

Module – 4

PAPER MAKING: Preliminary operations on pulp. Beating and refining of pulp. Non-fibrous materials. Fillers and loading material. Internal sizing. Wet and additive surface treatment. Paper coloring. Surface sizing. (5)

Module – 5

PAPER DRYING AND FINISHING: Types of dryers. Calendaring. Reeling and winding. Paper machine drives, cutting, winding and rewinding. Conversion of papers. (5)

Module – 6

PAPER QUALITY OF GRADES: Different grades of paper quality. Parameters and their evaluation. Saturation of paper. Special grade papers. Recycling of waste papers. (5)

Module 7

SUPPORTIVE OPERATIONS: Chemical recovery – water balance, oxidation, evaporation of black liquor, lime recovery. Quality control and safety aspects.ENVIRONMENTAL ASPECTS: Effluent characteristics of pulp and paper industries. Treatment methods. (5)

BOOKS:

1. Hand Book of pulp and paper Technology, by Kenneth W.Brill.
2. Wood and Cellulose Science, by A.J.Stemon, The Ronald Press Co., New York.
3. Paper Industry in India by V.Poddar, Weighcost Oxford and HBH Co., New Delhi.

CL7035 COLLOID AND INTERFFACIAL ENGINEERING

Module : 1

Introduction to colloidal material, surface properties, origin of chargeon colloidal particles, preparation & characterization of colloidal particles. [5]

Module : 2

Surfactants type (Anionic, cationic, Zwitterinic, Gemini and non-ionic). Theory of surfactants. CMC. Kraft temperature. Phase behavior of cone surfactant systems, surfactant geometry and packing. Emulsions, Microemutsions & Gels. [5]

Module : 3

Intermolecular Forces, Van-der waals forces (Kessorn, Debye, and London Interactions). Potential energy curve, Brownian motion and Brownian Flocculation. [5]

Module : 4

Surface and interfacial Tension. Surface free energy , Surface tension for curved interfaces, Surface excess and Gibbs equation. [5]

Module : 5

Contact angle, Wetting Young-Laplace equation, Dynamic properties of interfaces. Surface viscosity, Kelvin equation. [5]

Module : 6

Electrical phenomena at interfaces(Electronic kinetic phenomena, Electric doublelayer, short range forces). DLVO theory, capillary hydrostatics . thin film. [5]

Module : 7

Measurements technique: Surface tension, Interfacial Tension, Contact angle, Zeta potential , Particle size & its distribution. Electro osmosis phenomena, Streaming potential, Electro viscous flows.[5]

BOOKS:

1) A.W. Adamson and A.P Gast, Physical Chemistry of surfaces, Wiley Interscience , NY 1997 and surface.
2) P.C Hiemen and R.Rajgopalam, Principle of colloid and surface Chemistry NY Marcel Dekker, 1997.
3) 3) D.J.Shaw, Colloid and surface chemistry, Butterworth Heineman, Oxford,1992

CL 7037 RENEWABLE AND NONRENEWABLE ENERGY RESOURCES

Module 1

Introduction to Energy Science and Energy Technology; Energy sources and their availability. Prospects of Renewable energy sources; Energy conservation : Principle of energy conservation and Energy audit. Energy conservation Technologies – Co generation, waste heat utilization, Heat recuperators, Heat regenerators, Heat pipes,, Heat pumps Energy storage. (5)

Module 2

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. Fluidized bed combustion boilers for burning coal; fuels; 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. (5)

Module 3

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. (4)

Module 4

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. Mechanism and principle of combustion. Laminar flame propagation, theory & structure of flame. Burning velocity & its determination. Diffusion of flame & Flame stabilization. (5)

Module 5

Nuclear energy: Nuclear reactions, Nuclear Fuels and reactors, power generation.global, Indian Scenario. (3)

Module 6

[Alternate Engergy – I]

Geothermal energy: Introduction, Resources and Utilization of Geothermal energy, Different types of Geothermal Electric power plant and their operations for Geothermal Energy systems in India; **Wind energy:** Fundamentals and application, Wind Energy conversion system, Performance of wind machines, Electricity generation for wind; **Biomass Energy Resources:** Introduction, Biomass Conversion Process. Biogas from plant/animal wastes, community biogas plants. Biochemical conversion, Fermentation, liquid fuels from biomass; BioDiesel from oil producing seeds/algae; .Energy from waste : Incinerators for Agricultural / urban wastes.Environmental Considerations. **Energy from the oceans:** Introduction Ocean Energy conversion Technologies. Types of Ocean Thermal Electric Power Generation system and their operation. Tidal power plant; **Hydro Energy:** Introduction, types hydroelectric plants and energy conversion scheme, Impulse turbine and Reaction turbine. Classification of Hydro-Energy plants; (7)

