

**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-Poiseuille 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. PHI

**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 coefficients-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 Raoult's 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 Press
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 1

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 Raoult's, Henry & Dalton's Law. Humidity, Saturation & use of psychrometric 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 grinding, 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 Thickener,. **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, Hydraulic classifiers, Tabling, Jigging, Froth floatation, Dense media separation etc.Magnetic separation, Electrostatic 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**

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

(8 Lectures)

### **MODULE-6**

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

(7Lectures)

(6Lectures)

### **MODULE-7**

Torsion of circular shaft and power transmitted by the shaft. Combined bending and twisting of circular shaft-Equivalent B/ 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 1

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 reformat. Isolation of Benzene, Toluene, Xylene. Aromatics derived from thermal cracking of naphtha, 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 phthalic 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 & Bessel's interpolation for unevenly spaced points, Newton's general interpolation formula with divided differences. (5)

### Module 4

#### **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<sup>rd</sup> Rule. 3/8<sup>th</sup> Rule. (5)

### Module 6

#### **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 Delhi – H.C. Saxena.
4. Introduction to Numerical Analysis – Addison – Wesley Publishing Company – Froberg.)

## CL 4007 TRANSPORT PHENOMENA

### Module 1

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, Euler 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 processes 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- Bituminous coal, Bituminous 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 Energy – 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 advances. . 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 method 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-conventional, 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- 1** **Chemical 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 of 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, tricarboxylic 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)

**Module 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 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 sheet) and major engineering problems. Soaps, Detergents & Glycerin: Classification of cleansing compounds, uses, Methods of soap production, Methods of detergent manufacture, Methods of production of Glycerin. Process description & flow sheet of each process. (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 sythesis : 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, mass transfer 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 of electric field 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 practice classification of chromatographic techniques, gel filtration, ion exchange chromatography and 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 & V J Krukonic (Butterworth Heinmann)
3. Large scale adsorption and chromatography 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 techniques 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 and MWD. (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. Plastics 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-particle reactors.

### 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 System Analysis, MGH
2. Considine, D.M., "Process/Industrial Instruments and Controls Handbook", McGraw Hill, 1993
3. Ogunnaika B.A. and Ray W.H., "Process Dynamics, Modeling and control". Oxford University Press, U.K. 1994
4. Alciatore D.G. and Histan 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 dual method (5)

### Module 6

Multivariable problems without constraints (Direct Search Method: Simplex, Hooks-Jeeves and Powell'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 Optimality (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 trial 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 1**

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: O. 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, Pyrites. 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, Nitrogenous 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. Nielsson, *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. Morphology 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, Langmuir – 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, 2<sup>nd</sup> 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 ore etc. 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 Flotation 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 and irreversible 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

|                 |   |   |
|-----------------|---|---|
| <b>Module 1</b> | Petrophysical properties of Reservoir Rock Properties: Porosity, permeability, fluid saturation, effective and relative permeability, wettability and capillary pressure.   | 5 |
| <b>Module 2</b> | Reservoir Fluids: Reservoir fluid characteristics, reservoir fluid sampling, PVT properties determination, different correlations and laboratory measurements. Phase behavior of hydrocarbon system.  | 5 |
| <b>Module 3</b> | 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 |
| <b>Module 4</b> | Reservoir Pressure Measurements and Significance: Techniques of pressure measurement. Reservoir Drives: Reservoir drive mechanics, Drive indices and recovery factors.  | 5 |
| <b>Module 5</b> | Reserve estimation: Estimation of petroleum reserve, resource & reserve concept, latest SPE/ WPC/ IS classification, volumetric material balance. Generalized MBE & Gas MBE.  | 5 |
| <b>Module 6</b> | 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 |
| <b>Module 7</b> | Displacement process, Immiscible, Buckley & 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 Manual: 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, Barbitol, 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 (Salicylic 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, biologicals, hormones and vitamins and manufacture of  $\beta$  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, 6<sup>th</sup> ed. (20<sup>th</sup> Indian Reprint), Prentice-Hall, 1999.
2. B. K. Razdan: —Medicinal Chemistry, 1<sup>st</sup> edition, CBS Publishers, 2011.
3. M.g.Gopala Rao, & Marshall Sitting Dryden's Outlines of chemical Technology, EWP
4. G.T. Austin, Shrevells Chemical Process Industries, McGraw Hill
5. Groggins, Unit Processes in Organic Synthesis, 5<sup>th</sup> 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 (2<sup>nd</sup> 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 (2<sup>nd</sup> 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, Miscellaneous 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. Recycling 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. Fourné, Franz, "Synthetic Fibres, Machines, and Equipment, Properties", Hanser Publishers, 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. Buthreortle 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 1

Types of environments and their pollutants. Classification of pollutants. Legislative aspects including water act. 1974, Air Act 1981 and effluent 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, sonoluminescence, adsorption, Ion exchange, solvent extraction, stripping, Membrane Separation techniques – ultrafiltration, 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) 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- Bituminous coal, Bituminous 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 Energy – 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 advances. . 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-conventional, 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  $\Delta T_{min}$  , 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 Configuration, 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 COMBUSTION 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, Conservation 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. "Principles of Combustion" - John Wiley and Sons, 2005.
3. Strehlow R. A., "Fundamentals of combustion" - McGraw Hill Book Company, 1984.
4. Borman, G.L. and Ragland, K.W., Combustion Engineering, 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. Rheometry 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 Spectrum, 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., Wereley, 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, hemp ceramic fibre: silicon carbide, 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