Module 7

[Alternate Energy – II]

Solar energy: Solar radiation & its measurement, different types of solar collectors. Solar energy storage system & application of solar energy in water heating, space heating/cooling, solar distillation, solar pumping, solar cooking, solar furnace, solar green houses, electric power generation etc. Solar Photovoltaic. Recent Advances **Fuel cell:** Introduction, design & principle operation of fuel cell, classification of fuel cells- Alkaline Fuel Cell, Solid Oxide Fuel Cell, ProtonExchange Fuel Cell, Direct Methanol Fuel Cell – Applications and recent advanes. . Conversion efficiency, type of electrode, catalyst, flow fields current collectors, fuel cell stack. Basic battery theory, characteristics and advantages for bulk energy storage. **Hydrogen energy :**Introduction, production of hydrogen

energy: electrolysis, thermo-chemical, Biotechnology methods etc. Hydrogen storage & transportations. Safety & management. Hydrogen technology development in India. (6)

REFERENCES

1. S. Sarkar, *Fuels and Combustion*. Sangam books Ltd
2. Himus, *Elements of Fuel technology*.
3. J. Brame and King, *Fuels: Solid, liquid and gaseous fuels*, Kessinger Publishing, LLC, 2007.
4. S. Rao and Dr. B.B. Parulekar, *Energy Technology, Non-convential, Renewable and Conventional*, Khanna Publishers.
5. G.D. Rai, *Non-conventional Energy Sources*, Khanna Publishers
6.D.S. Chauhan and S.K. Srivastava, *Non- Conventional Energy Resources*, New Age International Pvt Ltd.
7.G.N. Tiwari, *Fundamentals of Renewable Energy Sources*, Narosa Publishing House.

CL 7039 MULTIPHASE FLOW

Module-1
Introduction to multiphase flow, types and applications, Common terminologies, flow patterns and flow pattern maps.

Module-2
One dimensional steady homogenous flow. Concept of choking and critical flow phenomena.One dimensional steady separated flow model. Phases are considered together but their velocities differ. Phases are considered separately, flow with phase change.

Module-3
Hydrodynamics of solid-liquid and gas-solid flow.

Module-4
Flow in which inertia effects dominate, energy equations. The separated flow model for stratified and annular flow.

Module-5
General theory of drift flux model. Application of drift flux model to bubbly and slug flow. Principles of hydraulic and pneumatic transportation. An introduction to three phase flow.

Module-6

Measurement techniques for multiphase flow. Flow regime identification, pressure drop, void fraction and flow rate measurement.

Module-7
Empirical correlation formation in hydrodynamics study of multi phase flow.

REFERENCES

1. One dimensional Two Phase Flow by G. B. Wallis.
2. Measurement of Two Phase Flow Parameters by G.F.Hewitt.
3. Flow of Complex Mixtures by Govier and Aziz.
4. Two Phase Flow by Butterworth and Hewitt.
5. Handbook of Multiphase systems by Hetsroni.

CL 7041 PROCESS INTEGRATION

Module 1: Introduction to Process Integration: Introduction to Process Intensification and Process Integration(PI). Areas of Application and Techniques available For PI, Onion Diagram, Process Integration in Chemical Industries, Formulation of a Design Problem, Chemical Process Design and Integration, Hierarchy of Chemical Process Design and Integration, Continuous and Batch Processes, New Design and Retrofit, Approaches to Chemical Process Design and Integration, Process Control.

Module 2: Pinch Technology: Pinch Technology-an overview: Introduction, Basic concepts, How it is different from energy auditing, Roles of thermodynamic laws, problems addressed by Pinch Technology. Key steps of Pinch Technology: Concept of ΔT_{min} , Data Extraction, Targeting, Designing, Optimization-Supertargeting. Basic Elements of Pinch Technology: Grid Diagram, Composite curve, Problem Table Algorithm, Grand Composite Curve.

Module 3: Heat Exchanger Networking: Targeting of Heat Exchanger Network, Designing of Heat Exchanger Networks, Hot Composite Curve, Cold Composite Curve, Problem Table Algorithm, Grand Composite Curve, Area Targeting by Uniform Bath formula and Unit Targeting by Eulers' formula, Heuristics for Pinch Design, Maximum Energy Recovery Design, Evolution of Network.

Module 4: Reactor Networking: Choice of Idealized reactor model and reactor performance. Reactor configurations: Temperature Control, Gas-Liquid and Liquid Liquid Reactors, Choice of Reactors. Heat Integration characteristics of reactors,Appropriate placements of reactors. Use of GCC for Heat Integration of reactors.

Module 5: Distillation Integration: Distillation sequencing, Heat Integration characteristics of Distillation column, appropriate placement of distillation column, various configurations for heat integration of distillation column.

Module 6: Mass Exchanger Network Synthesis: Mass Exchanger Network, Minimum Mass Separating Agents (MSA), Mass exchange networks for minimum external MSA. Minimum Number of Mass Exchangers.

Module 7: Evaporators, Dryers , Steam Systems and Cogeneration, Cooling Systems : Heat Integration , Appropriate Placement, Evolving Design of Evaporators, Heat Integration , Appropriate Placement, Evolving Design of Dryers, Steam System Configruation, Cogeneration Targets, Design of Cooling Water Networks

TEXT-BOOKS

1. Chemical Process Design and Integration Robin Smith, John Wiley and Sons. Ltd., New Delhi, 2005.
2. Product & Process Design Principles Warren D. Seider, J. D. Seader and Daniel R. Lewin, Wiley Publication.

Reference Book

1. Heat Exchanger Network Synthesis U. V. Shenoy, Gulf Publication.

CL7043 COMBUSITON ENGINEERING

Module 1 : Introduction: Introduction to combustion, Applications of combustion, Types of fuel and oxidizers, Characterization of fuel, Various combustion mode, Scope of combustion.

Module 2 : Thermodynamics of Combustion: Thermodynamics properties, Laws of thermodynamics,

Stoichiometry, Thermo-chemistry, adiabatic temperature, chemical equilibrium.

Module 3: Chemistry of Combustion: Basic Reaction Kinetics, Elementary reactions, Chain reactions, Multistep reactions, simplification of reaction mechanism, Global kinetics.

Physics of Combustion: Fundamental laws of transport phenomena, Conservations Equations, Transport in Turbulent Flow.

Module 4: Premixed Flame: One dimensional combustion wave, Laminar premixed flame, Laminar flame propagation- theory and structure of flame, Burning velocity measurement methods, Effects of chemical and physical variables on Burning velocity, Flame extinction, Ignition, Flame stabilizations, Turbulent Premixed flame.

Module 5: Diffusion Flame: Gaseous Jet diffusion flame, Design of gas burner& interchangeability of gases.Liquid fuel combustion, Atomization, Spray Combustion,

Module 6: Solid fuel combustion. Thermodynamics & kinetics of coal combustion process. Design of pulverized fuel flames and burners. Application to the design of pulverized fuel furnace and fluidized combustion process.

Module 7:Combustion and Environment: Atmosphere, Chemical Emission from combustion, Quantification of emission, Emission control methods.

BOOKS:

1. D. P. Mishra, Fundamentals of Combustion, Prentice Hall of India, New Delhi, 2008.
2. Kuo K.K. â€œPrinciples of Combustionâ€ • John Wiley and Sons, 2005.
3. Strehlow R Â A., Â â€œFundamentals of combustionâ€ • McGraw Hill Book Company, 1984.
4. Borman, G.L. and Ragland, K.W., Combustion Enginnering, McGrawHill International Editions, 1998.
5. Clive Davis, Calculations in Furnace Technology, Pergamon Press, Oxford, 1970

CL 7045 PHARMACEUTICAL TECHNOLOGY

Module 1: Introduction to pharmaceutical terminology-dose, dosage regimen, dosage form, route of administration, introduction to pharmacopeias

Module 2: Classification of dosage forms with brief introduction to tablets, tablet coating, capsules, sustained release dosage form, liquids, semisolids, emulsions, suspensions, pharmaceutical aerosols

Module 3: General introduction to dosage form preparation –influence of physicochemical properties on stability, bioavailability, transport of active moiety to site of action

Module 4: Principles of Pharmaceutical Processing-mixing. Milling, drying, compression and consolidation of powdered solids, liquids

Module 5: Basic chemical principles related to emulsions and suspensions, rheology of drugs, clarification and filtration

Module 6: Product processing-containers and packaging materials science, production management

Module 7: Stability testing and kinetic principles, quality control and assurance, drug regulatory affairs

CL 7047 NON NEWTONIAN FLOW

Module 1: Nature of Materials: Pseudo Plastics, Dilatants, Bingham Plastics, Rheopexy and Thixotropy, Shear Flow, Viscosity Models, Dependence of Viscosity on Temperature & Pressure.

Module 2:

Governing Equations for Non-Newtonian Fluids

Review of Continuity Equation and Equation of Motion, Constitutive Equations of various Non-Newtonian Fluids, Problems Related to the Development of Constitutive Equations, Evaluation of Relevant Physical Properties

Module 3: Fluid Flow Phenomena for Non-Newtonian Fluids

Flow through Circular, Annulus and Slit Cross Sections, Flows in Packed and Fluidised Beds, Flow around Submerged Objects, Visco-Elastic Effects, Mixing and Agitation

Module 4: Heat Transfer characteristic of Non-Newtonian Fluid Flow

Temperature Distribution and Heat Transfer in Laminar and Turbulent Flows, Boundary Layer with and without Heat Transfer

Module 5: Rheometry

Techniques of measurement of Shear in Capillary Viscometer, Rotational Viscometer, Torque Rheometer. Rhermetry of food and polymers

Module 6: Rheology of Particulate systems

Drag force on sphere, Rheology of Suspensions, flow over polymers, terminal velocity, bubbles, packed bed, fluidization.

Module 7: Polymer Rheology

Non Newtonian Viscosity models, Visco-Elasticity of Polymers, Linear Visco-Elastic Models, Model to Molecule Analogy, Boltzmann Stress Superposition Principles, Relaxation Specturm , Dynamic Response, Experimental Techniques to Determine Transition and Relaxation in Amorphous Polymer, Time-Temperature Superposition.

BOOKS:

R.P. Chhabra and J.F. Richardson Non-Newtonian Flow and Applied Rheology**, Elsevier**(Second Edition)
ISBN: 978-0-7506-8532-0

CL 7049 MICROFLUIDICS

Module 1: Introduction
Origin, Definition, Benefits, Challenges, Commercial activities, Physics of miniaturization, Scaling laws.

Module 2: Micro-scale fluid mechanics
Intermolecular forces, States of matter, Continuum assumption, Governing equations, Constitutive relations. Gas and liquid flows, Boundary conditions, Slip theory, Transition to turbulence, Low Re flows, Entrance effects. Exact solutions, Couette flow, Poiseuille flow, Stokes drag on a sphere, Time-dependent flows, Two-phase flows, Thermal transfer in microchannels. Hydraulic resistance and Circuit analysis, Straight channel of different cross-sections, Channels in series and parallel.

Module 3: Capillary flows
Surface tension and interfacial energy, Young-Laplace equation, Contact angle, Capillary length and capillary rise, Interfacial boundary conditions, Marangoni effect.

Module 4: Electrokinetics
Electrohydrodynamics fundamentals. Electro-osmosis, Debye layer, Thin EDL limit, Ideal electroosmotic flow, Ideal EOF with back pressure, Cascade electroosmotic micropump, EOF of power-law fluids. Electrophoresis of particles, Electrophoretic mobility, Electrophoretic velocity dependence on particle size. Dielectrophoresis, Induced polarization and DEP , Point dipole in a dielectric fluid, DEP force on a dielectric sphere, DEP particle trapping, AC DEP force on a dielectric sphere.

Module 5: Microfabrication techniques
Materials, Clean room, Silicon crystallography, Miller indices. Oxidation, photolithography- mask, spin coating, exposure and development, Etching, Bulk and Surface micromachining, Wafer bonding. Polymer microfabrication, PMMA/COC/PDMS substrates, micromolding, hot embossing, fluidic interconnections.

Module 6: Microfluidics components
Micropumps, Check-valve pumps, Valve-less pumps, Peristaltic pumps, Rotary pumps, Centrifugal pumps, Ultrasonic pump, EHD pump, MHD pumps. Microvalves, Pneumatic valves, Thermopneumatic valves, Thermomechanical valves, Piezoelectric valves, Electrostatic valves, Electromagnetic valves, Capillary force valves. Microflow sensors, Differential pressure flow sensors, Drag force flow sensors, Lift force flow sensors, Coriolis flow sensors, Thermal flow sensors. Micromixers, Physics of mixing, Pe-Re diagram of micromixers, Parallel lamination, Sequential lamination, Taylor-Aris dispersion. Droplet generators, Kinetics of a droplet, Dynamics of a droplet, In-channel dispensers, T-junction and Cross-junction, Droplet formation, breakup and transport. Microparticle separator, principles of separation and sorting of microparticles, design and applications. Microreactors, Design considerations, Liquid-phase reactors, PCR, Design consideration for PCR reactors.

Module 7: Few applications of microfluidics Drug delivery, Diagnostics, Bio-sensing.

REFERENCES:
1. Nguyen, N. T., Werely, S. T., Fundamentals and applications of Microfluidics, Artech house Inc., 2002. Bruus, H., Theoretical Microfluidics, Oxford University Press Inc., 2008.
2. Madou, M. J., Fundamentals of Microfabrication, CRC press, 2002.
3. Tabeling, P., Introduction to microfluidics, Oxford University Press Inc., 2005.
4. Kirby, B.J., Micro- and Nanoscale Fluid Mechanics: Transport in Microfluidic Devices, Cambridge University Press, 2010.
5. Colin, S., Microfluidics, John Wiley & Sons, 2009.

PC7009 POLYMER COMPOSITES

Module-1: Polymer composite systems: Types of composites, reinforcements, Types of Resin.

Module-2: Natural fibre: Jute, sisal, cotton, heamp ceramic fibre: silicon carbaide, zinc, Alumina, glass, synthetic fibre: polyethylene, polyester, nylon, Kevlar etc

Module-3: Thermoset, elastomer - resins (polyesters, epoxide, vinyl ester, phenol formaldehyde, polyimide, reinforced polyolefin,

Module-4: Semicrystalline and amorphous polymers - PEEK, PP, PEK, PBT, PC, ABC, nylon etc.) additives, reinforcements (particulate, fibrous, gaseous).

Module-5: Processing techniques - open mould, hand lay up spray up, vacuum bag moulding, pressure bag moulding, autoclave moulding, closed mould, SMC, DMC, RTM.

Module-6: Continuous manufacturing process - pultrusion, filament winding, centrifugal casting. Application (sandwich constructions - aircraft, racing cars, helicopter rotor blades etc.)

Module-7: Mechanical behaviour of composites – Analysis of continuous fibre composites, and short fibre composites. Deformation behaviour of single ply and laminates. Creep, Fatigue Impact. Electrical, and thermal properties.

BOOKS:

1. Dyson, R.W., "Engineering Polymers", Blackie, 1990.
2. Crawford, R.J., Plastics Engineering, Pergamon Press.
3. Richardson, T., Composites – a design guide industrial press Inc., New York, 1987.

PC 7011 PLASTICS PRODUCT DESIGN

Module 1:
Plastic part design process. Material Selection : Comparative properties of thermodynamics and Thermo set materials. Design related plastics material properties. Test standards. [5]

Module 2:
Process Selection Criteria : Injection Moulding, Extrusion, Calendaring , Thermoforming, Blow Moulding, Compression and Transfer moulding, Casting, Filament, Pultrusion etc. [5]

Module 3:
Structural Design: Part Geometry, Stress concentration, Support, loading conditions, [5]

Module 4:
Beams, plates, shells/pressure vessels, Torsion, columns, dynamic loads. [5]

Module 5:
Rapid prototyping: stereo lithography, laser sintering, automated filament extrusion prototyping, laminated object manufacturing, prototype part casting, prototype injection mould tooling, structural foam prototypes. Co-ordinate measuring . Experimental stress [5]

Module 6:
Assembly of injection moulded parts: Design aspect of press fit, snap joint, mechanical fastening welded joint, adhesive joint. [5]

Module 7:
Case History: compact discs, tie cables, stack of shelves, park bench, bearing, gear, pipe and tubes, shaft pulley, living hinge, connector and bracket using living hinge, joint cap, injection blow moulded bottle etc. [5]

BOOKS:
1. Robert A.Malloy, ―Plastic part design for Injection Moulding, Hanser Publishers, Munich Vienna New York, 1994.
2. Paul A. Tres, ―Designing Plastic Parts for Assembly, 2nd , Revised Edition, Hanser Publishers, Munich Vienna New York, 1994.
3. N.G. Mc Crum, C.P. Buckley and C.B. Bucknall, Principles of Polymer Engineering, Oxford Science Publications, New York, 1997.
4. Belofsky, H., ―Plastics Product Design and Process Engineering, Hanser Publishers, Munich Vienna New York, 1994.

PC7013 SURFACE COATING AND ADHESION TECHNOLOGY

Module 1: Fundamental types of surface coating: Lacquer, paint, varnish, and enamel. Lacquer: Constituents - (resins, plasticizer, solvent and diluent), oleo resinous varnishes: Constituents - (drying oil, solvent, drier, pigment - thinners) mechanism of drying, formulation. [5]

Module 2: Paints: Constituents - (resin, binder, solvent, pigment etc.) formulation, varnish, type, lacquer type, polymer emulsion paints, enamel paints, stoving enamel [5]

Module 3: Pigments - role and significance of (a) Interactions between pigments and vehicle (b) wetting and dispersion of pigment particles, effects of pigments on flow properties and hiding power. Additives in paints- wetting and dispersing agent, anti settling and anti sagging agent, antiskinning agent, anti flooding and fungicidal agent. [8]

Module 4: Coating Processes - extrusion, roller coating, blade, kiss, dip coating, flow coating, curtain coating, spray painting, electro deposition, chemiphoretic deposition. New technologies - water borne coating, curable coating, powder coating, high solid liquid coating. Industrial coating - (appliance finishes, automotive finishes, coil coatings, can coatings, marine coatings, aircraft finishes, building coatings, paper coatings). [7]

Module 5: Paint properties and their evaluation - Surface treatment of polymers. (mechanism of film formation, factors affecting coating properties, barrier properties of coatings, mechanical, optical, ageing, rheological, adhesion, floating, flooding, silking properties - surface defects.) [5]

Module 6: Theories of adhesion- mechanical interlocking, electrostatic attraction, diffusion, adsorption, chemisorptions. Properties significant for adhesives and their tests: Cohesive strength, surface tack, peel strength. [5]

Module 7: Adhesives based on - starch, dextrin, cellulose ester, cellulose ether, natural gum resins, acrylic resins, epoxy resins, phenolics, neoprene rubber adhesives, polyvinyl alcohol, polyvinyl acetate. Adhesive papers, general tapes, pressure sensitive adhesive. Printing inks, formulation, methods of printing. [5]

BOOKS REFERENCE:

1. Surface Coating Science & Technology - edited by Swaraj Paul, John Wiley & Sons.
2. Handbook of Adhesives - Skeist, Irving, Van Nostrand, New York, 1990. 3rd Edn.
3. Introduction to Paint Chemistry, Bentley & Turner.

PC 7015 RUBBER PRODUCT TECHNOLOGY

Module- 1

History and growth of rubber technology, general consideration of diene polymers. Natural and synthetic (rubber) Lattices, composition, stability, gelation, preparation of dry rubber from natural rubber latex, types and grades of rubber. Physics of raw vulcanised rubber – Entangled rubber elasticity, Linear viscoelasticity of rubber [5]

Module- 2

Rubber compounding and Vulcanization principle and mechanism, Mastication, mixing and compounding. Additives - fillers, accelerators, activators, antioxidants, antiozonants, sulfur etc. Theory and technology of reinforcement. [7]

Module- 3

Machineries: Mills, Mixers, Extruders, Calendars etc. [8]

Module- 4

Manufacturing of Dipped goods from latex, latex foam, Latex thread, latex treated coir. Rubber coated fabrics, Rubber footwear technology. Using textile, leather, PVC. Extruded rubber profile.

Module- 5

Hose technology, conveyor & V- Belt., Rubber coveredrolls, metal rubber bonding.

Module- 6

Tyre technology :Compounding & processing technology [5]

Module- 7

Thermoplastic Elastomer & its potential application, reverse engineering in rubber industries. Technology & manufacture of automic rubber compounds, rubber cables, synthetic Elastomer in industrial application.

TEXT BOOKS:

1. Rubber Technology and Manufacture: Blow C.M. 2nd Edn. Numbers Butterworth
London. 1982
2. Dr. Werner Hoffmann. Rubber Technology Handbook, Hanser Publication, NY, 1996
3. Rubber Technology, Morton,M., N.Y. Vannostrand Reinhold Company, 1973. 2nd Ed
4. Polymer Physics, Rubinstein,M,Colby R.H. Oxford University press , 2003